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Integration of a methodology using digital technologies for sustainability assessment in decision making about water management building system

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Abstract

Water scarcity, especially the availability of potable water, is exacerbated by global warming and poses a significant challenge. The construction industry significantly impacts water usage, prompting the development of certifications and standards aimed at mitigating buildings' environmental impact.

The thesis examines the green building concept with a focus on water conservation, utilizing Building Information Modeling to analyze this concept within the framework of sustainability by following the LEED certification system. Despite efforts to quantify sustainable buildings clearly, the complexity of sustainability and its assessment presents challenges. Integrating BIM and LEED as a framework for green certifications, this study develops a methodology in the Visual Programming Language. This methodology, created in Dynamo for BIM modeling software, aims to simplify assessment parameters and calculations and assist users in selecting appropriate strategies and parameters to acquire credits.

A conceptual model of a case study building was developed to be analyzed using various indoor water-consuming fixtures and outdoor landscaping choices. The study calculated and analyzed both indoor and outdoor potable water usage, demonstrating that strategic design decisions can significantly conserve water. For validation, a comparative study was conducted across three scenarios, providing informative charts, monthly water consumption statistics, and reduction percentages.

This integrated approach facilitates the decision-making process for achieving certification and water saving solutions, thus saving considerable time and resources.

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Introduction

Water scarcity is one of the most pressing global challenges of the 21st century, exacerbated by climate change and rapid urbanization. As the world deals with the dual crises of declining freshwater resources and an increasingly unpredictable climate, the need for innovative and sustainable solutions becomes paramount. The introduction section of this thesis is divided into several chapters, each addressing critical subjects to provide a better understanding and prepare for the subsequent 'Methodology' section.

The first chapter focuses on the global water crisis. It examines the relationship between water and climate change, emphasizing the need for global action. Subsections within this chapter explore the causes and effects of climate change on freshwater resources in Italy and the role of cities in the water crisis.

Moving forward, the second chapter provides an overview of international building rating systems that promote sustainability and water efficiency. It covers various global standards, including the Sustainable Development Goals (SDGs), and compares different green building rating systems such as BREEAM, LEED, CASBEE, and Green Star NZ. This chapter highlights the role of these systems in sustainable urban development.

The third chapter is dedicated to LEED certification, a prominent green building rating system. It traces the history of LEED, explains its rating systems and program requirements, and outlines the certification process. The chapter also discusses the benefits of LEED certification and provides a detailed case study of a historic building in Italy that has achieved LEED certification.

The fourth chapter explores the intersection of digital technologies and sustainability assessment. It highlights how modern innovations can enhance water management and sustainability practices, offering new tools and methodologies for effectively tackling the water crisis.

The final chapter concludes by outlining the objectives of the research, setting the stage for a comprehensive exploration of integrating a method using digital technologies for automated sustainability assessment.


Tolga Subasi : Urmia Lake,Iran

The Global Water Scarcity Crises

The Earth's abundant water resources are distributed in various forms and qualities on Earth, totaling approximately 1.4 billion cubic kilometers globally. Nearly 97% of this is saltwater in the oceans. Despite this vast volume, freshwater essential for human use is relatively scarce, with an estimated 35 million cubic kilometers, much of which is inaccessible as it is locked in glaciers, snow cover, or deep groundwater. Only a small fraction of freshwater is readily available in river flows, surface lakes, groundwater, soil moisture, or rainfall, presenting significant challenges like inadequate access to safe water and sanitation, contamination from human and industrial waste, ecological disruptions, and concerns about water shortages exacerbated by climate change.

Covering 70% of the Earth's surface, water is a critical resource for human health and well-being and is recognized as a human right by the United Nations. However, data from the United Nations Water Program (UN Water) reveal significant global disparities in access to clean water and sanitation, with millions suffering from water-related diseases and socioeconomic deprivation. As the world's population grows, addressing water issues becomes increasingly urgent, especially given the impact of climate change on freshwater resources.

The global water crisis, highlighted as the top global risk by the World Economic Forum, underscores the urgency of ensuring access to clean water and safe sanitation, particularly in developing and underdeveloped countries where lack of access is most acute. Despite constitutional recognition of the right to water in some countries, disparities persist, emphasizing the need for a global approach to ensure equitable access to water resources. This recognition should not imply free and unlimited access but rather responsible consumption and measures to reduce waste.

By establishing limitations on water consumption and promoting the worldwide recognition of the human right to water, we can mitigate the risks associated with water scarcity and foster equitable access to this vital resource. Such measures address immediate challenges and contribute to long-term sustainability and resilience in the face of evolving environmental and demographic pressures.

Due to its abundance and importance, water management is considered one of the critical challenges facing humanity in the twenty-first century. The World Wildlife Fund estimates that over 1 billion people struggle to source safe drinking water, while 2.7 billion people endure water scarcity for at least one month annually. The lack of clean drinking water will continue

To be one of the greatest humanitarian crises in the coming years, recognized as one of the most significant future threats to global pandemic response efforts, prompting some countries to take risk-mitigation measures.

1.The Global Water Crisis

Water stress, a condition where there's insufficient water of good quality to meet the demands of both people and the environment, is on the rise globally. Figure 1, a map from the World Resources Institute, provides a overview of global water risk, highlighting regions with varying levels of risk from low (yellow) to extremely high (red).

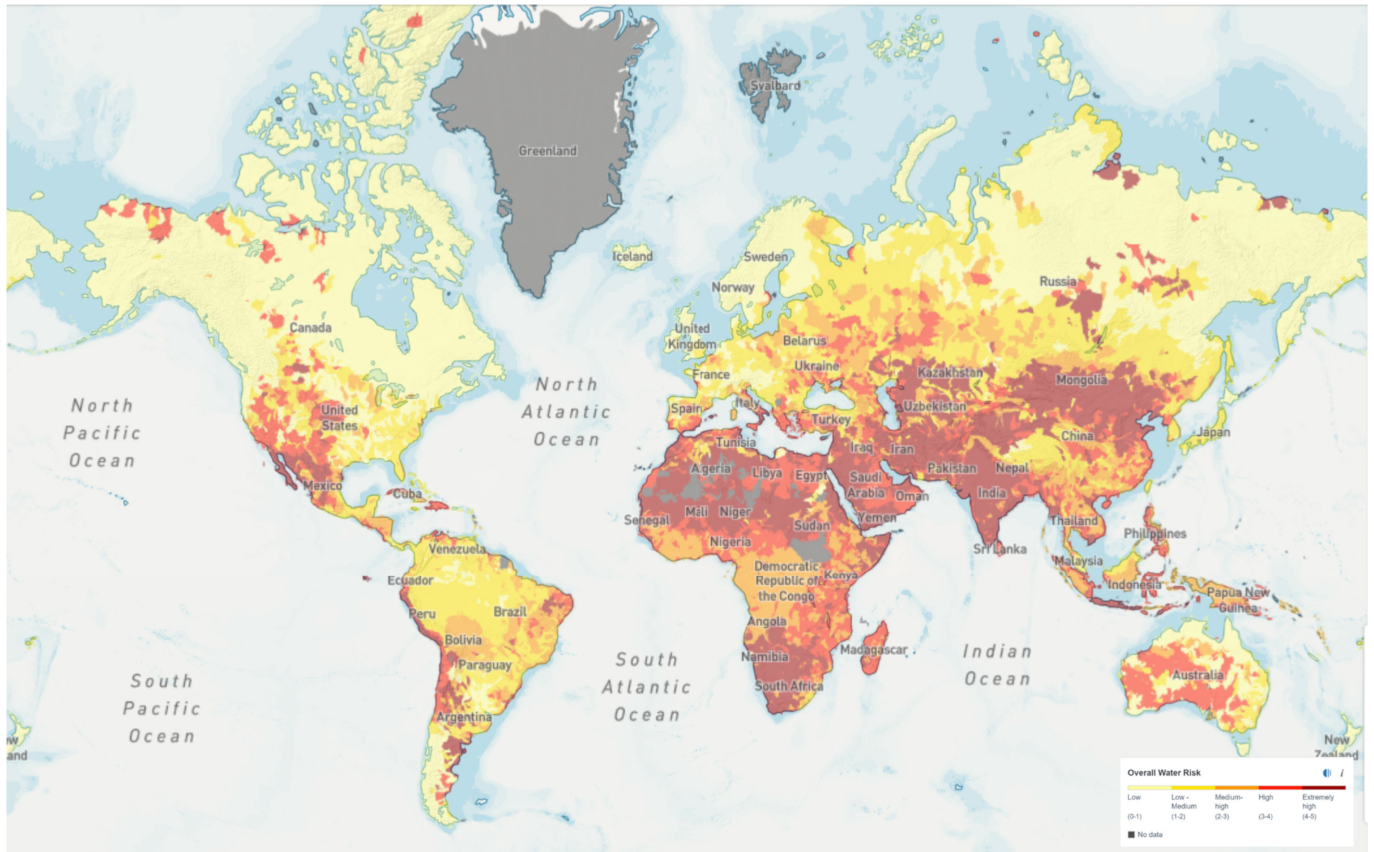


Figure 1 : Map of Global water risk ; Source: World Resource Institute

Key observations reveal hot spots of water risk predominantly in Africa, the Middle East, South Asia, East Asia, Australia, and parts of the Americas.

These high-risk areas face challenges due to limited freshwater availability, increasing demand, poor water management, and environmental degradation. These challenges have profound implications, affecting sustainable development, agriculture, industry, and human health. Furthermore, climate change exacerbates these issues by altering precipitation patterns and increasing the frequency of droughts. To address these urgent water-related challenges, strategic interventions such as investment in water infrastructure, promotion of sustainable practices, and international cooperation are essential.

The second figure projects water stress trends for 2050, indicating intensification and expansion of high-stress zones, particularly in Africa, the Middle East, South Asia, East Asia, and parts of the Americas. Factors such as population growth, climate change, and economic development contribute to heightened water stress, which necessitate infrastructure investment, sustainable practices, and effective policy governance.

By comparing the current and projected water stress maps, it's evident that proactive measures are imperative to manage water resources sustainably and ensure water security for affected regions. Strategic recommendations include investing in water infrastructure, promoting sustainable practices, developing climate adaptation strategies, and fostering international cooperation to mitigate future risks effectively.

Comparing the two maps reveals that many current high-risk areas will continue to experience high stress, indicating persistent and possibly worsening conditions due to population growth, economic development, and climate change.

In contrast, low-risk zones remain stable, suggesting effective water management practices. The persistence of high-stress zones underscores the need for long-term water management strategies, infrastructure investment, sustainable practices, and strong policy frameworks to address future water challenges and ensure water security.

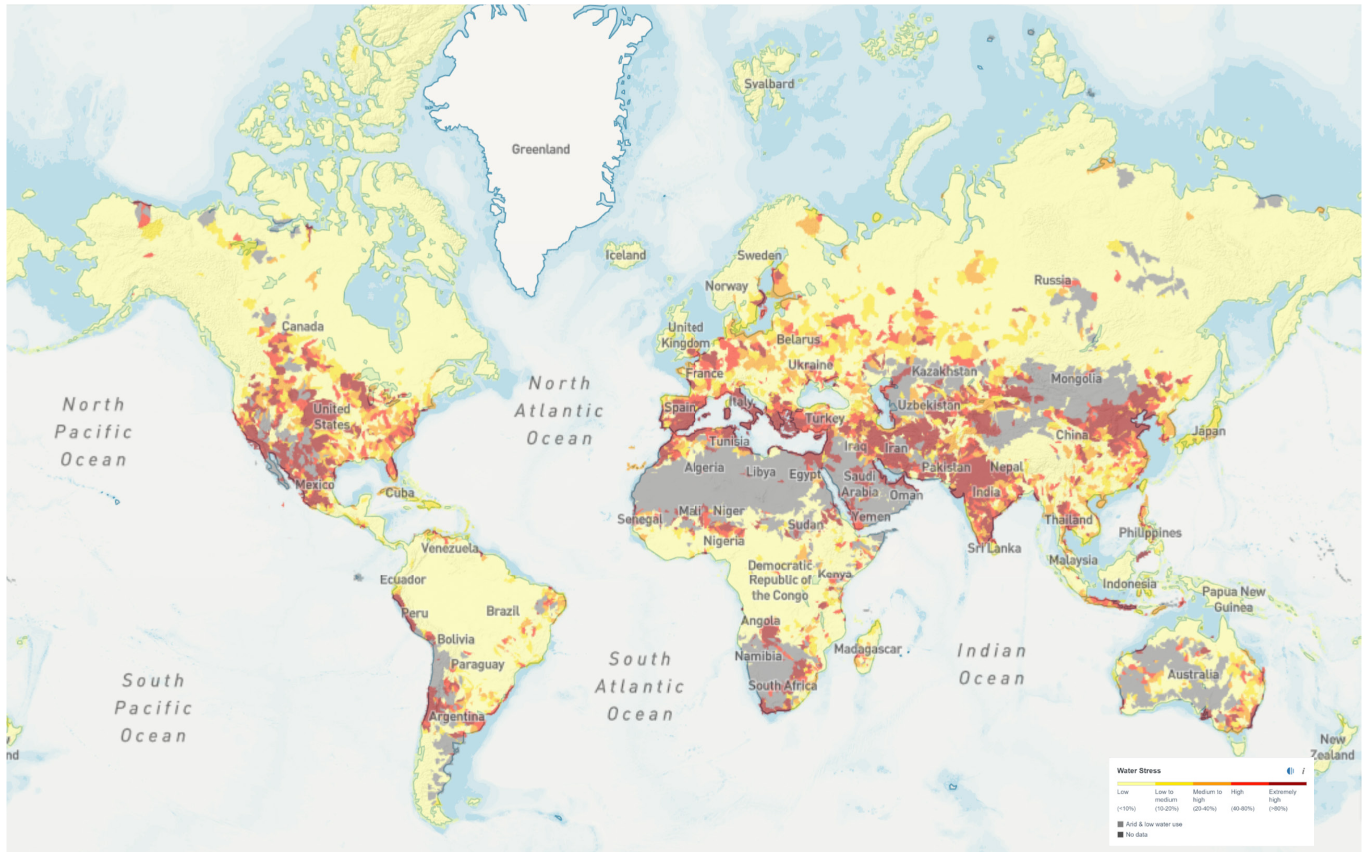


Figure 1 : Map of water stress trend in 2050 ; Source: World Resource Institute

1.1.Water and Climate Change: A Global Imperative

Climate change poses a formidable threat to the world's water resources, with urgent consequences for millions of children globally. According to a report by UNICEF released on March 15, 2024, climate change-induced disruptions in weather patterns are leading to more frequent and intense extreme weather events, exacerbating water scarcity, and contaminating water supplies. This has a profound impact on children's access to safe water, which is essential for their survival.

The report highlights that extreme weather events and changes in water cycle patterns are making it increasingly challenging to access safe drinking water, particularly for vulnerable children. With approximately 74 percent of natural disasters between 2001 and 2018 being water-related, the frequency and intensity of such events are expected to escalate due to climate change. Around 436 million children live in areas of high or extremely high water vulnerability, where water scarcity and low levels of drinking water service intersect, placing them at heightened risk.

Disasters, such as floods and droughts, can destroy or contaminate entire water supplies, increasing the risk of waterborne diseases like cholera and typhoid, to which children are particularly vulnerable. Rising temperatures also facilitate the proliferation of deadly pathogens in freshwater sources, further jeopardizing children's access to safe water. Contaminated water poses a significant threat to children's lives, as water and sanitation-related diseases remain leading causes of death among children under 5 years old.

Moreover, climate change exacerbates water stress, leading to increased competition for water resources and potential conflicts. By 2040, almost one in four children is projected to live in areas of extremely high water stress. Rising sea levels are also compromising freshwater sources, further jeopardizing essential water resources relied upon by millions.

The urgency of addressing these challenges is underscored by the fact that climate change is happening now. UNICEF emphasizes the importance of adapting water and sanitation services to mitigate the water-related effects of climate change, which will protect children's health and save lives. Transitioning to solar-powered water systems and improving water efficiency can also reduce greenhouse gas emissions, contributing to safeguarding children's futures.

1.2. Safe Water: Right for All

In addition to addressing the impacts of climate change, ensuring access to safe water, sanitation, and hygiene is critical for children's well-being, as emphasized in another UNICEF report released on March 14, 2024. Safe water, sanitation, and hygiene are fundamental for preventing the spread of diseases and promoting maternal and child health.

The report highlights that 2.2 billion people still lack access to safely managed drinking water, and 3.6 billion people do not have access to safely managed sanitation. This lack of access disproportionately affects rural populations, with 8 out of 10 people who lack even basic drinking water living in rural areas.

Moreover, the report emphasizes the critical role of handwashing with soap and water in preventing the spread of diseases, yet 2.3 billion people still lack basic handwashing facilities at home. Climate change further exacerbates these challenges by destroying, drying up, and contaminating water sources, placing additional strain on already vulnerable communities.

To address these issues, UNICEF calls for greater political prioritization and increased funding to improve household access to water, sanitation, and hygiene, particularly targeting communities most at risk. Achieving Sustainable Development Goal 6, which aims to ensure access to safe water, sanitation, and hygiene for all, requires concerted efforts and investments in building resilient water and sanitation systems.

In conclusion, addressing the challenges posed by climate change and ensuring access to safe water, sanitation, and hygiene are critical for safeguarding the health and well-being of children worldwide. By taking proactive measures and prioritizing investments in water and sanitation infrastructure, we can mitigate the impacts of climate change and ensure a healthier and more sustainable future for all. (UNICEF, 2024)

1.3.Climate Change and Freshwater in Italy

Italy, facing many challenges adapting to climate change, currently experiences widespread impacts of climate change, including an increase in extreme events such as heatwaves, droughts, and more frequent flooding[1][2]. As a result, the preservation of the coastal city of Venice has become crucial due to the impact of sea level rise[3]. The economic, social, and environmental impacts of climate change, coupled with the escalating health risks, pose significant challenges for Italy[4]. In response, Italy has taken proactive measures such as making education on climate change compulsory and incorporating environmental protection into its constitution to safeguard future generations[5] [6]. Additionally, Italy is actively involved in international agreements like the Paris Agreement and the EU Adaptation Strategy, as well as bilateral treaties focused on sustainable development, climate defense, and biodiversity protection[7]. To further mitigate its environmental impact, Italy is transitioning towards a more sustainable consumption model, prioritizing renewable energy over fossil fuels.[8]

1.3.1. Causes

The factors responsible for the greenhouse gas emissions in Italy are:

1. Energy consumption: Italy is the 3rd largest consumer of energy in the European Union after Germany and Franc. Italy's significant consumption of energy, primarily derived from petroleum products like petrol and natural gas, contributes to greenhouse gas emissions. Italy's dependency on imported energy, particularly natural gas from Russia, further exacerbates this issue .[9]

2. Transportation: Italy's transportation sector is a major contributor to greenhouse gas emissions. Over the years, emissions from this sector have shown fluctuations, with a peak around 2005. Despite some reduction efforts, emissions have remained significant, with Italy emitting approximately 100 to 106 million tonnes of CO2 annually until 2019. In 2022, there were attempts to weaken EU rules on car emissions, reflecting ongoing challenges in reducing emissions from transportation.[10] [11] [12]

3. Fossil fuels: Italy's reliance on fossil fuels, including petroleum, natural gas, and coal, for energy production and heating is a significant source of greenhouse gas emissions. Although renewable energy sources like wind and solar power have seen growth, fossil fuels remain dominant.[13] [14] [15]

4. Industrial emissions: Industrial activities in Italy have historically contributed to greenhouse gas emissions. While emissions increased until around 2008, efforts to transition to renewable energy sources have led to a decline since then. Most industrial emissions stem from energy supply for electricity and manufacturing processes. [16] [17] [18][19] [20]

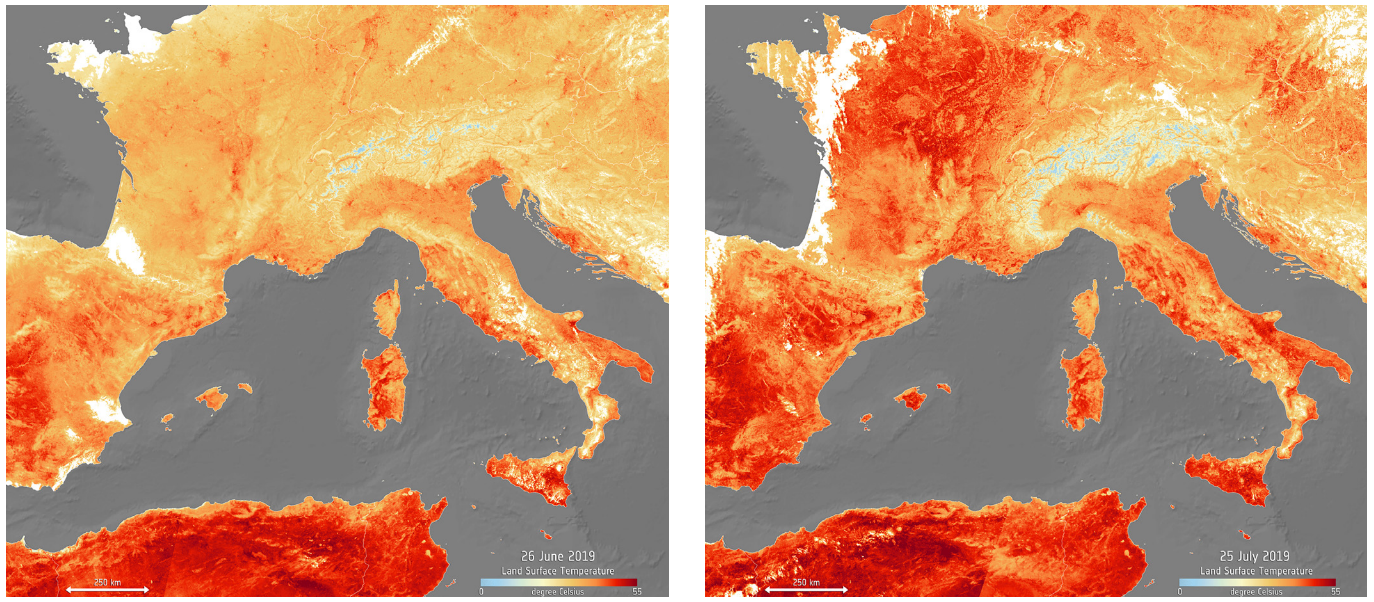


Figure3. Land Surface temperature ; Source: ESA Standard Licence . Note: It is getting increasingly hot all over the world, Italy being just one of many feeling the negative affects.

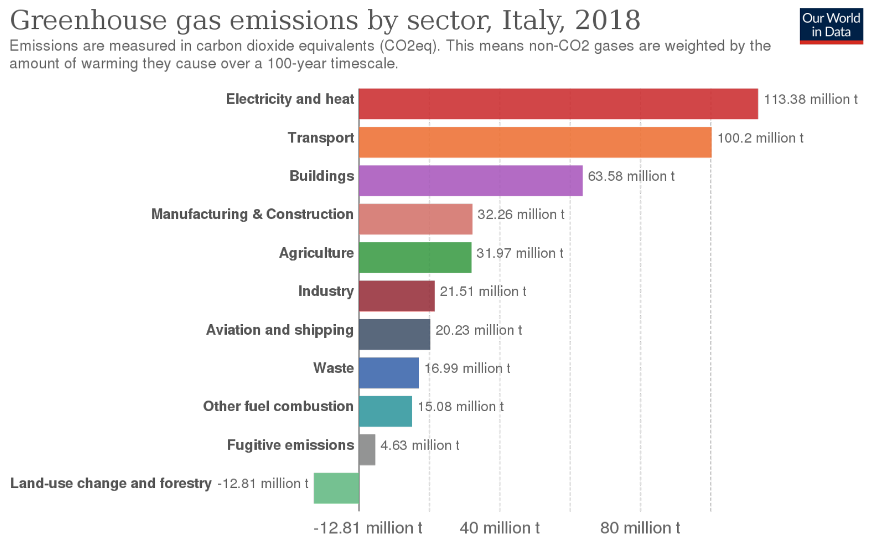
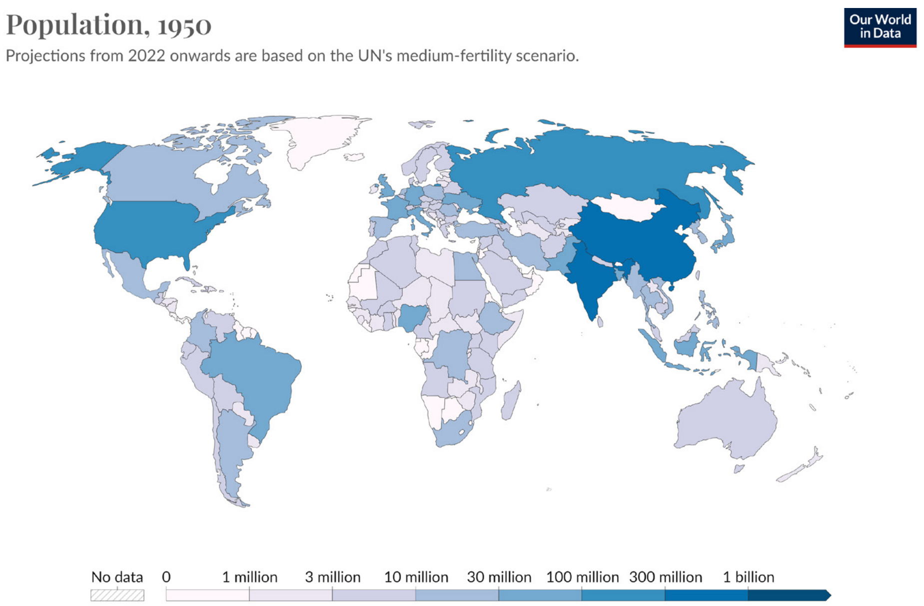
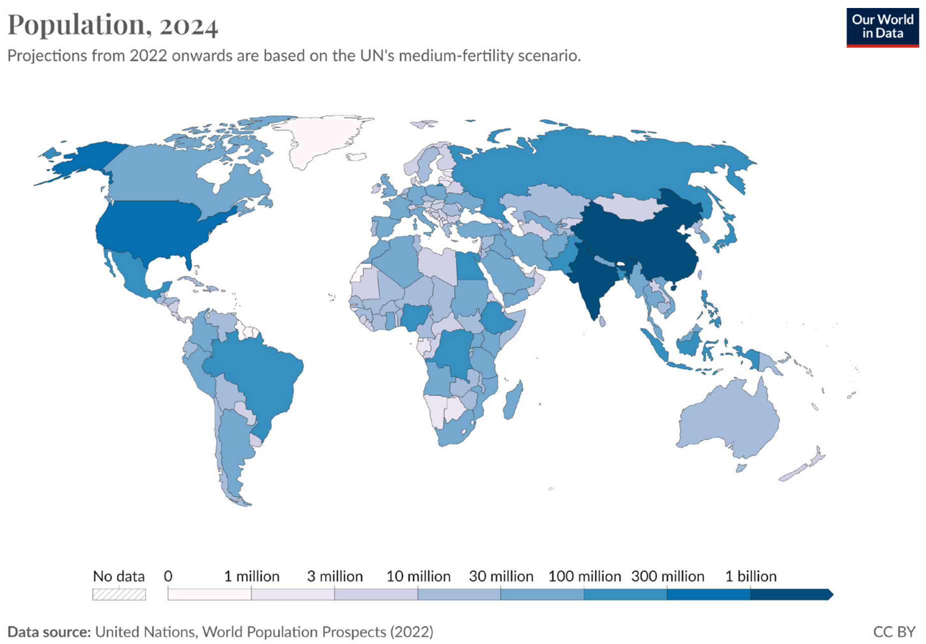


Figure 4: Greenhouse gas emissions by sector ,Italy ,2018Source: CAIT Climate Data Explorer via Climate Watch(www.ourworldindata.org) . Note: Greenhouse gases are weighted by their global warming potential value (GWP100). GWP100 measures the relative warming impact of one molecule of a greenhouse gas, relative to carbon dioxide, over 100 years.





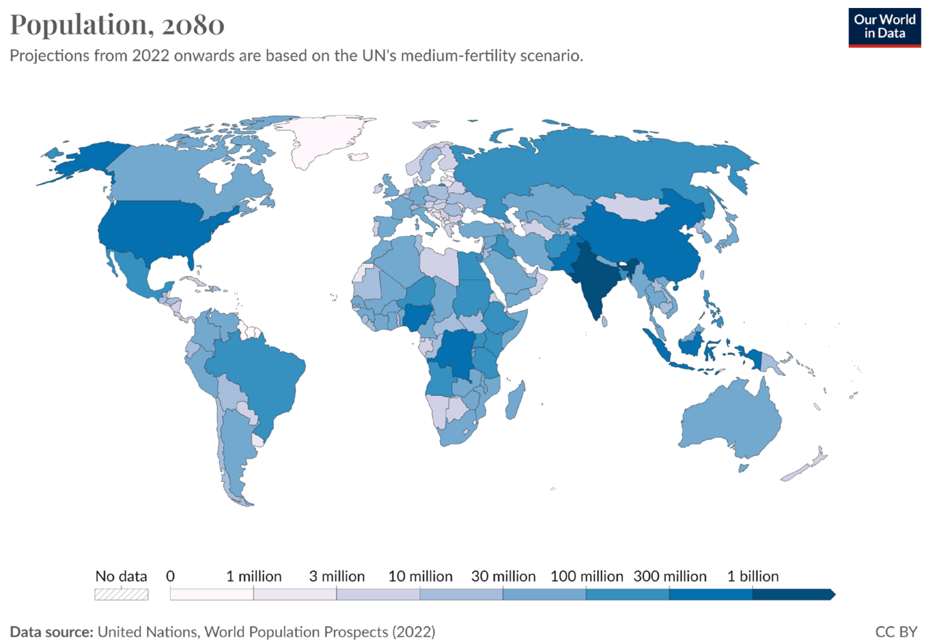


Figure5. Population in 1950 , 2024 and 2080; Source: United Nations

5. Forests: While not directly emitting greenhouse gases, forest management practices and wildfires in Italy can impact carbon sequestration and release. Efforts to manage forests and combat wildfires are essential in mitigating emissions indirectly related to forest cover.[21] [22] [23]

1.3.2. Effects

The impacts on the natural environment in Italy are substantial and diverse, affecting various aspects such as temperature and weather patterns, sea level rise, water resources, ecosystems, and biodiversity.

1. Temperature and Weather Changes: The climate in Italy is undergoing notable changes, including rising temperatures, melting glaciers, an increase in extreme floods due to rising sea levels and heavy rainfall, and more frequent and prolonged droughts[24]. These variations were particularly evident in July 2021, where heavy rains caused significant damage, followed by a record-breaking temperature of 48.8 degrees Celsius in Sicily a month later, prompting red alerts in 26 cities.[25] Furthermore, Italy has experienced a decrease in precipitation, with the winter of 2022 leaving the country with one-third less rainfall. Despite this, the average temperature has increased, both in winter and summer.[26] [27]
2. The Italian climate is gradually shifting towards tropicalization, with consequences attributed to climate change[27]. These changes are observable at a regional level, such as temperature fluctuations in the Lazio region, home to Rome, one of Italy's warmest regions [24]. Rome itself has seen a rise in its average temperature from 14.6°C in 1980 to 16.3°C in 2022, indicating a warming trend over the past four decades. Further analysis reveals that between 1900 and 2018, temperatures in July and January have increased by 1.4°C and 1.2°C, respectively, with this upward trend continuing [24].
3. Looking ahead, two scenarios have been outlined for Italy based on IPCC reports[28]. The first scenario (RCP4.5) predicts a gradual increase in greenhouse gas emissions before stabilizing and decreasing by the end of the century, while the RCP8.5 scenario depicts the most extreme case with no regulation of emissions. Both scenarios anticipate an increase in temperature, fewer cold days, longer dry spells, and reduced summer rainfall in Italy between 2021 and 2100, with notable differences in precipitation patterns between the north and south of the country.[30]
4. Short-term projections from 2021 to 2050 indicate a further temperature increase of up to +2°C for southern Italy during June, July, and August under the RCP8.5 scenario[31]. The impacts of climate change are becoming increasingly visible, with the year 2022 classified as the fifth hottest year ever recorded in Italy. These changes not only affect temperature and weather patterns but also lead to modifications in sea levels, highlighting the urgency of addressing climate change.[32]
5. Sea Level Rise: With global warming, polar ice caps and glaciers are melting, leading to a rise in sea levels. Coastal areas in Italy are particularly vulnerable to flooding, posing risks to human settlements, infrastructure, and ecosystems. Increased human activities along coastlines exacerbate these risks.[33] [34] [35]
6. Water Resources: The risk of groundwater contamination arises from the anticipated rise in sea levels and increased flooding along the Italian coastlines. This poses a threat of saltwater intrusion into coastal freshwater beds, potentially leading to soil desiccation due to diminished freshwater resources.[36] [37]
7. Studies conducted in southern Italy, particularly in regions like Murgia and Salento, shed light on the local impacts of rising sea levels. These areas heavily rely on groundwater for both irrigation and drinking purposes. However, the natural replenishment rate of freshwater into groundwater aquifers is insufficient, rendering them vulnerable to exploitation (e.g., through illegal wells) and intrusion by seawater. Consequently, certain locations along Salento's coast have already experienced salinity levels of up to 7 g/L. Continued salinization is expected to significantly reduce groundwater discharge, resulting in up to a 16% decrease in water availability for household use .[38]
8. The severity of the situation became apparent in the summer of 2022 when the government declared a state of emergency due to drought conditions affecting the River Po.[39]
9. Ecosystems: Climate change impacts ecosystems throughout Italy, leading to habitat destruction, wildfires, and loss of biodiversity. Sensitive ecosystems like karst landscapes are particularly vulnerable to human activities such as quarrying, deforestation, and pollution. Coastal ecosystems face ad-

ditional threats from infrastructure development like railways and sea walls, contributing to habitat loss and degradation.[40][41][42][43][44]

10. Biodiversity: Increased temperatures and extreme weather events pose significant threats to biodiversity in Italy[48][49]. Droughts, wildfires, and habitat destruction due to urbanization lead to declines in species populations and ecosystem health. Conservation efforts are crucial to protecting Italy's rich biodiversity, which comprises a significant portion of Europe's species[48][51].

Overall, these impacts underscore the urgent need for mitigation and adaptation strategies to address climate change and protect Italy's natural environment for future generations.

2. Role of Cities

Cities play a crucial role in dealing with water and climate challenges. They face issues like climate change, infrastructure challenges, and rapid urbanization and population growth. They stand at a critical nexus where the impacts of climate change intersect with the demands of growing urban populations, making them both highly vulnerable and potentially transformative in addressing these challenges. A recent example is the water problem in Chennai, India, which shows how cities worldwide struggle with similar issues , . where natural water resources, exacerbated by climate changes, are strained by population growth and inadequate management practices.

Several factors underscore the importance of cities in addressing water and climate challenges. The United Nations estimate that by 2050, two-thirds of the global population will reside in cities. Concentration of people places immense pressure on urban infrastructure, much of which is susceptible to extreme weather events like floods and droughts. Moreover, essential services in cities, including water supply, from domestic use to industrial production, are intricately linked to water availability and a reliable water supply.

Furthermore, the interconnection between water and energy is crucial to consider. Providing clean water to people needs a lot of energy, from treating water to delivering it to homes and businesses. So, it's crucial to think about how water and energy are connected when planning cities.

But cities face a big problem: there's more demand for water, but resources are getting scarce because of climate change. This concentration of people places immense pressure on urban infrastructure, much of which results in extreme weather events like floods and droughts. This puts cities in a tough spot, making it crucial for them to deal with water and climate issues.

To tackle these tough challenges, cities need to change how they think about things, as Einstein suggested. Creating smart cities for the future It is essential to look at everything related to water, encompassing water demand, supply, and management. This includes finding ways to reducing waste, enhancing efficiency, and reevaluating economic priorities to manage water demand effectively.

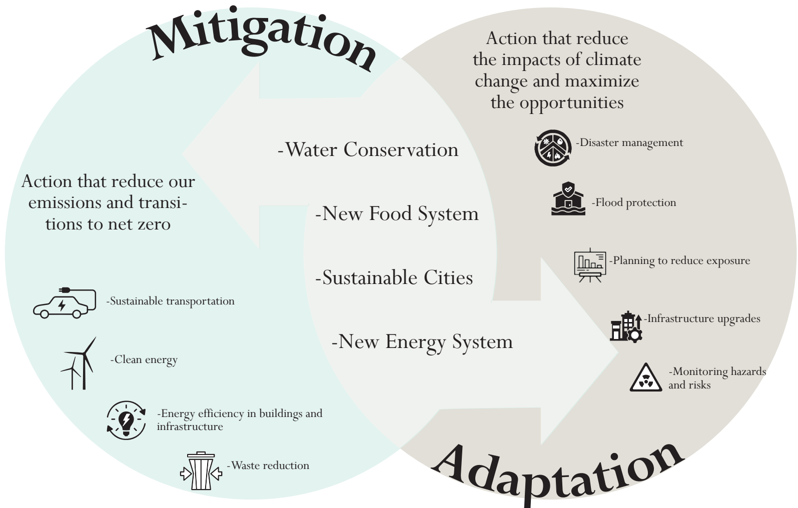


Figure6. Mitigation and adaptation ; Source:Provided by the author

Also, any innovative solutions and technology to make cities better at water monitoring and data analysis must also consider the climate. At the same time, Climate-resilient cities require both adaptation and mitigation measures .

Climate Resilient Cities: Adaptation and Mitigation

Addressing climate change involves two primary strategies: adaptation and mitigation. To build resilience and smart cities, they must invest in both preparatory and adaptive measures, setting ambitious yet achievable goals that translate into tangible risk management strategies. Effective adaptation efforts are essential for reducing vulnerability and enhancing resilience to the existing impacts of climate change. It's crucial to recognize that mitigation and adaptation strategies are interconnected and must be pursued together to effectively combat climate change.[53][55]

2.1. Mitigation

Mitigation involves efforts directed at reducing the severity of climate change impacts by taking action to prevent or decrease the emission of greenhouse gases into the atmosphere. By taking action preventing the emission of greenhouse gases into the atmosphere, mitigation endeavors to alleviate the overarching impact of climate change on the environment and society.[53][55]

Climate change mitigation

Climate change mitigation involves a range of strategies and actions designed to prevent the long-term impacts of climate change. At its core, mitigation focuses on the reduction of greenhouse gas emissions. This involves implementing policies and practices aimed at managing heat emissions, principally working towards a more sustainable future for urban areas and their residents.[53][55]

Climate change Mitigation Strategies

These strategies aim to comprehensively address heat-related challenges from various perspectives, catering to different vulnerable groups and fostering urban heat resilience within planning frameworks.

- Mobility: To meet the European Union's carbon reduction objectives , which aim to limit temperature increase to 1.5°C and achieve net-zero greenhouse gas emissions, and cultivate more livable cities, mobility strategies must prioritize walkability, cycling infrastructure, and improved access to public transportation. Additionally, promoting shared mobility options at the street level can ensure equitable transportation access for all.
- Grey Infrastructure: Implementing shade structures, cool pavements, and optimizing building and street orientations are essential components of grey infrastructure initiatives.
- Green Infrastructure: Urban greening involves creating a network of planned and unplanned green spaces within cities, offering multiple benefits such as cooling effects, shading, reduction of heat island effect , flood risk reduction, creation of ecological habitats, and enhancing psychological well-being.
- Water Infrastructure: As mentioned previously, climate change exacerbates water demand during extreme heat events, putting stress on water capacity and leading to unequal access to potable water. Therefore, implementing effective water management strategies is crucial to address water scarcity issues and ensure equitable access to water resources.[53][55]

Developing mitigation & adaptation strategies: case study for Porte de Montreuil

The Porte de Montreuil urban project is a comprehensive initiative aimed at revitalizing and transforming the area into a sustainable, interconnected, and vibrant metropolitan square. Situated on the eastern belt of Paris, covering approximately 35 hectares, this project is part of a broader strategy to upgrade the gateways to Paris into metropolitan areas of Greater Paris. It extends from Porte de Bagnolet in the north to Porte de Vincennes in the south and is strategically located to improve connections between Paris and its neighboring cities, particularly Montreuil and Bagnolet.[53][54][55]

The vision for the project revolves around creating a dynamic and multi-functional public space that serves as a gateway between the three surrounding communities. This square will undergo a significant transformation to become a focal point for social interaction, cultural exchange, and economic activity while ensuring landscape continuity and environmental sustainability.[53][55]

Key objectives of the project include:

1. Reducing Motor Traffic: A primary focus is on reducing motor traffic along the ring road by relocating vehicle traffic to the periphery of the roundabout. This will improve pedestrian safety and accessibility within the area.

2. Enhancing Pedestrian Safety and Accessibility: By prioritizing pedestrians and creating a sizable public space at the center of the square, the project aims to enhance pedestrian safety and accessibility, making it more conducive to walking and cycling.

3. Fostering Economic Growth: The project seeks to stimulate economic growth by revitalizing the Montreuil flea market and fostering better connectivity with neighboring areas. This includes creating opportunities for local businesses, entrepreneurs, and artisans.[53][54][55]

4. Environmental Sustainability: Environmental sustainability is a core pillar of the project. It aims to become Paris's first zero-carbon neighborhood by implementing innovative approaches to reduce emissions. This includes on-site geothermal and photovoltaic energy production, as well as the use of sustainable construction materials.

5. Green Belt and Biodiversity: The project incorporates a green belt strategy, featuring heavily planted permeable surfaces to improve biodiversity and provide habitat for urban wildlife. This not only enhances the ecological value of the area but also contributes to the overall well-being of residents.

