Politecnico di Torino

Master of Science in Building Engineering

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Feasibility analysis of new technologies for green facades

Use of soil-less solution and greywater treatment for green facades

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ABSTRACT

The earth for a long time and to an increasing extent has been suffering the effects of our neglect of the environment around us. it is therefore urgent to take measures that restore healthy coexistence and respect for an asset whose importance is fundamental to human life.

Today the building construction is one of the oldest and less efficient sectors in terms of technological development and in terms of waste during each phase. One of the key aspects to improve the building impact on the environment is to reduce his energy demand. This could be an easy task to a new building, it is possible to design without major problem an energy efficient building, the same cannot be said for the existing one. Probably the most efficient way to improve an existing building is to add a double skin façade, which is an additional layer that aim to reduce the energy demand for heating and cooling.

In this work the focus will be to assess which are the new technologies for the façade of the building. Compare the traditional double skin façade with a green façade, and to have a better comprehension of the future development of this kind of façade with the implementation of grey water management system, and the soil-less solution of moss. This different kind of façade will be evaluated in term of feasibility in order to understand if this is a sustainable solution or if more work is needed to improve this technology.

La terra da parecchio tempo e in crescente misura sta subendo gli effetti della nostra negligenza verso l'ambiente che ci circonda. è perciò impellente adottare misure che ripristino una sana coesistenza e rispetto verso un bene la cui importanza è fondamentale per la vita umana.

Oggi l'edilizia è uno dei settori più vecchi e meno efficienti in termini di sviluppo tecnologico e di sprechi in ogni fase. Uno degli aspetti chiave per migliorare l'impatto dell'edificio sull'ambiente è ridurre la sua domanda di energia. Questo potrebbe essere un compito facile per un nuovo edificio, è possibile progettare senza grossi problemi un edificio efficiente dal punto di vista energetico, ma lo stesso non si può dire per quello esistente. Probabilmente il modo più efficiente per migliorare un edificio esistente è quello di aggiungere una facciata a doppia pelle, che è uno strato aggiuntivo che mira a ridurre la domanda di energia per il riscaldamento e il raffreddamento.

In questo lavoro si cercherà di valutare quali sono le nuove tecnologie per la facciata dell'edificio. Confrontare la tradizionale facciata a doppia pelle con una facciata verde e comprendere meglio lo sviluppo futuro di questo tipo di facciata con l'implementazione del sistema di gestione delle acque grigie e la soluzione senza suolo del muschio. Questo diverso tipo di facciata sarà valutato in termini di fattibilità per capire se si tratta di una soluzione sostenibile o se sono necessari ulteriori interventi per migliorare questa tecnologia.

CONTENTS

1. INTRODUCTION

The rising crisis of climate change has proved to be one of the most pressing global challenges of our time. The increasing concentrations of greenhouse gases, primarily carbon dioxide, methane, and nitrous oxide, have led to a significant rise in global temperatures, resulting in drastic changes to weather patterns, sea levels, and ecosystems. The built environment, particularly the construction industry, plays a pivotal role in both contributing to and mitigating this crisis.

The construction sector is responsible for a substantial portion of global carbon emissions, due to the production of building materials, energy consumption during construction, and the operational energy use of buildings. Traditional building materials such as concrete and steel are highly energy-intensive to produce, leading to considerable carbon footprints. Moreover, the energy required to maintain, heat, and cool buildings contributes further to greenhouse gas emissions.

In response to these challenges, the industry has been increasingly focusing on sustainable building practices and technologies aimed at reducing environmental impact. The adoption of green building standards, such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method), promotes the use of energy-efficient designs, renewable energy sources, and sustainable materials. These standards encourage the integration of features such as enhanced insulation, solar panels, and green roofs, which can significantly reduce a building's carbon footprint.

Furthermore, vertical greenery systems (VGS) and green facades are being incorporated into urban landscapes to mitigate the effects of climate change.

These systems not only enhance the aesthetic appeal of buildings but also contribute to energy savings, improved air quality, and increased biodiversity. Direct systems, where plants grow directly on the building surface, and indirect systems, which use supporting structures, are both effective in promoting sustainability and resilience in the built environment.

European environment agency state that Almost 75% of the building stock is currently energy inefficient and more than 85% of today's buildings are likely to still be in use in 2050.

The EU's renovation wave will play a key role in massively upgrading existing buildings in Europe. It will help make them more energy efficient and adapted to climate change. This will be an important element in achieving a climate-neutral EU by 2050.

Housing accounts for 52% of the EU’s material footprint, making it the sector with the highest environmental impact. About one third of the Union’s material consumption goes to construction. The use of buildings accounts for 42% of the total energy consumption and 35% of greenhouse gas emissions. [1]

It is essential to make the building energy efficient.

2. TRADITIONAL DOUBLE SKIN FAÇADES

One of the most effective ways to improve the energy efficiency of a building is to enhance the performance of the envelope. The relation of the interior space with the exterior environment is the key of creating a sustainable building, this is translated in the current architecture in the focus on the façades, since they are the element with the most impact in term of energy efficiency, ventilation and lighting.

Conventional façades can lead to poor natural ventilation, low level of daylighting, thermal discomfort, and increased energy consumption. [2] That is where double-skin façades are implemented, a general definition is that a DSF is a special type of envelope, where a second "skin", that can be transparent or opaque, is placed in front of a regular building façade.

2.1. Classification of façades

Double skin façades split in two major groups, the airtight (the "cappotto" for Italian building) and the ventilated. [2]

In practical terms is useful to categorize to four conditions:

- Closed
- Mechanical exhaust
- Natural convection to outside
- Window ventilation

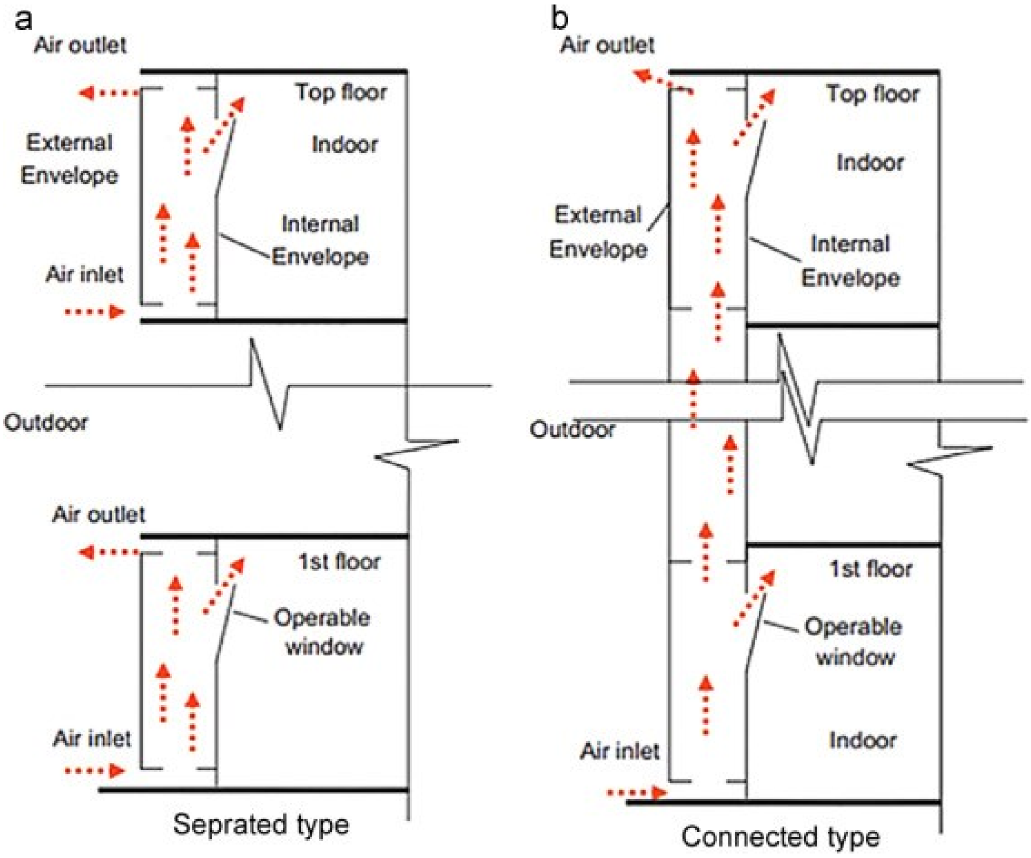
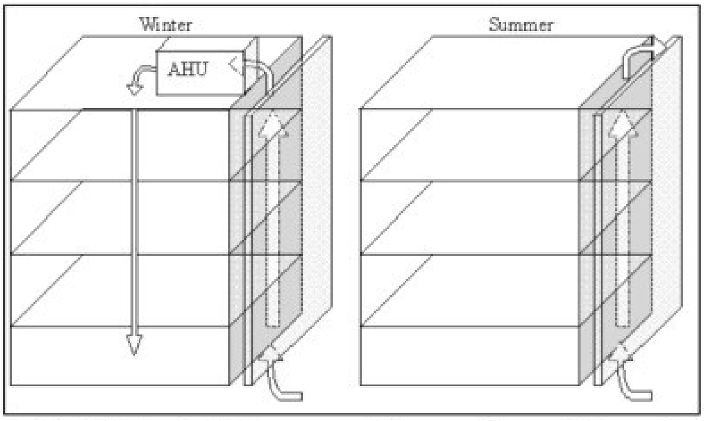
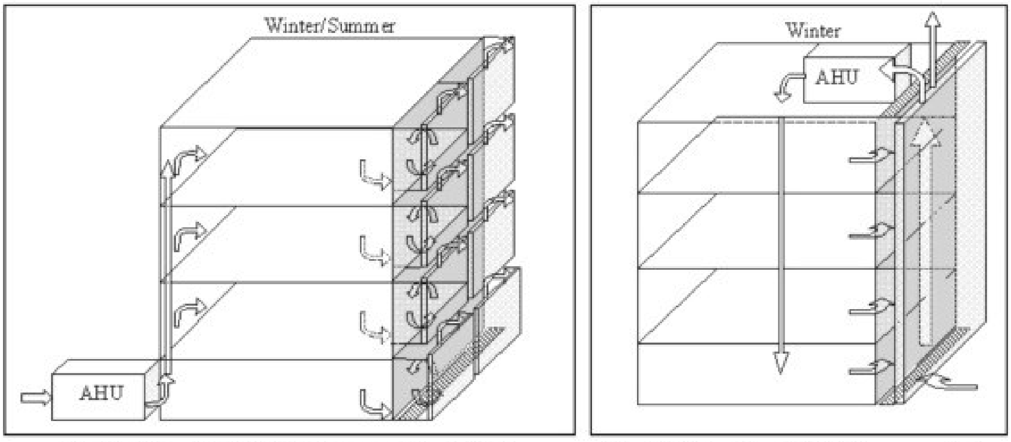