6. Flexibility and Innovation: The project emphasizes flexibility in programming and design, with 100% of the spaces designed to be reversible, allowing for adaptability over time. This includes the ability to convert spaces from offices to housing, minimizing the need for future demolition and construction.[53][54][55]

7. Localized and Responsible Economy: A key focus is on promoting a localized and responsible economy, with close attention paid to the origin of materials and equipment used for the project. Approximately 80% of construction materials are sourced from the Paris surroundings, supporting local businesses and reducing the project's carbon footprint.

2.2. Adaptation

Adaptation involves proactively recognizing the adverse effects of climate change and implementing measures to prevent or mitigate them. Essentially, it requires adjusting to current conditions while anticipating the future consequences of climate change. From an urban standpoint, adaptation relates to the process of responding to the challenges and transformations in the urban environment. The most important point of understanding adaptation lies in its post-strategy aspect—a response mechanism devised by people, communities, and local stakeholders to address existing climate-related challenges. Individuals within cities and territories are increasingly exposed to the impacts of climate change, and adaptation involves the capacity to respond to these challenges through strategic actions and behaviors.[53][54][55]

Figure7 : Porte De Montreuil; source : porte-de-montreuil

Urban Adaptation

Urban adaptation involves the development of strategies and policies aimed at enhancing the resilience and sustainability of cities. Urban adaptation recognizes cities' vulnerability to multiple pressures like climate change, population growth, and resource constraints. Successful implementation requires thorough risk assessments using robust data and models to develop flexible adaptation measures. Inclusive stakeholder involvement is vital for effective decision-making, alongside adequate financial and technical resources to support planning and implementation. [53][54]

City adaptation policies and strategies

Urban adaptation policies and management strategies play a crucial role in shaping resilient cities able to live alongside the challenges posed by climate change. These policies serve as a strategic framework, guiding actions, resource allocation, and regulatory measures necessary for adaptation efforts. [53][54][55]

Key strategies aimed at enhancing urban resilience, sustainability, and livability include:

- Climate-resilient infrastructure: Cities can enhance their resilience by investing in infrastructure designed to withstand the impacts of climate change, such as extreme weather events and rising temperatures.
- Integrated urban planning and design: Incorporating adaptation considerations into urban planning processes is essential. This involves integrating climate risk assessments and vulnerabilities into land-use planning, infrastructure development, and building design. Strategies may include incorporating green spaces, implementing sustainable transportation options, and promoting mixed land use to mitigate climate risks and enhance overall urban resilience.
- Community engagement and capacity building: Engaging with local communities, stakeholders, and residents is critical for raising awareness and building capacity to adapt to climate change. This may involve education and outreach programs, participatory planning processes, and community-based adaptation initiatives that empower communities to take ownership of adaptation efforts. [53][54][55]
- Water management: Effective water resource management is essential for urban adaptation. Cities can implement strategies such as rainwater harvesting systems, constructing water storage facilities, water conservation measures, stormwater management systems, and floodplain zoning to mitigate water-related risks and ensure water security in the face of climate change-in-

duced challenges like droughts and floods.

- Coastal protection and sea-level rise adaptation: Coastal cities facing sea-level rise and coastal erosion can implement adaptation measures such as coastal defense infrastructure, beach nourishment projects, and ecosystem-based approaches like mangrove restoration to protect coastal communities and infrastructure from the impacts of sea-level rise and storm surges.
- Data-driven decision-making: Investing in robust data collection, monitoring, and analysis systems is essential for informed decision-making in urban adaptation. Cities can leverage data and technology to assess vulnerabilities, track climate-related risks, and prioritize adaptation measures based on scientific evidence and local context.

Example of Resilient city: Urban Canopy in Toulouse, France:

The Urban Canopy project in Toulouse, France, was initiated by start-up Urban Canopy, in collaboration with the city council of Toulouse and the Pont Paris Tech school. The canopies are designed to address the urban heat island effect in the area, as well as to increase biodiversity and reduce air pollution. The installation process is self sufficient, with a reserve supplied by rainwater and an electronic box ensuring autonomy. A drip irrigation system is installed using sensors linked to the control box, which activates automatically when the plant is fully grown after three years. The canopies create shaded areas, which help to reduce the temperature below them by avoiding the absorption of heat by the ground. This project is a cost-effective way of improving the outside temperature and reducing air pollution while increasing biodiversity. [53][54][55]

3. Smart Cities, Smart Water

Every city facing infrastructure or operational challenges or concerns about maintaining quality of life in the face of population growth, or a changing environment has benefits to gain from a unified smart-city approach. Amid the array of smart city components, water management strategies emerge as a pivotal aspect. Smart city technology has proven to be a game changer in water management, revolutionizing how cities handle their water resources. Harnessing technology to optimize water usage, prevent waste, and ensure equitable distribution forms a cornerstone of smart city sustainability. Leveraging innovation to improve water management leads to increased efficiency, cost savings, and proactive decision-making. By optimizing water management processes with accurate and real-time data, smart cities can increase infrastructure efficiency, reduce energy consumption, and lower costs.[15][35] Here are some concepts for promoting understanding and acceptance among utility and government decision-makers, plus several examples of benefits already being garnered by smart cities large and small.[56][57]

3.1. Benefits

Cost-Benefit Advantages: The adoption of smart-grid advanced metering infrastructure (AMI) in the water industry yields economic benefits beyond revenue maximization, extending to utility and city management. This includes optimizing maintenance activities to realize additional savings while enhancing water distribution efficiency.[58]

Energy Efficiency: Utilizing real-time data analysis to monitor pump and blower performance and aligning operations with forecasted demand patterns significantly reduces energy consumption. This not only lowers operational costs but also contributes to environmental sustainability by minimizing the carbon footprint associated with water management.

Water Conservation: Smart-city initiatives that assess various factors such as source water quality, treatment efficiency, and consumption patterns enable proactive decision-making to address water scarcity challenges. By identifying opportunities for water reuse and promoting efficient usage behaviors, cities can better manage their water resources amidst population growth and changing climatic conditions.[58][59]

- Future Preparedness: The adaptive nature of smart-city strategies ensures resilience in the face of evolving urban challenges. This includes accommodating the impacts of population growth on infrastructure demand through cost-effective solutions and leveraging digital technologies to optimize resource allocation and infrastructure utilization.
- Optimized Resource Allocation: By pooling resources for essential functions like billing and data communication, smart cities achieve economies of scale while maximizing the efficiency of existing infrastructure. Additionally, integrating sustainable energy sources into water management processes contributes to long-term resource optimization and environmental stewardship.
- Streamlined Workforce Transition: Smart-city platforms facilitate seamless knowledge transfer as experienced personnel retire, ensuring continuity in operations and service delivery. Automation and digitization of operational support systems simplify on boarding processes for new employees, enabling smoother workforce transitions and preserving institutional knowledge.


Figure 8. Urban Canopy project in Toulouse, France ; Source : www.urbancanopee.com.au

3.2. Encompassing All Dimensions

The benefits of smart city implementation in terms of cost-effectiveness and performance today are just the tip of the iceberg, with potential for rapid expansion into other interconnected advantages. For instance, regions suffering from periodic water scarcity can amplify resource conservation efforts by identifying and rectifying non-revenue water losses due to leaks, optimizing pipeline pressure, and fine-tuning energy consumption. As water stress persists or escalates, insights derived from smart-water systems can expedite the transition to water reuse, marking a significant leap in operational efficiency.[58][59]

A smart-city strategy goes beyond current operational management, emphasizing preparing for the future. The ability to accommodate future growth without making existing infrastructure obsolete is crucial for sustaining economic development and preserving residents' quality of life while ensuring affordable utility rates. Integrating data management across regional infrastructure — including utilities, communication networks, and emerging electric-vehicle charging stations — creates new benefits extending beyond the individual services provided. This integration facilitates:

- Enhanced communication efficiency and rapid emergency response times.
- Facilitation of collaborative efforts yielding cost-effective outcomes.
- Driving forward environmentally responsive initiatives.

3.3. Water-Smart Cities

Smart city capabilities offer a diverse range of applications at various cost and capability levels, making them accessible and beneficial to cities and water utilities of all sizes. Within the realm of water management, solutions can broadly be categorized into two main categories: water-smart innovative-based and water-smart low-impact development solutions. However, regardless of the chosen approach, the consideration of investment costs and potential returns is paramount. [60]

3.3.1. Water-Smart Innovative-Based Solutions:

The discourse on Information and Communication Technology (ICT) tools in the water sector underscores the global challenge of water scarcity and the potential of ICT to address it. ICT encompasses technologies enabling access, storage, transmission, and processing of information. The integration of ICT tools in the water sector has gained momentum over the last decade, with hydro-informatics systems being at the forefront. These systems employ advanced sensors like LIDAR to gather detailed data on hydro-environments, aiding in better management of water resources. The European Union has prioritized ICT applications for sustainable growth, recognizing their role in natural resource management.[60][61][62][63][64]

ICT tools play a pivotal role in improving land and water management, particularly in regions facing water scarcity. They facilitate efficient water supply and irrigation management, leading to enhanced food production. These tools enable the collection, processing, and management of remote data, which would otherwise be challenging and costly. Additionally, ICT tools offer various capabilities such as saving and transferring information quickly, improving standardized procedures, and fostering collaboration and communication. [60][61][62][63][64]

The discussion extends to specific ICT applications in the water sector, including meters, sensors, SCADA systems, and information systems like Geographic Information Systems (GIS) and Enterprise Resource Planning (ERP) systems. These technologies aid in monitoring water quality, detecting leakages, optimizing energy consumption, and enhancing decision-making processes. Furthermore, hydraulic models and decision support systems are highlighted for their role in effectively managing water distribution networks and addressing challenges in urban water management. Overall, the integration of ICT tools holds promise for achieving sustainable water resource management and addressing the complex challenges posed by water scarcity. [60][61][62][63][64]

Water-smart innovative-based solutions entail the adoption of cutting-edge technologies and advanced strategies to optimize water management processes. While these solutions may require higher initial investments, they often promise significant long-term benefits in terms of efficiency, reliability, and sustainability. Some examples include:

1. Smart Metering and Monitoring: Deploying sensors and IoT-enabled devices throughout the water distribution network to monitor usage in real-time, detect leaks, and optimize water flow.
2. Advanced Water Treatment Technologies: Implementing membrane filtration, reverse osmosis, or UV disinfection systems to purify wastewater for direct reuse or replenishment of water sources.
3. Integrated Water Management Platforms: Utilizing data analytics and modeling software to integrate various components of the water cycle, from supply and distribution to consumption and wastewater treatment, for holistic management and optimization.
4. Desalination Plants: Investing in desalination infrastructure to convert seawater or brackish water into freshwater, thus diversifying water sources and mitigating the impacts of droughts or water scarcity.

These innovative-based solutions represent the frontier of water management technology, offering unparalleled efficiency and resilience in the face of increasingly complex water challenges. [60][61][62][63][64]

In Västerås, Sweden, despite its modest population of 150,000 residents, the municipal utility has embraced a comprehensive smart city approach that extends well beyond water and wastewater management. Their initiative spans data networks, electric vehicle charging infrastructure, hydropower generation, the power grid, emergency management, and predictive maintenance for roads, lights, and other city assets. [60][61][62][63][64]

Meanwhile, in Ho Chi Minh City, Vietnam, home to over 10 million residents, the adoption of a smart city approach was prompted by the urgent need to address the significant loss of treated drinking water—almost 30 percent—due to aging infrastructure. By harnessing real-time insights derived from digital data collected across the water distribution network, the city's water utility aims to cut water losses, enhance drinking water quality, and improve residents' living standards.

The Pure Water San Diego , United States, initiative serves as a example of an integrated water reuse program devised to counterbalance the rising costs associated with importing drinking water from external sources. Embedded within this smart city's water sustainability program, it contains a range of strategies, including water conservation, recycling, and reuse initiatives. These projects underscore how smart city principles help communities to manage growth and cope with quality-of-life challenges through collaborative resource management and information sharing across multiple utilities.[60][61][62][63][64]

3.3.2. Water-Smart Low-Impact Development Solutions:

Water-Smart Low-Impact Development Solutions refers to approaches and strategies aimed at managing water resources in an environmentally friendly and sustainable manner while minimizing negative impacts on the surrounding environment. This concept integrates "water-smart" practices, which emphasize efficient and responsible water use, with low-impact development techniques, which focus on managing stormwater runoff and preserving natural hydrological processes. [60][61][62][63][64]

Water-smart solutions often include measures such as rainwater harvesting, graywater recycling, water-efficient landscaping, and the use of water-saving technologies in buildings. These practices aim to reduce overall water consumption, promote water conservation, and minimize the strain on water resources.[60][61][62][63][64]

Low-impact development strategies, on the other hand, focus on mitigating the adverse effects of urban development on the natural water cycle. This can involve techniques such as permeable pavement, green roofs, rain gardens, bioswales, and retention ponds, which help to capture, treat, and infiltrate stormwater runoff. By mimicking natural hydrological processes, these solutions aim to reduce flooding, erosion, and pollution while enhancing water quality and preserving ecosystem health. [60][61][62][63][64]

Together, Water-Smart Low-Impact Development Solutions represent a holistic approach to water management that balances the needs of human development with environmental sustainability, resilience, and conservation. [60][61][62][63][64]

The section titled "Core Concepts in Water Efficiency" within Chapter 3 provides detailed information on the subject of Water-Smart Low-Impact Development Solutions. Readers can find comprehensive coverage of this topic within that specific section of the chapter. [60][61][62][63][64]

Water Efficiency in Historical Buildings

In traditional architecture the theme of Water Management has been subject to variations, even significant ones, concerning the climatic zone to which the building belongs, resulting in efficient collection and management devices of particular historical value, both integrated with the building itself, is located in the immediate surrounding areas.

Even if water is a precious commodity anywhere in the world, in countries where this element is scarce, buildings are equipped with large cisterns, generally underground, for collecting rain, connected to a network of pipes such as drainage channels. gutters and downspouts, but also to particular flooring arrangements.

Furthermore, water has historically been used as an ornamental element (think, for example, of the fountains that completed the architecture of parks and gardens in historic buildings), or as a climate mitigation system integrated into buildings located in hot-dry areas. The rediscovery and re-evaluation of the technical components used in historical plant systems promote the knowledge and in-depth study of traditional techniques, representative of an ancient relationship between man-site-resources, in which the complex, careful, and sensitive use of water presents the characteristics of sustainability, linking the modern culture of saving water resources to the roots of history and local construction tradition.

Carrying out and enhancing interventions in historic buildings aimed at saving and sustainability in the use of water can contribute to raising people's awareness of the problem of over-exploitation of water resources: In fact, if the building is used for public functions, in addition to the historical and cultural value, it can also become evidence of good practices in sustainable construction.

Through the credits of the Water Management thematic area, in addition to the reduction of water consumption for civil uses, it is therefore possible to enhance the contribution of pre-industrial devices for the collection and management of rainwater restored through restoration or redevelopment, as well as improving the efficiency of fountains and water features present in the external spaces.

For the integration of new devices, with a view to respecting the "minimum intervention," which characterizes processes of a conservative nature, it is preferable to make use, where this is technically feasible, of the existing shafts present in the historic building, in order to preserve the existing elements without compromising the historical material or any decorative elements.

The operational strategies to be adopted to achieve the environmental objectives set for the thematic area of water management are developed in the topics listed below:

Reduction in the use of drinking water. Reduce drinking water consumption by promoting efficient use of the resource through the use of devices that allow water saving objectives to be achieved. Alternatively, it is possible to reuse non-potable water for uses that allow it. Both strategies can be adopted for both internal and external uses, but not without the integration of appropriate systems and accessories that can have a significant impact on the existing building. For this reason, priority should be given to the refunctionalization of historical devices (ducts, drains, cisterns, etc.) for the collection of rainwater or the insertion of devices that increase the efficiency of the water system. In particular, it is important to underline that the use of water for uses outside buildings, mainly for irrigation and for fountains and water features in general, can affect up to 30% of total water consumption. Consumption reduction strategies such as the use of native plants or the introduction of recirculation systems for fountains can therefore induce significant benefits for the consumption of the resource.

Monitoring and accounting of the volumes of water consumed. The first step in improving water consumption efficiency is to determine current consumption and usage levels of the resource. Taking into account that drinking water consumption determines energy consumption (e.g., domestic hot water), strategies aimed at reducing the use of drinking water contribute to the general efficiency of buildings. It is therefore essential to promote efficient management of the resource through monitoring consumption and the consequent identification of water saving opportunities for all internal and external subsystems.(Historical GBC)

Consideration of Investment Costs and Returns:

While water-smart solutions are undeniably appealing, cities and water utilities must carefully evaluate the investment costs. Whether choosing low-cost or innovative solutions, it's crucial to assess financial viability and potential ROI. This includes considering direct infrastructure costs, long-term savings, operational efficiencies, and environmental benefits.

Additionally, "recovery money" should be a key part of the decision-making process. This means exploring cost recovery through water tariffs, user fees, grants, and incentives. By strategically managing financial resources and aligning investments with long-term goals, cities and utilities can maximize the benefits of water-smart solutions while ensuring economic sustainability.

Figure 9 . Västerås, Sweden

Figure 10 .Ho Chi Minh City, Vietnam

Figure 11 .San Diego , United States

International Building Rating System

The construction industry plays a crucial role in meeting societal needs, improving quality of life, and fostering economic growth. However, it faces heavy criticism for its significant contribution to carbon emissions, environmental degradation, and global warming due to extensive resource utilization and energy consumption. Buildings consume a substantial portion of global resources, freshwater, wood, and raw materials, and account for a significant percentage of energy usage and greenhouse gas emissions.

Recognizing the importance of sustainability, there's been a push for "green" practices in construction, leading to the introduction of various green building rating systems aimed at minimizing resource consumption and pollution. BREEAM stands as one of the earliest rating tools, followed by LEED, HQE, DGNB, Green Star, CASBEE, BEAM, and BCA Green Mark Scheme. Certified buildings typically consume less energy and provide better living environments. Despite their focus on green credentials.

These systems may overlook broader sustainability aspects. Updates and revisions to these rating systems are ongoing to adapt to evolving sustainability standards. While numerous studies have explored individual rating systems and their credits, there's a lack of comprehensive comparison among them and their effectiveness in promoting sustainability. This paper aims to address this gap by systematically reviewing the development and performance of prominent global rating systems, including LEED, BREEAM, CASBEE, and Green Star, to identify their similarities, differences, strengths, weaknesses, and their comprehensive assessment of sustainability aspects.

1. International Standards

1.1. Sustainable Development Goals (SDGs)

The Sustainable Development Goals (SDGs) represent a set of interconnected objectives outlined within the 2030 Agenda for Sustainable Development, a framework devised by the United Nations to underscore the intricate relationship between human well-being and the natural environment. Adopted by the UN General Assembly on September 25, 2015, this comprehensive document comprises 17 overarching goals, complemented by 169 specific targets to be achieved by 2030. Replacing the Millennium Development Goals established in 2000, which spanned a 15-year period, the SDGs encompass a range of initiatives, including poverty eradication, improved health and education, reduced inequality, economic growth, climate action, and the preservation of natural resources like oceans and forests. Each thematic area is delineated in detail. With unanimous endorsement from all 193 UN member states, concerted efforts are underway to enact policy measures aimed at realizing these goals, with countries encouraged to submit voluntary annual national progress reports to track advancements towards the SDGs.[1]

The 2030 Agenda's goals and targets are based on the concept of 5P:

- People: End poverty and hunger in all their forms and dimensions, ensuring that all individuals can realize their potential in dig-

nity, equality, and within a healthy environment.
- Planet: Protect the planet from degradation by promoting sustainable consumption and production, effectively managing natural resources, and taking urgent action on climate change to ensure it can sustain present and future generations.
- Prosperity: Ensure that all individuals can lead prosperous and fulfilling lives, fostering economic, social, and technological progress in harmony with nature.
- Peace: Foster peaceful, just, and inclusive societies free from fear and violence. Sustainable development relies on peace, and vice versa; they are interdependent goals.

In the thesis, I am dedicated to exploring four specific targets outlined within the Sustainable Development Goals (SDGs):

Goal 3 emphasizes the imperative of ensuring healthy lives and promoting well-being for all at every stage of life. This multifaceted goal encompasses a broad spectrum of health-related issues, including maternal and child health, infectious diseases, non-communicable diseases, substance abuse, road safety, and sexual and reproductive health. By striving for universal health coverage and enhancing health equity, Goal 3 aims to ensure that individuals worldwide have access to essential health services without facing financial hardships.[1]

Goal 6 centers on the critical objective of ensuring the availability and sustainable management of water and sanitation for all. Addressing diverse water-related challenges, this goal seeks to guarantee access to clean water and adequate sanitation facilities for every individual. Its targets span achieving universal access to safe drinking water, improving water quality, increasing water-use efficiency, and promoting integrated water resources management. Ultimately, Goal 6 endeavors to ensure global access to clean water and sanitation, essential elements for health, well-being, and sustainable development.[1]

Goal 11 underscores the necessity of creating inclusive, safe, resilient, and sustainable cities and human settlements. Addressing a myriad of urban challenges, this goal advocates for the development of livable, environmentally friendly cities accessible to all inhabitants. Targets within Goal 11 encompass improvements in housing, transportation, urban planning, disaster risk reduction, cultural and natural heritage preservation, environmental sustainability, and public space accessibility. Its overarching aim is to foster sustainable urban development that enhances quality of life, promotes social inclusion, and builds resilience to disasters and climate change.[1]

Goal 13 prioritizes urgent action to combat climate change and its far-reaching impacts. Acknowledging the imperative of addressing environmental, social, and economic ramifications, this goal advocates for a comprehensive approach to climate action. Targets within Goal 13 include strengthening resilience to climate-related hazards, integrating climate change measures into national policies, enhancing education and awareness on climate change mitigation and adaptation, mobilizing financial resources, and promoting effective climate change-related planning and management. By emphasizing concerted efforts at all levels, Goal 13 aims to mitigate climate change and build resilience to safeguard the planet and future generations.

Furthermore, the goals advocate for the establishment of movements and international associations to promote and implement sustainable principles within the construction sector, exemplified by initiatives like the LEED Certification promoted by the World Green Building Council.[1]

To assess the advancements towards achieving the 17 Sustainable Development Goals, the ASviS (Italian Alliance for Sustainable Development) was established on February 3, 2016, through collaboration between the Unipolis Foundation and TorVergata Rome University. Its primary objective is to elevate the significance of the 2030 Agenda and institute a monitoring system for the goals. Subsequently, efforts are directed towards formulating a viable national strategy to attain these objectives and catalyze the transition of industries and public institutions towards sustainability.[1]

The ASviS report on sustainable development, compiled in 2021 with data from 2020, underscores the significant challenges in achieving annual progress, which is fundamental for meeting the 2030 targets. Notably, in 2020, only three goals witnessed improvements: clean energy (Goal 7), climate action (Goal 8), and peace and justice (Goal 16). Conversely, three goals remained stagnant: food and agriculture (Goal 2), clean water (Goal 6), and innovation (Goal 9), while the others experienced deterioration.

In juxtaposition with other European Union nations, Italy's deficiencies are evident, with 10 indicators falling below the European average. The implementation of PNRR (National Recovery and Resilience Plan) holds promise in advancing towards these targets. Additionally, the ASviS proposes several measures:

- Revise the PNIEC (National Integrated Plan for Energy and Climate) to align with European standards, aiming for a 55% emissions reduction by 2030.
- Cease public funding for fossil fuels.
- Develop strategies for gender equality and reducing youth unemployment.
- Enhance the foundation of research and studies for environmental sustainability in the future.

2. Green vs sustainable buildings

Green and Sustainable building have often been used interchangeably, though they are distinct concepts. it described Green building as meeting specific criteria for environmental performance. In 2008, it was characterized as encompassing strategies, techniques, and construction products that are less resource-intensive or pollution-producing than regular construction.

Some times it is detailed it as utilizing land and energy efficiently, conserving water and other resources, improving indoor and outdoor air quality, and increasing the use of recycled and renewable materials.The concept of Green building has evolved to be accepted as providing people with healthy, efficient space and natural harmonious architecture with maximum resource savings, environmental protection, and reduced pollution throughout its lifecycle.[2]

Similarly, Sustainability has faced ambiguity and uncertainty in its definition. The Brundtland Commission in 1987 defined sustainable development as meeting the needs of the present without compromising the ability of future generations to meet their own needs. Despite various definitions, sustainability generally revolves around environmental, social, and economic impacts, with the institutional dimension gaining recognition more recently.

The institutional dimension, introduced in 1995, focuses on interpersonal processes such as communication and cooperation, resulting in information and systems of rules governing societal interaction. Various indicators are used to evaluate institutional sustainability, such as participatory political systems, non-discriminatory education, social security systems, and gender equity.[2]

While both Green and Sustainability concepts may seem vague initially, they can be clar-

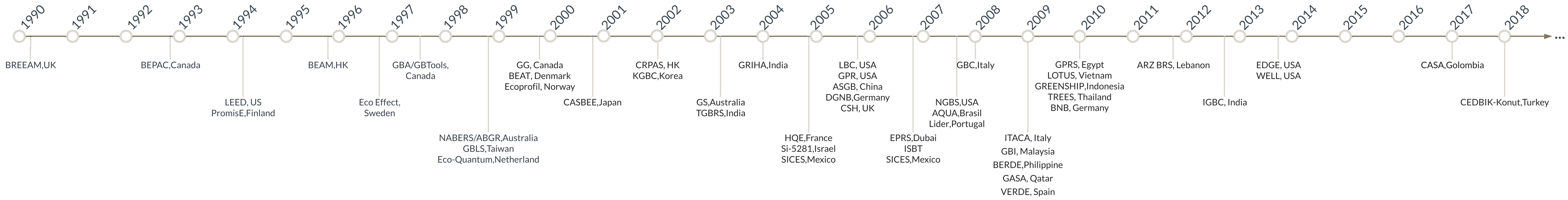


Figure 12 : International rating system timeline ; Source:provided by the author

ified through detailed examination. Green building evaluations typically focus on environmental aspects such as energy, land, water, and materials, while sustainability is assessed through four main pillars: environmental, social, economic, and institutional. These concepts continue to evolve, with new dimensions like culture and epistemology suggested to be integrated into the assessment of sustainability.[2]

2.1. Green Building rating systems

In this investigation, thorough analysis was conducted on BREEAM, LEED, CASBEE, and Green Star NZ rating systems. These systems were chosen due to their global recognition and prominence, with BREEAM, LEED, and CASBEE being established leaders in the field. Additionally, Green Star NZ was included despite being a relatively new system, as it has recently released its latest version and New Zealand has experienced a notable rise in the registration of green buildings as a result.

2.1.1. BREEAM

BREEAM, pioneered by BRE (Building Research Establishment) in the UK, is recognized as the world's first green building rating assessment. Launched in 1990, it initially focused on offices and has since influenced subsequent major green rating systems like LEED, Green Star, and CASBEE. Known for its flexibility, BREEAM considers local codes and conditions while also being applicable internationally. It assesses a building's lifecycle from design and construction to operation and refurbishment, offering various manuals for different stakeholders. Over 560,000 certifications have been issued to date, with a consistent increase projected, reflecting its growing adoption worldwide. BREEAM certifications cover 80% of the European sustainable building certification market. While all sustainability pillars are evaluated by BREEAM, environmental considerations are predominant, categorized into eight main areas: Management, Energy, Transport, Water, Materials, Waste, Land Use & Ecology, and Pollution.[3]

2.1.2. LEED

LEED, developed by the US Green Building Council (USGBC), is a voluntary standard introduced in 1998 with its pilot version, LEED 1.0. Despite being launched after BREEAM, LEED has become the most widely adopted rating scheme globally, with over 79,000 projects across 135 countries in 2012, expanding to nearly 150 countries and territories by 2014, and now reaching over 160 countries and territories. The square footage of LEED-certified projects has significantly increased from around 0.15 billion to over 15 billion square feet between 2008 and 2016. Like BREEAM, LEED primarily assesses environmental factors, including Sustainable Sites, Water Efficiency, Energy and Atmosphere, Material and Resources, and Indoor Environment Quality. The criteria for evaluation span the building's entire lifecycle, covering Building Design and Construction, Interior Design and Construction, Building Operations and Maintenance, and Neighbourhood Development manuals.[4]

2.1.3. CASBEE

CASBEE, developed through collaboration between academia, industry, and local governments in Japan in 2001, remains focused on the Japanese context, resulting in a modest number of certified buildings (330 since 2004). Nevertheless, it boasts the broadest evaluation scope among the discussed rating systems. Despite its Japanese-centric nature, CASBEE began releasing a pilot version for global application in 2015. Its assessment covers various stages from design to renovation, with criteria outlined in CASBEE Buildings, CASBEE for Commercial Interiors, and CASBEE for Temporary Construction manuals. Additionally, CASBEE for Urban Development and CASBEE for Cities manuals serve as frameworks for evaluating groups of buildings.[5]

	BREEAM	LEED	CASBEE	Green Star NZ
Country	UK	US	Japan	NZ
Organizations	BRE	USGBC	JSBC	NZGBC
Flexibility	77 countries	160 countries	1 country	1 country
First version	1990	1998	2002	2007
Building adaptations	New Construction . In-Use Refurbish. and Fit-Out Communities	New Construction. Existing Buildings. Operations and Maintenance Comm. Interiors Core and Shell Schools Retail Healthcare Homes. Neighbor. Develop.	Pre-design New Construction . Existing Building and Renovation	Communities Buildings Design and As Built Interiors Performances
Categories	Management Health and Well-being Energy Transport Water Material Waste Land Use and Ecology Pollution Innovation	Integrative Process Location and Transportation Sustainable Site Water Efficiency Energy and Atmosphere Material and Resources Indoor Env. Quality Regional Priority Innovation	Indoor Environment Quality of Service On-site Environment Energy Resource and Materials Off-site Environment	Management Indoor Environment Quality Energy Transport Water Material Land Use and Ecology Emissions Innovation
Assessment method	Pre-weighted categories	Additive credits	BEE ranking chart	Pre-weighted categories
Certification levels	Pass ≥ 30 Good ≥ 45 Very Good ≥ 55 Excellent ≥ 70 Outstanding ≥ 85	Certified 40–49 Silver 50–59 Gold 60–79 Platinum ≥ 80	Poor: BEE < 0.5 Fairy Poor: BEE 0.5–1.0 Good: BEE 1–1.5 Very Good: BEE 1.5–3 or BEE ≥ 3 and Q < 50 Excellent: BEE ≥ 3 and Q ≥ 50	Min. Practice (1 star) Average Practice (2) Good Practice (3) Best Practice (4) Austr. Excellence (5) World Leader. (6)

Figure 13 .International rating system differences
Source:provided by the author,data extracted from "A critical comparison of green building rating systems"

2.1.4. Green Star NZ

The Green Star NZ rating scheme, initiated by the New Zealand Green Building Council (NZGBC) in 2007, draws its foundation from the Australian Green Star model. Being the youngest among the mentioned rating schemes, Green Star NZ stands out as it doesn't offer a manual for assessing buildings during their performance phase. Despite being on the market for just a decade, the number of certified buildings has shown a promising trend, experiencing a tenfold increase since 2009, totaling 125 certifications.[6]

2.1.5. Overview of BREEAM, LEED, CASBEE, and Green Star NZ

The establishment of BREEAM, LEED, and Green Star NZ by nonprofit third parties contrasts with CASBEE, where the government plays a dominant role alongside industry and academia. This collaborative approach in CASBEE allows for more frequent, precise, and thorough updates based on feedback received from various stakeholders. Consequently, CASBEE is regarded as a leader in assessing comprehensive area development projects, including groups of buildings or entire cities. Despite being established after BREEAM and LEED, CASBEE has developed rapidly, offering evaluations across a wide spectrum, albeit with a focus on the Japanese context.

Green Star NZ, being the most recent of the rating systems discussed, lacks an assessment manual for the operational phase of buildings. Consequently, the number of certified projects remains limited, although there has been a positive trend in certifications over the past decade.

Efforts to revise and update criteria are evident across all rating systems, with the latest versions being relatively recent. BREEAM and LEED have gained significant global adoption, whereas CASBEE and Green Star NZ are still in the earlier stages, primarily due to their limited flexibility and applicability beyond domestic projects.

Despite regional differences, BREEAM and LEED can be adopted by countries worldwide, utilizing either international or local standards for assessment. BREEAM tends to target the European market, while LEED is perceived as having a more transparent rating approach compared to BREEAM.

In terms of evaluation criteria, BREEAM, LEED, and Green Star NZ share similar categories, reflecting the influence of BREEAM on the latter two systems. CASBEE, however, has fewer categories, reflecting its unique approach and focus on the Japanese context.

The weighting of evaluation criteria varies across systems, with Energy being consistently prioritized due to the significant energy consumption of the construction industry. Material and Indoor Environment Quality/Health & Wellbeing are also given high importance, reflecting global concerns such as raw material consumption and occupant health.

The assessment methodology differs among the rating systems, with BREEAM and Green Star NZ utilizing pre-weighted categories, while LEED employs an additive credits approach. CASBEE's evaluation method is more complex, considering factors such as Built Environment Quality and Built Environment Load.

Overall, while these rating systems are voluntary, they are increasingly being mandated in certain regions or for specific purposes, demonstrating their growing influence on sustainable building practices.

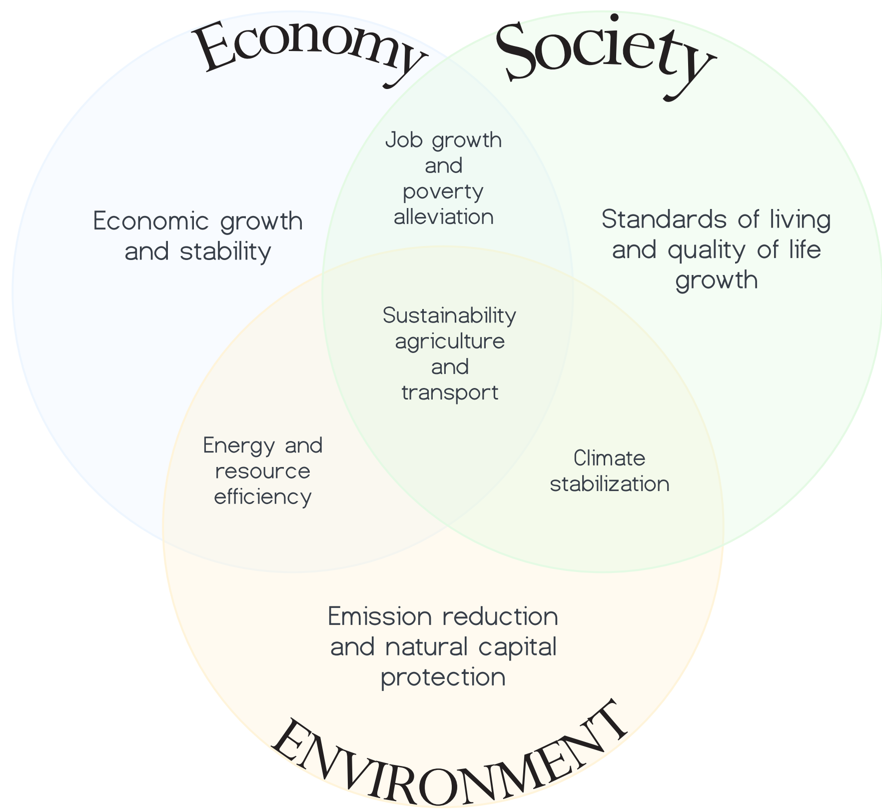


Figure 14:The Environmental, Economic, and Social Components of Sustainability; Source: Provided by the author

Namba Parks, Osaka

LEED Certification

The foremost green building assessment framework in the United States is LEED (Leadership in Energy and Environmental Design), developed by the U.S. Green Building Council (USGBC). The U.S. Office of Federal Environmental Executive defines "green building" as practices aimed at enhancing the efficiency of a building or site in energy, water, and material usage, while also mitigating its impact on human health and the environment.[1]

The emergence of the environmental movement in the 1960s, coupled with the 1973 OPEC oil embargo and subsequent energy crisis, prompted a reevaluation of reliance on fossil fuels in transportation and construction. This led to the growth of the green building movement through national and international conferences and meetings on energy, environmental issues, and building codes. [1] In 1993, the USGBC was established during a meeting at the American Institute of Architects (AIA), with key figures including David Gottfried, Michael Italiano, and S. Richard (Rick) Fedrizzi. Fedrizzi, serving as the CEO, played a crucial role in shaping the organization.

While the UK's BREEAM system took the lead in sustainability assessments for buildings back in 1990, the USGBC opted to work alongside the Natural Resources Defense Council (NRDC) to craft their own LEED certification, specifically customized to meet the needs of the American building industry. [4]The first version of LEED was solidified, adopted by the USGBC, and launched with the help of the Federal Energy Management Program in August of 1998.[5]

LEED's evolution from its initial version, LEED v1, to the latest iteration, LEED V4, reflects a continuous effort to refine its criteria and adapt to changing standards. LEED V2, introduced in 2000 with an expansion from 40 to 69 credits[1], expanded significantly, addressing shortcomings found in its predecessor. LEED V3, launched in 2007,set a new benchmark with increased points,up to 110 points[5],and updated guidelines, remaining the standard until 2016. Despite setbacks delaying the release of LEED V4, its impending implementation in 2016 signifies a significant step forward. As of year 2023, USGBC began to develop LEED v5. LEED v5 is the first version of the LEED rating system to be based on the June 2022 Future of LEED principles. A draft version was discussed at Green building 2023. A final version is expected to be published as of year 2024.

LEED V4 incorporates advancements in technology and stricter requirements for carbon reduction and human health [6], reflecting evolving governmental policies and industry standards. Additionally, while LEED offers flexibility in credit selection, projects must still meet prerequisites and earn a minimum of 40 points to achieve certification. The possible levels of certification are four:

- Certified (40-49 points);
- Silver (50-59 points);
- Gold (60-79 points);
- Platinum (80-110 points).

Buildings certified under LEED are globally renowned for their commitment to sustainable architectural principles, resulting in reduced consumption and cost savings over their lifecycle.

Figure 15: Certification levels and related score; Source: www.gbcitalia.org

This not only minimizes harmful emissions into the environment but also ensures occupants benefit from healthy and comfortable spaces. The certification, outlined by the U.S. Green Building Council, encompasses various targets, including preserving water sources, biodiversity, and ecosystems, promoting material sustainability and reuse, enhancing quality of life, improving human health, fostering a green economy, and combating climate change. This comprehensive approach highlights the certification system's focus on addressing a broad spectrum of aspects related to both the outdoor environment and the building. The accompanying graph illustrates the significance attributed to each principal theme by the credits awarded (Figure 16).

1. Rating Systems: LEED V.4

The protocol contains five new macro-categories (Figure 17). There are five primary LEED rating systems reference guides, and each is directed towards a specific project type:

1) The Building Design + Construction (BD+C) designation is applied to projects involving new construction or significant renovation. Further categorization depends on specific project requirements:

- New Construction: Applicable to projects involving the construction of new buildings or major renovations, including enhancements to the building envelope and HVAC systems.
- Core & Shell: Pertains to the exterior shell of new construction or major renovations, as well as mechanical, electrical, and plumbing systems, excluding interior finishes.
- Retail: Designated for buildings intended for commercial purposes, such as shops and bars.
- Schools: Designated for educational facilities.
- Data Centers: Designated for facilities dedicated to storing high-density computer equipment, such as servers.
- Hospitality: Designated for buildings providing short-term accommodation, such as hotels and motels.
- Healthcare: Designated for facilities providing long-term care or operating as hospitals with continuous service.
- Warehouses and Distribution Centers: Designated for buildings utilized for the storage of products and materials.
- Homes and Multifamily Lowrise: Designated for residential buildings up to three stories, either single-family or multi-family.
- Homes and Multifamily Midrise: Designated for multi-family residential buildings ranging from four to eight stories.

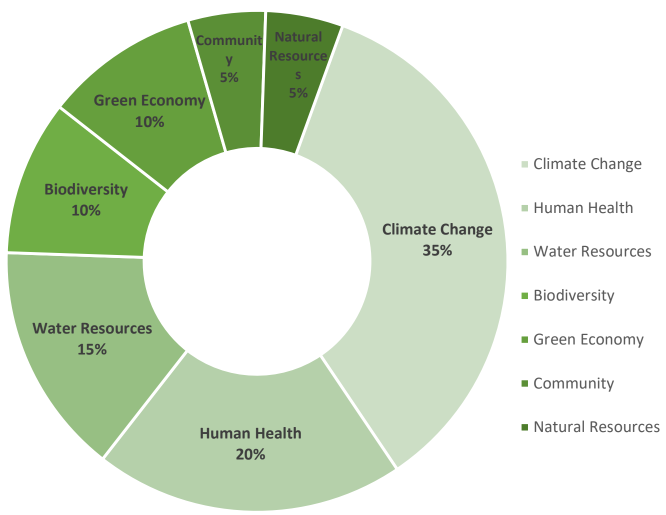


Figure 16: Pie chart of percentage about relevance of thematic given by points ; Source: www.usgbc.org

Figure 17: Rating Systems: LEED V.4 ; Source: www.gbcitalia.org

2) Interior Design and Construction (ID+C) is designated for projects requiring the definition of internal layouts and space designs. Similar to BD+C, it is applicable to Retail and Hospitality projects. Additionally, ID+C is suitable for Commercial Interiors, encompassing spaces distinct from those designated for Retail and Hospitality purposes.

3) Building Operation + Maintenance (O+M) applies to buildings that have been in operation for at least one year and remain fully functional. This designation is suitable for Retail, Schools, Hospitality, Data Centers, and Warehouses and Distribution Centers. Additionally, it is applicable to Existing Buildings that do not fit into any other designated category.

4) Neighborhood Development (ND) is designated for the creation of sustainable districts, whether they are newly developed or located near other buildings completed within the past three years. This category can be subdivided into two classifications:

- Plan: Intended for projects in the early design stages or under construction.
- Built Project: Designated for projects that have already been developed.

5)The Homes category is utilized for the design of residential buildings of various types. This includes Single Homes as well as Multifamily Lowrise and Midrise structures.

In the updated version of LEED (V4.1), a new rating system called Cities and Communities has been introduced, which integrates design, social equity, and human health factors. This system offers a choice between Plan and Design for developing cities and communities or for existing ones. It builds upon the previous performance-based approach to provide a comprehensive framework supporting planning, design, operation, and performance management phases for both new and existing urban areas. Certification under this system is based on various factors such as water efficiency, energy usage, greenhouse gas emissions, materials and resources, quality of life, innovation, and regional priorities.

Given that a project may encompass different functions, there exists a specific guideline known as the "40/60" rule to aid teams in selecting the appropriate rating system. This rule considers the percentage of square meters within the project dedicated to each function. There are three possible scenarios:

1) If the percentage of a function within the project is less than 40%, the corresponding rating system is not considered.

2) If the percentage exceeds 60%, the relevant rating system is automatically chosen.

3) If the percentage falls between 40% and 60%, the decision is left to the project team to determine the appropriate rating system to pursue.

2. Minimum Program Requirements (MPR) and Pre-requisite

LEED certification hinges on stringent adherence to minimum program requirements (MPRs), which meticulously outline project eligibility criteria and serve as the bedrock for maintaining the program's credibility and consistency. These requirements are meticulously crafted to offer unequivocal guidance, streamline the certification process, and uphold the integrity of the LEED program.

The minimum program requirements (MPRs) outlined below:

1.Permanent Location on Existing Land:

-This requirement mandates that LEED projects must be situated on permanent land, ensuring stability and minimizing disruptions to surrounding ecosystems. Projects designed to relocate at any point in their lifecycle are ineligible for LEED certification.

2.Reasonable LEED Boundaries:

- LEED boundaries must be thoughtfully defined to encompass all contiguous land essential for the project's operations. This includes areas altered during construction and those predominantly utilized by project occupants. The goal is to prevent unfair advantages by neither excluding nor artificially enlarging areas within the boundary.

3.Compliance with project size requirements:

- LEED projects must align with specified size criteria tailored to different rating systems. For example:

- LEED BD+C and LEED O+M projects require a minimum gross floor area of 1,000 square feet (93 square meters).

- LEED ID+C projects necessitate a minimum gross floor area of 250 square feet (22 square meters).

- LEED for Neighborhood Development projects should consist of at least two habitable buildings and not exceed 1500 acres in size.

- LEED for Homes projects must meet the definition of a "dwelling unit" as per applicable building codes.

In addition to the general MPRs, each credit category has its own prerequisites. Even if certain credits within a category are not pursued, adherence to these prerequisites is mandatory. Therefore, project teams meticulously address the prerequisites of each credit category after meeting the general MPRs, aiming to earn essential credits for certification while ensuring overall compliance.

3. LEED Credit Categories and Scorecard

LEED provides an independent third party certification that a building was designed and constructed using strategies aimed at an improved environmental performance in six key areas known as credit categories. In addition to this, there are two bonus categories “Innovation in Design” and “Regional Priorities” and an additional category “Integrative Process”.

The following mentioned categories are further subdivided into prerequisites and credits. The prerequisites are at the beginning of the main rating system credit categories in LEED v4 and they are mandatory. The purpose of prerequisites is to ensure a minimum level of achievement within each credit category. Points are not given for prerequisites. In the early days of LEED, many projects were registered but never certified due to the fact that project teams did not fully understand

the impact of the prerequisites on their projects.

On the other hand,all credits in each rating system adaptation are grouped in categories and listed after the prerequisites. Each category lists the total amount of possible points that can be achieved within that category. Each credit is assigned a single point or a range of points.

Also, a credit can be obtained for the integrative process, which is not within a category. The integrative process is stressed as the foundation for working through all the categories to achieve credits. Its purpose is to promote teamwork across all the disciplines and begins at the discovery or critical phase of the project. Also, an integrative process can help project teams achieve synergies across credit categories. A LEED assessment can be undertaken for every building typology during any stage of its life cycle.

Integrative Process: This credit encourages team members to collaborate effectively to enhance environmental and energy performance, as well as human well-being. Construction processes should be integrated starting from the early stages of design. The credits aim to facilitate ongoing communication among team members to discover cost-effective solutions together. Various disciplines involved in typical construction projects synergize efforts to mitigate common site issues, thereby reducing time and cost implications arising from changes or intersectoral interaction problems.

Location and Transportation: Credits within this category incentivize construction in pre-existing, urbanized areas to avoid unnecessary expenditure on new infrastructure and land development. This encourages efficient utilization of resources and reduces the need for additional street networks, bicycle lanes, and utility connections like electricity, water, and gas. The emphasis is on promoting locations with robust public transportation networks to reduce car usage and mitigate greenhouse gas emissions. Additionally, the presence of bicycle networks and designated parking spaces for bicycles within building premises is encouraged.

Sustainable Sites: This category directs its efforts towards preserving the natural environment surrounding the building, with a focus on ecosystem protection and biodiversity conservation. Credits are awarded for mitigating the heat island effect through measures such as avoiding the use of dark materials and minimizing light pollution on public streets. Additionally, it encourages the inclusion of vegetated open spaces to minimize runoff during rainfall events.

Water Efficiency: This category adopts an "efficiency first" strategy to curtail water wastage, addressing both indoor and outdoor water usage and metering. Key components include occupancy calculations to estimate water consumption and the installation of systems to capture rainwater for non-potable uses.

Energy and Atmosphere: This section of the protocol focuses on credits aimed at minimizing the use of oil, coal, and natural gas, which contribute to greenhouse gas emissions and are non-renewable resources. Achieving high performance involves implementing technical systems such as high-efficiency HVAC systems and integrating on-site renewable energy production, such as photovoltaic panels. Additionally, studies on building orientation are conducted to maximize the utilization of solar light and heat.

Materials and Resources: These credits prioritize the use of environmentally friendly materials, with a focus on both material performance and the resources required for their production. Life Cycle Assessment (LCA) calculations are employed to evaluate the environmental impact of materials throughout their entire lifecycle, from resource extraction to disposal.

Indoor Environmental Quality: Green buildings prioritize the well-being and comfort of occupants, prompting credits in this category to incentivize measures enhancing thermal, acoustic, and visual comfort within the structure.

Innovation: Given the rapid pace of technological advancement, the protocol allows for the adoption of new technologies not covered by other credits. Teams must provide documentation supporting the use of these technologies. Additional points are awarded for exemplary performances, often with stricter criteria, and for the involvement of a LEED Accredited Professional (LEED AP) to oversee the process.

Regional Priority: This credit encourages teams to address specific environmental and public health needs relevant to their region. Documentation must be provided to demonstrate how the project contributes to local goals and initiatives.

4. Checklists

Each LEED rating system adaptation has a centralized point of organization, called a checklist (sometimes referred to as a scorecard). In most cases, the checklist is a single-page list containing the name of the rating system adaptation and a series of categories that pertain to the site, transportation, water, energy, materials, indoor air, and innovation of the project. Within each category are prerequisites and credits that a project team selects for point attribution to achieve LEED certification. At the bottom of each checklist are the certification levels and their respective point thresholds.

The checklist is the first thing a project team considers when deciding which rat- ing system adaptation to use. During the predesign planning phase, a project team should use the checklist to roughly deter- mine which credits and certification level can be achieved. Figure 18 depicts a Scoring Checklist for LEED, specifically the one utilized in my case study.

5. LEED Certification Steps

Certification of a building involves several key stages:

In the initial phase, known as Pre-Assessment, a comprehensive analysis of the project is conducted to determine the feasibility of achieving a specific certification level. This involves

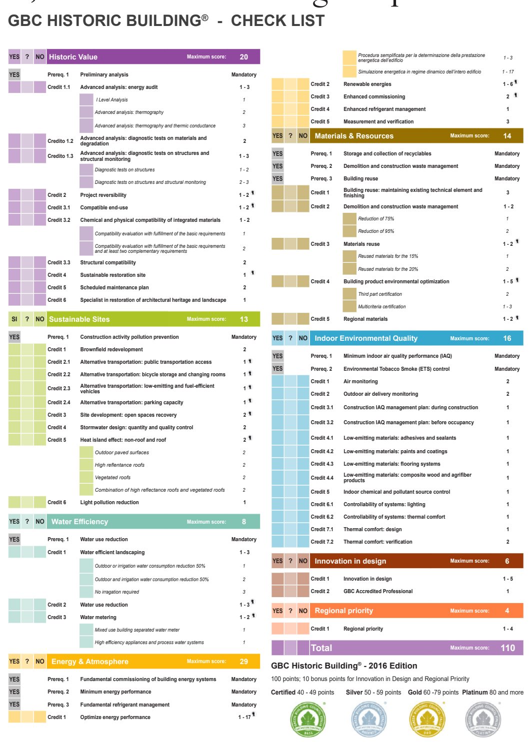


Image 18: Scorecard LEED V4 for BD+C: New Construction

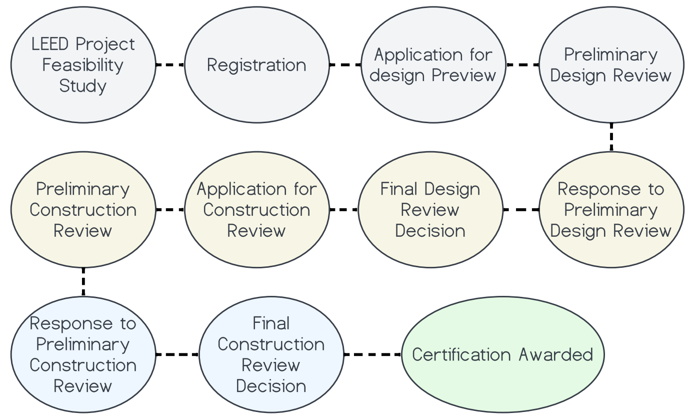


Figure 19: Path for a LEED split review

evaluating the Minimum Program Requirements, pre-requisites for each category, and assessing the economic viability of obtaining credits.

Following this, the second phase entails Online registration, where if the owner deems the potential LEED certification level satisfactory, the project is registered on the "LEED Online" platform by remitting a fee to the GBCI. The LEED AP oversees the process and coordinates the preparation of documentation by team members.

The subsequent step is the Application for Design review, where the LEED AP uploads all relevant documentation for design prerequisites and credits onto the LEED Online interface. Additionally, clarification may be sought for any project-related issues.

Afterward, the Preliminary Design Review and Response stage ensues, whereupon all submitted documents are evaluated by the GBC, resulting in a preliminary assessment.

The process then moves to the Final Design Review Decision phase, which involves a thorough revision of all design documentation. Transitioning to the Application for Construction review stage, all necessary documents pertaining to construction-phase credits are uploaded.

Subsequently, the Preliminary Construction Review and Response stage occurs, during which the revisor conducts a preliminary evaluation subsequent to document submission. Finally, the Final Construction Review Decision marks the conclusive phase of assessing construction credits.

In the LEED manual, the credits to be submitted during the design and construction phases are clearly delineated. Following the correct loading and revision of all documents, a final check is performed by a LEED reviewer before certification is requested from the USGBC. These steps constitute the "Split Review" approach, where assessment occurs separately for design and construction phases.

Alternatively, there's the option of a "Combined Review," where all documentation is evaluated at the project's conclusion. However, this approach carries greater risk, as changes become limited once construction begins, potentially resulting in a lower certification level or no certification if prerequisites aren't met.

The split review offers the advantage of assessing credit attainment during the design phase, allowing for potential project adjustments. This underscores the thesis's central idea: advocating for the integration of the LEED protocol into project design as a primary sustainability tool, rather than viewing it as a mere evaluation done later on.

6. Benefits related to LEED

In our modern world, LEED certification, endorsed by the Green Building Council (GBC), is widely recognized as a benchmark for eco-friendly building practices. LEED aims to reduce buildings' environmental impact while promoting the well-being of occupants, as emphasized by this organization. This certification plays a crucial role in creating a sustainable and resilient built environment, as noted by the GBC. It's important to consider global trends, like the push for net-zero CO_2 emissions by 2050 and initiatives from the European Commission, as highlighted by this council. Additionally, the significance of sustainable construction practices, endorsed by the GBC, cannot be overstated in combating climate change.

1. Environmental Impact Reduction is a core focus of LEED certification. LEED-certified buildings contribute to reducing energy consumption and carbon emissions significantly. Studies, like the one conducted by the University of California–Berkeley, emphasize the substantial decrease in greenhouse gases associated with LEED-certified buildings. This reduction is achieved through various measures, including efficient water usage and waste management practices. Additionally, LEED projects divert millions of tons of waste from landfills, thus aiding in environmental conservation and sustainability efforts.

- *Energy Efficiency*: LEED-certified buildings prioritize energy optimization through strategies like efficient HVAC systems, insulation, and lighting. By reducing energy consumption, these buildings contribute to lower greenhouse gas emissions, mitigating climate change and lessening the demand for fossil fuels.
- *Water Conservation*: LEED places a strong emphasis on water efficiency by advocating for water-saving fixtures, rainwater harvesting systems, and landscaping practices that minimize water consumption. This conserves water resources, particularly crucial in water-stressed regions, and helps alleviate pressure on freshwater sources and ecosystems.
- *Waste Management*: LEED promotes waste reduction and recycling initiatives throughout a building's lifecycle. By diverting waste from landfills and encouraging recycling and composting, LEED-certified projects minimize environmental pollution and conserve valuable resources.
- *Materials Selection*: LEED prioritizes the use of sustainable materials, such as recycled content, rapidly renewable resources, and low volatile organic compound (VOC) emissions. Choosing environmentally responsible materials helps reduce the carbon footprint of LEED projects and promotes sustainable sourcing practices.
- *Site Design and Land Use*: LEED encourages thoughtful site selection and design that minimizes environmental disruption and preserves natural habitats. Strategies like brownfield redevelopment, green infrastructure, and urban infill development protect ecosystems and promote sustainable land use practices.
- *Transportation and Access*: LEED-certified projects prioritize accessibility and promote alternative transportation options such as public transit, cycling infrastructure, and pedestrian-friendly design. By reducing reliance on single-occupancy vehicles, these projects mitigate traffic congestion and air pollution, contributing to a healthier environment.
- *Health and Well-being*: While not directly environmental, promoting occupant health and well-being is integral to reducing the overall environmental impact of buildings. LEED-certified buildings prioritize indoor environmental quality, enhancing air quality, thermal comfort, and access to natural light. This not only improves occupant comfort but also reduces the need for energy-intensive heating, cooling, and artificial lighting.

2. Accountability and Leadership: LEED certification ensures accountability in sustainable building practices through a rigorous third-party certification process overseen by the USGBC. The LEED plaque signifies that buildings adhere to stringent sustainability standards, fostering transparency and trust among stakeholders. This distinguishes LEED-certified buildings as exemplars of environmental responsibility.

3. Financial Benefits: The financial advantages of LEED certification are manifold. In addition to higher resale values and faster lease-up rates, LEED-certified buildings incur lower utility costs, with average energy savings of 25% compared to conventional structures. These energy-efficient features not only contribute to cost savings for building owners but also enhance long-term financial sustainability by reducing operational expenses over the building's lifecycle.

4. Employee Satisfaction and Health: LEED-certified buildings prioritize occupant health and well-being by implementing strategies to enhance indoor environmental quality. Features such as optimal thermal comfort, access to natural light, and superior indoor air quality contribute to increased employee satisfaction and productivity. This focus on occupant well-being is particularly appealing to younger workers who prioritize working in environmentally conscious and healthy environments.

5. Meeting ESG Goals: LEED certification aligns with Environmental, Social, and Governance (ESG) goals, providing investors with a recognized framework for measuring and managing sustainability performance in their real estate portfolios. Studies show that LEED-certified assets exhibit resilience during market downturns, reflecting their attractiveness to socially responsible investors seeking sustainable investment opportunities.

6. Tax Incentives: LEED certification may qualify for tax incentives in certain jurisdictions, offering additional financial benefits to building owners. These tax breaks, along with potential financial support opportunities through partnerships , enhance the affordability and attractiveness of pursuing LEED certification for building projects.

7. Data-driven Performance Measurement: LEED provides valuable data on building performance through its rating systems, enabling property managers, portfolio owners, and service providers to monitor and optimize operational efficiency. By tracking metrics such as energy, water, carbon emissions, waste generation, and human experience, LEED-certified buildings can continuously improve their sustainability performance and enhance overall operational effectiveness.

In summary, LEED certification provides a range of benefits, including environmental stewardship, financial viability, occupant well-being, and market competitiveness. These advantages highlight the significance of embracing sustainable building practices and showcase the value of pursuing LEED certification for building projects.

7. LEED At Present: GBC in 2023

The landscape of sustainable building practices in Italy, as outlined by the Green Building Council (GBC) and supported by data analysis, reflects a dynamic evolution over the past decade. With a focus on LEED and GBC certifications, this report delves into the remarkable growth and

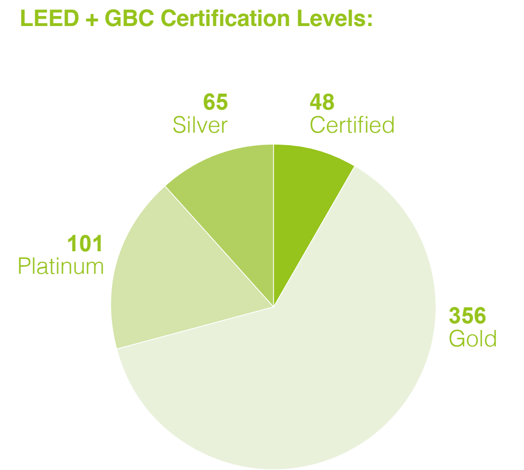


Figure 20: Pie chart of certified projects number for each level; Source: extracted from "impact report 2023" in gbcitalia.org

Number of buildings and their respective areas for LEED and GBC:	
Total number of projects:	1460
Number of registered projects:	890
Number of certified projects:	570
Total Gross Surface Area [square meters]:	19.851.417,45
Certified Gross Surface Area [square meters]:	9.191.525,18

Figure 21: Number of buildings and their respective areas for LEED and GBC; Source: extracted from "impact report 2023" in gbcitalia.org

distribution of registered and certified projects across various regions. Notably, the emphasis on achieving high levels of certification underscores a holistic approach to sustainability, evident in the pursuit of multiple objectives throughout the design and construction phases. As Italy embraces sustainable principles, exemplified by the doubling trend in certified construction, this study unveils the diverse geographical spread and intended uses of certified buildings. From the bustling urban centers like Milan to the more peripheral regions, sustainable construction is gaining traction, propelled by both international investment influence and grassroots efforts spearheaded by GBC Italia. Through rigorous certification systems like LEED, designers are equipped with essential tools to navigate the complexities of sustainable design and construction, fostering a culture of environmental stewardship and innovation. This introduction sets the stage for a comprehensive exploration of Italy's sustainable building journey, highlighting trends, challenges, and opportunities shaping the built environment in the 21st century.

From an initial examination of the various figures within the report describing the composition of the LEED and GBC certified built environment, it becomes apparent that 80% of these structures have attained a high level of certification (Gold or Platinum), as declared by the Green Building Council (GBC). This indicates that the achieved sustainability level results from pursuing diverse objectives across all thematic areas, reflecting a comprehensive sustainability approach in both design and construction phases. Figure 21 data also suggest that the trend of certified sustainable construction is experiencing a twofold increase within a few years: in addition to the existing 9 million square meters already certified, approximately another 10 million square meters are presently undergoing certification. The progress seems to differ across various regions of the country.

Figure 22 demonstrates an uneven distribution of certified buildings, both in terms of geographical locations and intended use. Certain regions, such as Lombardy, boast significant areas and numerous certified buildings. However, it's noteworthy that nearly all Italian regions exhibit some level of presence. While sustainable construction in Milan benefits from factors related to international investor influence, its proliferation and expansion in peripheral areas are also linked to cultural diffusion efforts promoted by GBC Italia across Italian provinces.

Figure 23 showcases disparities in total and certified certifications in the territorial distribution of LEED and GBC projects across different Italian regions. Lombardy and Veneto stand out with high numbers of both registered and certified projects, indicating a firm commitment to sustainable building practices. Conversely, regions like Basilicata, Calabria, and Valle d'Aosta appear to have relatively lower involvement in green building initiatives based on the provided data.

Lombardy leads in the number of total registered projects with 517, followed by Veneto with 344, and Lazio with 163. Other regions with significant numbers of total registered projects include Emilia Romagna (107), Piemonte (90), and Trentino Alto Adige (77). Some regions have very few or no registered projects, such as Basilicata, Calabria, and Valle d'Aosta. Lombardy also leads in the number of certified projects with 253, followed by Veneto with 53, and Lazio with 69. Emilia Romagna, despite having a significant number of registered projects, has 48 certified projects, indicating a lower certification rate compared to its registration rate. Some regions have very few or no certified projects, similar to the registered projects data.

Figure 23 highlights the diverse intended uses of certified buildings, emphasizing the possibility of applying these principles to all types of constructions and engaging the entire supply chain in terms of activities and scale, as declared by the Green Building Council.

The trend for registered and certified projects in figure 24, particularly under LEED and GBC, has experienced significant growth over the past decade according to the provided report from GBC Italia. Compared to 10 years ago, the number of buildings registered and certified under LEED and GBC in a year is now 10 times higher. Notable increases in professional attendance at GBC Italia's courses in 2016 and 2017 were mirrored by similar jumps in the number of buildings certified under LEED and GBC. In 2019, another notable increase in the number of trained individuals was observed, accompanied by a corresponding rise in LEED and GBC certified buildings. Overall, there has been a consistent upward trend in the number of registered and certified projects over the years, indicating the impact of GBC Italia's efforts on accelerating and spreading applied sustainability in the built environment.

Moreover, the Italian GBC website offers an Excel file for download, providing detailed data on buildings that are already certified and those awaiting certification as LEED projects. This file includes pertinent information such as project location (city, region, address), the adopted LEED rating system, associated points, certification level, and gross surface area, facilitating a comprehensive understanding of the context and aiding further analysis and decision-making processes. (Figure 25)

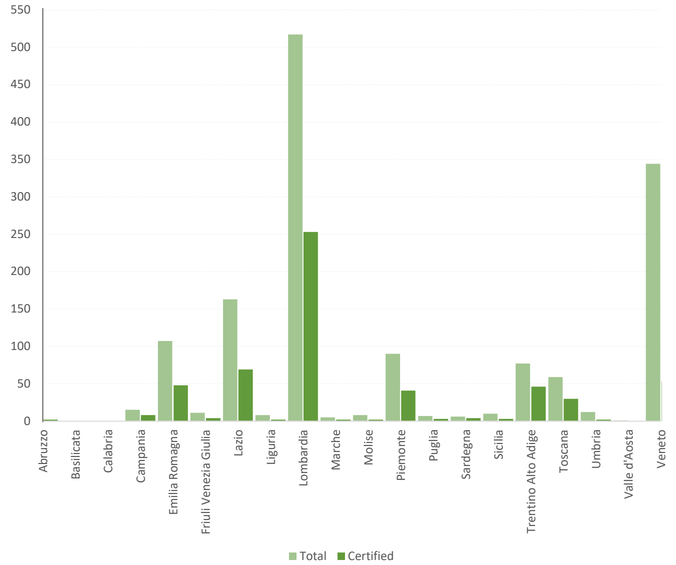


Figure 22: Territorial distribution LEED and GBC projects (Total and certified); Source: provided by the author ,data extracted from "impact report 2023" in gbcitalia.org

Figure 23: Territorial distribution LEED and GBC projects (Total and certified); Source: extracted from "impact report 2023" in gbcitalia.org

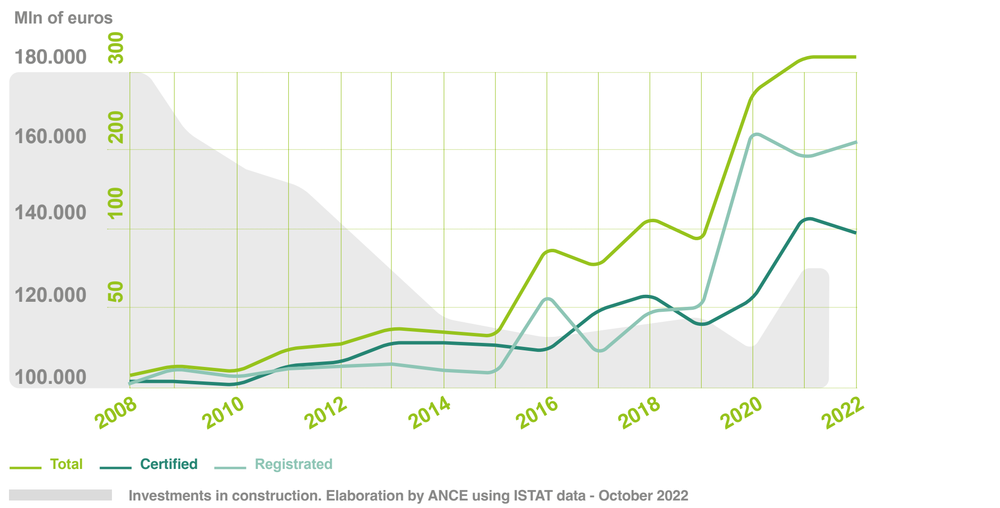


Figure 24: Territorial distribution LEED and GBC projects (Total and certified) Source:extracted from "impact report 2023" in gbcitalia.org

8. Italy GBC Historic Building

In recent years, Italy has witnessed a significant drive towards the restoration of its historical buildings, marking a shift where conservation practices take precedence in the construction industry. Latest statistics indicate that over two-thirds of the entire production value is attributed to interventions on the built heritage. Despite this, there remains a disconnect between restoration projects and existing sustainable management standards and tools.

In 2017, Assorestauro and GBC Italy forged a partnership aimed at fostering a culture of sustainable design for historical properties. Through joint efforts, they've conducted various awareness-raising activities such as webinars, seminars, and site visits, implementing the Historic Building protocol. Additionally, they facilitated the formation of an interministerial committee in 2021, comprising the Ministry of Culture and the Ministry of the Environment, to revise the Minimum Environmental Criteria (CAM) for construction, particularly focusing on historical and protected buildings. The resulting updated document remains in use.

Furthermore, in 2022, Assorestauro, in collaboration with Politecnico di Milano, initiated a research doctorate program focusing on the green conservation of architectural heritage. This research aims to assess the interest and commitment of Italian economic operators in the restoration sector towards sustainability. Notably, 44% of the surveyed operators were found to invest in sustainability, prompting further inquiry into enhancing data quality and expanding the project's international scope.

Special attention should be given to the application of the GBC Historic Building protocol, which introduces a specific section on the Historical Value of the building in addition to the traditional environmental themes. Within the Green Building Council Italia's Protocol, the credits for the various thematic areas have been developed with many similarities to the references in version 4.0 of the LEED protocol. Therefore, it is reasonable to compare them with the application numbers of the latest version of the LEED protocol.

As shown in figure 26, there is a clear difference in the distribution of credit weights and thematic areas compared to LEED 4.0 protocol. The "Historical Value" area in the GBC HB protocol serves the purpose of guiding a deep understand-

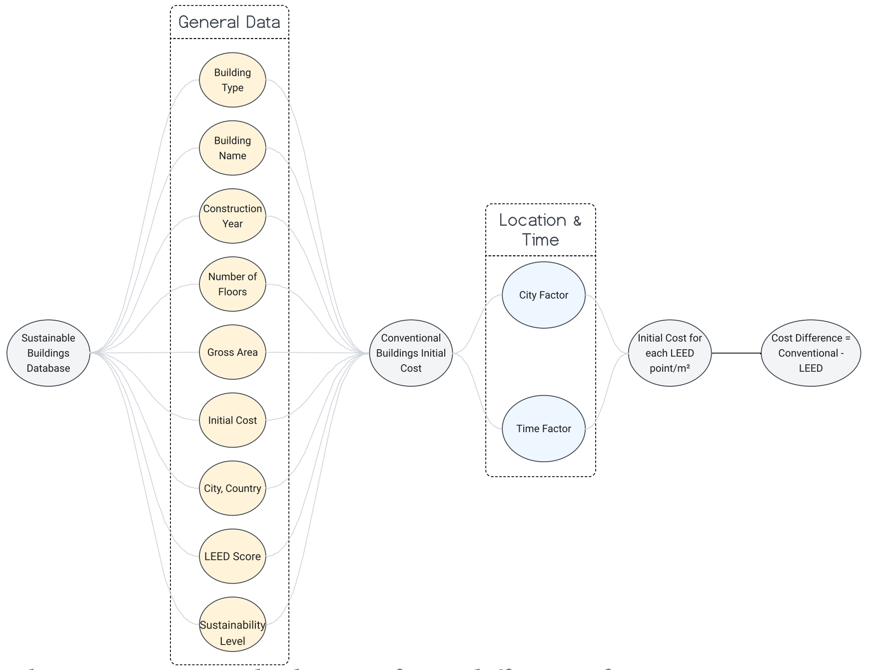


Figure 25: scheme about economic calculation of cost difference for LEED project -Model input data flowchart ; Source:provided by the author,data extracted from Initial cost assessment stochastic model for green buildings based on LEED score, Energy and Buildings, Volume 245, 2021

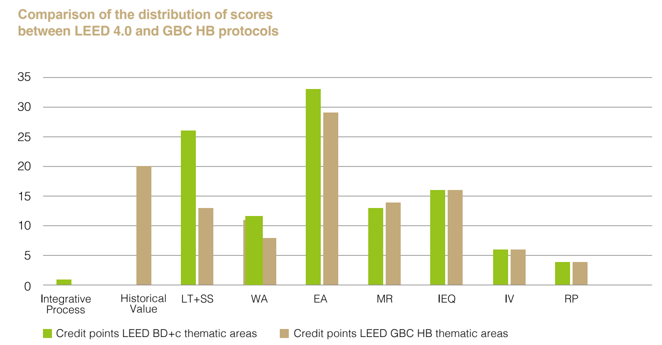


Figure 26: Comparison of the weight in total points for thematic areas in the LEED BD+C 4.0 and GBC HB protocols ; Source:extracted from "impact report 2023" in gbcitalia.org

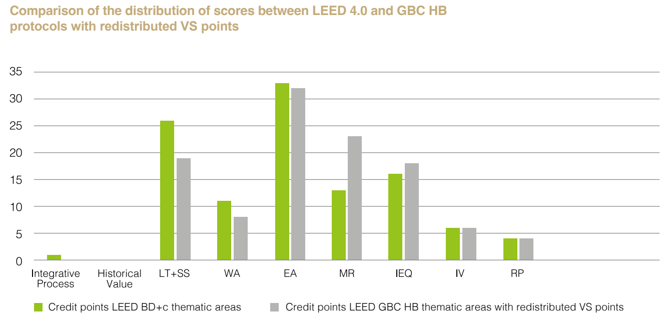


Figure 27: Comparison of the weight in total points for thematic areas in the LEED BD+C 4.0 and GBC HB protocols; Source:extracted from "impact report 2023" in gbcitalia.org

ing of the historical building under renovation, enabling more conscious and effective application of sustainable redevelopment and restoration strategies. It is possible to redistribute the points of the individual credits from the "Historical Value" area to other thematic areas based on their relevance. Credits VS 2, VS 3.1, VS 4, and VS 6 can be associated with the LT (Location and Transportation) and SS areas, credit VS 1.1 with the EA Energy and Atmosphere) area, credits VS 1.2, VS 1.3, VS 3.2, and VS 3.3 can be associated with the MR (Materials and Resources) area, and credit 5 with the IEQ (Indoor Environmental Quality) area.

The redistribution of VS credits shows how the GBC HB protocol, compared to LEED 4.0 protocol, emphasizes more on materials and indoor environmental quality. In a historic building, it is important to ensure the reuse of existing materials, combining a circular approach with the guarantee of preserving its historical value. The area related to indoor environmental quality acquires significant weight because, in historic architectures, due to existing constraints, it is more challenging to incorporate technological solutions for controlling air quality, ambient temperature, and natural lighting. The energy efficiency area of GBC HB carries the same weight as in the corresponding area of LEED 4.0 protocol.

Through deep energy investigations of historic buildings, as envisaged in the VS area, it is possible to leverage construction characteristics and bioclimatic solutions that are often already present in the existing historical architecture. Together with the integration of renewable energy production systems or the procurement of energy from renewable sources, a historic building can achieve high levels of efficiency. Building regulations often exempt historic buildings from meeting minimum energy efficiency standards to preserve their historic and architectural value. However, the GBC HB protocol, through the EA and VS credits, supports and encourages significant engagement in energy efficiency. The impact on the external environment is less emphasized in GBC HB compared to LEED 4.0, as historic buildings, by definition, are located within existing consolidated urban contexts, limiting the measures to reduce their impact on the overall context.

8.1. Example in Italy
The stables of the Rocca di Sant'Apollinare (PG)

The former stables of the Sant'Apollinare Fortress in Perugia are the first certified buildings according to HB GBC protocol. Dating back to the 17th-18th century, this ancient architectural construction is part of the Benedectine complex of historical buildings in the Umbrian countryside and today it houses offices and laboratories of the "Università degli Studi di Perugia". The complex, owned by the Foundation for Agricultural Education since 1892, was significantly damaged during the 2009 earthquake and therefore the project has focused on implementing cutting-edge strategies for seismic upgrading and energy efficiency improvement, with innovative measures linked to circular economy, energy efficiency and environmental sustainability.

Thematic Area of Excellence:

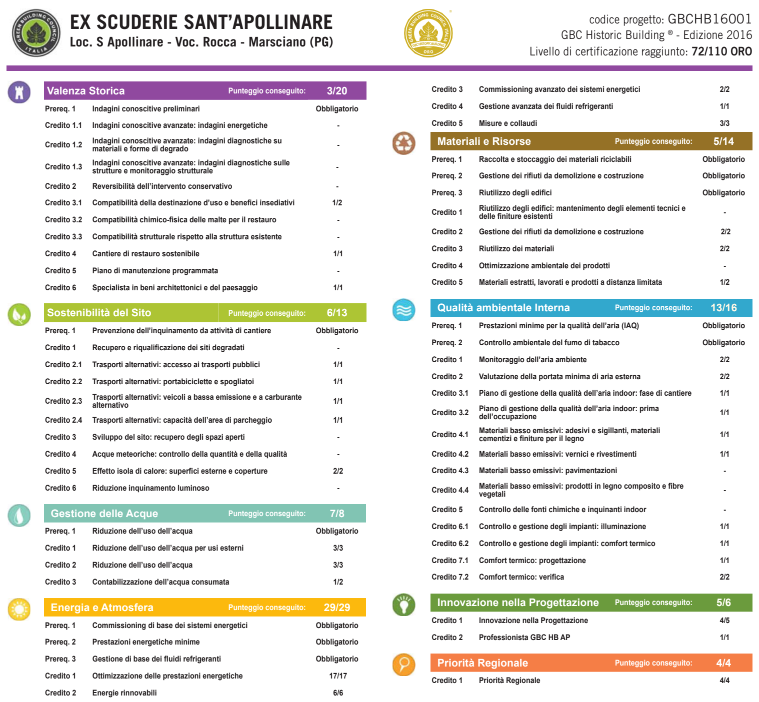
Water Management

The project of the former stables Sant'Apollinare includes several strategies aimed at preserving water resources. The construction phase included recovery of stormwater and in its operational phase, the building is equipped with a rainwater recovery system. Harvested rainwater is stored in a tank for irrigation in relevant green areas (although, during the design phase, the majority of the plant species were chosen to require minimal water) and for wc tank supply. Furthermore, specific technological elements have been introduced to reduce drinking water consumption, such as dual-flush wc tanks, faucet aerators and timed taps. Recently, the same project team has won European funding for a geothermal system which benefits from ground hydration from collected rain water, as envisaged in the GBC HB protocol.

Other Credit Categories

Historical Values

The former stables Sant'Apollinare restoration project ensured the reintegration of the historical image and the functional renovation of the building. Within the building, several pre-existing historical elements have been recovered and enhanced, while achieving high thermal and high energy performance levels. Moreover, innovative brick tiles with an antique effect and a spray engobe were employed on the roof, providing passive cooling benefits, while maintaining a traditional aesthetic appearance.


EX SCUDERIE SANT'APOLLINARE
Loc. S Apollinare - Voc. Rocca - Marsciano (PG)

codice progetto: GBCHB16001
GBC Historic Building ® - Edizione 2016
Livello di certificazione raggiunto: **72/110 ORO**

Valenza Storica	Punteggio conseguito:	**3/20**
Prereq. 1	Indagini conoscitive preliminari	Obbligatorio
Credito 1.1	Indagini conoscitive avanzate: indagini energetiche	-
Credito 1.2	Indagini conoscitive avanzate: indagini diagnostiche su materiali e forme di degrado	-
Credito 1.3	Indagini conoscitive avanzate: indagini diagnostiche sulle strutture e monitoraggio strutturale	-
Credito 2	Reversibilità dell'intervento conservativo	-
Credito 3.1	Compatibilità della destinazione d'uso e benefici insediativi	1/2
Credito 3.2	Compatibilità chimico-fisica delle malte per il restauro	-
Credito 3.3	Compatibilità strutturale rispetto alla struttura esistente	-
Credito 4	Cantiere di restauro sostenibile	1/1
Credito 5	Piano di manutenzione programmata	-
Credito 6	Specialista in beni architettonici e del paesaggio	1/1
Sostenibilità del Sito	Punteggio conseguito:	**6/13**
Prereq. 1	Prevenzione dell'inquinamento da attività di cantiere	Obbligatorio
Credito 1	Recupero e riqualificazione dei siti degradati	-
Credito 2.1	Trasporti alternativi: accesso ai trasporti pubblici	1/1
Credito 2.2	Trasporti alternativi: portabiciclette e spogliatoi	1/1
Credito 2.3	Trasporti alternativi: veicoli a bassa emissione e a carburante alternativo	1/1
Credito 2.4	Trasporti alternativi: capacità dell'area di parcheggio	1/1
Credito 3	Sviluppo del sito: recupero degli spazi aperti	-
Credito 4	Acque meteoriche: controllo della quantità e della qualità	-
Credito 5	Effetto isola di calore: superfici esterne e coperture	2/2
Credito 6	Riduzione inquinamento luminoso	-
Gestione delle Acque	Punteggio conseguito:	**7/8**
Prereq. 1	Riduzione dell'uso dell'acqua	Obbligatorio
Credito 1	Riduzione dell'uso dell'acqua per usi esterni	3/3
Credito 2	Riduzione dell'uso dell'acqua	3/3
Credito 3	Contabilizzazione dell'acqua consumata	1/2
Energia e Atmosfera	Punteggio conseguito:	**29/29**
Prereq. 1	Commissioning di base dei sistemi energetici	Obbligatorio
Prereq. 2	Prestazioni energetiche minime	Obbligatorio
Prereq. 3	Gestione di base dei fluidi refrigeranti	Obbligatorio
Credito 1	Ottimizzazione delle prestazioni energetiche	17/17
Credito 2	Energie rinnovabili	6/6
Credito 3	Commissioning avanzato dei sistemi energetici	2/2
Credito 4	Gestione avanzata dei fluidi refrigeranti	1/1
Credito 5	Misure e collaudi	3/3
Materiali e Risorse	Punteggio conseguito:	**5/14**
Prereq. 1	Raccolta e stoccaggio dei materiali riciclabili	Obbligatorio
Prereq. 2	Gestione dei rifiuti da demolizione e costruzione	Obbligatorio
Prereq. 3	Riutilizzo degli edifici	Obbligatorio
Credito 1	Riutilizzo degli edifici: mantenimento degli elementi tecnici e delle finiture esistenti	-
Credito 2	Gestione dei rifiuti da demolizione e costruzione	2/2
Credito 3	Riutilizzo dei materiali	2/2
Credito 4	Ottimizzazione ambientale dei prodotti	-
Credito 5	Materiali estratti, lavorati e prodotti a distanza limitata	1/2
Qualità ambientale Interna	Punteggio conseguito:	**13/16**
Prereq. 1	Prestazioni minime per la qualità dell'aria (IAQ)	Obbligatorio
Prereq. 2	Controllo ambientale del fumo di tabacco	Obbligatorio
Credito 1	Monitoraggio dell'aria ambiente	2/2
Credito 2	Valutazione della portata minima di aria esterna	2/2
Credito 3.1	Piano di gestione della qualità dell'aria indoor: fase di cantiere	1/1
Credito 3.2	Piano di gestione della qualità dell'aria indoor: prima dell'occupazione	1/1
Credito 4.1	Materiali basso emissivi: adesivi e sigillanti, materiali cementizi e finiture per il legno	1/1
Credito 4.2	Materiali basso emissivi: vernici e rivestimenti	1/1
Credito 4.3	Materiali basso emissivi: pavimentazioni	-
Credito 4.4	Materiali basso emissivi: prodotti in legno composito e fibre vegetali	-
Credito 5	Controllo delle fonti chimiche e inquinanti indoor	-
Credito 6.1	Controllo e gestione degli impianti: illuminazione	1/1
Credito 6.2	Controllo e gestione degli impianti: comfort termico	1/1
Credito 7.1	Comfort termico: progettazione	1/1
Credito 7.2	Comfort termico: verifica	2/2
Innovazione nella Progettazione	Punteggio conseguito:	**5/6**
Credito 1	Innovazione nella Progettazione	4/5
Credito 2	Professionista GBC HB AP	1/1
Priorità Regionale	Punteggio conseguito:	**4/4**
Credito 1	Priorità Regionale	4/4

Figure 28: Scorecard ex Scuderie ; Source: "GBC Italy" in gbcitalia.org

Figure 29: Scorecard ex Scuderie ; Source: "GBC Italy" in gbcitalia.org

Indoor air quality

During the design phase, indoor air quality was ensured through various measures, including the installation of a controlled mechanical ventilation system based on Class I standards and on CO_2 monitoring in the rooms. Indoor environmental quality was taken into account also by including prescribed lighting characteristics for the intended spaces and zone control of thermal conditions in order to maximize occupants' well-being.