Figure 1 - Design classification of DSFs, Bottom Schematic representation of the working modes for DSFs, Source [3]

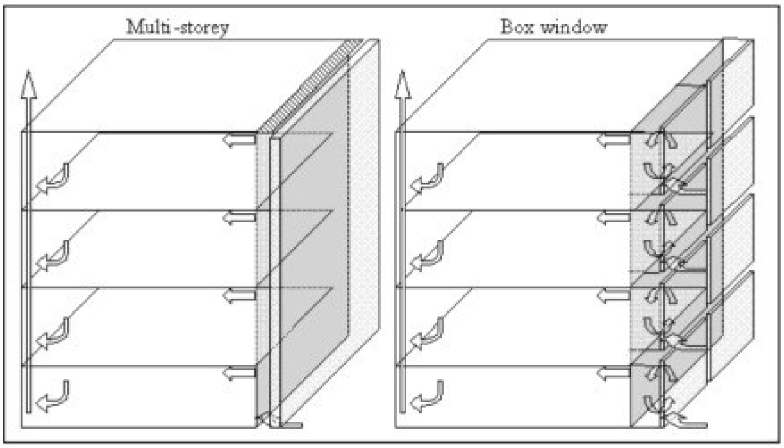


Double Skin Façade (DSF) as a central direct pre-heater of the supply air



Double Skin Façade (DSF) as an exhaust duct

Double Skin Façade (DSF) as a central exhaust duct for the ventilation system



Double Skin Façade (DSF) as an individual supply of the preheated air

Figure 2 - Different airflow patterns in DSFs. Source [2]

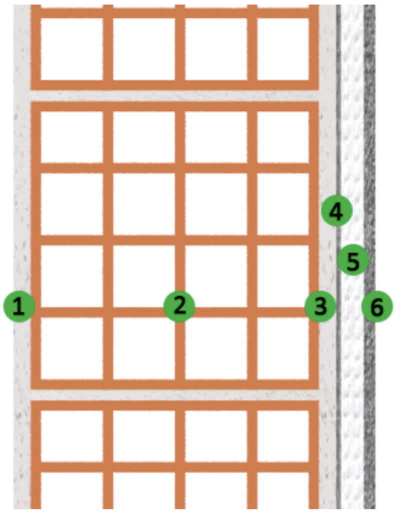
2.2. Stratigraphy

Generally, the double skin facades are similar of conception they have the requirement of enhance thermal (as the main one) and acoustic property, along with ad external envelope that has an aesthetic function and double as a layer of protection of the insulation and impermeabilization layer underneath.

In the following picture there will be a schema of the stratigraphy of a ventilated and non-ventilated double skin façade. Which is clear that the main change between the two system is the ventilated cavity, that need an additional layer of protection.

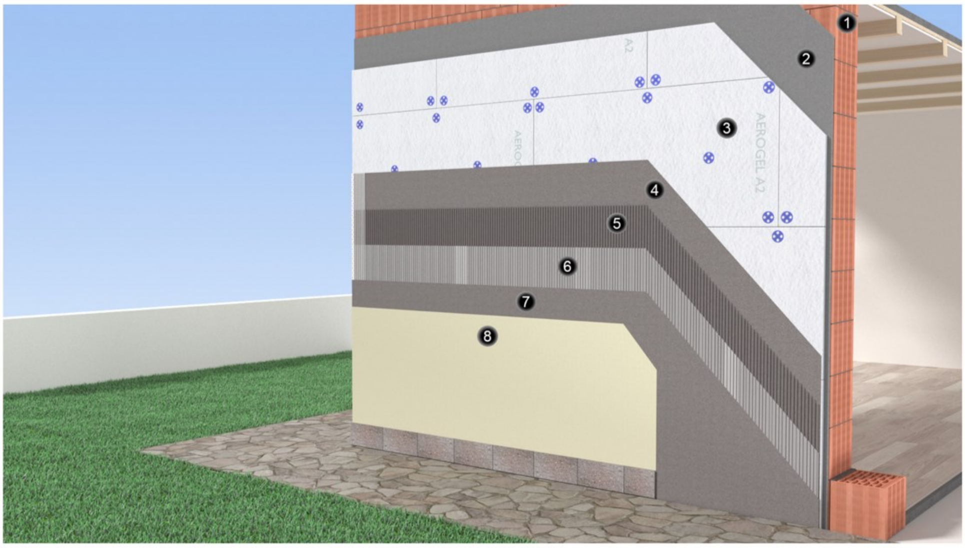
Other design could have the necessity to add layers, depending on the demand of the double skin facades, to have different structure, depending on the geometry and the material of the original façade, or to have a completely different approach, based on the requirement of the project.

This is therefore not representative of all the possible solution but is a schema of one of the most common stratigraphy.



1. Intonaco interno 15 mm
2. Blocco forato 250 mm
3. Intonaco esterno 15 mm
4. Adesivo
5. AEROGEL A2
6. Intonaco di fondo + finitura

Figure 3 - Stratigraphy of non-ventilated facades, section. source[4]



1.Parete perimetrale 2.Adesivo 3.AEROGEL A2 4.Livellatura 5.Rasatura 6.Rete di armatura 7.Lisciatura 8.Finitura

Figure 4 - Stratigraphy of non-ventilated facades, render. source[4]

Figure 5 - Stratigraphy of ventilated facades, section. source[5]