Innovation in design

The project aimed to transform the former stables Sant'Apollinare into a pilot building for post-seismic structural retrofit and thermal-energetical efficiency improvement interventions in historically and artistically valued contexts. Innovative aspects in design include the use of prototyped material, implemented for the first time in this project to be introduced later in the market. The building now serves as an open-air laboratory for educating University students and researchers.

Energy and atmosphere

The complex of the former stables Sant'Apollinare is highly energy efficient. The building's energy needs are met by a pilot trigeneration plant based on oleaginous biomasses from agricultural fields and by an innovative low-enthalpy geothermal plant. Both are renewable energy sources with a low environmental impact. The use of a radiant floor system for air conditioning reduces energy waste from thermal machines. These plant precautions together with active and passive strategies of efficiency improvement minimize the building's environmental footprint and ensure optimal conditions of environmental well-being inside the structure

Materials with reduced environmental impact and locally sourced were used:

Roof tiles: have been partially recovered. The new tiles have an aged effect which allows for a high albedo and are photocatalytic to reduce pollution.

The flooring is made of local gravel selected on the basis of the type of stone and its grain size (4/6 mm) in such a way as to be with a high albedo and permeable.

The external coat (10 cm) is made of locally sourced recycled cork and completely removable as requested by the Superintendency.

8.2. Example in Turin

The city of Turin provides compelling examples that underscore the significance of adhering to the LEED protocol for sustainable interventions in historical buildings, such as Palazzo Santander. This is particularly crucial given Italy's vast historical heritage and the pressing need to enhance energy and water efficiency, as well as indoor environmental quality, in protected ancient structures.

Palazzo Santander

Palazzo Santander is the headquarters of Santander Consumer Bank. Due to the great attention to the environment, the Bank wanted the headquarters to be housed in a building with sustainability certification according to a country protocol. The building is a protected historic building:

The building, with a rich history spanning 120 years, was initially constructed in 1899 as the headquarters for a Turin-based car manufacturer. Over the years, it underwent expansions and additions, including an Art Nouveau office building in the early 20th century. Following periods of serving as a school and training center for various organizations within the Fiat Group, it officially closed in 2008. Since 2010 a redevelopment plan, the choice of protocol fell on GBC Historic Building, has been underway for the entire area, culminating in the transformation of the building into Palazzo Santander over the past 20 months.

In line with contemporary values of environmental sustainability and social responsibility, the building underwent redesign to reflect these principles.

The location of the building is well connected by public transport and numerous bicycle racks have been provided inside the courtyard in order to reduce the use of cars by employees. A green area has been created in the courtyard that can be used by employees.

The surfaces of the internal courtyard have been designed to minimize the contribution to the urban heat island effect: there are large green surfaces or paving in light colours, with high solar reflectance.

The energy used for the building is 100% from certified renewable sources (from hydroelectric plants) eliminating the use of fossil fuels. During the construction site activities, 100% of the waste was separated. Inside the building it was preferred to use materials equipped with EPD.

Thanks to the incorporation of a dual net-

PALAZZO SANTANDER
Corso Massimo D'Azeglio, 33/E - 10126 Torino

codice progetto: GBCHB17003
GBC Historic Building ® - Edizione 2016
Livello di certificazione raggiunto: **44/110 BASE**

Valenza Storica	Punteggio conseguito:	**4/20**
Prereq. 1	Indagini conoscitive preliminari	Obbligatorio
Credito 1.1	Indagini conoscitive avanzate: indagini energetiche	1/3
Credito 1.2	Indagini conoscitive avanzate: indagini diagnostiche su materiali e forme di degrado	-
Credito 1.3	Indagini conoscitive avanzate: indagini diagnostiche sulle strutture e monitoraggio strutturale	2/3
Credito 2	Reversibilità dell'intervento conservativo	-
Credito 3.1	Compatibilità della destinazione d'uso e benefici insediativi	-
Credito 3.2	Compatibilità chimico-fisica delle malte per il restauro	-
Credito 3.3	Compatibilità strutturale rispetto alla struttura esistente	-
Credito 4	Cantiere di restauro sostenibile	-
Credito 5	Piano di manutenzione programmata	-
Credito 6	Specialista in beni architettonici e del paesaggio	1/1
Sostenibilità del Sito	Punteggio conseguito:	**9/13**
Prereq. 1	Prevenzione dell'inquinamento da attività di cantiere	Obbligatorio
Credito 1	Recupero e riqualificazione dei siti degradati	2/2
Credito 2.1	Trasporti alternativi: accesso ai trasporti pubblici	1/1
Credito 2.2	Trasporti alternativi: portabiciclette e spogliatoi	1/1
Credito 2.3	Trasporti alternativi: veicoli a bassa emissione e a carburante alternativo	1/1
Credito 2.4	Trasporti alternativi: capacità dell'area di parcheggio	-
Credito 3	Sviluppo del sito: recupero degli spazi aperti	2/2
Credito 4	Acque meteoriche: controllo della quantità e della qualità	-
Credito 5	Effetto isola di calore: superfici esterne e coperture	2/2
Credito 6	Riduzione inquinamento luminoso	-
Gestione delle Acque	Punteggio conseguito:	**4/8**
Prereq. 1	Riduzione dell'uso dell'acqua	Obbligatorio
Credito 1	Riduzione dell'uso dell'acqua per usi esterni	1/3
Credito 2	Riduzione dell'uso dell'acqua	2/3
Credito 3	Contabilizzazione dell'acqua consumata	1/2
Energia e Atmosfera	Punteggio conseguito:	**12/29**
Prereq. 1	Commissioning di base dei sistemi energetici	Obbligatorio
Prereq. 2	Prestazioni energetiche minime	Obbligatorio
Prereq. 3	Gestione di base dei fluidi refrigeranti	Obbligatorio
Credito 1	Ottimizzazione delle prestazioni energetiche	3/17
Credito 2	Energie rinnovabili	6/6
Credito 3	Commissioning avanzato dei sistemi energetici	2/2
Credito 4	Gestione avanzata dei fluidi refrigeranti	1/1
Credito 5	Misure e collaudi	-
Materiali e Risorse	Punteggio conseguito:	**4/14**
Prereq. 1	Raccolta e stoccaggio dei materiali riciclabili	Obbligatorio
Prereq. 2	Gestione dei rifiuti da demolizione e costruzione	Obbligatorio
Prereq. 3	Riutilizzo degli edifici	Obbligatorio
Credito 1	Riutilizzo degli edifici: mantenimento degli elementi tecnici e delle finiture esistenti	-
Credito 2	Gestione dei rifiuti da demolizione e costruzione	2/2
Credito 3	Riutilizzo dei materiali	-
Credito 4	Ottimizzazione ambientale dei prodotti	2/5
Credito 5	Materiali estratti, lavorati e prodotti a distanza limitata	-
Qualità ambientale Interna	Punteggio conseguito:	**4/16**
Prereq. 1	Prestazioni minime per la qualità dell'aria (IAQ)	Obbligatorio
Prereq. 2	Controllo ambientale del fumo di tabacco	Obbligatorio
Credito 1	Monitoraggio dell'aria ambiente	-
Credito 2	Valutazione della portata minima di aria esterna	-
Credito 3.1	Piano di gestione della qualità dell'aria indoor: fase di cantiere	-
Credito 3.2	Piano di gestione della qualità dell'aria indoor: prima dell'occupazione	-
Credito 4.1	Materiali basso emissivi: adesivi e sigillanti, materiali cementizi e finiture per il legno	-
Credito 4.2	Materiali basso emissivi: vernici e rivestimenti	-
Credito 4.3	Materiali basso emissivi: pavimentazioni	-
Credito 4.4	Materiali basso emissivi: prodotti in legno composito e fibre vegetali	-
Credito 5	Controllo delle fonti chimiche e inquinanti indoor	-
Credito 6.1	Controllo e gestione degli impianti: illuminazione	-
Credito 6.2	Controllo e gestione degli impianti: comfort termico	1/1
Credito 7.1	Comfort termico: progettazione	1/1
Credito 7.2	Comfort termico: verifica	2/2
Innovazione nella Progettazione	Punteggio conseguito:	**4/6**
Credito 1	Innovazione nella Progettazione	3/5
Credito 2	Professionista GBC HB AP	1/1
Priorità Regionale	Punteggio conseguito:	**3/4**
Credito 1	Priorità Regionale	3/4

Figure 30: Scorecard Santander Palace ; Source: "GBC Italy" in gbcitalia.org

Figure 31: Scorecard Santander Palace ; Source : www.lastampa.it

work for rainwater collection and the adoption of low-water requirement sanitary equipment, the building achieves a 39% reduction in water usage for internal purposes and a 100% reduction for irrigation compared to the reference case. An advanced plant system has been installed to manage space utilization intelligently and sustainability, supported by a monitoring system and equipment that enable real-time adjustments to environmental conditions. Energy consumption data for each area are monitored using dedicated devices, accessible both locally and through the building's Ethernet network for immediate reference. Self-service activation of meeting rooms and conference systems is easily achievable, accessible intuitively from individual workstations or touch monitors in interactive areas. Implementing dimmable lighting not only enhances visual comfort but also presents significant energy-saving opportunities. Furthermore, presence sensors are installed to automatically deactivate lighting in unoccupied rooms, ensuring optimal electricity usage and reducing overall lighting loads. Thanks to the internal insulation system, which cannot be applied to the external facade due to historical-artistic constraints, and the air conditioning via groundwater heat pump, the building was designed with great attention to occupant comfort, verified via questionnaire during the first year of occupancy. The sophisticated geothermal system comprises a groundwater withdrawal well, a heat exchanger for the multi functional heat pump's condensation, and a groundwater return well. The power plant incorporates a versatile refrigeration unit capable of simultaneously generating hot and chilled water. The distribution system provides both cold and hot fluids concurrently, adjusting heating and/or cooling contributions according to specific area requirements. Each terminal can independently supply hot and cold fluids as needed based on desired room temperatures and internal loads. The entirely LED lighting, coupled with intelligent management via BMS, further enhances energy efficiency; the lighting system is programmed to automatically switch off in unoccupied rooms. Overall, these features contribute to the building saving 24% of energy compared to the reference building.

9. Core Concepts in Water efficiency

All water conservation practices rely on the use of potable water, which refers to water meeting minimum standards for drinking, cooking, and domestic purposes. Potable water serves various functions beyond drinking, such as irrigation, handwashing, and toilet flushing. However, since significant resources are expended in treating water for safe consumption, using potable water for non-essential purposes is wasteful.

The Water Efficiency (WE) category within LEED rating systems takes a comprehensive approach to water management, addressing indoor and outdoor usage, specialized needs, and metering. It encourages the use of non-potable water sources and alternative water usage, aiming to minimize potable water use for non-drinking purposes and promote gray water treatment and reclamation.

Implementing a holistic plan that reduces both indoor and outdoor water consumption and explores alternative water sources can lead to substantial savings in potable water usage. Calculations in the WE category adhere to the Energy Policy Act (EPAct) of 1992, which establishes maximum flush and flow rates in buildings. Approximately 70% of daily water usage occurs indoors, encompassing activities in bathrooms, kitchens, and industrial processes.

To effectively reduce indoor water consumption, project teams must gain insight into water usage patterns within buildings. The primary objective of LEED water efficiency standards is to minimize potable water use indoors through conservation and recycling measures. LEED v4 mandates a minimum 20% reduction from baseline indoor water usage, emphasizing sustainable practices in water management.

Systems thinking plays a pivotal role in understanding and addressing water management challenges. By viewing water use as part of a larger system, organizations can identify interrelated factors and potential leverage points for change. Leverage points, where small adjustments can yield significant results, offer avenues for transformative action. For instance, by providing building occupants with data on energy and water usage, similar to the "Prius effect," behaviors can be influenced towards greater efficiency, thereby promoting sustainable water management practices.

9.1. Reducing INDOOR Water Use Strategies:

The strategies to reduce indoor water use reflect the WE category knowledge domains of indoor water use and water performance management. These strategies include using high-efficiency or no-flush fixtures, implementing a graywater or rainwater water reclamation system, and installing submeters that measure and report water flow.

1. Efficient Fixtures

Efficient fixtures, carrying labels like WaterSense, offer significant water savings compared to traditional models. Technologies such as ultra-low-flow water closets, dual-flush systems, and low-flow aerators contribute to reducing indoor water consumption while maintaining performance standards.

- Ultra-low-flow water closets: These employ pressure tanks for pressure-assisted or vacuum-assisted flushing, reducing water use from 6 lpf to 4.8 lpf. Though requiring more maintenance, they are increasingly utilized in commercial and industrial settings.
- Dual-flush water closets: Offering separate flush options for liquid and solid waste, they use 3 lpf to 3.7 lpf for liquid waste and 4.8 lpf to 6 lpf for solids, optimizing water usage without compromising flushing effectiveness.
- Ultra-low-flow urinals: Utilizing optimized valves for pressure-assisted flushing, these urinals reduce water use to 0.473 lpf.
- Low-flow aerators: In scenarios where fixture replacement is cost-prohibitive, low-flow aerators offer a cost-effective alternative by reducing water flow by up to 50% while maintaining perceived flow. Careful selection and periodic maintenance are necessary to preserve fixture performance.

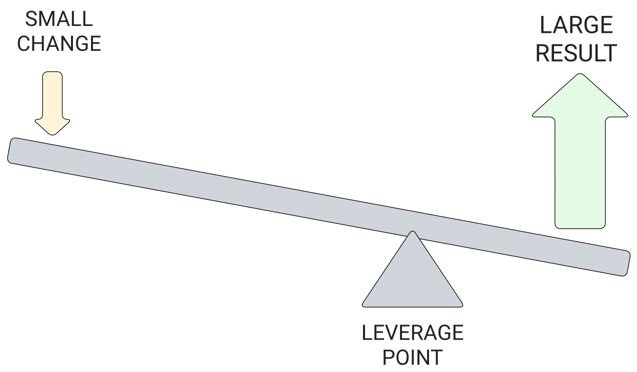


Figure 32: Leverage point approach
Source: provided by the author

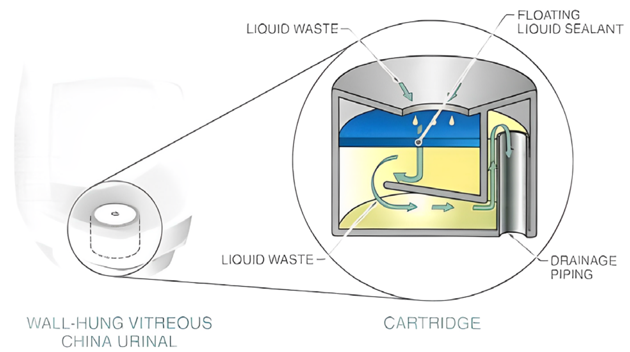


Figure 33: waterless urinals
Source: LEED handbook

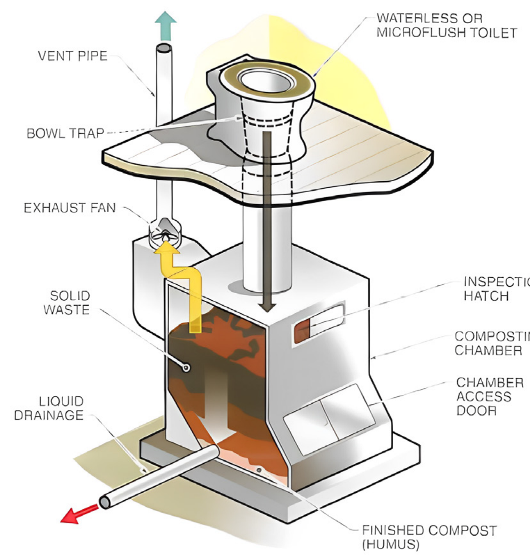


Figure 34: Waterless toilets;
Source: LEED handbook

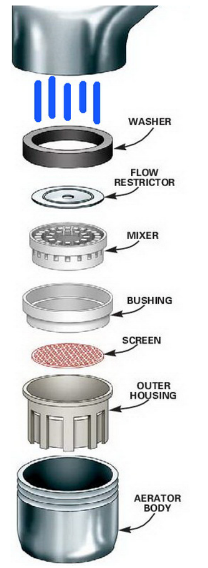


Figure 35: Low-flow aerators; Source: LEED handbook . It contains a flow restricter that reduces the flow and a mixer that adds air to the flow of water.

2. Waterless Fixtures

Waterless urinals and composting toilets have been in use for centuries. The use of waterless fixtures can result in considerable water savings, but the fixtures require more maintenance than traditional water-consuming fixtures. However, waterless urinals and toilets have increased in popularity due to the need to conserve water.

- Waterless urinals are designed to allow urine to flow through a trap device without the use of water. They are gaining popularity due to their water-saving potential, particularly in commercial settings where traditional urinals can consume significant amounts of water. These urinals can be found in various large venues like sports

Figure 36 :green (vegetated) roof

Figure 37 : Xeriscaping

stadiums and museums. Some waterless urinals use replaceable cartridges containing a liquid sealant to create an airtight barrier that prevents sewer gas from entering the room. Others utilize a trap with liquid sealant without the cartridge. Despite the term "waterless," these urinals still require regular maintenance and cleaning, often involving the use of water.

- Composting toilets are designed to convert solid waste into organic matter without using water. They consist of a single unit with a composting compartment, or multiple units connected to a remote composting tank. Aerobic microorganisms break down the waste using available water and oxygen, significantly reducing its volume. These toilets are an environmentally friendly option, especially in areas where water scarcity is a concern.

3. Water Reclamation Systems

Water reclamation system is a system designed to process water that was initially intended to be disposed of through sanitary or storm sewers. This processed water, known as reclaimed water, can then be reused in various applications instead of using potable water. The content mentions three subcategories of water reclamation systems:

- Rainwater harvesting: This involves collecting water from rooftops and paved or vegetated ground for reuse. Rainwater can be used for landscaping irrigation, bathing, clothes washing, or other nonpotable uses. It can also supplement water used in cooling tower applications.
- Graywater: it refers to water collected from showers, baths, lavatory sinks, and clothes washers within a building. It can be treated and reused for flush fixtures like toilets. Graywater may be filtered before reuse, and precautions such as back flow prevention are typically implemented.
- Reclaimed water: Reclaimed water is wastewater that has undergone treatment to meet regulatory standards for its intended nonpotable use. It may come from wastewater treatment plants and undergo treatment to remove harmful pathogens, organic material, and heavy metals. Reclaimed water can be used for various purposes such as landscaping, irrigation, dust control, fire protection, toilet flushing, industrial processes, and utility cooling. The level of treatment and quality of reclaimed water depend on its intended use and must be approved by the relevant authorities.

4. Submeters

Submeters is a device used for monitoring and measure total potable water usage in a building and its associated grounds. Metering water usage in kitchens and bathrooms allows buildings to track use, catch leaks, and make improvements. A leaking commercial faucet can use hundreds of liters of water a day. Installing submeters can reduce overall building water consumption by 30% to 40% in the first few months. Submeters can be installed in various areas such as irrigation

Figure 38 : Pevious surfaces

Figure 39 : Water storage tank

systems, indoor plumbing fixtures, domestic hot water heaters, boilers, reclaimed water systems, and other process water uses like humidification systems, dishwashers, clothes washers, and pools.

5. Process water

It refers to all the water within a building that is used for industrial purposes in building systems. This includes water used in boilers, cooling towers, and, in the case of restaurants or hotels, water used in dishwashers, clothes washers, and ice machines.

Efficient building systems are encouraged to reduce process water usage, as emphasized in WE Credit-Cooling Tower Water Use. Methods such as using reclaimed water or closed-loop water circulation systems can help reduce the reliance on potable water for industrial purposes. Closed-loop systems maintain water cleanliness and enable the reuse of process water for multiple cycles, reducing the need for fresh potable water.

Submeters play a crucial role in reducing potable water use for process water. By installing submeters to measure process water use, consumption trends can be tracked, fixture performance can be determined, and leaks can be pinpointed. Without submeters, it becomes challenging to efficiently track and measure these elements related to process water usage.

9.2. Reducing OUTDOOR Water Use Strategies

Outdoor water encompasses all water used outside the building, primarily for landscaping irrigation. Sprinklers and drip irrigation are the most prevalent methods. The WE category focuses on various approaches to reduce outdoor water consumption. Its intent is to reflect the knowledge domains of outdoor water use and water performance management within the WE category. Several strategies address landscaping types, while others target water sources and usage similar to indoor water use reduction.

1. Plant Native and Adapted Species

Native and adapted plant species require little to no water or pesticides. They are native to the region of the project and can survive the precipitation, drought cycles, and pests indigenous to that region. These considerations are aspects of the regional design part of the Project Surroundings and Public Outreach knowledge domain. The financial and environmental savings achieved in the use of water, pesticides, and labor (as opposed to the use of nonnative species) by incorporating all native and adapted species in landscaping are significant. Native species can be an important part of restoring habitats to their natural state.

2. Xeriscaping

Xeriscaping is a landscaping design approach that prioritizes water conservation through various strategies. It involves soil enhancements, efficient irrigation methods, and the use of native or adapted plant species to minimize water usage while maintaining an aesthetically pleasing outdoor environment. The process of xeriscaping typically encompasses several steps, including careful planning and design, strategic plant placement, soil improvements, adoption of efficient irrigation techniques such as drip irrigation,

Figure 40 : Bioswales

Figure 41 : Gabions

consideration of turf alternatives, application of mulching, and ongoing maintenance practices. Drip irrigation, in particular, is highlighted as a highly efficient watering method compared to traditional sprinkler systems, as it delivers water directly to the roots of plants, minimizing water loss due to evapotranspiration or runoff. With its focus on sustainable water management, xeriscaping offers a practical and environmentally conscious approach to landscaping.

3. Selecting Efficient Irrigation Technologies:

Drip irrigation is highlighted as a highly efficient method compared to traditional sprinkler systems, as it delivers water directly to plant roots, minimizing water loss.

4. Harvesting Rainwater

Capturing and harnessing rainwater represents a pivotal step in integrating nonpotable water sources into irrigation practices. Commercial rainwater collection often relies on cisterns, substantial tanks strategically positioned in or around buildings. Conversely, residential rainwater collection commonly involves the use of rain barrels and hoses. These methods not only promote water conservation but also serve as regional design considerations within the Project Surroundings and Public Outreach domain.

Rainwater management typically involves two key steps. Firstly, minimizing impervious areas such as hardscapes helps reduce excessive runoff. Secondly, employing green infrastructure and low-impact development techniques aids in managing runoff effectively, replicating natural hydrology and water balance on-site. A comprehensive approach integrating both methods can yield optimal results.

- Reduce Impervious Hardscape :To reduce impervious hardscape, various pervious surface alternatives can be employed. Green roofs, adorned with native plant beds, intercept rainwater, preventing runoff. For sidewalks and parking lots, porous pavement, asphalt, and grid pavers offer viable alternatives. However, the maintenance of porous surfaces is essential to re-

Figure 42 : Harvesting Rainwater Cycle

tain their permeability, as they are prone to clogging over time.
- Implement Rainwater Management : it involves collecting rainwater for reuse in irrigation, process water, or flushing fixtures within buildings. Sophisticated collection systems may even distribute rainwater through pipes within the building. However, it's important to note that rainwater is not suitable for drinking and may be subject to regulations in drought-prone regions.
- Passive rainwater management systems redirect rainwater to designated planted areas, facilitating natural infiltration into the soil. Rain gardens, dry ponds, and bioswales serve as effective features to capture and filter rainwater before draining it back into the earth. Similarly, inexpensive methods like berms or swales can channel rainwater to landscaped areas for irrigation, mitigating runoff and soil erosion. In areas vulnerable to flash floods, gabions offer protection against soil erosion by slowing down water movement. These structures, composed of rocks held together by wire mesh, allow water saturation into the soil while preventing erosion.
- Active rainwater management systems are essential for supplementing irrigation needs during dry periods. These systems capture, store, and transport rainwater to desired areas between rainfall occurrences. Typically, commercial buildings utilize large cisterns for rainwater collection, which may undergo treatment for drinking water purposes using filters and pumps.

5. Using Nonpotable Water for Irrigation:

Reclaimed water, treated to nonpotable standards, is utilized for irrigation in many areas, particularly in the western United States, helping to reduce reliance on freshwater sources.

6. Installing Submeters:

Metering outdoor water usage is essential for effective management and achieving reductions in water consumption, aiding in cost savings and conservation efforts.

Edoardo_Tresoldi_Simbiosi_©_Roberto_Conte_9

Digital Technologies and Sustainability Assessment

The Architecture, Engineering, and Construction (AEC) sector faces substantial challenges, such as climate change and rising energy costs. Effective water management has become increasingly crucial due to population growth, urbanization, and environmental concerns. To address these challenges, it is essential to utilize water resources efficiently and optimize consumption and distribution systems.

Professionals in the AEC sector, responsible for various stages of building and infrastructure projects, are under growing pressure to adopt sustainable building practices. The urgency for sustainability has intensified, leading to a focus on innovative solutions to reduce environmental impact and enhance energy efficiency. Over the past three decades, national and international green building certification bodies have emerged, providing frameworks to promote sustainability in construction projects. One prominent certification system in this domain is the Leadership in Energy and Environmental Design (LEED) green building rating system, which is the focus of chapter three of the introduction of the thesis. Although LEED is globally recognized, various regions may have their own localized green building standards and rating systems. Central to green building certification programs is the accumulation of points across different categories to achieve the final certification level. The LEED system offers multiple choses to earn points, including water efficiency. However, meeting the specific sustainability criteria within the LEED framework often requires advanced digital analysis and modeling tools.

In response to these sustainability demands, the concept of green Building Information Modeling (BIM) has become important. As concerns about the consequences and depletion of nonrenewable resources grow, BIM is increasingly employed to predict and monitor the environmental impacts of construction. Research has shown that BIM can significantly contribute to various aspects of sustainable design and support the LEED certification process.[1][2][3][4]. Autodesk highlights that addressing decision-making challenges early in the design and construction process allows project stakeholders, including clients and designers, to collaborate effectively and access a shared source of information. BIM technologies provide a strong foundation for meeting sustainability rating requirements, prompting a surge in research interest in BIM-based technology for sustainability certification.

In recent decades, alongside the implementation of green and sustainable construction, BIM has offered a collaborative three-dimensional platform to digitally model and investigate all stages of the construction process of green buildings in a virtual environment. With BIM, designers can make environmentally friendly choices early in the building life cycle, providing insight into how different design alternatives influence building sustainability and performance, thereby avoiding the time spent re-entering building information and secondary data needed for investigation. Consequently, project members can design, evaluate, organize actions, and identify potential compatibility among equipment and spaces within a three-dimensional digital environment. Additionally, employing BIM tools enables owners to better monitor the progress of their building design and construction phases.[3][4]

Developing a three-dimensional parametric model within BIM facilitates information-centric project management, contrasting with the conventional document centered method, by serving as a central storage of project-related information. This allows project members to examine and adapt the building design before its physical implementation. Furthermore, designers and engineers can efficiently integrate, manage, and share information among architectural, structural, electrical, mechanical, construction, design, and facility-management teams throughout the building life cycle within an integrated working system, enabling reliable integration of sustainability analysis into the design process. Sustainable strategies combined with BIM can create high-performance and efficient building designs, replacing conventional drawing-based design.

Parametric modeling is recognized as a useful tool for achieving this objective, as it produces adjustable models that can be combined with assessment, optimization, and automation tools.

Software providers also reference sustainability demands, offering several parametric modeling tools based on 3D software for managing either the entire project or specific parts of its life cycle. **Revit**, for instance, is widely utilized by owners, architects, engineers, mechanic engineers and designers to generate parametric models.

Numerous information levels and data are entered into BIM models, known as BIM dimensions. These dimensions include: 3D (geometric, graphical, and non-graphical information), 4D (timeline, scheduling, and extent), 5D (cost assessment), 6D (sustainability), and 7D (facility management during the project life cycle).

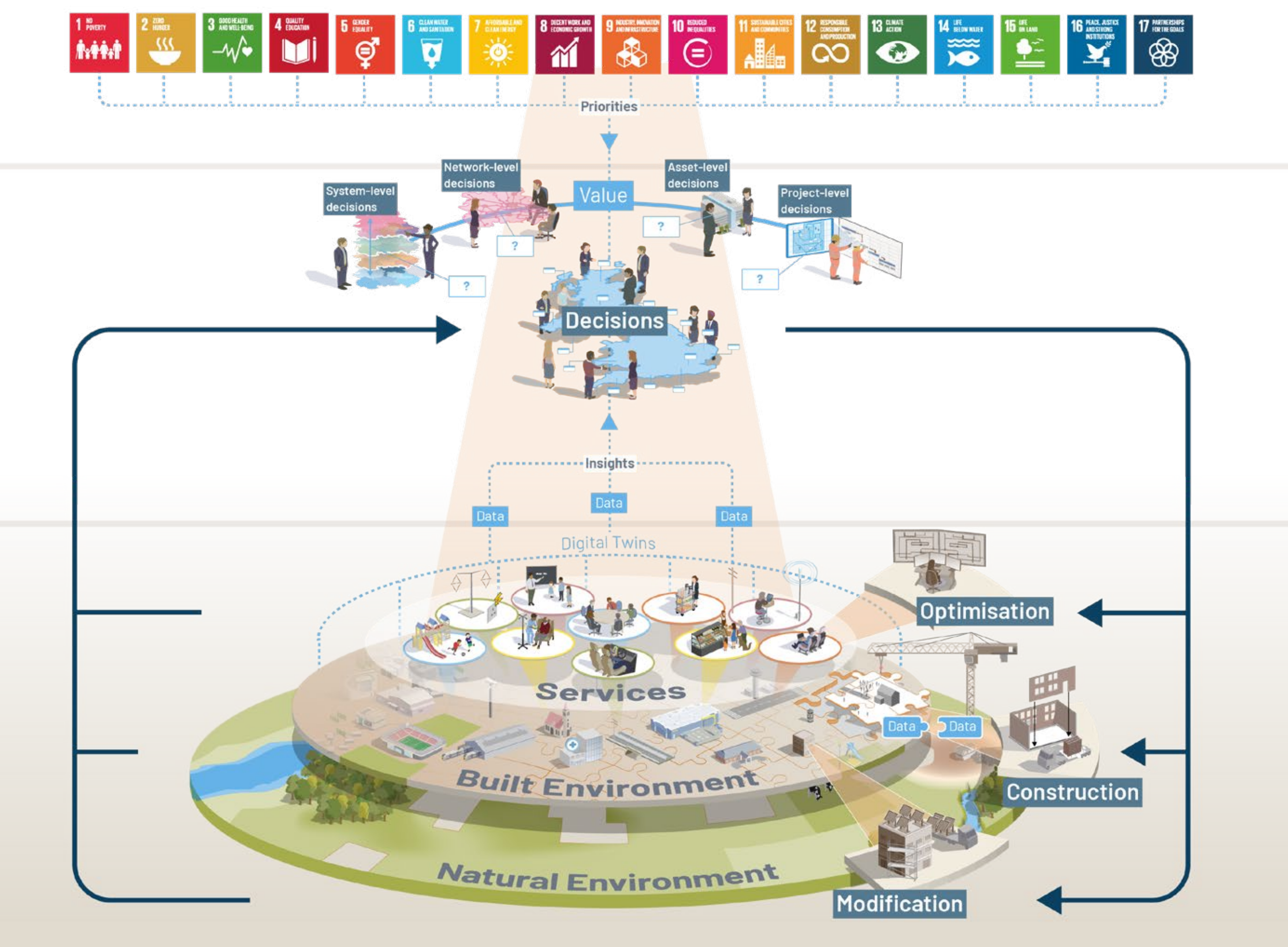


Figure 43 : Integration of green building and technology;
Source : "Transforming Infrastructure Performance: Roadmap to 2030"

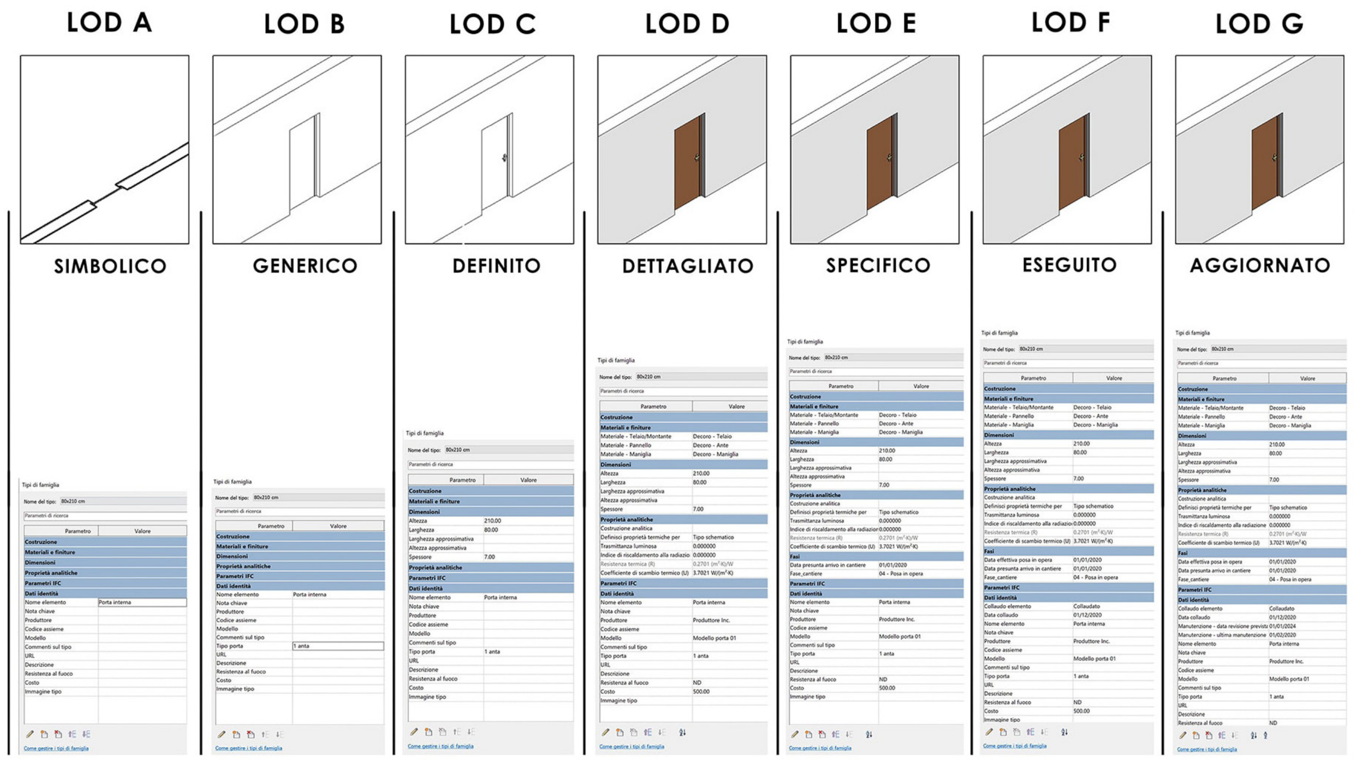


Figure 44 : Table of Level Of Detail ; Source : "4mgroup.it"

Apart from these dimensions, BIM implies five levels of development (LOD), an industry standard specifying how the 3D geometry of the building model can achieve various levels of sophistication. The LODs include: LOD 100 (building location and space), LOD 200 (quantity, size, and form), LOD 300 (clash detection, scheduling, and visualization), LOD 400 (MEP systems), and LOD 500 (building operation and maintenance).

BIM data can be integrated with building performance and simulation applications, such as Autodesk Green Building Studio, Ecotect, Autodesk Project Vasari, IES-VE, and Bentley AECOSim. This integration allows these applications to be effective decision-making tools for designing high-performance buildings. Additionally, these tools can be personalized through plug-ins, which expand their initial capabilities. These plug-ins, often designed by third parties, enable the inclusion of performance simulations within the BIM environment, facilitate problem-solving using optimization methods, and significantly automate processes.

One fundamental issue in some projects is the use of a dynamic description to flexibly control the parameters of the designed object, best achieved through a mathematical description. Utilizing third-party software is common for assessing LEED credits. Project teams can use the software platform to perform the required LEED estimates for credits that need comprehensive numerical evaluation, such as energy simulation, lighting evaluation, water utilization, material characteristics, and integrated design. Coordinating BIM software and LEED credit requirements is an initial step in integrating BIM with LEED.

Autodesk Dynamo, a VPL intended for use with Autodesk Revit, is a graphical programming interface that lets you customize your building information workflow. Dynamo is an open source visual programming platform for designers. It is installed as part of Revit along with Revit specific programming nodes. It can be used to assess if a building developed in Revit would gain points for LEED Credits. The Dynamo tool obtained the required data from the Revit model and determined a "Pass" or "Fail" for LEED Credits.

Ur Rehman et al.22 identified and implemented methods to achieve green building parameters for energy and water saving for multi-family houses provided by the LEED certification scheme using BIM tools such as Autodesk

Revit, Insight, and Green Building Studio.[3] Since a visual programming language (VPL) allows featuring a third party without any skills in C-coding language, several researchers have adopted it to streamline the integration process. Kensek et al.23 demonstrated an application of BIM for LEED using a VPL as an intermediary.[5]

Sanhudo and Martins(2018) aimed to address the challenges of assessing sustainability in the construction industry by integrating Building Information Modeling (BIM) with green certifications, specifically LEED. They propose a BIM-based software plugin that simplifies and automates sustainability assessments, with a focus on stormwater runoff management. This tool helps users easily calculate runoff and implement low-impact development best practices, ultimately promoting more efficient and sustainable building practices.[4] For this purpose, Revit was used as the BIM model inventor, Dynamo as the visual programming language, and Dynamo player as the user interface.

Dynamo contains nodes and packages, each designed to perform specific functions. Users can also incorporate Python scripts within Dynamo, significantly extending its capabilities. Python scripts in Dynamo allow for more complex and customized operations that might be cumbersome or impossible with standard nodes alone. This includes advanced data manipulation, custom algorithms, and intricate geometry processing. Through Python scripting, users gain direct access to the Revit API (application programming interface), enabling interactions with and manipulations of Revit elements beyond the predefined capabilities of Dynamo nodes. (Figure 45)

Python scripts empower users to create custom functions and reusable scripts, automating repetitive tasks, streamlining workflows, and implementing unique solutions tailored to specific project requirements. For those already familiar with Python, scripting in Dynamo provides a powerful and intuitive way to interact with Revit, reducing the learning curve and facilitating

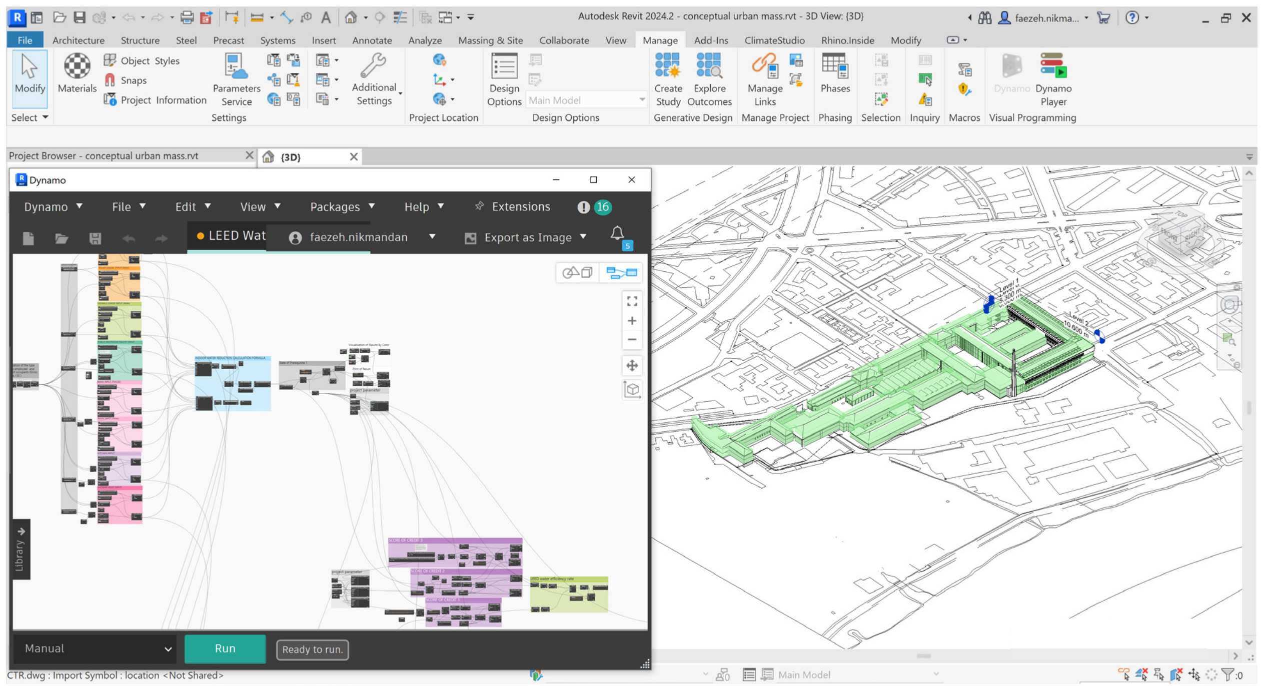


Figure 45 : Dynamo in Revit Environment; Source : Provided by the author

the quick implementation of complex solutions. Python scripts often offer performance advantages over complex node-based solutions, especially when handling large datasets or intricate operations.(Figure 46)

The integration of Python in Dynamo for Revit grants users greater control and flexibility, allowing them to utilize a wide array of programming techniques to enhance their design and automation processes within the Revit environment. Additionally, artificial intelligence (AI) can provide robust error handling and debugging capabilities, which are invaluable when developing complex workflows and ensuring reliable execution.

AI,a branch of computer science focused on creating intelligent machines with human-like reasoning, learning, and problem-solving capabilities, has seen numerous applications in the architecture, engineering, and construction (AEC) industry. Studies have explored using AI techniques, such as machine learning (ML), to address AEC challenges.

In my research, ChatGPT, as an AI tool, supported the debugging and optimization of my code in the chart-providing process. AI facilitated the detection and correction of syntax and logical errors, offered optimization suggestions, assisted in tracing runtime errors, and contributed to code documentation. While AI provided valuable support, all final decisions and implementations were made by the author to ensure the accuracy and integrity of the code.

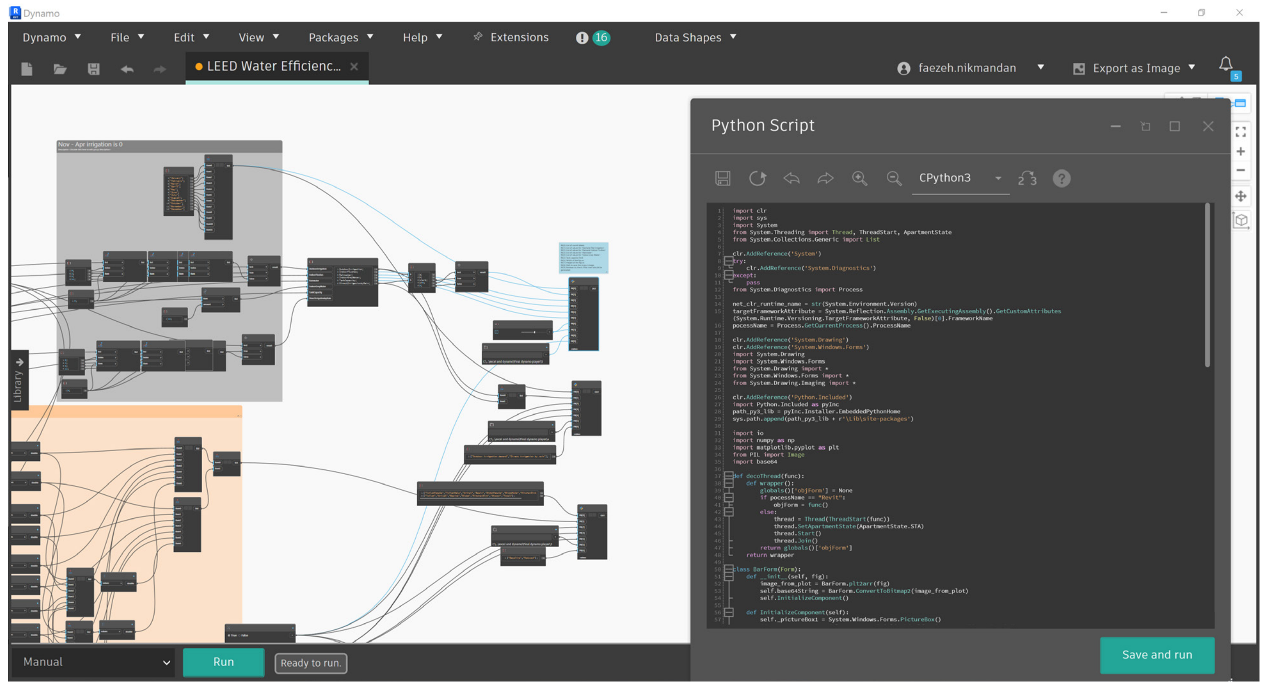


Figure 46 : Python scripts in Dynamo Environment ; Source : Provided by the author

Objectives

The primary objective of this thesis is to develop an automated sustainability assessment methodology using Building Information Modeling (BIM) to facilitate water efficiency in building design. Given the increasing concerns over water scarcity exacerbated by global warming, the thesis emphasizes the importance of integrating sustainable practices within the construction industry, particularly through the implementation of green building certifications like LEED (Leadership in Energy and Environmental Design).

To achieve this, the thesis analyzes LEED sustainability criteria related to water and establishes a framework for automated building sustainability assessment using BIM, leveraging its capabilities to simplify the evaluation of sustainable building practices during the early design stages. By focusing on water conservation, the study aims to enhance the accuracy and efficiency of sustainability assessments, providing a tool for architects ,designers ,engineers and owners . Recognizing the early design phase as crucial for making impactful sustainability decisions, the thesis evaluates various design alternatives that prioritize water efficiency. By implementing low-impact development strategies, the study identifies leverage points where small changes can lead to significant water conservation outcomes.

Furthermore, the thesis integrates digital technologies, specifically Visual Programming Language (VPL) tools like Dynamo, to automate the sustainability assessment process. This integration simplifies the complex calculations and assessments required for obtaining LEED credits, making the process more accessible and less time-consuming for users. The use of VPL allows for the creation of parametric BIM models that include LEED requirements, enabling users without extensive informatics knowledge to engage in sustainable design practices effectively.

In addition, the thesis focuses on developing an easy-to-use in-program add-in utilizing Dynamo and Dynamo Player. This tool is designed to expedite decision-making processes and assist users in selecting effective strategies to attain LEED credits. By simplifying the assessment parameters and calculations, the add-in helps users make informed decisions quickly, enhancing the overall efficiency of the sustainable design process.

Overall, this thesis aims to create a practical methodology that integrates BIM and LEED, focusing on water efficiency to promote sustainable building practices. The developed tools and methods will provide invaluable guidance to various stakeholders, enabling them to achieve significant water conservation and contribute to broader sustainability goals.

Methodology

The assessment of water management strategies within the framework of smart cities involves a multifaceted decision-making process that requires a structured approach for thorough evaluation. To tackle this complexity, a comprehensive framework has been adopted, integrating the GBC Historic Building certification and LEED protocols. This framework holds particular relevance in Italy, targeting "historic buildings" specifically. Structured around various categories, such as Historic Value, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation, and Regional Priority, the rating system provides a holistic approach to assessment.

This chapter describes the development methodology of a quantitative approach for evaluating water efficiency based on LEED protocols of the Historical Green Building Council. Implementation of the evaluation approach consists of two methods: manual assessment of water consumption, which is traditional yet time-consuming, and evaluation via integration between LEED, Building Information Modeling (BIM), and Visual Programming Language (VPL).

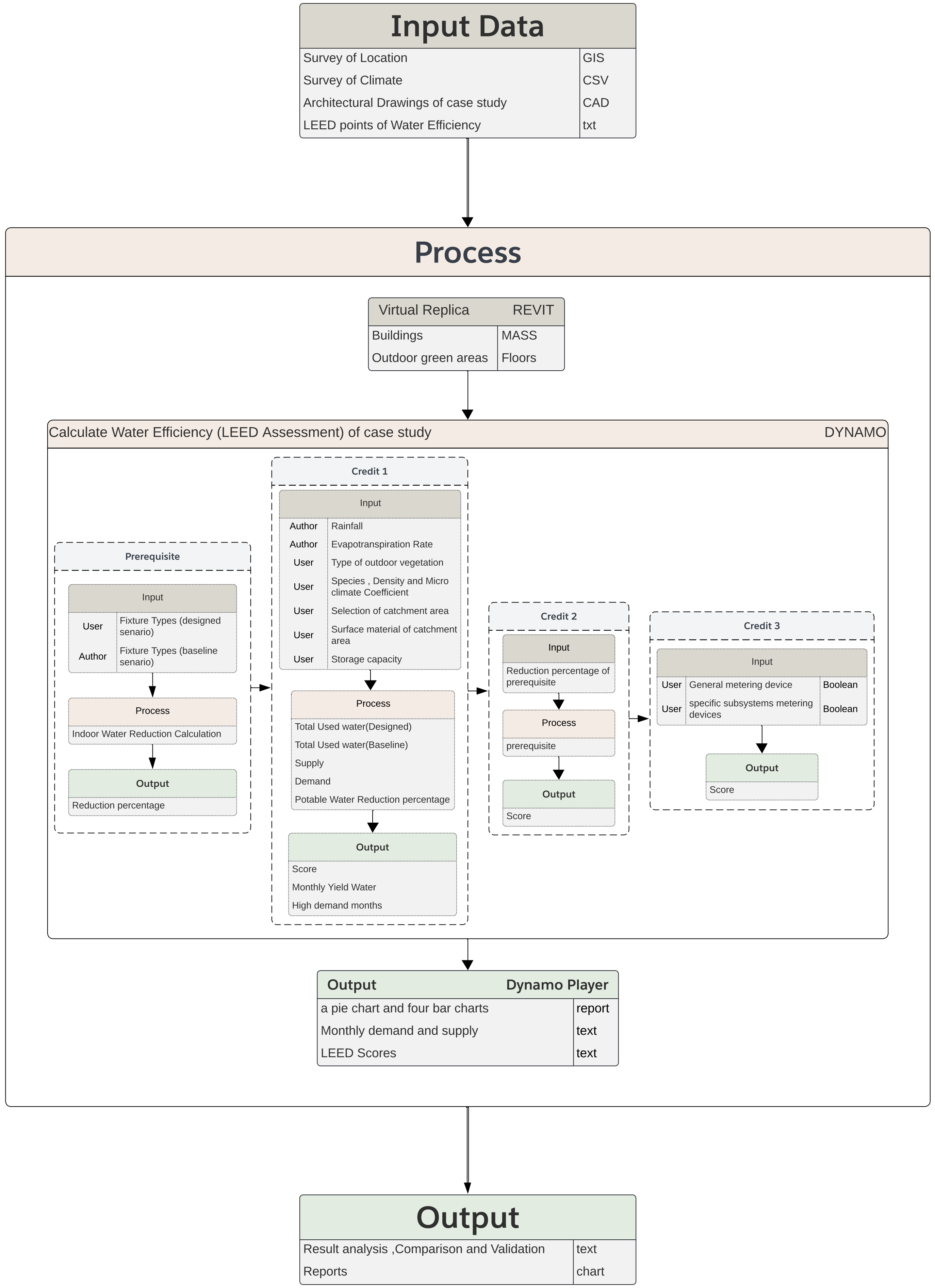
General Workflow

The implementation process is divided into three phases: "input data," "process data and evaluation," and "output and results." The methodology initiates with the data collection phase, gathering essential information for subsequent stages. Input data encompasses climate surveys and investigations into building placements and green areas. Climate survey data, including historical rainfall data from reliable sources like Agenzia Regionale Per La Protezione Dell'ambiente Della Piemonte (Arpa Piemonte) is utilized, along with software tools like Climawat and ET0 Calculator for determining evapotranspiration parameters.

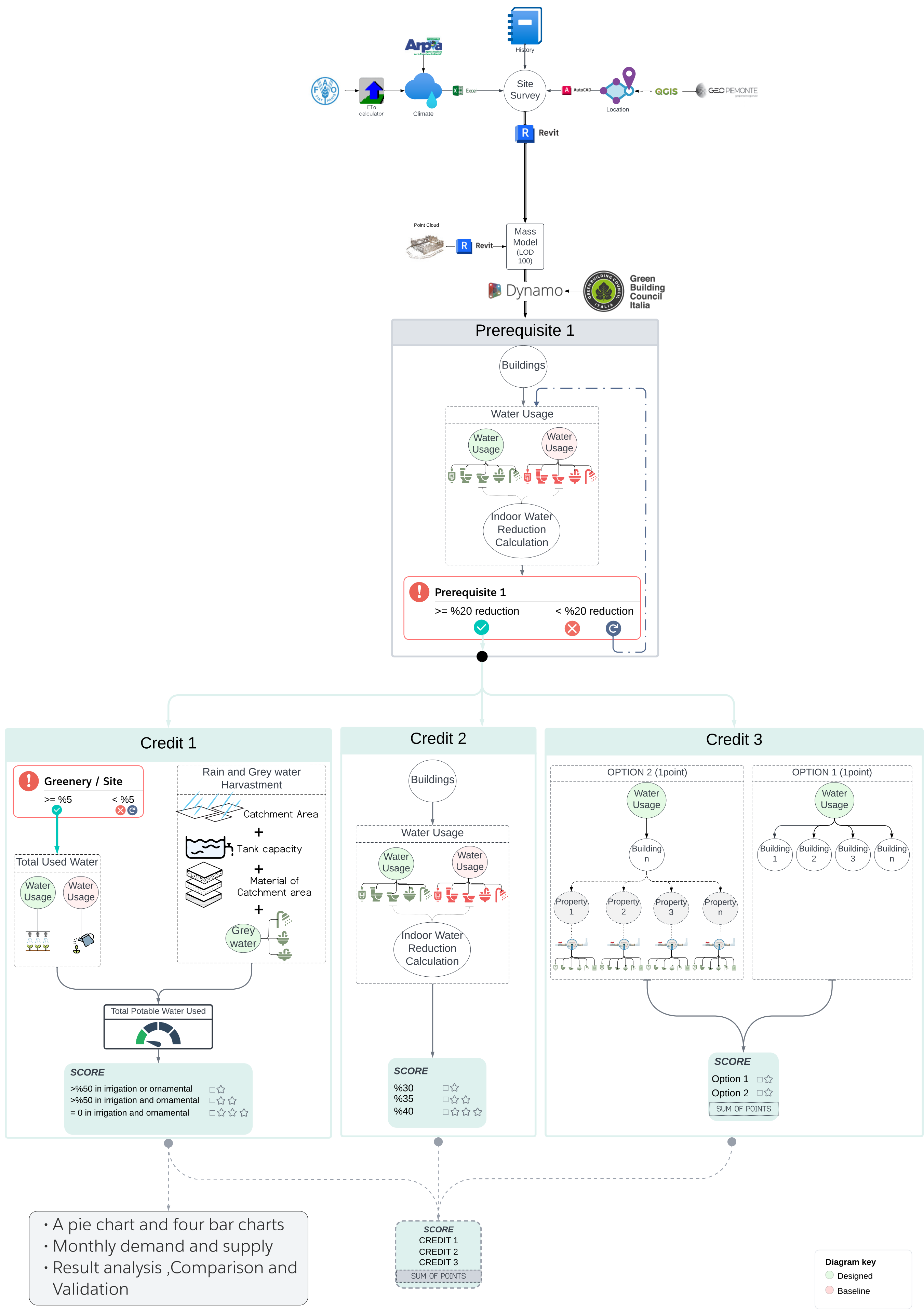
The processing phase necessitates creating a digital replica of the case study using Revit 2024. This choice was made because Revit is not only a modeling tool but also a BIM software, where each component contains its own information. Using Revit also helps avoid potential issues related to data exchange and interoperability. As the aim of this research is to explore water efficiency during the conceptual and preliminary design stages with low-impact development, a BIM model is created at a sufficient level of detail (LOD) to ensure the authenticity and cross-validation of the results. As the methodology achieves its goals by simply requiring users to input the horizontal areas of the case study, a fundamental key to the correct performance of the software is the adequate categorization of the elements corresponding to these areas. In simpler terms, these horizontal areas consisting of buildings and green zones must each correspond to the following Revit Categories:Buildings as Mass model category and Green zones as Floors category. In addition, it should be stressed that the low LOD adds to the pursued methodology simplicity, allowing its application in the earliest project phases, eliminating unnecessary burdens with model detailing.

To apply LEED water efficiency protocols, Visual Programming Language tools like Dynamo are employed due to their interoperability with Revit. Dynamo's scripts, through dynamo-player ,as interface, facilitates accessibility for users regardless of their familiarity with VPL and enabling to engage with the process.

Ultimately, the output generated through this methodology aids in monitoring, calculating, simulating, evaluating, and making decisions regarding water-efficient strategies. These strategies encompass a range of measures such as water-saving fixtures, rainwater harvesting systems, greywater recycling, and minimizing potable water usage. Furthermore, innovation in design addresses specific water management challenges, including landscaping practices and the integration of tailored water-efficient technologies. While this study focuses on the preliminary rating assessment of water efficiency, further research into life cycle cost assessment is warranted for a comprehensive understanding.



Input Data
Survey of Location
GIS
Survey of Climate
CSV
Architectural Drawings of case study
CAD
LEED points of Water Efficiency
txt
Process
Virtual Replica
REVIT
Buildings
MASS
Outdoor green areas
Floors
Calculate Water Efficiency (LEED Assessment) of case study
DYNAMO
Prerequisite
Input
User
Fixture Types (designed senario)
Author
Fixture Types (baseline senario)
Process
Indoor Water Reduction Calculation
Output
Reduction percentage
Credit 1
Input
Author
Rainfall
Author
Evapotranspiration Rate
User
Type of outdoor vegetation
User
Species , Density and Micro climate Coefficient
User
Selection of catchment area
User
Surface material of catchment area
User
Storage capacity
Process
Total Used water(Designed)
Total Used water(Baseline)
Supply
Demand
Potable Water Reduction percentage
Output
Score
Monthly Yield Water
High demand months
Credit 2
Input
Reduction percentage of prerequisite
Process
prerequisite
Output
Score
Credit 3
Input
User
General metering device
Boolean
User
specific subsystems metering devices
Boolean
Output
Score
Output
Dynamo Player
a pie chart and four bar charts
report
Monthly demand and supply
text
LEED Scores
text
Output
Result analysis ,Comparison and Validation
text
Reports
chart



History
Site Survey
Climate
Location
QGIS
Revit
Point Cloud
Revit
Mass Model (LOD 100)
Dynamo
Green Building Council Italia
Prerequisite 1
Buildings
Water Usage
Water Usage
Water Usage
Indoor Water Reduction Calculation
Prerequisite 1
>= %20 reduction
< %20 reduction
Credit 1
Greenery / Site
>= %5
< %5
Rain and Grey water Harvastment
Catchment Area
Tank capacity
Material of Catchment area
Grey water
Total Used Water
Water Usage
Water Usage
Total Potable Water Used
SCORE
>%50 in irrigation or ornamental
>%50 in irrigation and ornamental
= 0 in irrigation and ornamental
Credit 2
Buildings
Water Usage
Water Usage
Water Usage
Indoor Water Reduction Calculation
SCORE
%30
%35
%40
Credit 3
OPTION 2 (1point)
OPTION 1 (1point)
Water Usage
Water Usage
Building n
Building 1
Building 2
Building 3
Building n
Property 1
Property 2
Property 3
Property n
SCORE
Option 1
Option 2
SUM OF POINTS
• A pie chart and four bar charts
• Monthly demand and supply
• Result analysis ,Comparison and Validation
SCORE
CREDIT 1
CREDIT 2
CREDIT 3
SUM OF POINTS
Diagram key
Designed
Baseline

Water Efficiency

All water conservation is based on the use of potable water. Potable water is water that meets the minimum requirements for drinking, cooking, or domestic purposes. According to data from the European Commission, in Europe, buildings account for 14% of all potable water consumption. People use potable water not just for drinking but for irrigation, handwashing, and flushing toilets as well. Since a large amount of energy, cost, and infrastructure goes into treating water so it is safe to drink, it is wasteful to use potable water for purposes in which it is not required. The Water Efficiency (WE) category in the LEED rating systems addresses water holistically, looking at indoor use, outdoor use, specialized uses, and metering. It also recognizes nonportable water usage and alternative water sources.

As mentioned previously, implementation of the methodology requires a digital replica of the case study ,typically achieved with a lower Level of Detail . According to the provided guideline from Historical GBC, the rating system is a four-step process.(Table 1)

1. Prerequisite

The prerequisite mandates the presence of at least one toilet room in the building used daily. To achieve a 20% reduction in overall indoor water usage compared to the baseline case (excluding irrigation), specific strategies must be implemented. The baseline case calculation should consider data for commercial and/or residential activities. In this methodology, the building's function is assumed to be an office, encompassing fixtures like toilets, urinals, taps, showers, and kitchen sinks. Certain equipment and appliances such as commercial steam cookers, dishwashers, ice-makers, and washing machines are excluded from the water consumption reduction calculation.

Calculation

The calculation methodology for determining prerequisite involves comparing the calculated designed case with the baseline case. The reduction in water use is measured as the difference between these two cases, expressed as a percentage. This methodology considers the consumption levels of accessories and fixtures by estimated consumption of occupants by taking into account of each fixtures' duration or flow rate.

Occupancy consumption estimation relies on calculating Full-Time Equivalent (FTE) occupants and users, connected to the specific utilization of fixtures. FTE is used to calculate the number of occupants in a building with associated average daily water fixture use. FTE is determined based on a standard 8-hour per day presence period (40 hours per week), with an 8-hour presence having an FTE value of 1.0. Assuming that the case study is an office or commercial and industrial proj-

Credit	Title	Score
Prerequisite 1	Reduction of water use	Obligatory
Credit 1	Reduction in the use of water for external purposes	1-3 Points
Credit 2	Reduction of water use	1-3 Points
Credit 3	Accounting for water consumed	1-2 Points

Table 1 : Water Efficiency Historical GBC

ect, in the absence of precise occupancy data, the guideline book of the GBC of Italy offers a reference point for estimation, suggesting an average allocation of 55 m² per employee.

To facilitate calculations, facilities are categorized into groups according to their equipment usage levels. These groups include Toilet (Female and Male), Urinals (Male), Taps and basin , Bidets (Female and Male), Kitchen sink taps, and Showers.(Table 2)

Dynamo Script

At this stage, the calculations are started by extracted data from shared parameter of Revit masses,such as Gross Floor Area, and the input data entered by the Dynamo-player user, to calculate the improved percentage of reduced water usage (equation 3) by calculation of daily water use for each fixture type in baseline scenario (equation 1)and designed scenario(equation 2).

It is important, among the various options in the input data (Table 3) entered by the Dynamo-player user, strategies should be based on low-impact development strategy. Data on the flow rate of fixtures and equipment , as illustrated in Table 3, help in selecting optimal options for the designed case study.

Upon completion of the calculations in dynamo player, confirmation will be received in output section regarding whether the prerequisite has been achieved or not.

Fixture Type	Maximum Installed Flush/Flow Rate		Duration (sec)	Default Uses per Day
	Baseline	Reduced		Employees (FTE)
Toilet (male)	6 lpf	4 lpf	n/a	1
Toilet (female)	6 lpf	4 lpf	n/a	3
Urinal	4 lpf	2 lpf	n/a	2
Public lavatory (restroom) faucet	2 lpm	2 lpm	15	3
Kitchen faucet	9 lpm	6 lpm	30	1
Bidets (Female)	9 lpm	5 lpm	30	1
Bidets (Male)	9 lpm	5 lpm	30	0.5
Showerhead	10 lpm	7 lpm	300	0.1

Table 2 : Default uses of sanitary equipment, by type of occupation/presence.

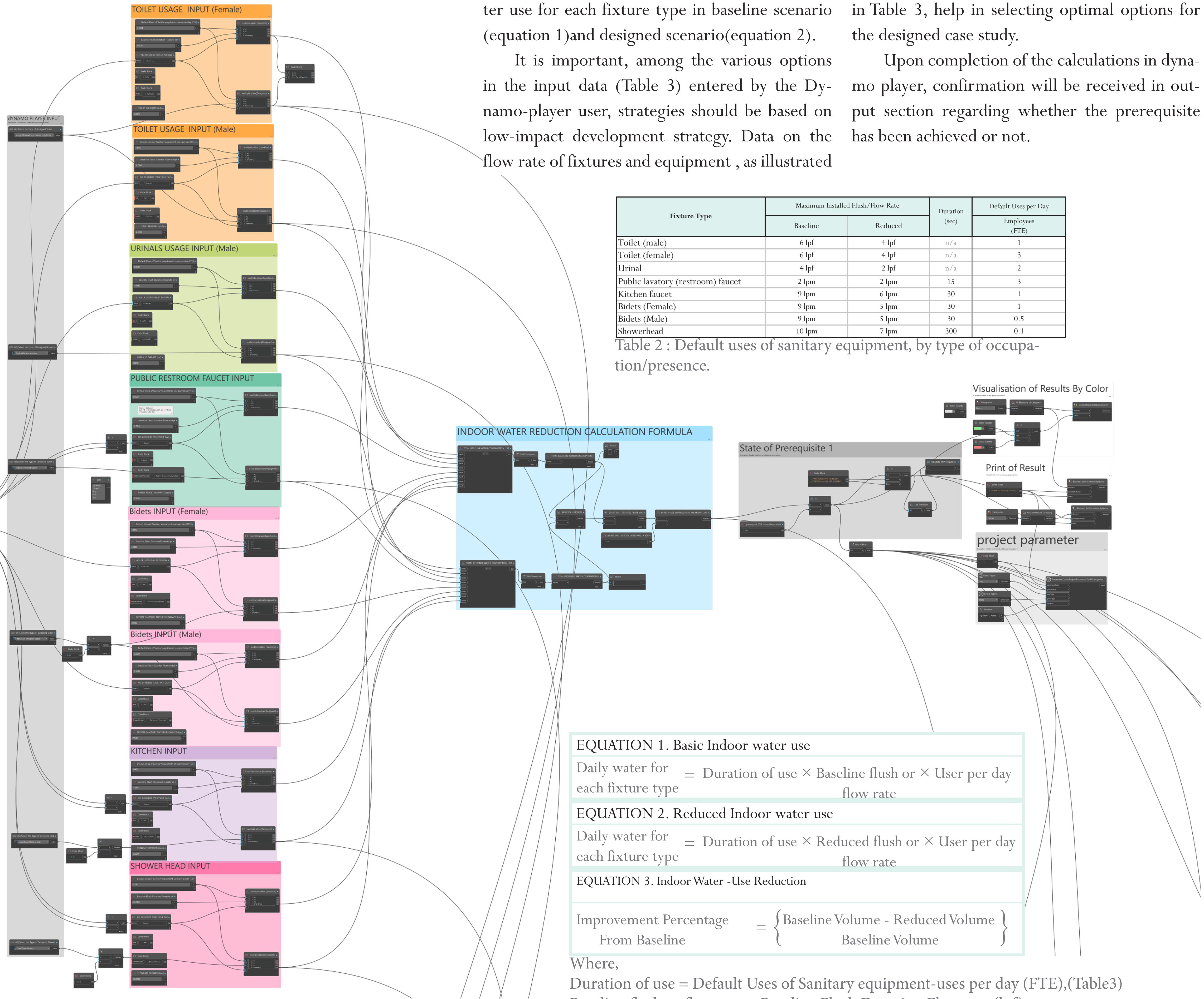


Image 2 : Prerequisite script Workflow on Dynamo

Example of plumbing equipment and accessories and water consumption			
Plumbing Equipment and Accessories	Flow Rate(lpf)	Plumbing Equipment and Accessories	Flow Rate(lpm)
Conventional toilets	6.0	Public conventional basin	0.475
High efficiency toilets (HET), single gravity drain	5.0	Public Efficient basin	0.38
HET, single flow with pressure regulator	4.0	private conventional basin	9.0
HET, double flow (full jet)	6.0	private medium Efficient basin	6.0
HET, double flow (reduced jet)	4.0	private High Efficient basin	4.0
HET, nebulized flow	0.2	Conventional Bidet	9.0
Toilet without water	0.0	Medium Efficient Bidet	6.0
Conventional urinal	4.0	High Efficient Bidet	4.0
High efficiency urinal	2.0	Conventional kitchen sink	9.0
Urinal without water	0.0	Low flow kitchen sink	6.0
		Conventional shower	10.0
		Low flow shower	7.0

Table 3 : Example of plumbing and accessories and water consumption
lpm : Liter per minute
lpf : Liter per flow

EQUATION 1. Basic Indoor water use

$$\text{Daily water for each fixture type} = \text{Duration of use} \times \text{Baseline flush or flow rate} \times \text{User per day}$$

EQUATION 2. Reduced Indoor water use

$$\text{Daily water for each fixture type} = \text{Duration of use} \times \text{Reduced flush or flow rate} \times \text{User per day}$$

EQUATION 3. Indoor Water -Use Reduction

$$\text{Improvement Percentage From Baseline} = \left\{ \frac{\text{Baseline Volume - Reduced Volume}}{\text{Baseline Volume}} \right\}$$

Where,
Duration of use = Default Uses of Sanitary equipment-uses per day (FTE),(Table3)
Baseline flush or flow rate = Baseline Flush Duration Flow rate (lpf)
User per day = Number of Users
Baseline Volume = Sum of all actual daily water usage from each fixture per day
Reduced Volume = Sum of all reduced daily water usage from each fixture per day

2. Credit 1

This credit can only be obtained if there are green areas requiring irrigation constitute at least 5% of the total lot area.

Calculations

To determine the percentage of the reduction in potable water usage for credit 1, it is necessary to establish the current water consumption for the project and then compare it to the designed situation. Separate calculations are required for water used in irrigation, fountains, and water features. Each green area, must be consistent across both baseline and designed scenarios,is assessed individually to determine its water usage in irrigation. These areas are classified into five categories : Trees ,Shrubs , Flowers , Mixed and Turf (Table 4). Determination of specific class for the green areas is rather subjective ; Despite this, landscape planning professionals should still give a general idea of classification,K_s,K_d and K_{mc},that are explained in the following paragraphs. It's important to note that assuming 100% of any category for whole project is not realistic, especially if the project includes significant areas for trees, shrubs, and flower beds. It is recommend selecting the category in which a species comprises over 60% of that kind.

The Coefficient of External Areas of Relevance (K_L) quantifies the volume of water loss due to Evapotranspiration Rate (ET_0). ET_0 represents the total water required to cultivate a specific reference plant and is expressed in millimeters. The value of ET_0 is typically referenced to the months with the highest evapotranspiration effects and consequently, the greatest demand for irrigation, for example, the month of July .For the monthly ET_0 calculation, two software developed by the *FAO* has been used:

- *Climawat*, that provides the climatic data of the nearest station, according to the case study was Torino;
- *ET_0 Calculator*, that reads the data exported from *Climawat* and provides the values of the evapotranspiration coefficient (ET_0) in mm/day for each month of the year.

ET_0 is influenced by factors such as plant species (K_s), local microclimate (K_{mc}), and plant density (K_d), as outlined in Equation 4 and 5.These factors must be determined for each relevant outdoor area.

- The Species Factor (K_s) accounts for the variation in water requirements among different species, which are categorized as high, medium, or low (as illustrated in Table 4).
- The Density Factor (K_d) accounts for both the number of plants and the total leaf area of the green zone. It helps to quantify how dense the vegetation cover is in a particular area. Areas with sparse vegetation will have lower K_d values, indicating lower evapotranspiration rates. Conversely, areas with denser vegetation will have higher kd values, indicating higher evapotranspiration rates. The kd value varies depending on the percentage of land shaded by trees or covered by shrubs and bushes. For instance, a low percentage of shade cover (e.g., 25%) corresponds to a lower kd value, while higher percentages of shade cover result in higher kd values. In systems with mixed vegetative cover, where trees cover under-story species and bushes, evapotranspiration tends to increase. This represents the highest level of density, with kd values ranging between 1.0 and 1.3.
- The Microclimate Factor (K_{mc})considers environmental factors such as temperature, wind, and humidity in the external area under consideration. Various external features, such as buildings, paved areas, reflective surfaces, and slopes, can influence the microclimate of an area. For example, parking areas can increase the effects of temperature and wind on adjacent areas. The average value of kmc is 1.0, which is applicable to conditions where the evapotranspiration rate is not significantly influenced by external features such as buildings, paved surfaces, reflective surfaces, or slopes. High K_{mc} values indicate situations where the evaporation potential is increased due to specific environmental conditions. These conditions include surfaces that absorb or reflect heat, areas exposed to particular ventilation conditions, or areas affected by factors like traffic islands and wind tunnel effects. Examples of areas with high K_{mc} values include parking lots, western sides of buildings, western and southern slopes, and areas prone to wind tunnel effects. Conversely, low K_{mc} values correspond to areas where the microclimate is less influenced by external factors. Examples include the north side of buildings, courtyards, areas under large over-

Factors of the Relevant External Area									
Type Of Vegetation	Species Factor (Ks)			Density Factor(Kd)			Microclimate factor(Kmc)		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Trees	0.2	0.5	0.9	0.5	1.0	1.3	0.5	1.0	1.4
Shrubs	0.2	0.5	0.7	0.5	1.0	1.1	0.5	1.0	1.3
Flowers	0.2	0.5	0.7	0.5	1.0	1.1	0.5	1.0	1.2
Mixed	0.2	0.5	0.9	0.6	1.1	1.3	0.5	1.0	1.4
Turf	0.6	0.7	0.8	0.6	1.0	1.0	0.8	1.0	1.2

Table 4: Species ,Density and Microclimate factor in classified vegetation

Type of Irrigation	IE
Aspirators and watering cans	0.625
Drip systems	0.9

Table 5 : Type of irrigation

Credit 1	Points	Conditions
Option 1	1	Reduction in consumption for irrigation **or** ornamental purposes by **50%**
Option 2	2	Reduction in consumption for irrigation **and** ornamental purposes by **50%**
Option 3	3	**No use** of drinking water for external and/or ornamental purposes (1.Use only water collected from rainfall, reclaimed waste water 2.particular types of vegetation that do not require permanent irrigation systems)

Table 6 : LEED score for credit 1

Month	Average Rainfall [mm]	Average ET0 [mm]
January	29.45	9.3
February	10.2	17.4
March	14.9	43.4
April	52.55	69
May	121.55	93
June	151.25	111
July	68.75	127.1
August	107.85	99.2
September	44.8	63
October	53.95	34.1
November	44.8	12
December	32.55	6.2
Annual	732.6	684.7

Table 7 : Monthly Rainfall and ET_0

hangs, and the north side of slopes.

The specific Evapotranspiration Rate (ET_L) is calculated for each area by multiplying the value of ET_0 with the K_L, as indicated by equation 5. It is also necessary to determine irrigation efficiency (IE), identifying the types of irrigation used for each relevant outdoor area.(See Table 5)

And finally,the Controller Efficiency (CE) represents the percentage reduction in water consumption resulting from the application of controllers with weather sensors or humidity sensors. This value can be derived from manufacturers' documentation or from detailed calculations by the outdoor space designer.

Dynamo Script

The initial step involves defining the Revit floor compound as green areas(see Image 3). Then , Python script is utilized in dynamo to apply table 4 on input data. For instance, these data must be inserted by user in shared parameter of each garden or by selecting in dynamo player and python transforms them to the values that listed in table 4 and 5.

The baseline and designed case is calculated separately for each garden. By defining the species factor (k_s), density factor (k_d), and efficiency of irrigation (IE) the designed case could involve the replacement of species in the relevant external areas characterized by low water consumption (such as shrubs) with others with higher consumption (such as turf). Obviously ,due to the location ,the same values of the microclimate factor (k_{mc}) and the evapotranspiration rate (ET_0) is calculated in dynamo script.

In the next stage, Potable water Reduction Percentage (equation 9) is obtained from TAU and TAPU; Total Water Used (TAU) is calculated for both baseline and designed case (equation 6 and 8) and Total Potable Water Used (TAPU) is calculated for each relevant outdoor area by applying equation 7 and 11 for designed case. The percentage of reduction is calculated from the total amount of potable water used for irrigation, indoor flushes. To decrease the consumption of potable water, a solution is to harvest rainwater and store indoor wastewater/ greywater.

As mentioned previously, the calculation requires location-specific data, including monthly rainfall amounts and monthly ET_0. This methodology is applicable to any other case study by simply changing the rainfall data and monthly ET_0 values(Table 7). For the case study, this data is obtained from the Torino Giardini Reali

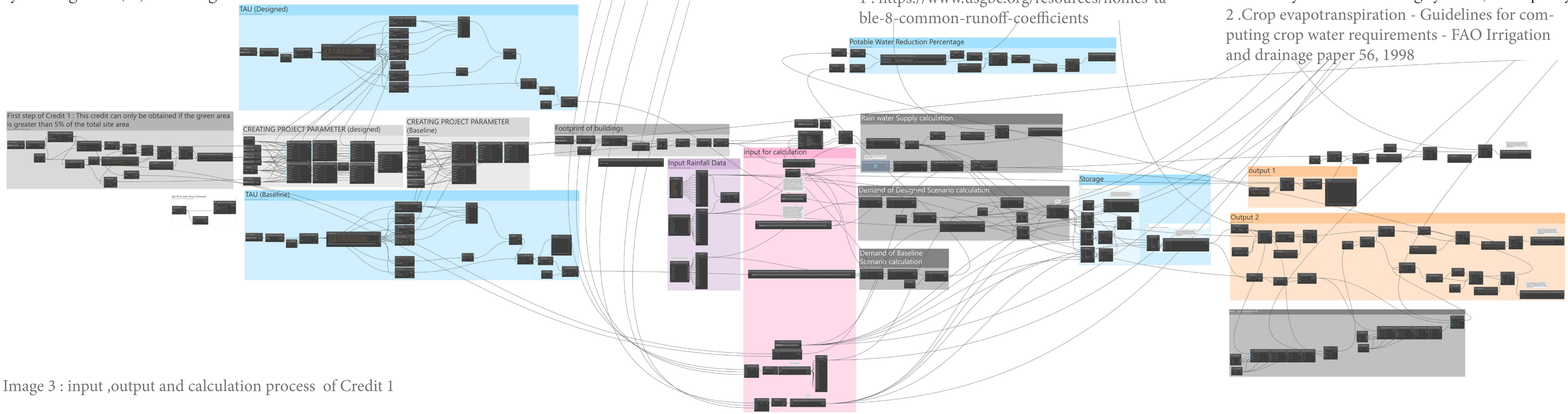


Image 3 : input ,output and calculation process of Credit 1

station of Arpa Piemonte, and ET_0 data obtained from *Climawat* and *ET_0 Calculator*. The case study data can be modified or input by the user using the Dynamo Player. These data include:

- Area of rain collection (m^2)
- Area of irrigation(m^2)
- Surface material of rain collection area:The Runoff Coefficient is the percentage of the total precipitation that falls on a collection area and runs off the surface to potentially be collected. Surfaces that are smooth and non-porous generally have a higher percentage of runoff. These values are approximations and are based on the typical construction method of the roof type. It does not account for wind, evaporation, etc., and assumes that the gutter system is properly installed and maintained. The value is unitless and is from usgbc.org.[1]
- Plant water used coefficient :The Plant Water Use Coefficient is the percentage of the evapotranspiration (ET_0) that a given type of plant needs for growth and/or healthy appearance. The value may also be referred to as the crop coefficient, plant factor, or landscape coefficient, and is typically in the range from 0.1 (low) to 1.2 (high). Drought-tolerant, native plants are in the lower end of this range, and plants like cool-season turf grasses and garden vegetables are at the higher end of the range. The value is unitless and is from FAO.org.[2]
- Supplementary water to store: Grey water or wastewater used in the building can be stored and used for irrigation and toilet flush purposes.
- Estimated monthly **indoor** water demand (liter) : it is required to replace the amount of potable water used in toilet or urinals flush with collected water
- Capacity of the storage tank(liter)

In collecting water, supply and demand dynamics revolve around the collection and utilization of rainwater, so the calculations are consist of two parts:

Supply:

The supply refers to the amount of supplementary water to store and rainwater that can be collected from precipitation. This depends on factors like rainfall patterns, catchment area (such as rooftops or land surface), and the efficiency of the harvesting system (like capacity

1 . https://www.usgbc.org/resources/homes-table-8-common-runoff-coefficients

2 .Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56, 1998

of storage tanks ,gutters and pipes).

The supply of rainwater is inherently variable and depends on historical rain data of the case study.(Equetion10)

Demand:

Demand refers to the usage or requirement of water for various purposes like irrigation or indoor purposes.

The demand for rainwater depends on factors such as area of the irrigation ,type of existing plants .

The result of these calculations provide decision-makers with valuable insights, such as the amount of potable water used for irrigation and the identification of months when rainfall directly on the irrigation area is insufficient, prompting the need for rainwater storage. If demand exceeds supply, additional water sources like greywater collected from washing basins and kitchen sinks may be necessary. Furthermore, it helps assess whether the capacity of the user-inserted storage tank is adequate. Conversely, if supply exceeds demand, there may be opportunities to store excess rainwater for future use or to release it into the environment to recharge groundwater reserves.

Once the amount of TAPU is calculated, and the percentage of reduction in drinking water in consumption for irrigation or ornamental purposes reaches 50%, it receives 1 point. If the reduction in consumption for both irrigation and ornamental purposes reaches 50%, it receives 2 points. Additionally, if there is no use of drinking water for external and/or ornamental purposes, it receives 3 points. (See table 6)

3. Credit 2

The credit score is determined based on the calculations of prerequisites, as outlined in Table 8.

EQUATION 4. The Coefficient of Relevant Outdoor Areas

$$K_L = K_s \times K_d \times K_{mc}$$

EQUATION 5. Evapotranspiration Rate

$$ET_L\,[mm] = ET_0\,[mm] \times K_L$$

EQUATION 6. Total Used Water of Designed Outdoor

$$TAU\,[L] = \left\{ Area_{(m^2)} \times \frac{ET_L\,[mm]}{IE\,[-]} \right\} \times (1 - CE) \times 1.0\,[L/(m^2 \times mm)]$$

EQUATION 7. Total Potable Used Water of Designed Outdoor

$$TAPU\,[L] = TAU\,[L] - (\text{Collected Grey water} + \text{Rain water})\,[L]$$

EQUATION 8. Total Used Water of Baseline Outdoor

$$TAU\,[L] = \left\{ Area\,(m^2) \times \frac{ET_L\,[mm]}{IE\,[-]} \right\} \times 1.0\,[L/(m^2 \times mm)]$$

EQUATION 9. Potable Water Reduction Percentage

$$\text{Reduction}\,[\%] = \left\{ 1 - \frac{TAPU_{\text{designed case}}}{TAU_{\text{baseline case}}} \right\} \times 100$$

EQUATION 10. Supply

$$\text{Estimated monthly supply to collection tank}_{(L)} = \text{Average monthly rainfall}_{(L/m^2)} \times \sum_{i=1}^{n} \left(\text{Area of rain collection}_{i\,(m^2)} \times \text{Runoff coefficient}_i \right) + \text{Monthly indoor supply}_{(L)}$$

EQUATION 11. Demand of Designed scenario

$$\text{Total monthly demand}_{(L)} = \text{EQUATION 6} + \text{Monthly indoor demand}_{(L)}$$

Credit 2	
Percentage Reduction	Points (BD+C)
30%	1
35%	2
40%	3

Table 8: LEED score for Credit 2

4. Credit 3

General and permanent meters for water measurement, dividing the water for external uses (irrigation, fountains, etc.) and for internal uses.