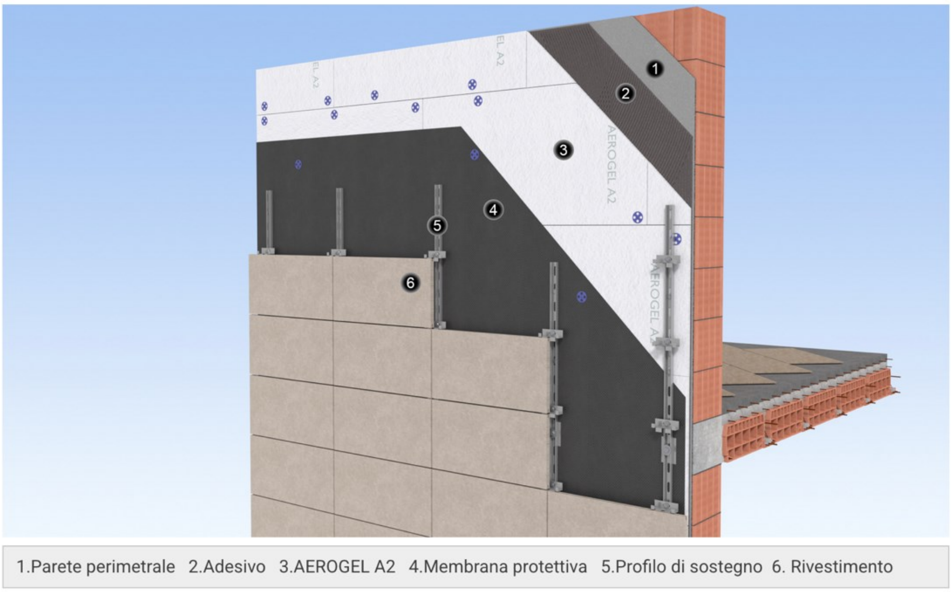


Figure 6 - Stratigraphy of ventilated facades, render. source[5]

2.3. Limitations with the systems

Double skin facades are widely used in modern architecture to improve energy efficiency, indoor comfort, and aesthetics. However, their traditional designs present several problems in terms of performance, maintenance, and compliance with European regulations.

• Fire safety risks

- **Problem:** Traditional Double-skin facades can act as chimney-like structures, facilitating the rapid spread of fire between floors.

- **Regulations:** The EN 1364-1 and EN 1363-1 standards define fire resistance tests for facades. After incidents like the Grenfell Tower fire, stricter national regulations (e.g., Germany’s DIN 4102, UK’s Approved Document B) impose fire stops, non-combustible materials, and compartmentalization measures.

- **Challenges:** Retrofitting Double-skin facades to meet these new fire safety requirements can be complex and costly.

• Overheating & Thermal Performance

- **Problem:** Traditional Double-skin facades can cause excessive heat accumulation in summer, requiring additional cooling.

- **Regulations:** The Energy Performance of Buildings Directive (EPBD) requires buildings to reduce cooling energy demand. The ISO 52016 standard assesses the thermal behavior of facades.

- **Challenges:** Many traditional Double-skin facades fail to integrate adaptive shading or ventilation strategies, leading to poor energy performance.

Airflow & Ventilation Inefficiencies

- **Problem:** Double-skin facades rely on natural or mechanical ventilation, but poor design can lead to stagnant air, condensation, and mold growth. In colder climates, air leakage issues can create drafts and discomfort.

- **Regulations:** The EN 15251 standard defines acceptable indoor air quality and comfort levels.

- **Challenges:** Older Double-skin facades often lack smart control systems to regulate airflow efficiently.

Acoustic Performance Limitations

- **Problem:** Traditional DSFs can amplify external noise (traffic, aircraft, industrial sounds) if not properly sealed.

- **Regulations:** ISO 16283-3 and EN 12354-3 define acoustic insulation for facades.

- **Challenges:** Achieving optimal ventilation without compromising sound insulation remains a design difficulty.

• Maintenance & Cleaning Complexity

- **Problem:** Double-skin facades require frequent maintenance to clean the inner cavity, remove debris, and check mechanical systems. Accessing the ventilated cavity for maintenance can be difficult and expensive.

- **Regulations:** According to ISO 15686-1, maintenance combines all technical and administrative actions, including supervision, that are necessary to reinstate an element to a condition in which it fulfills adequate performance requirements.[6]

- **Challenges:** Many older Double-skin facades lack proper cleaning access points, leading to dust accumulation and reduced efficiency.

• Cost & Return on Investment

- **Problem:** Initial installation costs for Double-skin facades are high. Many traditional DSFs do not deliver expected energy savings, making the return of investment longer than expected.

- **Regulations:** The EU Taxonomy for Sustainable Finance promotes cost-effective energy solutions, discouraging inefficient DSF implementations.