- **Interventions with the presence of multiple functional units**

(1 Point)

For projects with multiple functional units, such as offices, residential areas, commercial spaces, and museums, it is essential to implement separate accounting for each functional unit. This includes both internal and external water usage, irrespective of whether the unit is rented to third parties or owned by the same properties. This intervention ensures comprehensive monitoring of water consumption within the project.

- **Installation of water meters**

(1 Point)

Alternatively, the installation of additional water meters can further enhance water management practices. Alongside the general requirement, one additional meter should be installed to monitor specific subsystems:

- Irrigation: Accounting for a minimum of 80% of the irrigated area, excluding areas with native vegetation that don't require routine irrigation.
- Interior taps and accessories: Covering at least 80% of the taps and accessories mentioned in Prerequisite- Reduction of water use. This meter accounts for direct or indirect water use, subtracting any other measured volume.
- Domestic hot water: Monitoring at least 80% of the total volume of domestic hot water usage, with provisions for systems employing hot water recirculation.
- Cooling towers: Metering the replacement water for all cooling towers serving the system.
- Recycled water: Tracking recycled water regardless of usage rate, with special attention to systems with makeup water supply connections to accurately determine recycled water components.
- Other process waters: Monitoring at least 80% of expected daily process water consumption, encompassing various subsystems like humidifiers, dishwashers, washing machines, and swimming pools.
- Water for external uses, excluding irrigation: Recording water usage for fountains and water features, covering a minimum of 80% of the total usage.

Implementing these options ensures comprehensive monitoring and efficient management of water resources within the project, contributing to sustainability goals and resource conservation efforts.

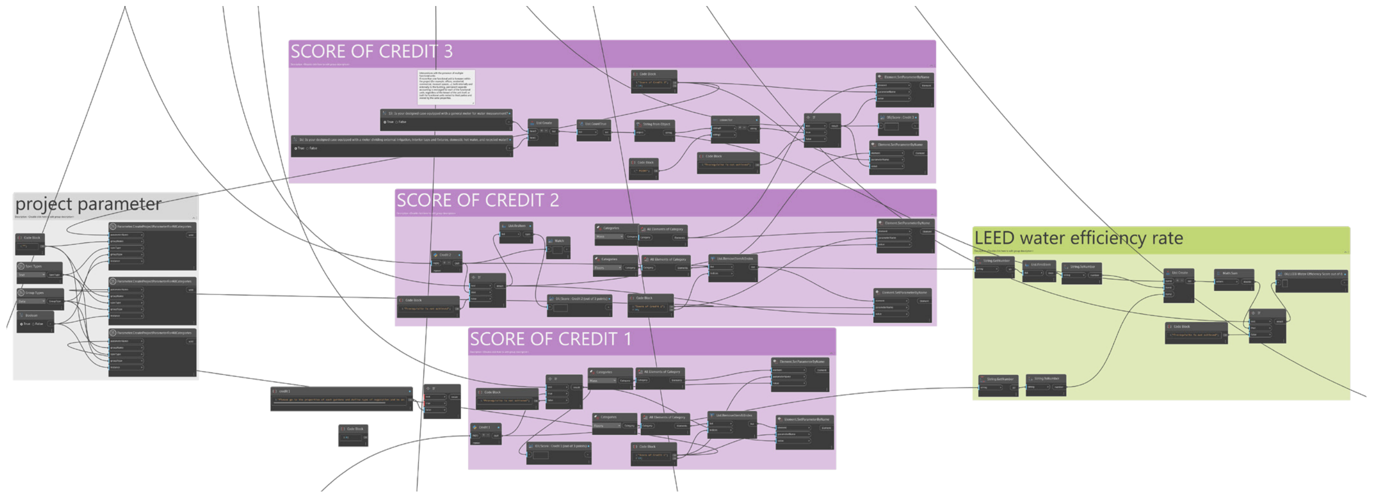


Image 4 : Calculation of LEED scores

Ex Manifattura Tabacchi

The city of Turin, Italy, has undergone significant historical and industrial transformations, shaping its identity and urban landscape over the years. Initially serving as the capital city of Italy from 1861 to 1865, Turin held prominence as one of Europe's leading political centers. However, its trajectory took a new direction in the 20th century with the rise of industrialization.

During the Italian economic boom, Turin emerged as a vital industrial hub, earning the title of the "Automobile Capital" due to its association with major automotive manufacturers like FIAT. This industrial expansion spurred rapid urban development, nearly tripling the city's population through immigration and attracting a workforce to support the growing industries. By 1971, Turin's population had surged to 1.2 million, accompanied by a significant expansion of urban infrastructure, with industrial buildings dominating the skyline.

However, the prosperity of the industrial era was not immune to challenges. The industrial crisis of the 1970s and 1980s dealt a severe blow to Turin's economy, leading to the closure or downsizing of many industrial giants. This downturn resulted in widespread unemployment and a sharp decline in population, leaving behind a legacy of abandoned industrial areas and buildings such as Ex Nebiolo ,Palazzo del Lavoro, Ex Tecumseh , Ex Fimit and other examples depicted in the following page's map.

Despite these setbacks, Turin experienced a resurgence in the early 21st century, buoyed by a revival of its cultural and tourism sectors. The city became a magnet for students, tourists, and international events, such as the 2006 Winter Olympic Games and the 2022 Eurovision Song Contest.

In recent years, Turin has embraced a process of urban renewal, repurposing its industrial infrastructure to meet the demands of contemporary city living. Former industrial sites have been transformed into vibrant public spaces, university campuses, museums, and commercial hubs, breathing new life into the urban fabric.

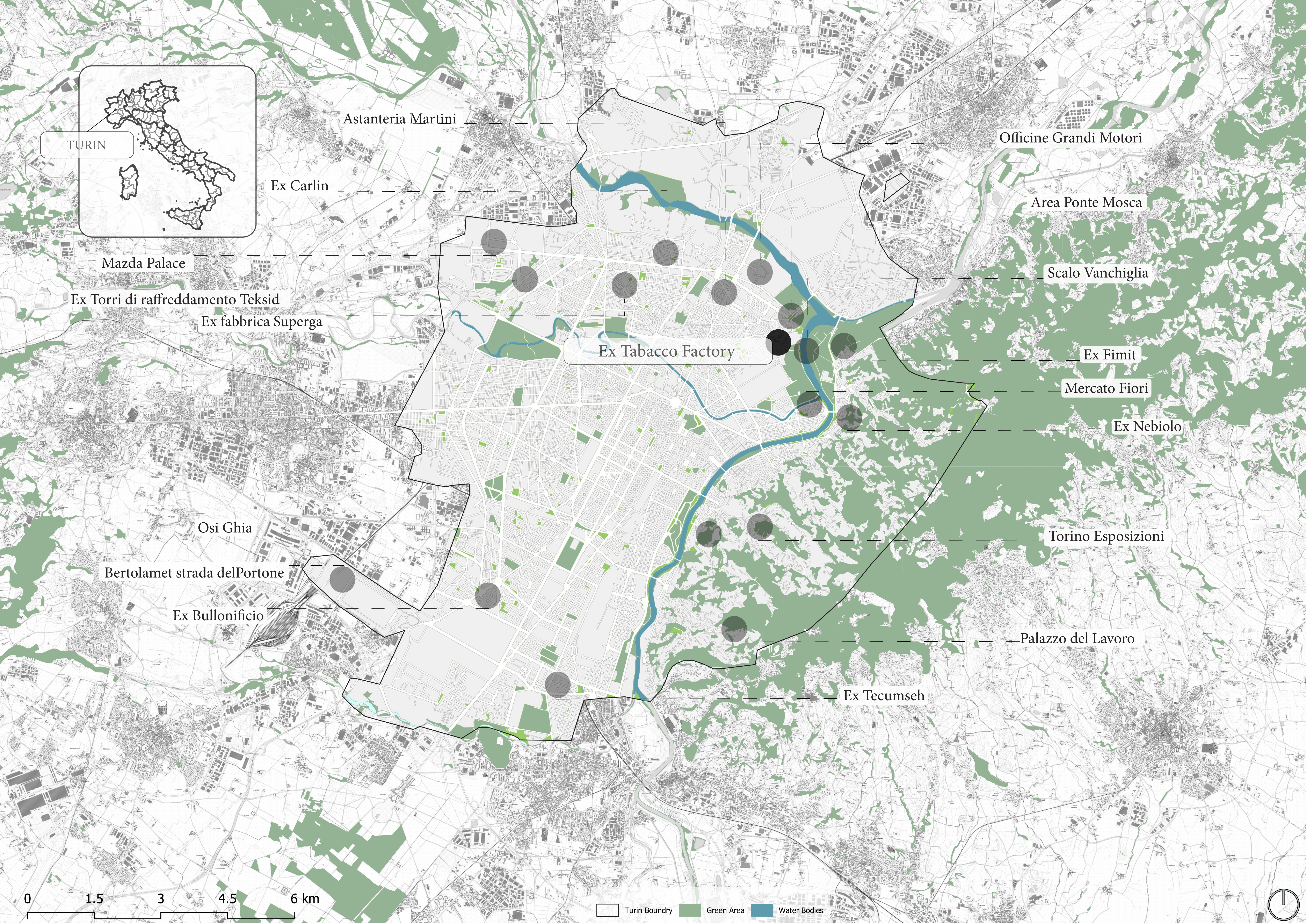
Among these sites, A prime example is the former Tabacco factory, which in 2002 designed to be transformed into public service zones, with the University Enrollment Center housed within its historic walls. This adaptive reuse not only honors Turin's industrial legacy but also showcases its forward-thinking approach to urban development.

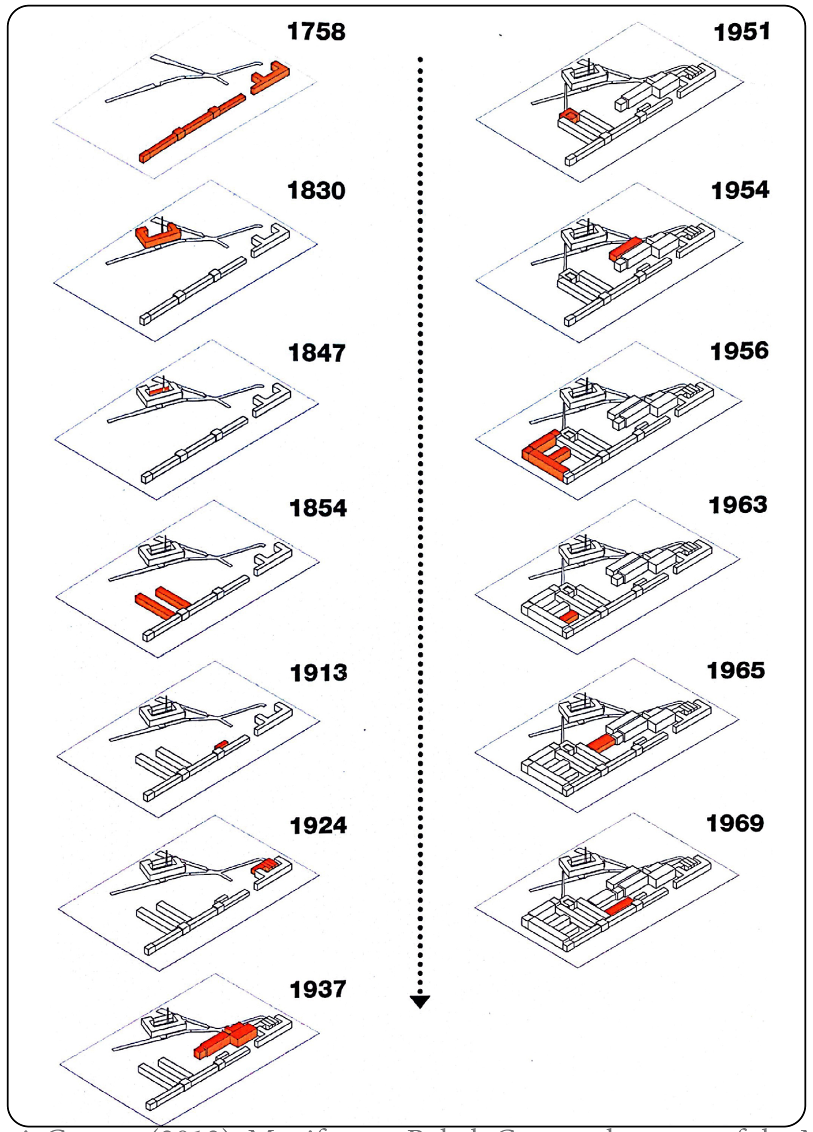
Preserving Turin's industrial heritage while propelling its urban development forward demonstrates the city's commitment to sustainability. Thus, the integration of sustainability principles, such as LEED certification and water efficiency, is vital. Therefore, my thesis focuses on assessing the water efficiency rating of the former Tobacco factory, adhering to the standards and guidelines established by GBC Italy, as outlined in Chapter 3 of the introduction.

1. Brief History Of Former Tobacco Manufacturing Area

The history of the Tabacco factory, situated in the northern region of the city, intertwines with the socio-economic evolution of Turin, Italy, from the 16th century to the present day. Initially established as part of the Viboccone park commissioned by Duke Emanuele Filiberto in the mid-16th century, it served various purposes including sericulture, breeding, and leisure. However, successive generations showed less interest, and the property suffered damage during French sieges in the 17th and 18th centuries. [2]

In 1758, under the reign of Carlo Emanuele


TURIN
Astanteria Martini
Officine Grandi Motori
Ex Carlin
Area Ponte Mosca
Mazda Palace
Scalo Vanchiglia
Ex Torri di raffreddamento Teksid
Ex fabbrica Superga
Ex Tabacco Factory
Ex Fimit
Mercato Fiori
Ex Nebiolo
Osi Ghia
Torino Esposizioni
Bertolamet strada delPortone
Ex Bullonificio
Palazzo del Lavoro
Ex Tecumseh
0
1.5
3
4.5
6 km
Turin Boundry
Green Area
Water Bodies



Extracted from: Debrevi, Geneva (2013). Manifattura Rehab Centre: the reuse of the Manifattura Tabacchi of Turin as a rehabilitation centre. Thesis discussed at the Polytechnic of Turin. Speaker: Croset P., Ambrosini G., Berta M., Rolando A

III, the factory underwent a transformation. Architect Benedetto Ferroggio was commissioned to construct the tobacco production facility within the park, converting the ruins of the Viboccone palace into the new complex. This marked the beginning of the factory's prominence in the city's industrial landscape, alongside a paper mill for playing cards, both state monopolies.[1]

By the early 19th century, the Tobacco Factory emerged as the city's largest production company, with locations in via della Zecca and Regio Parco. Consolidation efforts led to the relocation of operations primarily to the Royal Park section by 1855. Renovation works in 1858 further solidified its status as a key industrial site.[1]

Throughout its history, the factory complex expanded to accommodate various functions, including the presence of the Financial Police, workshops, railway connections, entertainment areas, and schools for employees' children. Notably, during World War II, it played a role in the resistance movement, with employees actively involved in anti-fascist activities.[2]

However, from the mid-20th century, the factory experienced decline, culminating in its closure in 1996. Despite its cessation, efforts were made to repurpose the area.

In 2002, a variant to the Master Plan was approved, transforming the site into areas for public services. The building's architectural and historical significance was recognized, leading to interventions aimed at preserving its heritage while adapting it for contemporary use, involves transforming the former Manifattura Tabacchi site in Turin into a multi-functional hub.[2] The key objectives and features of the project include:

Urban Redevelopment and Urban Planning:

The project aims to revitalize the area by integrating new functionalities and improving urban mobility. This includes the construction of Metro line 2 and the inclusion of the nearby municipally owned complex called Ex Fabbrica FIMIT. Integration with the new Metro line 2 will significantly improve connectivity, linking the site to major transport hubs and the city center. The project emphasizes regenerating public spaces to make them more accessible and integrated with surrounding areas, including redesigning the connection between the Metro stop and the site. The plan also focuses on green and sustainable development by increasing green areas, improving energy efficiency, and installing photovoltaic systems on new buildings.

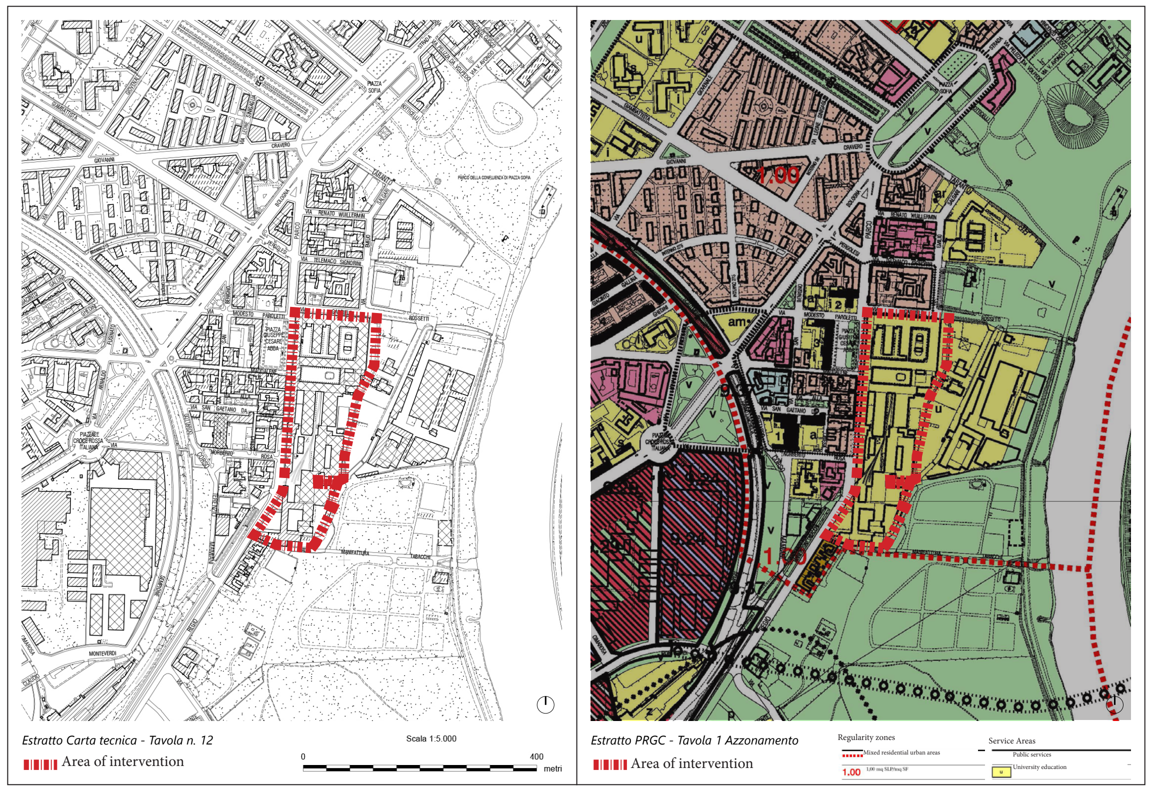
Monumental Protection: The property is protected under DCR 113 of 2019 and legislative decree 42/2004, ensuring its historical and architectural elements are preserved.

Vision and Purpose ; The redevelopment aims to create a multifunctional hub with university residences, cultural institutions, and public spaces. A museum dedicated to the history of industry and innovation will be established, along with spaces for exhibitions and public discussions.

Implementation and Guidelines : Detailed conservation efforts will maintain the historical integrity of the buildings while adapting them for modern uses, preserving significant architectural features and integrating new technologies sensitively. An educational path will showcase the site's historical and architectural evolution, enhancing its cultural value.

University Residences : The redevelopment includes constructing university residences to support the local student population. These residences will be integrated with other university facilities and cultural institutions, creating a dynamic educational environment.

Overall, the redevelopment of the Manifattura Tabacchi site in Turin is a multifaceted project aimed at preserving its historical significance while transforming it into a modern, functional, and sustainable urban space. Today, the tobacco factory stands as a testament to Turin's industrial past, its adaptive reuse reflecting the city's commitment to heritage conservation and urban renewal.[2]



Extracted from: pdf of "Relazione Illustrativa" in www.manifatturatabacchitorino.concorrimi.it

2.Application of Methodology on Ex Manifattura Tabacchi

To evaluate the capabilities of the proposed method, the case study was developed. The methodology was applied to a BIM model to acquire a LEED assessment for the building site and to generate solutions enabling proper water management.

A BIM model with a LOD 500 in Revit can provide a comprehensive amount of information, making it exceptionally useful for both precise and preliminary assessments across various subcategories of the GBC checklist. The detailed data encompassed in an LOD 500 model includes specific elements related to historical features, detailed energy modeling, precise material specifications, and exact water usage calculations. Such a level of detail is invaluable for finalizing design decisions and achieving high accuracy in sustainability assessments, allowing for thorough analysis and precise scoring in each subcategory.

In the preliminary design phase, however, the level of detail required can vary depending on the subcategory being assessed. For instance, in the context of water efficiency, an LOD 100 is generally sufficient. This level includes basic estimations of water use reduction based on planned efficient fixtures and preliminary irrigation plans, which provides an approximation of water savings without the need for complete detail like exact plumbing layouts and water usage calculations found in LOD 500. In contrast, other preliminary LEED assessments might require a higher LOD than 100. For example, assessing energy and atmosphere might benefit from an LOD 300 to perform simplified energy modeling, considering general HVAC system efficiency and basic insulation values, which provide more precise early-stage energy performance estimates than an LOD 100 model could offer.

The focus of this thesis is specifically on water and water efficiency; however, working on a case study and calculating LEED scores involves all categories of the GBC checklist. Hence, it is advantageous to have a central BIM model with high LOD, that can link different approaches of the categories' calculations. This integrated approach ensures that as various aspects of the project are developed, all related data can be centrally managed and updated, facilitating a more coordinated and comprehensive sustainability assessment. By leveraging a central BIM model, different categories of LEED calculations can be automated and connected, providing a complete view of the building's performance across all relevant sustainability metrics.

In conclusion, LOD 100 is enough for water efficiency calculations in a conceptual and preliminary assessment, it is important to highlight that this level of detail captures the essential information needed for early decision-making. An LOD 100 model can provide basic, yet reliable, estimates of water savings through efficient fixture selection and preliminary irrigation planning. This streamlined approach allows for timely and cost-effective assessments, aligning with the early stages of design where detailed specifications are not yet finalized. Furthermore, future studies and theses can build upon this foundation by integrating higher levels of detail for other categories of LEED calculations, progressively automating and integrating these aspects into the central BIM model. This evolution towards a complete BIM model dataset will enhance the accuracy and efficiency of sustainability assessments, ultimately leading to more informed and sustainable building designs.

The following processes were applied:

The model was initiated by importing architectural drawings of the Manifattura Tabacchi, which is acquired from *Drawing To The Future Lab,* in CAD format to Revit. Few elements needed to be accurately modeled: buildings were modeled as mass models from In-Place Mass of the massing and site tabs, and the Floor category was used to specify green zones and the territory of the site. These three layers from top, illustrated in the image 5, are the only elements contributing to the methodology.

Once the LOD 100 of the case study was completed, the Dynamo Player was opened to run the simulation, and the Dynamo script should be launched. By inserting a few inputs or selecting options from the list of each parameter on the Dynamo Player, the solution priorities must be established.

By running the Dynamo Player, the program can assist the user in differentiating between pursuable and non-pursuable LEED credits, enabling the identification of the best strategy for water-efficient design in preliminary phases. The results are discussed in the result section of this chapter.

To assess the effectiveness of the proposed methodology , various strategies were applied to show outputs in different scenarios. The first scenario involves low water consumption, the sec-

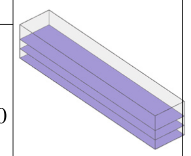
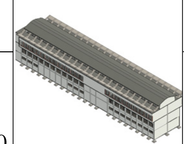
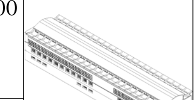
GBC checklist	Goals	Detailed and Precise Assessment			Conceptual Design Assessment		
		From BIM	LOD		From BIM	LOD	
Regional Priority	• Addressing local environmental priorities and challenges. • Adapting strategies to fit regional climatic and cultural contexts. • Promoting sustainability measures that are particularly relevant to the local area.	Specific adaptations or designs addressing regional issues.	500		• Address regional environmental concerns based on general local guidelines. • Use common strategies for the region's specific priorities.	100	
Sustainable Sites	• Site selection to minimize environmental impact. • Protecting and restoring habitats. • Encouraging alternative transportation to reduce emissions. • Managing rainwater and minimizing heat island effects.	Site plan, landscape design, transportation access points, rainwater harvesting systems.	500		• Evaluate site selection, access to public transportation, and preliminary landscape designs. • Conduct basic site analysis for heat island effect and rainwater management.	100	
Water Efficiency	• Reducing water consumption through efficient fixtures and fittings. • Implementing water reuse and recycling systems. • Efficient landscaping to reduce irrigation needs. • Innovative wastewater technologies to treat and reuse water.	Plumbing fixtures, irrigation systems, water usage calculations.	500		• Estimate water use reduction based on the planned efficient fixtures and preliminary irrigation plans. • Incorporate basic water recycling and reuse concepts.	100	
Energy and Atmosphere	• Optimizing energy performance to reduce consumption. • Utilizing renewable energy sources. • Implementing enhanced commissioning for building systems. • Managing refrigerants to minimize ozone depletion and climate impact.	Detailed energy modeling, HVAC system specifications, renewable energy system designs.	500		• Use simplified energy modeling tools to estimate energy performance. • Consider general HVAC system efficiency, basic insulation values, and potential for renewable energy.	300	
Materials and Resources	• Encouraging the use of sustainable materials with low environmental impact. • Promoting recycling and reuse of materials. • Reducing waste through effective construction waste management. • Selecting regional materials to reduce transportation impacts.	Material specifications, quantities, waste management plans.	500		• Select materials known for sustainability, such as those with recycled content or local sourcing. • Plan for basic construction waste management and material reuse.	300	
Indoor Environmental Quality	• Ensuring high indoor air quality with effective ventilation systems. • Using low-emitting materials to reduce pollutants. • Providing thermal comfort for occupants. • Maximizing daylight and views to improve occupant well-being. • Enhancing acoustic performance for a better indoor environment.	HVAC system details, material specifications, lighting design, acoustic treatments.	500		• Ensure good indoor air quality through basic ventilation plans and the selection of low-emitting materials. • Estimate daylighting and views using simple daylight modeling tools.	300	
Innovation	• Encouraging innovative solutions that enhance building sustainability. • Rewarding exemplary performance in specific sustainability areas. • Incorporating unique strategies that push beyond standard practices. • Engaging LEED accredited professionals to ensure best practices.	Documentation of innovative solutions, performance metrics.	500		• Identify and document any innovative sustainability strategies planned for the project. • Focus on straightforward innovations that do not require detailed calculations.	300	
Historic Value	• Preserving and restoring historically significant features and structures. • Ensuring modifications respect and enhance the historic character of buildings. • Integrating modern sustainability practices without compromising historical integrity.	Specific elements related to historical features, materials used, and any modifications made.	500		•Include significant historical features and plans for preservation. •Use general guidelines for integrating modern sustainability practices without detailed specifications.	300	

Table 9 : Level of Detail in different phases for different GBC categories

ond scenario involves medium water consumption, and the third scenario involves high water consumption.

3.Scenarios Common Parameters

In all scenarios, the baseline situation remains constant and location-based data such as ET_0 (evapotranspiration rate), rainfall, K_{mc} (microclimate factor), and the area of the case study remain constant as well. The determination of the Controller Efficiency (CE) value is not considered in any of the scenarios. Additionally, the selections in credit 3 are the same in all scenarios.

It is noteworthy that although all green areas could have been selected their own species type, K_s (species factor), and K_d (density factor), a standard framework for comparing the scenarios was adopted, using the same values for species type, K_s, and K_d.

Upon selecting the strategies, those strategies were chosen in which the prerequisites reached above 20% to proceed with the rest of the procedure.

Implementation and Results

In this section, the proposed methodology is applied to the case study under these three different water consumption scenarios: low, moderate, and high,and the results are analyzed to understand the effectiveness of each scenario in terms of water usage, savings, efficiency and consequently help to make decisions. The table below summarizes the key parameters and settings for each scenario.

		Low water consumption scenario	Moderate water consumption scenario	High water consumption scenario	
		senario 1	**senario 2**	**senario 3**	
Prerequisit - Credit2	Toilet	Toilet without Water	Single Flow with pressure regulator	Conventional Toilet	HET,Single Gravity Drain
	Urinal	Urinal without Water	High Efficient Urinal	Conventional Urinal	High Efficient Urinal
	Basin	Public Efficient Basin	Public Efficient Basin	Public Conventional Basin	Public Conventional Basin
	Bidet	High Efficient Bidet	Medium Efficient Bidet	Conventional Bidet	Medium Efficient Bidet
	Kitchen sink	Low Flow Kitchen Sink	Low Flow Kitchen Sink	Conventional Kitchen Sink	Low Flow Kitchen Sink
	Shower	Low Flow Shower	Low Flow Shower	Conventional Shower	Conventional Shower
Credit 1	Species type	Shrubs	Turf	Mixed	Mixed
	Ks	low	medium	high	high
	Kd	low	medium	high	high
	Irrigation type	Drip system	Drip system	Aspirators and watering	Aspirators and watering
	Catchment area	rooftop	rooftop	rooftop	rooftop
	Tank capacity(L)	0	600,000	600,000	600,000

Table 10 : Table of Scenarios

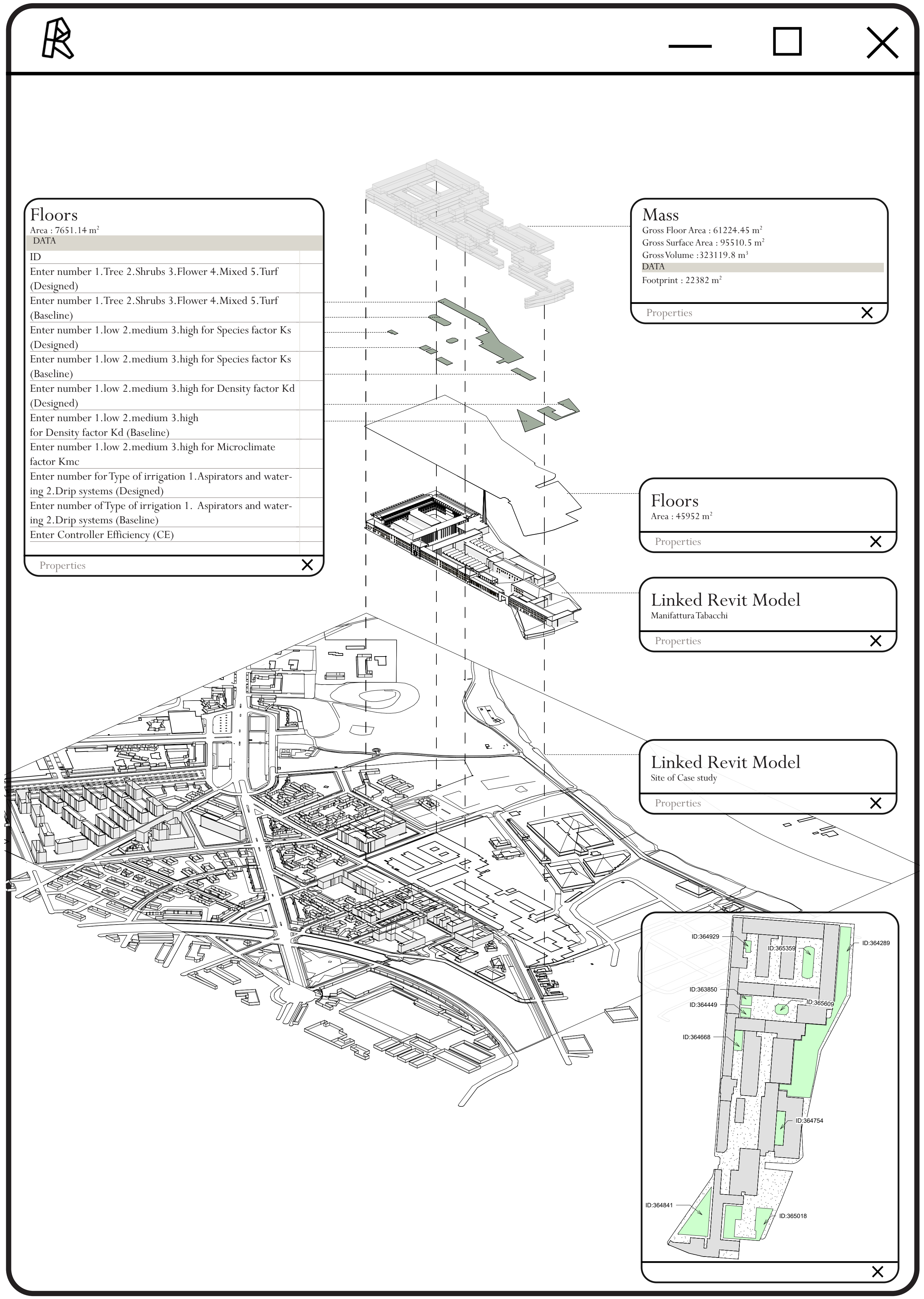
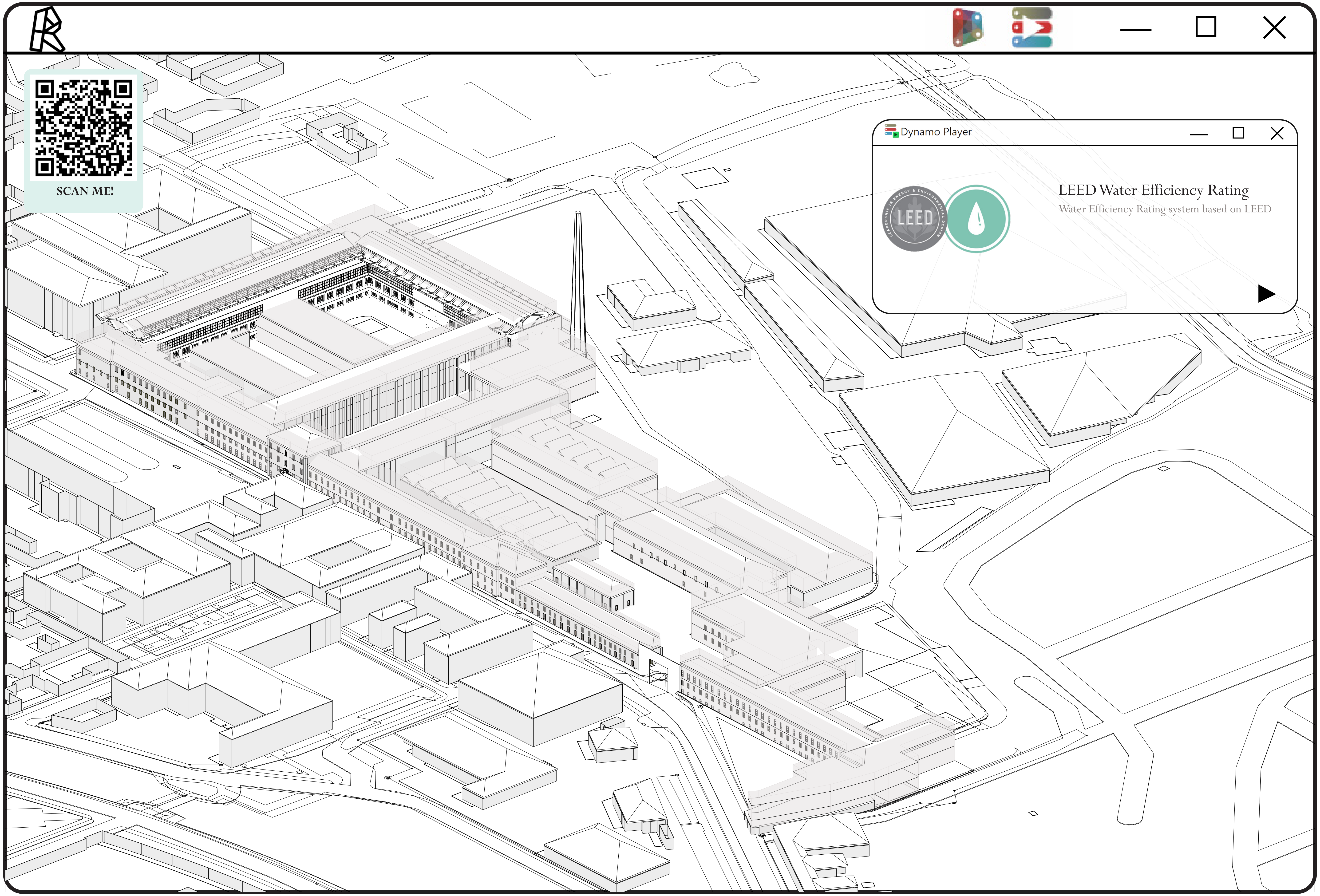


Image 5 : Revit environment

How it works as an example:

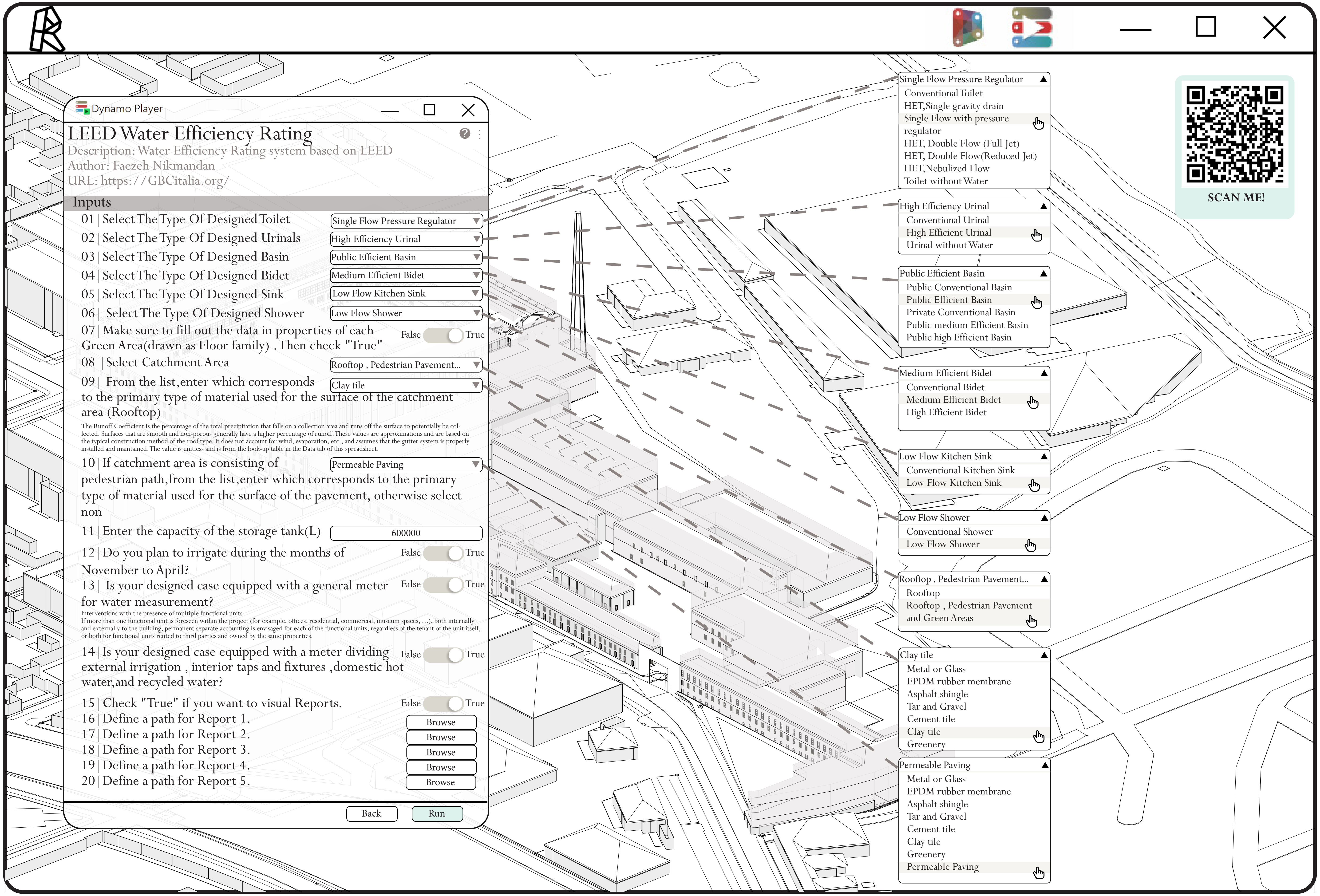
1.Lunching the Dynamo-Player



How it works as an example:

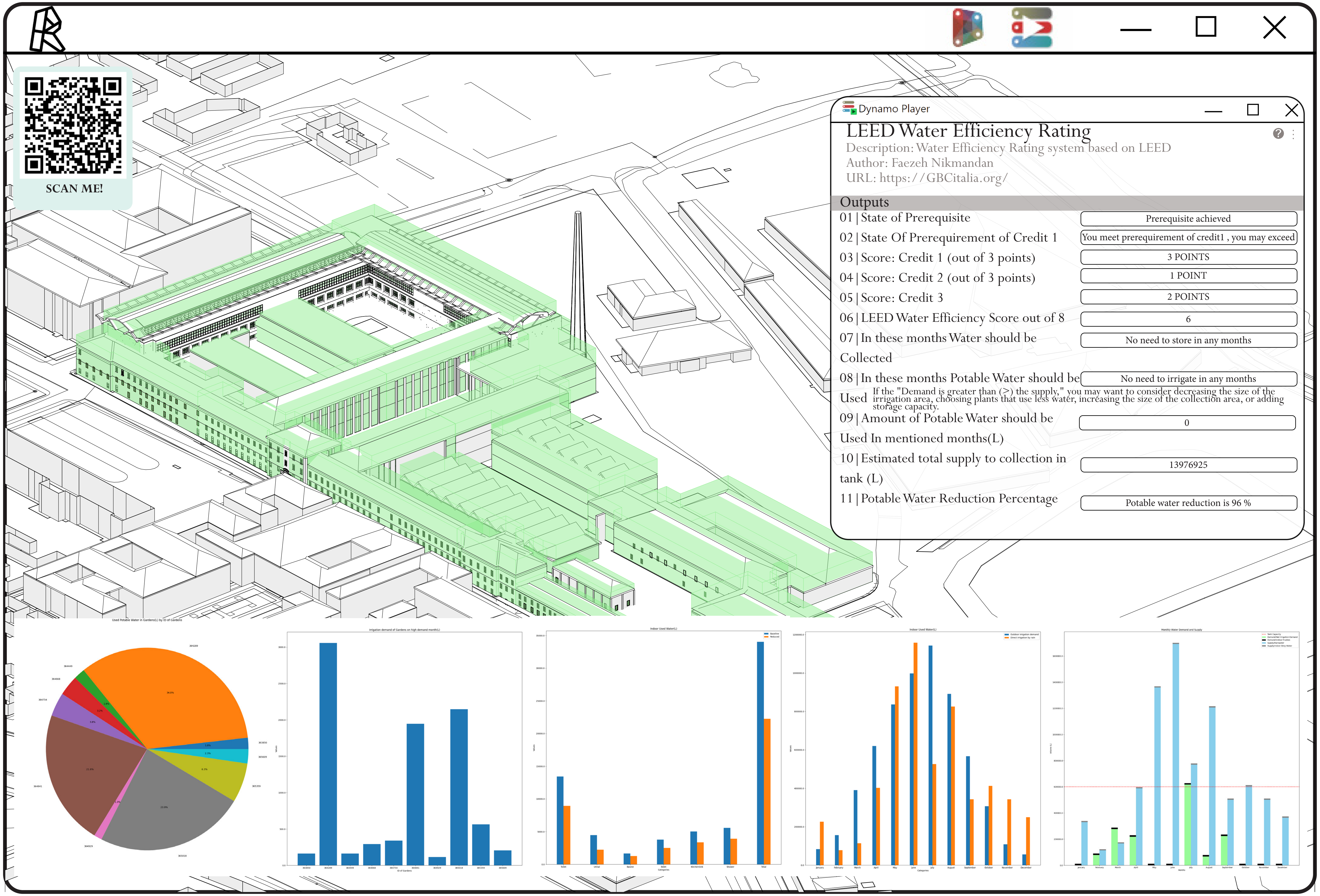
2.Filling out input data

3.Run the calculation



How it works as an example:

4.Results



Inputs of Scenario 1

Outputs of Scenario 1

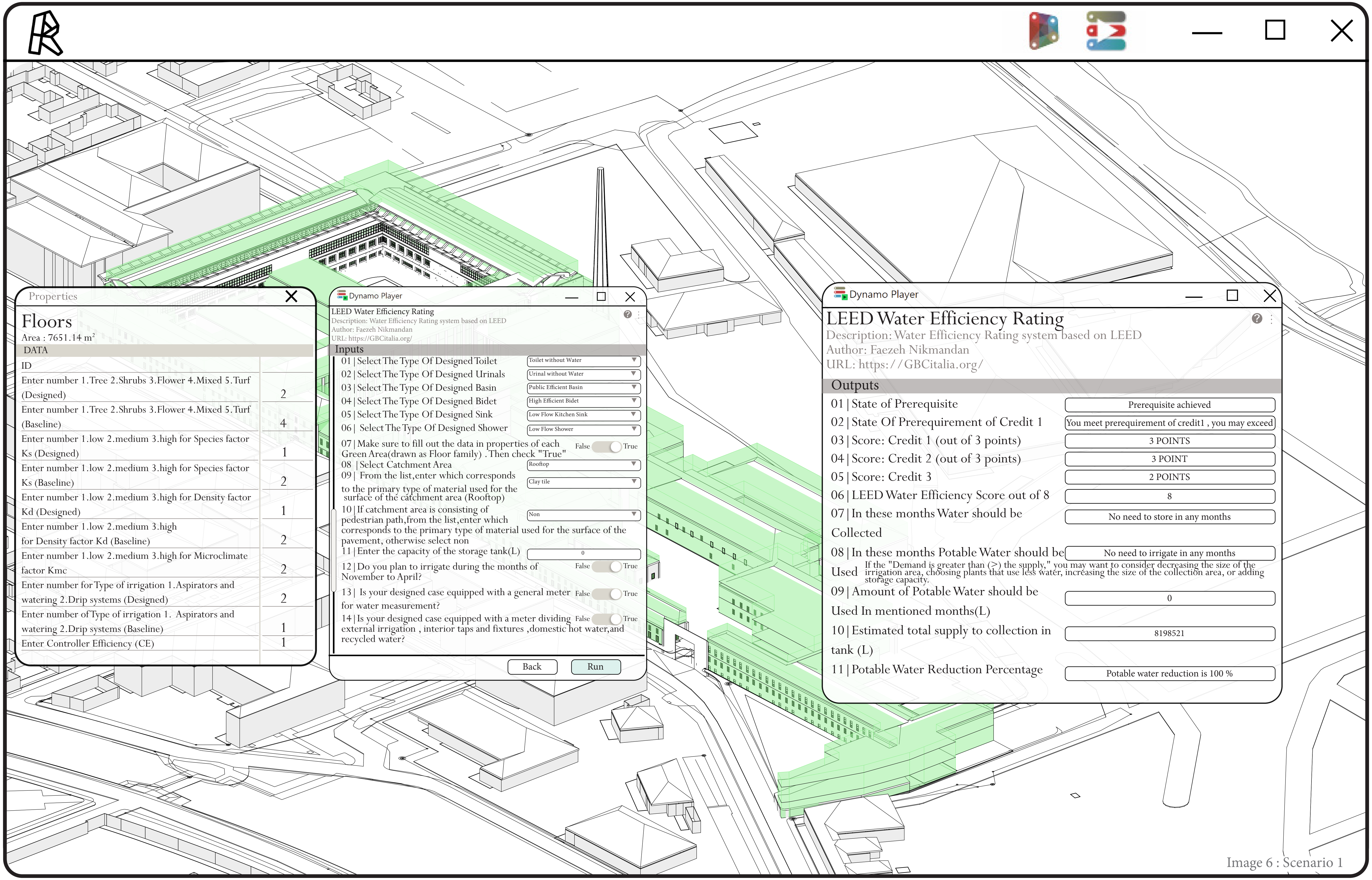


Image 6 : Scenario 1

3.1. Scenario 1

For Scenario 1, which involves low water consumption, the methodology was applied to assess water efficiency. The image 6 illustrates the strategies implemented and the followings are their respective outcomes.

The pie chart of report 1 illustrates the distribution of potable water usage across 10 gardens. Notably, one garden (ID 364299) accounts for 49.9% of the total water usage, while the rest is distributed among the other gardens with smaller percentages.

The bar chart of report 2 shows the irrigation demand of each garden during a month with high water demand. Garden ID 364299 has the highest demand at 4279.35 liters, while Garden 364619 has the lowest at 103.52 liters.

The chart of report 3 compares the baseline and reduced indoor water usage across various fixtures and equipment. Significant reductions are observed in the designed situation, especially for toilets and bidets, contributing to the overall reduction in water consumption.

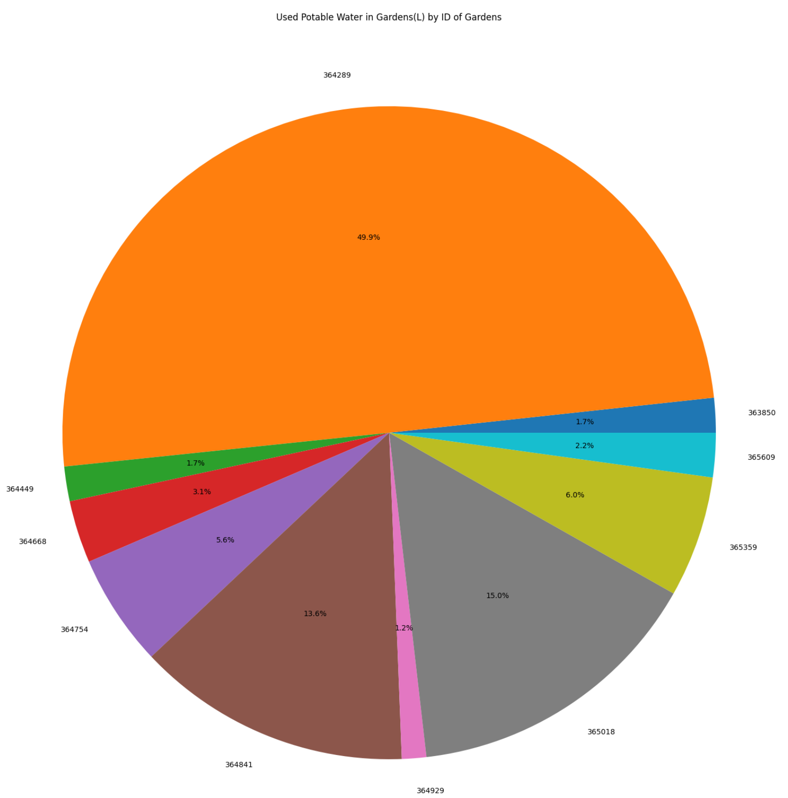
Th chart of report 4 compares the total monthly outdoor irrigation demand with the amount of irrigation directly provided by rain. It shows that direct rain irrigation always exceeds the demand, ensuring that neither potable water is required for outdoor irrigation ,nor stored rain water.

The report 5 illustrates the monthly demand for net irrigation and indoor flushes (both zero) against the supply from rainwater and indoor greywater in this scenario. The consistent supply from rainwater and greywater indicates an ample water source to meet the demands.

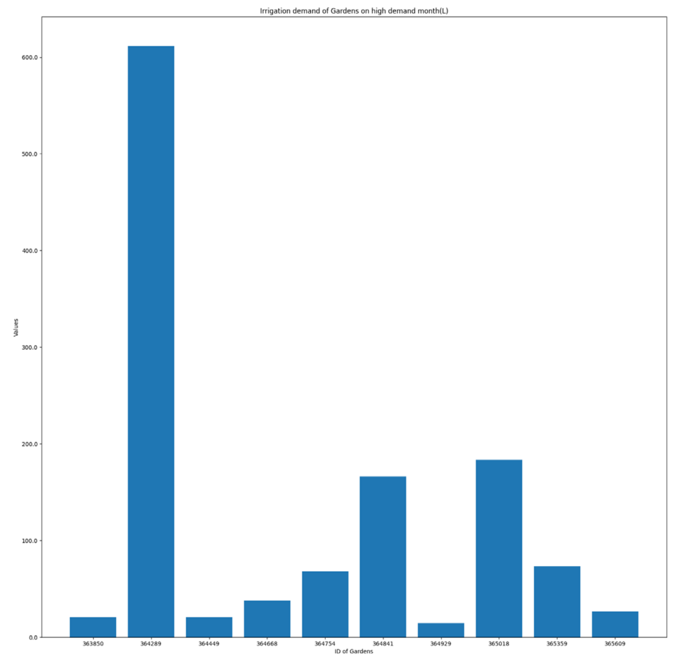
Conclusion

For Scenario 1, the proposed methodology has successfully achieved significant water savings, meeting all prerequisites and earning full points for the GBC water efficiency credits. The charts and data illustrate that the irrigation demands are well-managed with harvested rainwater, and indoor water usage is substantially reduced in the designed situation compared to the baseline.

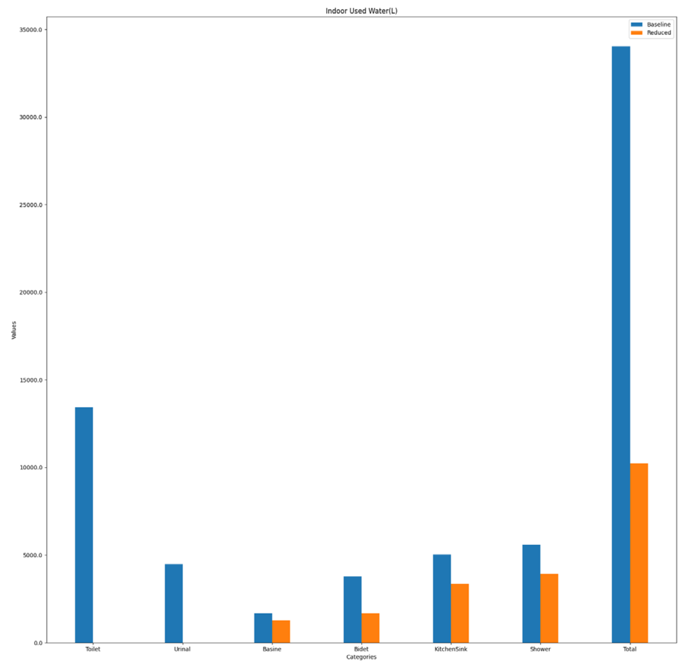
These results indicate the effectiveness of the methodology in promoting water efficiency and sustainability, aligning with GBC standards.



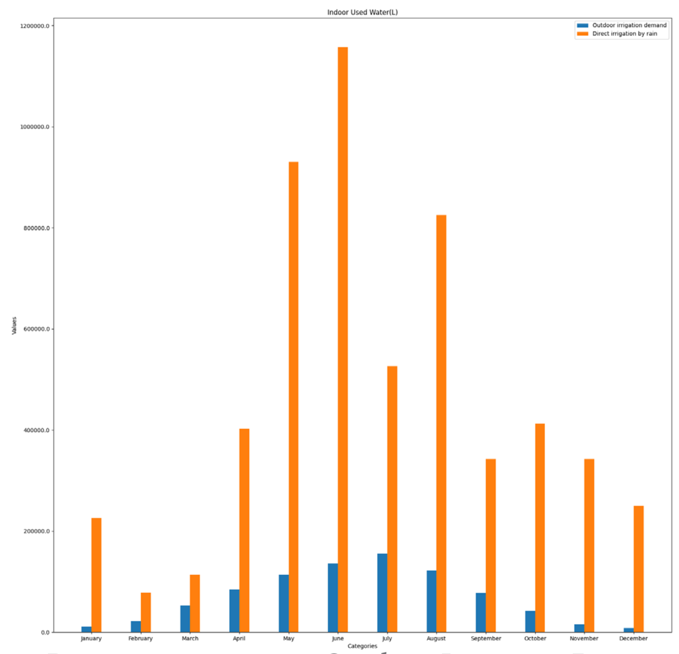
Peport1 - scenario1 -Used Potable Water in Gardens by ID



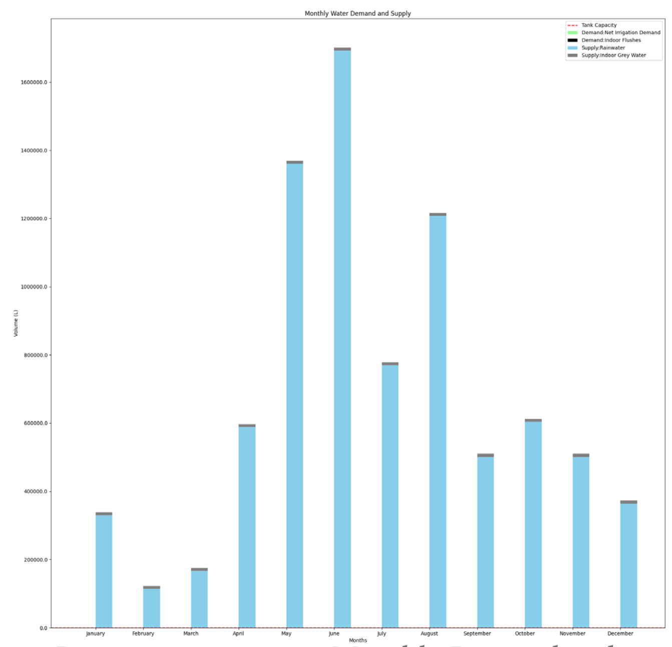
Peport2 - scenario1-Irrigation Demand of Gardens on High Demand Month (Liters)



Peport3 - scenario1-Indoor Used Water (Liters)



Peport4 - scenario1- Outdoor Irrigation Demand vs. Direct Irrigation by Rain (Liters)



Peport5 - scenario1 -Monthly Demand and Supply

Input and Output of Scenario 2 - First run

Input and Output of Scenario 2 - Second run

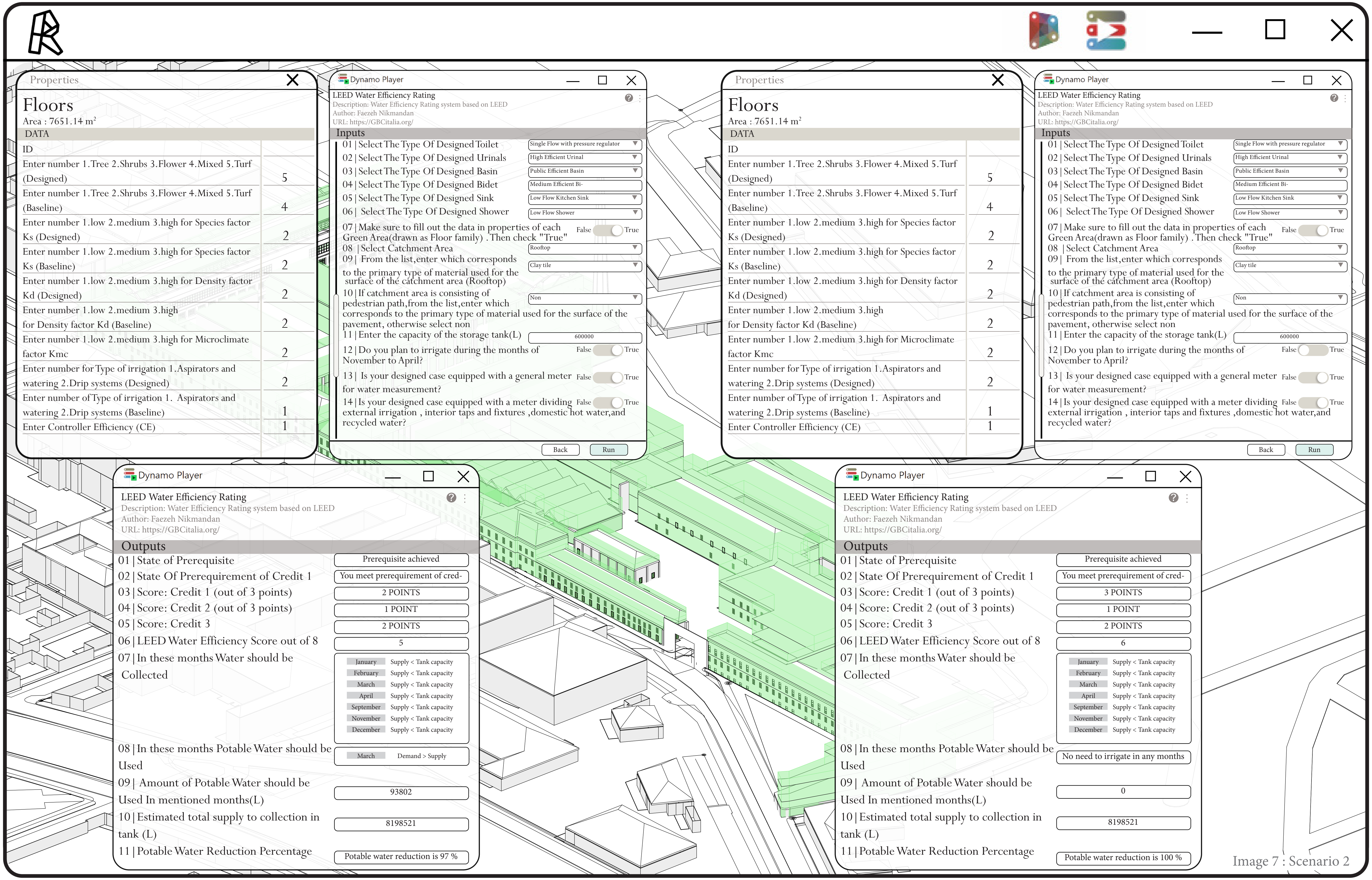


Image 7 : Scenario 2

3.2. Scenario 2

The pie chart shows the percentage of water used in each garden categorized by ID. Since it remains the same as Scenario 1, it indicates that the distribution of water usage among the gardens did not change.

Report3 compares indoor water usage in the baseline situation versus the designed scenario. It shows a significant reduction in water usage in the designed scenario, especially in the "Toilet" and "Bidet" categories.

Report 4 shows the irrigation demand for each month and how much of it is met by direct rain irrigation. The direct irrigation by rain generally exceeds the irrigation demand, except for the months of February, March, April, July, and September, where the demand is higher than the supply. The demand is highest in July, while direct rain irrigation peaks in June. This indicates the need for additional water sources or storage during these months.

Report5 shows the supply significantly exceeding the demand in most months. The tank capacity limit line is at 600,000 liters, indicating that the rainwater supply generally exceeds the irrigation demand, especially during the months when irrigation is not required (May, June, October, November, and December). In March, there is a notable shortfall where the demand exceeds the supply, indicating the need for potable water usage. The system's tank capacity of 600,000 liters is adequate for most months except for a few peak rainwater collection months like June and July, where the supply can exceed the tank capacity.

Conclusion

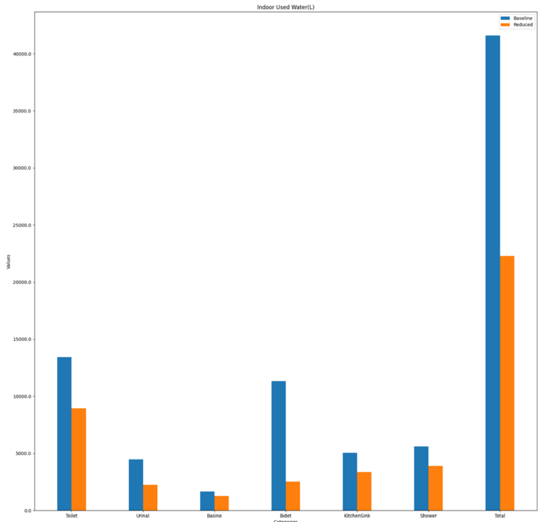
Scenario 2 (First Run) demonstrates a high potential for reducing potable water usage through effective rainwater harvesting and grey water reuse systems. The overall water management strategy is effective, but there are specific months that require additional attention to balance demand and supply. By addressing the identified gaps and optimizing storage and usage practices, further improvements in water efficiency can be achieved, leading to better GBC scores and more sustainable water management.

Comparison of Both Runs in Scenario 2:

In the first run, irrigation is carried out year-round, ensuring consistent water supply throughout the year. Conversely, in the second run, irrigation is restricted to the period from April to November, aligning with the growing season and eliminating irrigation demands during the non-growing months.

The irrigation demand in the first run is higher overall due to the need to supply water continuously throughout the year. This approach leads to significant peaks in demand during the mid-year months when irrigation needs are at their highest. In contrast, the second run focuses on meeting the irrigation demands only during the growing season, resulting in higher demands during these specific months and no irrigation demand during the off-season.

Rainwater plays a significant role in both runs, contributing notably throughout the year in the first run, with the highest contributions occurring in May and June. In the second run, the pattern of rainwater contribution is similar during the irrigation months, but there is no contribution during the non-irrigation months.



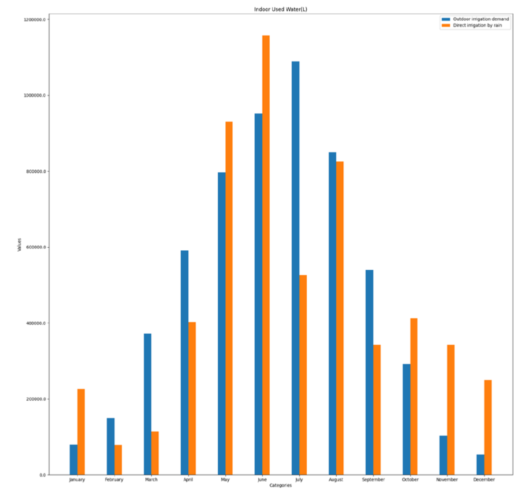
Report 3 - scenario2(first run) -Indoor Used Water (Liters)

In the first run, the net irrigation demand is spread across the entire year. During some months, the demand exceeds the supply from rainwater and greywater, necessitating the use of potable water to meet the shortfall. However, in the second run, the net irrigation demand is concentrated within the growing season months and is effectively managed using rainwater and greywater, thus eliminating the need for potable water altogether.

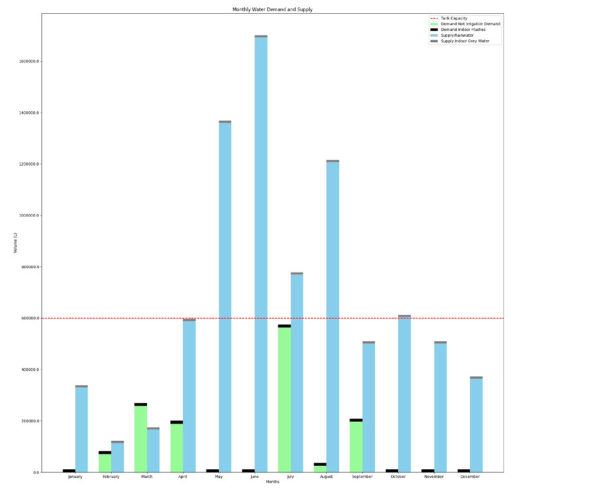
The indoor flush demand remains constant at 11,200 liters per month in both runs. This baseline water usage is unaffected by the changes in irrigation strategies, highlighting a steady requirement for indoor water use regardless of seasonal irrigation demands.

The overall water efficiency in the first run results in a 97% reduction in potable water use. Despite this high efficiency, some months still require additional potable water due to higher irrigation demands. In the second run, the efficient use of rainwater and greywater during the irrigation months results in a 100% reduction in potable water use, indicating no need for potable water at any time. This demonstrates a superior water management strategy compared to the first run.

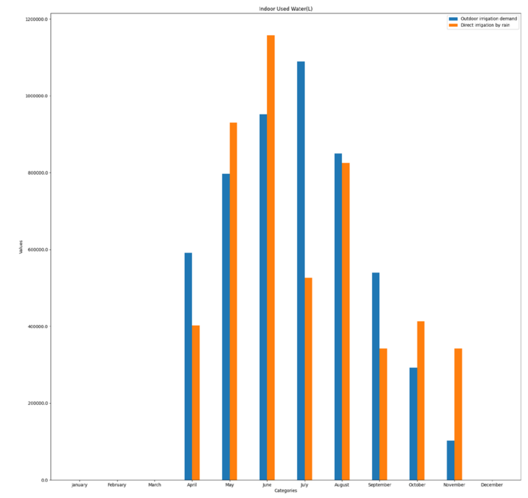
Reflecting these efficiency improvements, the GBC water efficiency score for the first run is 5 out of 8 points. The second run, with its more efficient water management strategy, achieves a higher score of 6 out of 8 points, underscoring its enhanced effectiveness in reducing potable water use.



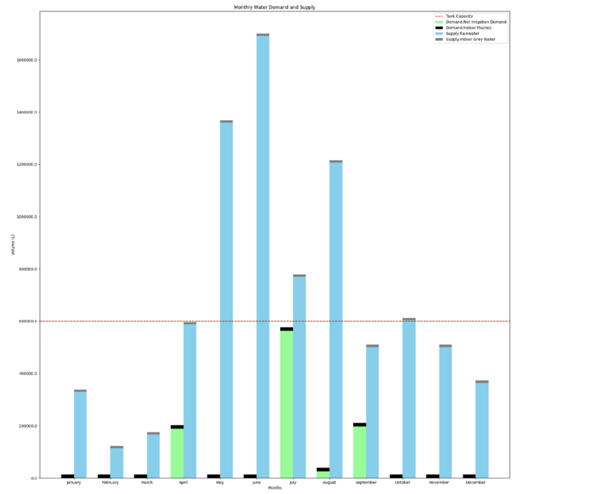
Peport4 - scenario2(first run) - Outdoor Irrigation Demand vs. Direct Irrigation by Rain (Liters)



Peport5 - scenario2(first run) -Monthly Demand and Supply



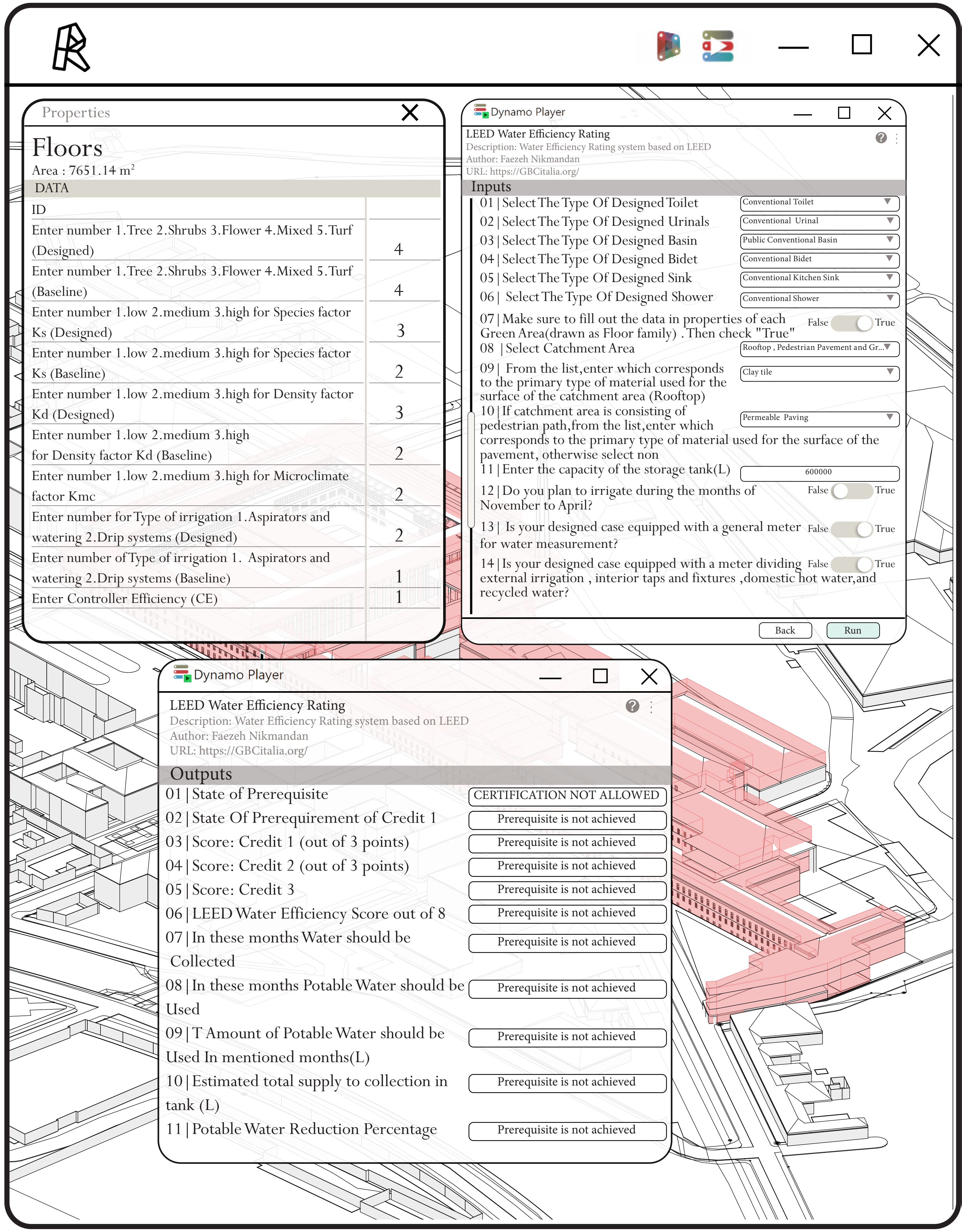
Peport4 - scenario2(second run) - Outdoor Irrigation Demand vs. Direct Irrigation by Rain (Liters)



Peport5 - scenario2(second run) -Monthly Demand and Supply

Input and Output of Scenario 3 - First run

Input and Output of Scenario 3 - Second run



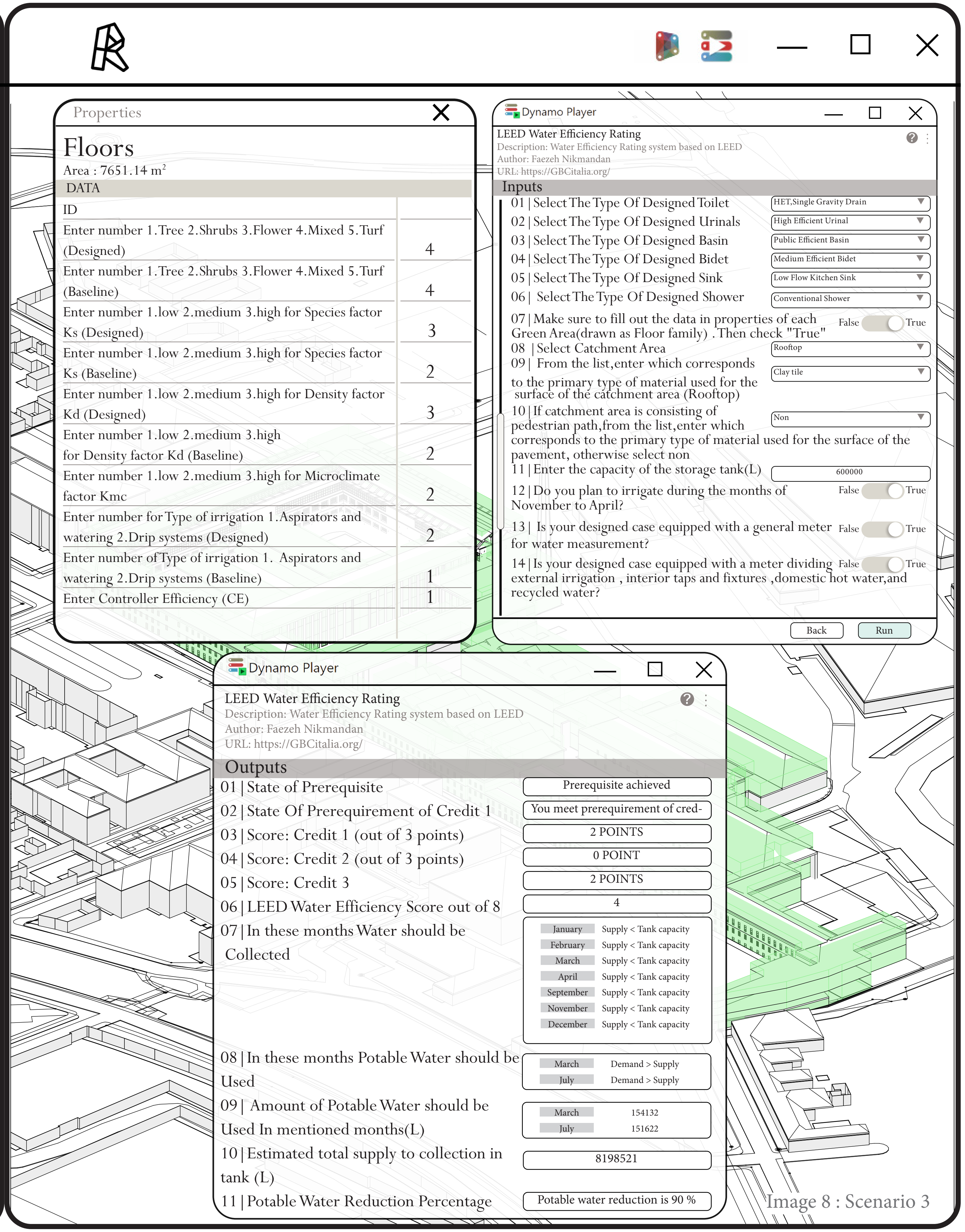


Image 8 : Scenario 3

3.3. Scenario 3

In the first simulation run for Scenario 3, where gardens are in a high water-consuming state due to a mixed variety of species and high density, and all fixtures and equipment were conventional. This led to the simulation being halted because the prerequisites were not met. To visually indicate this failure, the buildings in the simulation turned red.

In the second run, low-impact development strategies were applied to the water fixtures and equipment. The second run provided the following results:

Since the pie chart is the same as in all Scenario , report 2 indicates that the garden 364299 uses 5000 liters each month.

According to Report 3, low-impact development strategies were applied to the water fixtures and equipment, except for the shower fixture, which was kept conventional. As a result, the total reduction is above 20%, and the prerequisite has been achieved.

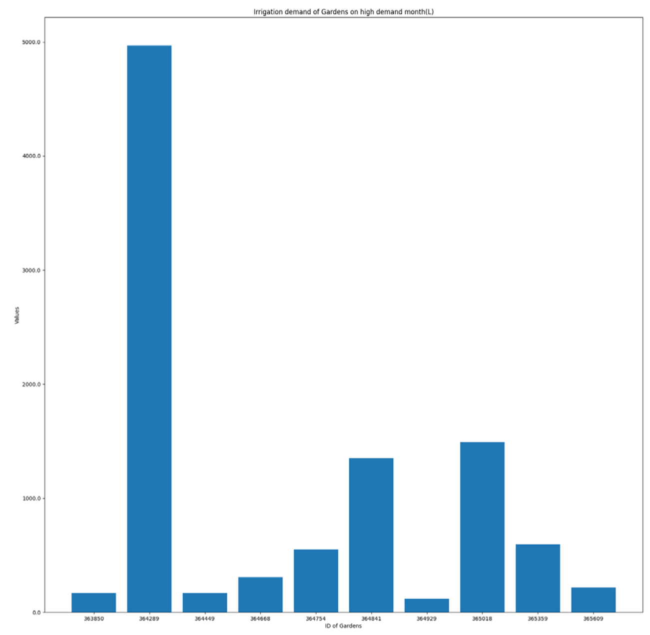
The report 4 revealed that irrigation demand reached its peak in July, with a requirement of 1,264,198.41 liters. This high demand highlights the intense water needs during this summer month. On the other hand, rainwater contributed significantly to irrigation in May and June, with direct irrigation amounts of 929,996.47 liters and 1,157,235.42 liters, respectively. Despite this substantial contribution from rain, the demand in July still surpassed the available rainwater, indicating a gap that must be addressed either by tapping additional water sources or by implementing more efficient irrigation practices.

Report 5 shows distinct peaks in net irrigation demand during March, April, July, and September, with July again being the highest at 738,182.31 liters. Indoor water demand for flushing remained steady throughout the year. While the greywater supply was consistent, it was relatively minor compared to both the demand and the rainwater supply. The highest rainwater supply was observed in May and June, mirroring the findings from Report 4. These months provided sufficient water, but the irrigation demands in July and March still exceeded the available supply, necessitating the use of additional potable water to meet the needs.

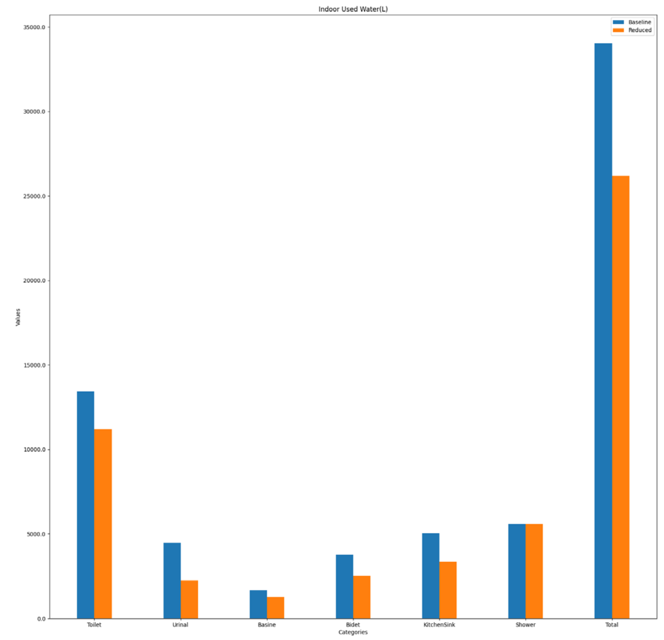
Overall, these analyses underscore the importance of considering seasonal variations in both water demand and supply. Efficient irrigation strategies and supplemental water sources are crucial for managing high-demand periods, particularly during the peak summer months.