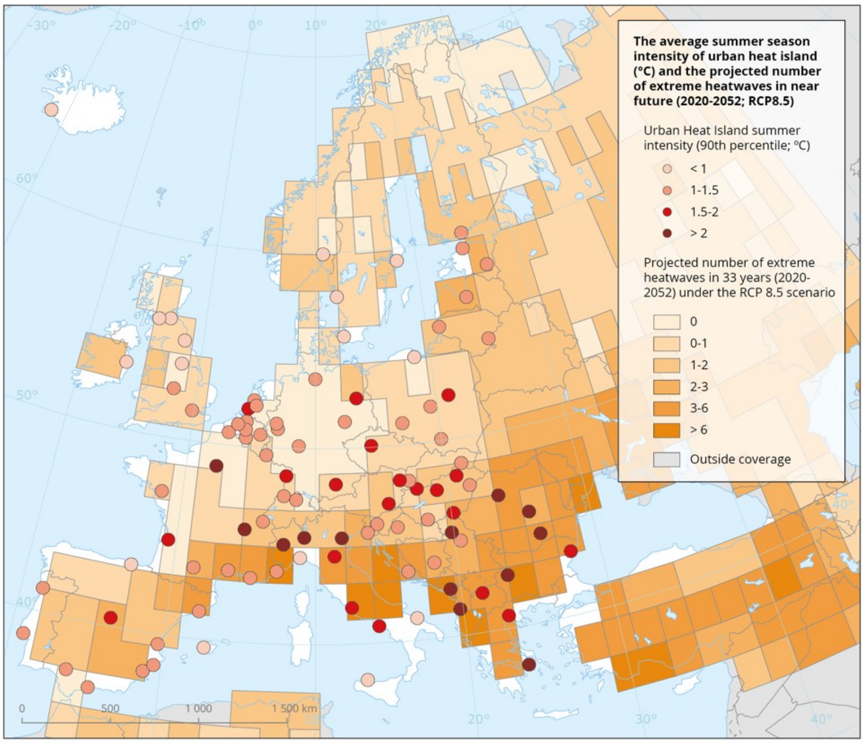
- **Challenges:** Justifying Double-skin facades in climates where simpler facade solutions (e.g., triple-glazing + shading) provide similar benefits at a lower cost.

- ## Urban Heat Island phenomenon

Urban heat island Is a problem that affect all around the world areas dense of structures.

The urban heat island (UHI) phenomenon is caused by the replacement of green spaces with hard buildings and pavements that have high heat capacity. This causes urban surfaces to absorb and retain large amounts of heat, increasing temperatures in urban areas. The urban heat island effect negatively affects the thermal environment of the city and increases the energy consumption of buildings. Island heat mitigation is a critical issue in densely populated Italian cities.

The European Environment Agency has mapped the phenomenon across the territory.



Reference data: ©ESRI

Figure 7 - The average summer season intensity of urban heat island. Source [7]

3. VERTICAL GREENERY SYSTEM

3.1. Green facades

- Direct system (climb on the wall)

The vegetation grows direct on the wall without any support or structure to keep the plants attached. For this application is used self-adhering plants (that can be also helped with minimal support).

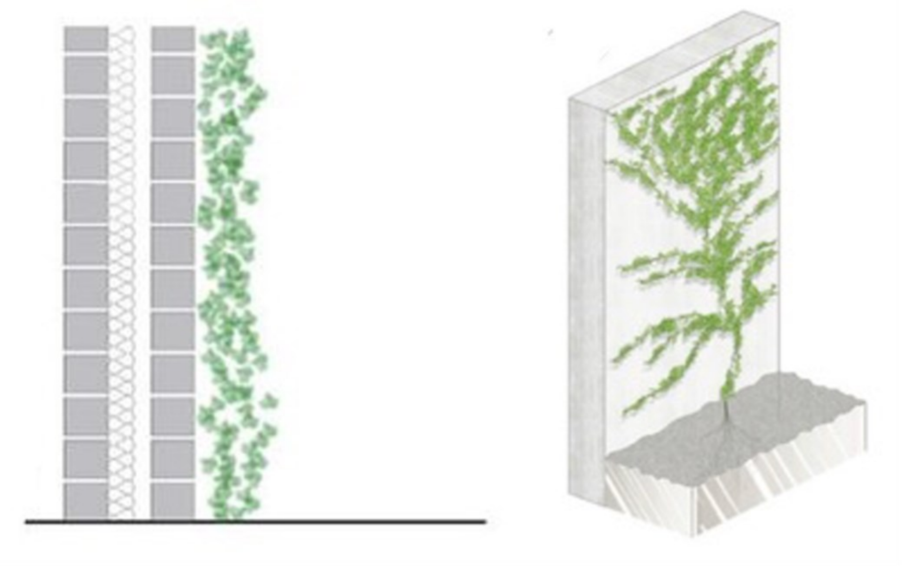


Figure 8 - Structure of Direct green façades. Source [8], [9]

The most common plants used are Ivy (Hedera helix), Parthenocissus tricuspidate (American vine). This system although, does have some issue, even if it is economical and easy to install and do not require additional facilities, it can damage the wall surfaces and it require a strong and durable wall to be installed.