Conclusion

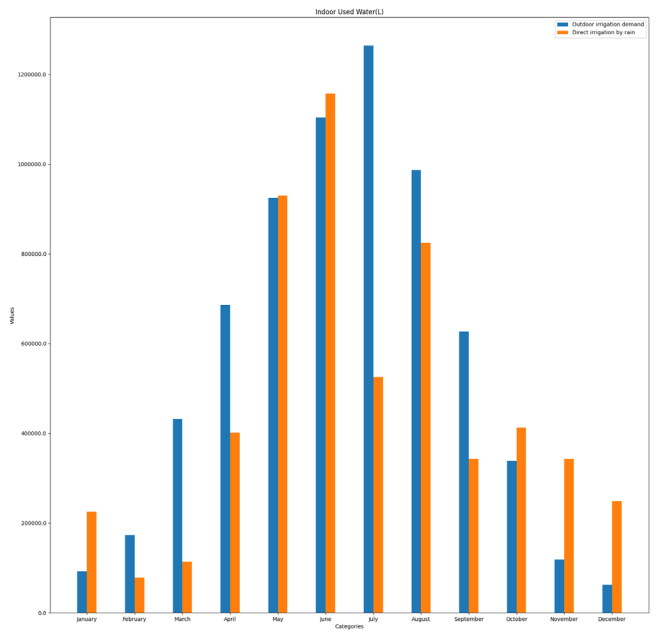
The scenario demonstrated that high water-consuming gardens significantly increase water demand, particularly for irrigation. While increasing the tank capacity achieved a 90% reduction in potable water usage, additional potable water was still required during peak demand months, notably March and July. Contributions from rainwater and greywater were substantial but insufficient to fully meet the high irrigation needs. This highlights the challenges of managing high water-consuming landscapes and underscores the importance of efficient irrigation practices and supplemental water sources. The LEED Water Efficiency Score of 4 out of 8 indicates room for improvement, particularly in reducing potable water use during peak demand periods.



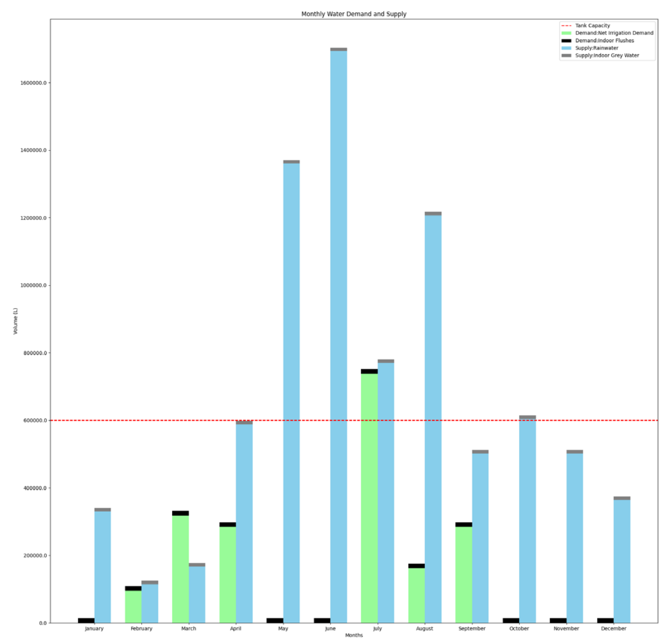
Peport2 - scenario3(second run) -Irrigation Demand of Gardens on High Demand Month (Liters)



Peport3 - scenario3(second run) -Indoor Used Water (Liters)



Peport4 - scenario3(second run) - Outdoor Irrigation Demand vs. Direct Irrigation by Rain (Liters)



Peport5 - scenario3(second run) -Monthly Demand and Supply

Results

The three scenarios highlight the effectiveness of the proposed methodology in guiding sustainable design and decision-making processes for achieving LEED certification. Each scenario provides valuable insights into the interplay between water efficiency and compliance with LEED requirements.

Scenario 1

This scenario demonstrates that utilizing efficient fixtures and low water consumption species can achieve 100% potable water reduction. The catchment area was limited to rooftops, and the collected rainwater, managed by gutters, was efficiently utilized. This approach shows that focusing on indoor efficiency and appropriate plant selection can lead to significant water savings without the need for large-scale infrastructure.

The success achieved without permeable paving indicates that high-tech indoor fixtures and low-demand greenery can meet sustainability goals in a cost-effective manner. This emphasizes the potential of achieving water efficiency through targeted, low-cost measures rather than expensive infrastructure changes.

Scenario 2

Both the first and second runs in this scenario succeeded in achieving LEED compliance. The first run, covering the entire year, resulted in a LEED score of 5 due to the water demand in March. The second run, which focused irrigation from April to November, improved the LEED score to 6 by avoiding unnecessary irrigation in March. This scenario illustrates how strategic planning and operational adjustments can enhance LEED scores.

This scenario showcases the potential for significant water savings through operational strategies. It demonstrates that not all efficiency gains require high-cost infrastructure changes, highlighting the value of strategic adjustments in operational practices to achieve water savings and improve LEED scores.

Scenario 3

The first run with conventional fixtures did not meet prerequisites, underscoring the limitations of high water demand scenarios. The second run, incorporating low-impact development strategies, showed improved outcomes but still required supplemental potable water during peak demand periods in March and July. This scenario reveals the challenges of managing high water-consuming landscapes and the importance of efficient irrigation practices.

The use of permeable materials for pedestrian paths in the first run did not meet prerequisites, suggesting that investing in high-efficiency indoor fixtures yields better results. This highlights the importance of prioritizing investments in areas with the highest impact on water efficiency. The findings indicate that focusing on indoor efficiency and low-demand greenery can be more effective than investing in permeable pavements for achieving sustainability goals.

Final Outcome

The three scenarios were used as examples to demonstrate the efficacy of the proposed methodology in steering sustainable design and decision-making processes to attain LEED certification, particularly in water efficiency. Each scenario serves as a rich source of insights into the intricate relationship between water efficiency strategies and the fulfillment of LEED prerequisites.

However, stakeholders must bear in mind that achieving LEED certification requires a holistic approach that balances the water efficiency category with other pivotal categories such as Sustainable Sites, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation in Design Process, and Regional Priority.

For instance, in Scenario 1, where shrubs were chosen due to their low density and species factor, were in contrast with LEED's emphasis on green sites. Moreover,in scenario 1 and 3, the implementation of high-efficiency fixtures and the application of permeable paving , although beneficial for water management, incurs additional expenses. Consequently, decision-makers face the challenge of weighing municipal water costs and sustainability goals against investments in permeable paving, high-capacity tanks and advanced indoor water fixtures.

These scenarios serve as compelling illustrations of the effectiveness of the proposed methodology. They provide invaluable guidance to architects, landscape planners/designers, owners, and other stakeholders, empowering them to make informed decisions during the preliminary and design phases of water-efficient projects and to ascertain the LEED score .

Conclusion

This study presents a methodology using a Dynamo script, developed as a tool to automate LEED credits, contributing to the water efficiency aspect of the LEED assessment system. This methodology was successfully implemented for Manifattura Tabacchi, facilitating the integration of potable water conservation within the LEED framework during the early stages of design.

The case study and implemented scenarios confirmed that this methodology is effective using a low Level of Detail (LOD) model requirement, requiring minimal effort and easily obtainable inputs. It provides invaluable guidance to architects, landscape designers, owners, and other stakeholders, enabling them to make informed decisions during the preliminary and design phases of water-efficient projects and to determine the LEED score.

A key aspect of the study is its emphasis on balancing water efficiency strategies with the fulfillment of LEED prerequisites. It provides five informative charts and texts addressing the following questions: how much water is used to irrigate each garden, which garden has a high demand for irrigation, in which month it is necessary to store water, in which months the stored water was insufficient thus requiring the use of potable water and how much (in liters), whether the tank capacity is adequate, which months have a high demand for stored water, the percentage of reduced potable water, and the final scores of LEED credits.

Although this study focuses solely on the prerequisites and credits related to water efficiency, it suggests that the concept of automating the remaining LEED categories is viable. Achieving LEED certification requires a holistic approach that balances the water efficiency category with other LEED categories.

Furthermore, while the study includes calculations for water conservation goals, it does not consider the life cycle cost and pay-back period. It is recommended that future research addresses these aspects.

Glossary

- BIM: Building Information Modeling
- BREEAM: Building Research Establishment Environmental Assessment Method
- DGNB: German Sustainable Building Council
- EA: Energy & Atmosphere
- EC: Embodied Carbon
- EE: Embodied Energy
- CLT: Cross Laminated Timber
- GBRS: Green Building Rating Systems
- GHG: Greenhouse Gas
- LCA: Life Cycle Assessment
- LCC: Life Cycle Costing
- LCI: Life Cycle Inventory
- LCIA: Life Cycle Impact Assessment
- LEED: Leadership in Energy and Environmental Design
- MR: Materials & Resources
- OC: Operational Carbon
- OE: Operational Energy
- WBLCA: Whole Building Life Cycle Assessment
- WE: Water Efficiency

-Process water: water used, in fact, for industrial processes and for some systems serving buildings, such as, for example, cooling towers, boilers and chillers

-Non-potable water: see drinking water.

-Drinking water: water intended for human consumption defined by Presidential Decree 236/1988 – Implementation of Directive no. 80/778/EEC concerning the quality of water intended for human consumption pursuant to art. 15 of law 16 April 1987, n. 183, art. 2, as "all water, whatever its origin, in its current state or after treatment, which is supplied for consumption; or reused by food companies through incorporation or contact for the manufacture, treatment, conservation, placing on the market of products and substances intended for human consumption and which may have consequences for the healthiness of the final food product." According to the same Presidential Decree, art. 3, point 1 "The quality requirements are assessed on the basis of the values and indications relating to the parameters referred to in Annex I." For the values, in this regard, see Annex I of the aforementioned Decree.

-Gray water: waste water that does not contain faecal matter or urine (Source: UNI EN 12056-1:2001 – Gravity drainage systems inside buildings - General requirements and performances, point 3.1.4).

-Sewage: waste water containing faecal matter or urine (Source: UNI EN 12056-1:2001 – Gravity drainage systems inside buildings - General requirements and performance, point 3.1.5).

-Wastewater: water contaminated by use and all water that flows into the waste system; for example domestic and industrial waste water, condensation water and also rainwater if discharged into a waste water drainage system" (Source: UNI EN 12056-1:2001 - Gravity drainage systems inside buildings - General requirements and performances, point 3.1.1).

-Aquifer: An underground rock formation that passes through water or a group of formations that supplies surface water, wells, or springs.

-Compost-toilets (dry toilets): sanitary dry waste installations that collect and treat human excreta through microbiological processes.

-Dual-flush: cassettes with two modes of operation, one dispensing more than the other, where the highest.flush option (full) is no greater than 6 l and the reduced flush option (partial), is not greater than two thirds of the quantity of the largest drain" (Source UNI EN 997:2012 - Sanitary appliances - Independent toilets and toilets combined with cistern, with integrated siphon, point 3.21).

-Waterless (or composting) toilets: dry sanitary equipment and accessories that contain and treat human waste through microbiological processes.

-Full-Time Equivalent – FTE: The standard building occupant, who spends 40 hours per week within the designed building. For part-time or after-hours occupants, the FTE value is calculated by dividing the hours they spend inside the building by 40. Obligatory Multiple shifts are included or excluded based on credit purposes and requirements.

-Waterless urinal: sanitary equipment that receives urine, conveying it to the drainage system, operating completely dry (Source: UNI EN 13407:2007 – Wall-mounted urinals - Functional requirements and test methods, point 3.6).

-Flow regulators: limit the time the water flows. There are generally manual opening and automatic closing devices, most commonly installed on sink and shower taps.

-Timed Push Button Faucets: Manually activated, automatic shut-off control devices that are used to limit the duration of water flow. These types of automatic controls are most commonly installed as sink or shower taps.

-Automatic component sensors: motion sensors that automatically switch washbasins, sinks, toilets and urinals on and off. Sensors can be mains- or battery-powered.

-Waste water treatment: transport, storage, treatment and disposal of waste water of waste water generated at the project site

-Drinking water: water intended for human consumption defined by Presidential Decree 236/1988 –Implementation of Directive no. 80/778/ EEC concerning the quality of water intended for human consumption pursuant to art. 15 of law 16 April 1987, n. 183, art. 2, as "all water, whatever its origin, in its current state or after treatment, which is supplied for consumption; or reused by food companies through incorporation or contact for the manufacture, treatment, conservation, placing on the market of products and substances intended for human consumption and which may have consequences for the healthiness of the final food product." According to the same Presidential Decree, art. 3, point 1 "The quality requirements are assessed on the basis of the values and indications relating to the parameters referred to in Annex I." For the values, in this regard, see Annex I of the aforementioned Decree.

-Gray water: waste water that does not contain faecal matter or urine (Source: UNI EN 12056-1:2001 – Gravity drainage systems inside buildings - General requirements and performances, point 3.1.4)

-External area of relevance on the site in question: total area of the site from which the building's own area has been deducted, including walkways, paved surfaces, bodies of water, patios, etc.

-Historic garden: A historic garden is an architectural composition which from a historical or artistic point of view presents a public interest and whose material is mainly vegetal, therefore living and as such perishable and renewable. They are relevant in the architectural composition of the historical garden:

. Its plan and the different soil profiles

. Its vegetal masses: their essences, their volumes, their play of colours, their spacings, their respective heights

.Its built or decorative elements

. Moving or stagnant waters

Expression of the close relationship between civilization and nature, it is testimony to a culture, a style, of an era, possibly of the originality of a creator. The designation of historic garden applies both to modest gardens and to orderly or landscape parks. Whether or not it is linked to a building, of which it is then the inseparable complement, the historic garden cannot be separated from its urban or rural, artificial or natural environmental surroundings.

-Drip Irrigation: High efficiency irrigation system through which water is delivered at low pressure, with a net, at ground level or underground. From these devices, water is distributed to the ground through a network of perforated pipes or emitters. Drip irrigation is a type of microirrigation.

-Conventional Irrigation: Most common irrigation systems used in building location areas. Usually, these irrigation systems use pressure to convey the water and allow its distribution to the heads of the sprinklers located in the area.

-Micro-irrigation: irrigation systems with a low number of sprinklers and micro-spouts or drip systems designed to save water with small volume applications The waterers and sprinklers are installed at a distance of about a few centimeters from the ground, while the drip system is positioned on the ground, or just below the ground.

References

Introduction

1. The Global Water Scarcity Crises

1.Levantesi, Stella. "Assessing Italy's climate risk". Nature Italy: www.nature.com/articles/d43978-021-00136-0
2."Italy Climate-ADAPT". climate-adapt.eea.europa.eu. :www.climate-adapt.eea.europa.eu
3.Umgiesser, Georg . "The impact of operating the mobile barriers in Venice (MOSE) under climate change" (PDF). Journal for Nature Conservation.
4."Italy Faces National Climate Emergency to Add to Debt Woes". www.Bloomberg.com. : www.venezia2021.corila.it
5.Jones, Gavin. "Pressure builds for schools to put climate change study on curriculum". : www.reuters.com
6."Historic' vote means Italian state must now protect animals and ecosystems". euronews. green.: www.euronews.com
7."Traité entre la République française et la République italienne pour une coopération bilatérale renforcée". elysee. :www.elysee.fr
8."Italy – Countries & Regions". IEA. : www.iea.org
9."International – U.S. Energy Information Administration (EIA)". www.eia.gov
10."Italy". Climate Transparency. : www.climate-transparency.org
11."Italy" greenhouse gas emissions from the transport sector 1990–2018". Statista. : www.statista.com
12.Simon, Frédéric . "Revealed: How Italy tried diluting EU car emission rules". : www.euractiv.com.
13."IEA Key energy statistics 2010" (PDF). Archived from the original (PDF) www.archive.org
14.data from Terna - Italian electric grid
15."Il rapporto Comuni Rinnovabili 2015". Comuni Rinnovabili (in Italian). Legambiente.
16."Italy – Industrial pollution profile 2020 — European Environment Agency". European Environment Agency.
17."EEA greenhouse gases – data viewer — European Environment Agency". www.eea.europa.eu.
18."Italy – Industrial pollution profile 2020 — European Environment Agency". European Environment Agency.
19."Key World Energy Statistics 2021" (PDF).
20."CO2 Emissions from Fuel Combustion 2020 : Highlights". Archived from the original on 16 April 2021.
21.Agnoletti, Mauro; Piras, Francesco; Venturi, Martina; Santoro, Antonio. "Cultural values and forest dynamics: The Italian forests in the last 150 years". Forest Ecology and Management
22.Pettenella, Davide. "Italian Forestry Strategy approved after long consultation". MedForest.
23.Rome, Wanted in (28 June 2022). "Rome battles wildfires amid record June heatwave". Wanted in Rome.
24."Previsioni Meteorologiche per ROMA (RM)". meteo aeronautica.
25."Réchauffement climatique : record européen de chaleur battu en Italie". maxisciences.
26."Giornata Acqua: il Po a secco come ad agosto, sos siccità". coldiretti.
27."Clima: inverno pazzo con +0,55 gradi e piogge dimezzate". coldiretti.
28."Climate Change 2021 – Le basi fisico-scientifiche | IPCC – Focal Point Italia" (in Italian).
29."Rapport IPCC". IPCC.
30."analisi de rischio, cambiamenti climatici in Italia" (PDF). Euro-Mediterranean Climate Change Centre Foundation.
31."Scenari climatici per l'Italia". Euro-Mediterranean Climate Change Centre Foundation.
32. "Clima: il 2022 è il V anno più caldo di sempre". coldiretti.
33.Iturbide, Maialen; Fernández, Jesús; Gutiérrez, José Manuel; Bedia, Joaquín; Cimadevilla, Ezequiel; Díez-Sierra, Javier; Manzanas, Rodrigo; Casanueva, Ana; Baño-Medina, Jorge; Milovac, Josipa; Herrera, Sixto; Cofiño, Antonio S.; San Martín, Daniel; García-Díez, Markel; Hauser, Mathias; Huard, David; Yelekci, Özge. "Repository supporting the implementation of FAIR principles in the IPCC-WGI Atlas".
34.Strauss, Benjamin H; Kulp, Scott A; Rasmussen, D J; Levermann, Anders (1 November 2021). "Unprecedented threats to cities from multi-century sea level rise".
35."Fourth National Communication under the UN Framework Convention on Climate Change" (PDF). Ministry for the Environment, Land and Sea.
36."Fifth National Communication under the UN Framework Convention on Climate Change" (PDF). Ministry for the Environment, Land and Sea.
37."Climate Crisis: Po hit by severe drought after 100 days without rain". ANSA.it.
38.Masciopinto, Costantino; Liso, Isabella Serena. "Assessment of the impact of sea-level rise due to climate change on coastal groundwater discharge". Science of the Total Environment.
39.Povoledo, Elisabetta. "Drought Tightens Grip on Northern Italy". The New York Times.
40."Climate: risks and future strategies in Italy". EurekAlert!.
41."Karst Landscapes – Caves and Karst (U.S. National Park Service)". www.nps.gov.
42.Calò, Fabiana; Parise, Mario (December 2006). "Evaluating the Human Disturbance to Karst Environments in Southern Italy". Acta Carsologica.
43."Why We Should Protect Karst Landscapes | Heinrich Böll Foundation | Southeast Asia Regional Office". Heinrich-Böll-Stiftung.

44.Cinelli, Irene; Anfuso, Giorgio; Privitera, Sandro; Pranzini, Enzo. "An Overview on Railway Impacts on Coastal Environment and Beach Tourism in Sicily (Italy)". Sustainability.
45."What is coastal squeeze?". GOV.UK.
46.Horowitz, Jason. "Glacier Tragedy Shows Reach of Europe's New Heat". The New York Times.
47."Italy glacier tragedy has 'everything to do' with climate change". EUobserver.
48."IUCN, 2013a, Italy's Biodiversity at Risk. A Call for Action" (PDF). Brussels, Belgium: International Union for Conservation of Nature. May 2013. Archived from the original (PDF) .
49."Italian wildfires 'three times worse' than average as heatwave continues". The Local Italy.
50.Blaškovic, Teo. "Thousands of animals perish, 1 500 people evacuate as massive wildfires ravage Sardinia, Italy". The Watchers.
51.Ivardiganapini, Cecilia. "Land Being Lost to Urbanization: A Threat to Biodiversity in Italy". Climate Scorecard.
52.IPCC , AR6 Climate Change: The Physical Science Basis, Working Group I contribution to the Sixth Assessment Report.
53.net zero cities
54.C40 Reinventing Cities Porte de Montreuil – Paris, France.
55. Uccrn.education
56.UNESCO World Water Assessment Programme. "Smart Water Solutions."
57.World Bank Group. "Integrating Smart Water Solutions in Water Sector Operations: Harnessing Information and Communications Technologies for Improving Water Services."
58.United Nations. "Water Efficiency and Sustainable Urban Water Management."
59.Global Water Partnership. "Smart Solutions for Water Management: Examples from Around the World."
60. United Nations Development Programme (UNDP). "Water and ICT."
61.European Commission. "ICT for Water Management."
62.World Bank. "Information and Communication Technologies (ICTs) in Water Sector." Available at: https://www.worldbank.org/en/topic/water/brief/information-and-communication-technologies-in-water-sector
63.Global Water Partnership. (2018). "Harnessing the Potential of ICTs in Water Management."
64.United Nations Educational, Scientific and Cultural Organization (UNESCO). "Hydroinformatics for the Water Sector."

2. International Building Rating System

1.Sustainable Development Goals (SDGs) in "dgs.un.org"
2. Dat Tien Doan , Ali Ghaffarianhoseini, Nicola Naismith, Tongrui Zhang ,Amirhosein Ghaffarianhoseini, John Tookey ."A critical comparison of green building rating systems".
3.breeam.com
4.www.usgbc.org
5. www.ibecs.or.jp
6. nzgbc.org.nz

3.LEED Certification

1."White Paper on Sustainability, A Report on the Green Building Movement". Building Design & Construction (BDC).
2."About USGBC". US Green Building Council (USGBC).
3."USGBC Statistics". U.S Green Building Council (USGBC).
4."World Green Building Trends 2016". DODGE Data & Analytics. July 2016.
5."Certification".Green Building Council Italia
6. Leed Green Associate Exam Preparation Guide Leed V4 Edition Heather C. Mccombs

4.Digital Technologies and Sustainability Assessment

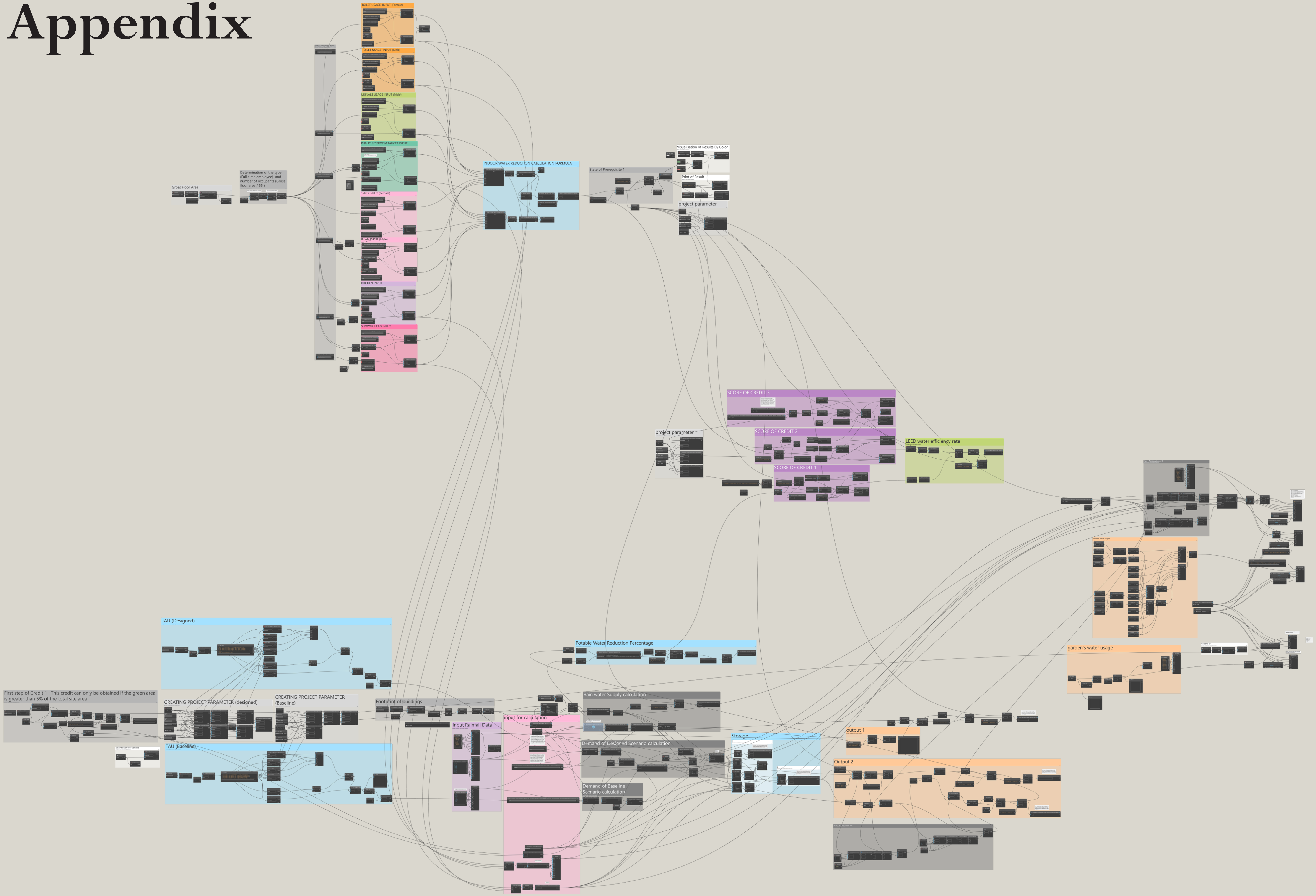
1.Park, H. "A Stochastic Planning Model for Battery Energy Storage Systems Coupled with Utility-Scale Solar Photovoltaics." Energies2021,14, 1244.
2.Cascone, S.; Leuzzo, A." Thermal Comfort in the Built Environment: A Digital Workflow for the Comparison of Different Green Infrastructure Strategies." Atmosphere 2023,14, 685.
3. Hafiz Saeed Ur Rehman, Muhammad Aamer Raza, Rehan Masood,Muhammad Arif Khan, Sabahat Alamgir, Muhammad Afzal Javed, Krishanu Roy & James B.P. Lim (2022):" A multi-facet BIM based approach for Green Building design of new multi-family residential building using LEED system," International Journal of Construction Management,
4. Luís Sanhudo , João Poças Martins:"Building information modeling for an automated building sustainability assessment"- DOI:10.1080/10286608.2018.1521393
5.Kensek, K.; Ding, Y.; Longcore, T. "Green building and biodiversity: Facilitating bird friendly design with building information models". J. Green Build. 2016, 11, 116–130.

Methodology

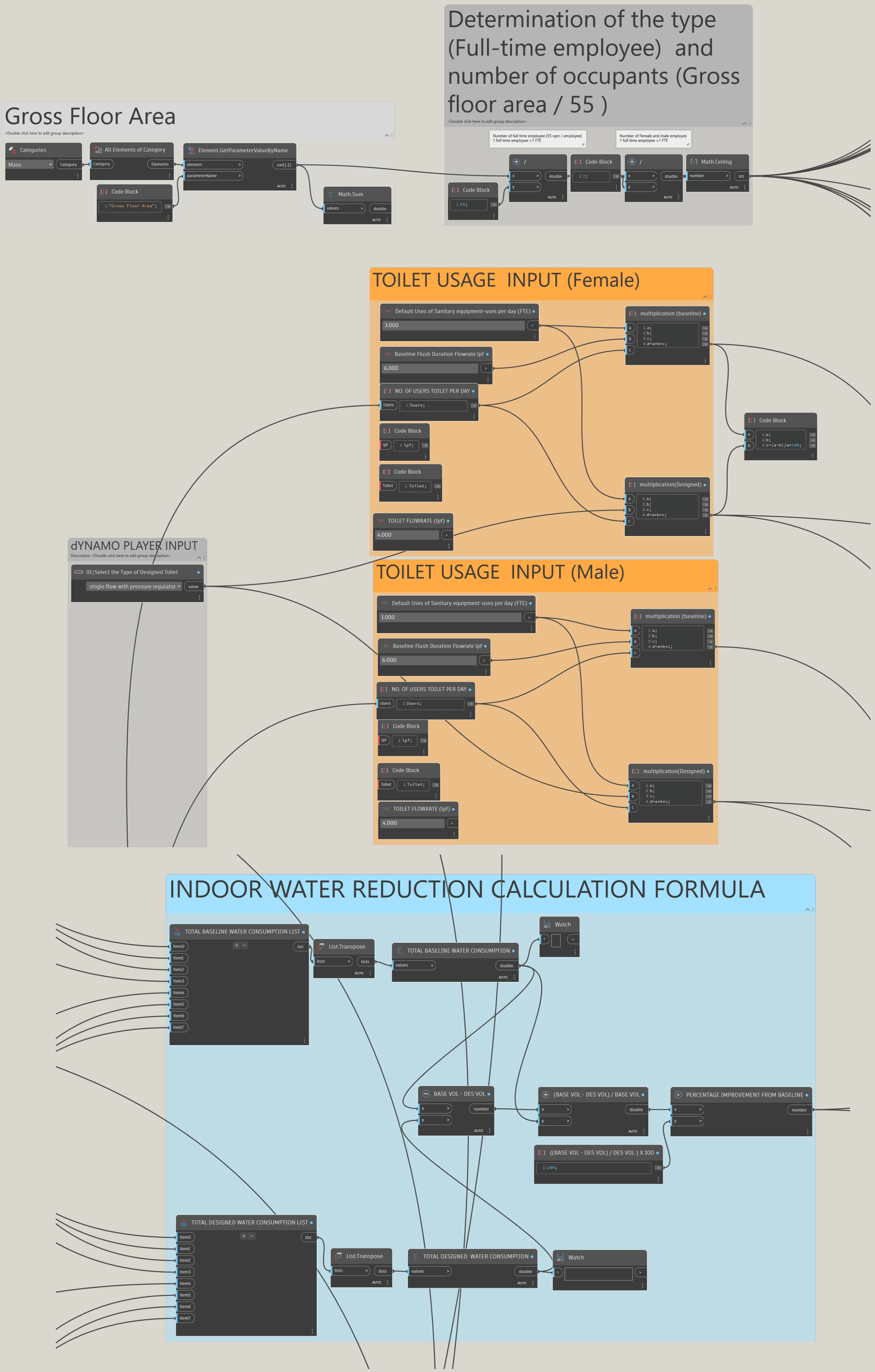
2. Ex Manifattura Tabacchi

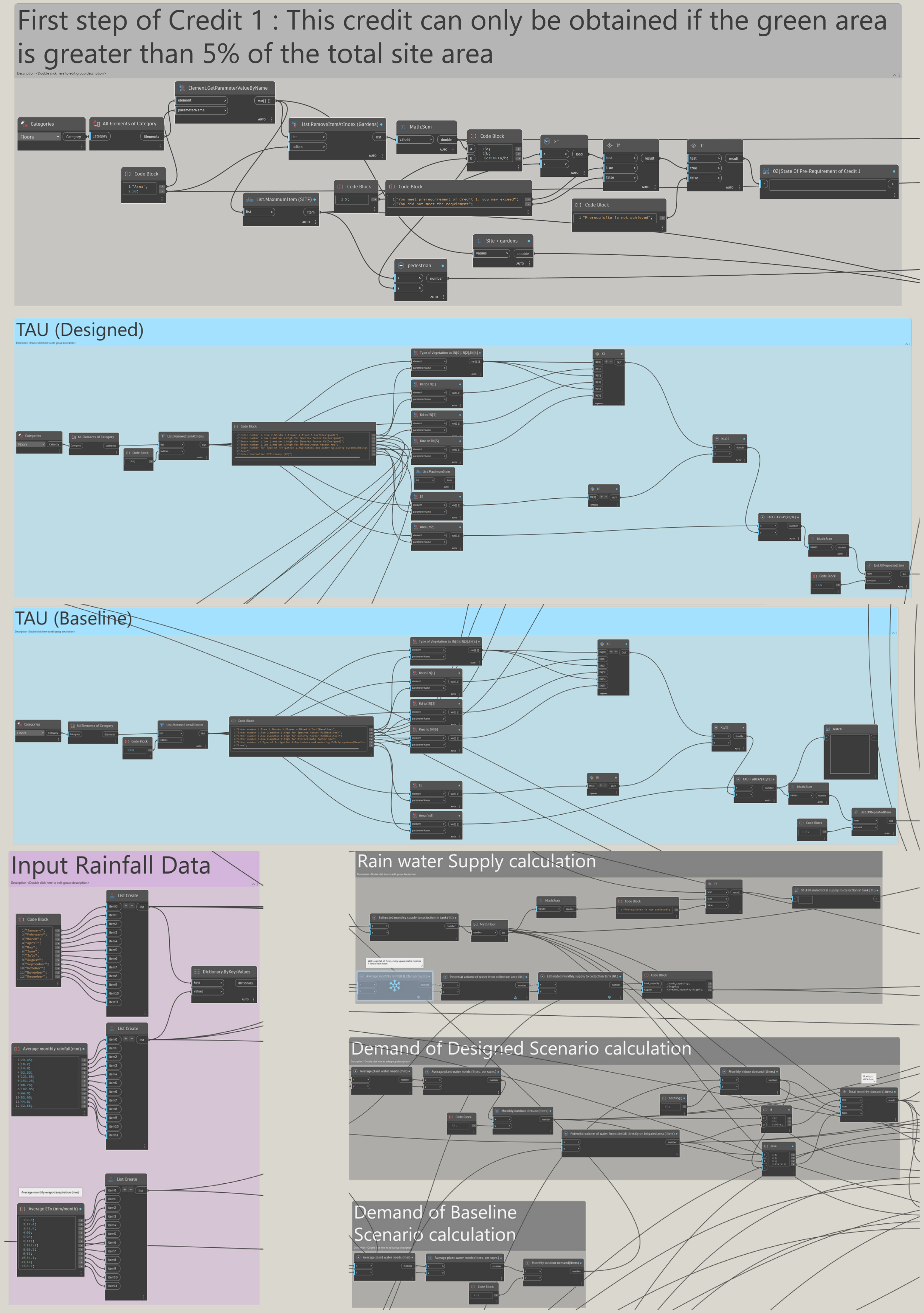
1. www.istoreto.it
2. www.immaginidelcambiamento.it
3. www.unito.it
4. areeweb.polito.it
5. areeweb.polito.it
6. www.icanaliditorino.it
7. www.manifatturatabacchitorino.concorrimi.it

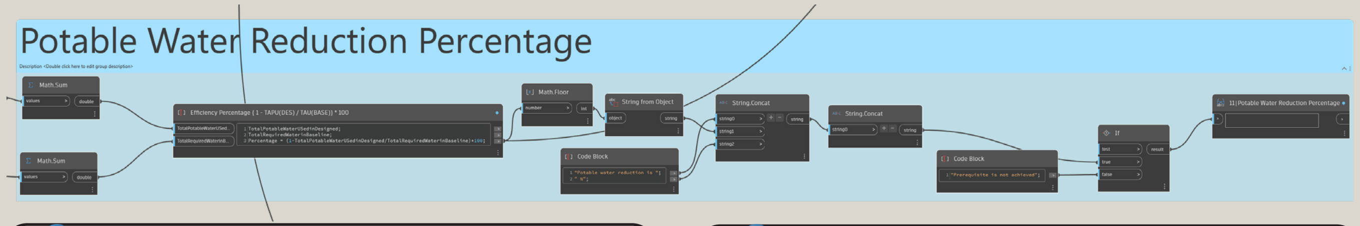
Appendix



TOILET USAGE INPUT (Female)
TOILET USAGE INPUT (Male)
URINALS USAGE INPUT (Male)
PUBLIC RESTROOM FAUCET INPUT
Bidets INPUT (Female)
KITCHEN INPUT
SHOWER HEAD INPUT
Gross Floor Area
Determination of the type (Full-time employee) and number of occupants (Gross floor area / 55)
INDOOR WATER REDUCTION CALCULATION FORMULA
State of Prerequisite 1
Visualisation of Results By Color
Print of Result
project parameter
SCORE OF CREDIT 3
project parameter
SCORE OF CREDIT 2
SCORE OF CREDIT 1
LEED water efficiency rate
TAU (Designed)
Potable Water Reduction Percentage
garden's water usage
First step of Credit 1 : This credit can only be obtained if the green area is greater than 5% of the total site area
CREATING PROJECT PARAMETER (designed)
CREATING PROJECT PARAMETER (Baseline)
Footprint of buildings
Rain water Supply calculation
input for calculation
Input Rainfall Data
output 1
Storage
Demand of Designed Scenario calculation
TAU (Baseline)
Output 2
Demand of Baseline Scenario calculation


Gross Floor Area
Determination of the type (Full-time employee) and number of occupants (Gross floor area / 55)
TOILET USAGE INPUT (Female)
dYNAMO PLAYER INPUT
TOILET USAGE INPUT (Male)
INDOOR WATER REDUCTION CALCULATION FORMULA


First step of Credit 1 : This credit can only be obtained if the green area is greater than 5% of the total site area
TAU (Designed)
TAU (Baseline)
Input Rainfall Data
Rain water Supply calculation
Demand of Designed Scenario calculation
Demand of Baseline Scenario calculation




```
# Get the inputs
dataEnteringNode = IN

# Initialize the result list
result = []

# Iterate through each pair of input lists
for i in range(len(IN[0])):
    # Initialize the variables for Ks, Kd, and Kmc
    Ks, Kd, Kmc = 0, 0, 0

    # Calculate Ks
    if IN[0][i] == "Tree" and IN[1][i] == "low":
        Ks = 0.2
    elif IN[0][i] == "Tree" and IN[1][i] == "medium":
        Ks = 0.5
    elif IN[0][i] == "Tree" and IN[1][i] == "high":
        Ks = 0.9
    elif IN[0][i] == "Shrubs" and IN[1][i] == "low" :
        Ks = 0.2
    elif IN[0][i] == "Shrubs" and IN[1][i] == "medium":
        Ks = 0.5
    elif IN[0][i] == "Shrubs" and IN[1][i] == "high":
        Ks = 0.7
    elif IN[0][i] == "Flower" and IN[1][i] == "low" :
        Ks = 0.2
    elif IN[0][i] == "Flower" and IN[1][i] == "medi-
um":
        Ks = 0.5
    elif IN[0][i] == "Flower" and IN[1][i] == "high":
        Ks = 0.7
    elif IN[0][i] == "Mixed" and IN[1][i] == "low" :
        Ks = 0.2
    elif IN[0][i] == "Mixed" and IN[1][i] == "medium":
        Ks = 0.5
    elif IN[0][i] == "Mixed" and IN[1][i] == "high":
        Ks = 0.9
    elif IN[0][i] == "Turf" and IN[1][i] == "low" :
        Ks = 0.6
    elif IN[0][i] == "Turf" and IN[1][i] == "medium":
        Ks = 0.7
    elif IN[0][i] == "Turf" and IN[1][i] == "high":
        Ks = 0.8
    # Calculate Kd
    if IN[2][i] == "Tree" and IN[3][i] == "low":
        Kd = 0.5
    elif IN[2][i] == "Tree" and IN[3][i] == "medium":
        Kd = 1.0
    elif IN[2][i] == "Tree" and IN[3][i] == "high":
        Kd = 1.3
    elif IN[2][i] == "Shrubs" and IN[3][i] == "low":
        Kd = 0.5
    elif IN[2][i] == "Shrubs" and IN[3][i] == "medium":
        Kd = 1.0
    elif IN[2][i] == "Shrubs" and IN[3][i] == "high":
        Kd = 1.1
    elif IN[2][i] == "Flower" and IN[3][i] == "low":
        Kd = 0.5
    elif IN[2][i] == "Flower" and IN[3][i] == "medi-
um":
```

```
        Kd = 1.0
    elif IN[2][i] == "Flower" and IN[3][i] == "high":
        Kd = 1.1
    elif IN[2][i] == "Mixed" and IN[3][i] == "low":
        Kd = 0.6
    elif IN[2][i] == "Mixed" and IN[3][i] == "medium":
        Kd = 1.1
    elif IN[2][i] == "Mixed" and IN[3][i] == "high":
        Kd = 1.3
    elif IN[2][i] == "Turf" and IN[3][i] == "low":
        Kd = 0.6
 elif IN[2][i] == "Turf" and IN[3][i] == "medium":
        Kd = 1.0
    elif IN[2][i] == "Turf" and IN[3][i] == "high":
        Kd = 1.0

    # Calculate Kmc
    if IN[4][i] == "Tree" and IN[5][i] == "low":
        Kmc = 0.5
    elif IN[4][i] == "Tree" and IN[5][i] == "medium":
        Kmc = 1.0
    elif IN[4][i] == "Tree" and IN[5][i] == "high":
        Kmc = 1.4
    elif IN[4][i] == "Shrubs" and IN[5][i] == "low":
        Kmc = 0.5
    elif IN[4][i] == "Shrubs" and IN[5][i] == "medium":
        Kmc = 1.0
    elif IN[4][i] == "Shrubs" and IN[5][i] == "high":
        Kmc = 1.3
    elif IN[4][i] == "Flower" and IN[5][i] == "low":
        Kmc = 0.5
    elif IN[4][i] == "Flower" and IN[5][i] == "medium":
        Kmc = 1.0
    elif IN[4][i] == "Flower" and IN[5][i] == "high":
        Kmc = 1.2
    elif IN[4][i] == "Mixed" and IN[5][i] == "low":
        Kmc = 0.5
    elif IN[4][i] == "Mixed" and IN[5][i] == "medium":
        Kmc = 1.0
    elif IN[4][i] == "Mixed" and IN[5][i] == "high":
        Kmc = 1.4
    elif IN[4][i] == "Turf" and IN[5][i] == "low":
        Kmc = 0.8
    elif IN[4][i] == "Turf" and IN[5][i] == "medium":
        Kmc = 1.0
    elif IN[4][i] == "Turf" and IN[5][i] == "high":
        Kmc = 1.2

    # Calculate KL using the formula
    KL = Ks * Kd * Kmc

    # Append the result to the result list
    result.append(KL)

# Output the result list
OUT = result
```