- Indirect system (has a structure)

The vegetation grows on supports that are attached on the façades but separated from the building, such as grids or nets. The plants grown in pots or on the ground and climb the structure that can be made of steel wood or composite materials. With the support made out of wire mesh (stainless steel wires), wooden or synthetic material racks.

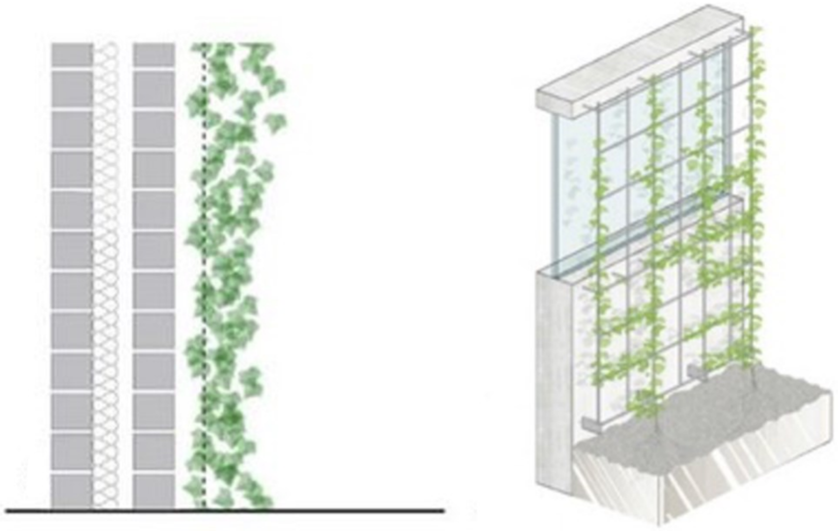


Figure 9 - Structure of Indirect green façades. Source [8], [9]

This system has little to none risk of damage the structure underneath and is much easier to do maintenance, on the other hand it requires a sturdy support system and sufficient space to be installed.

3.2. Living Walls (LWS)

They are high-tech systems in which plants grow in modules or panels fixed to the façade. The key feature of this system is that the vegetation is inserted in light substrates (rock wool, felt, earth), it is integrated irrigation system and fertilization system.

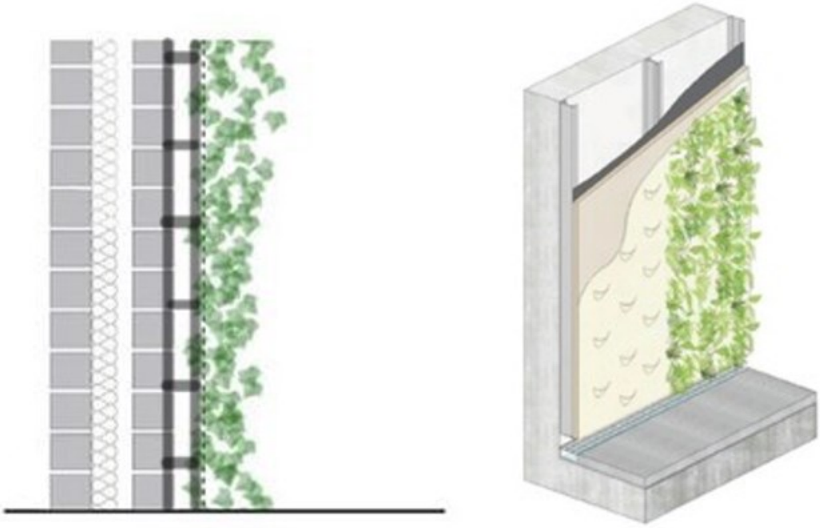


Figure 10 - - Structure of Living Walls. Source [8], [9]

This kind of double skin has great differences with the previous system described, thermal and acoustic proprieties are the main parameters that are enhanced, along with this it is possible to have a wider choice of plants. This system can be applied for indoor use also.

The downside of the living wall is the high cost of installation and maintenance and the complexity of the system.

- ## Modular Green Façades

It is a variation of the living walls, based on prefabricated modules containing substrate and plants. The pre-assembled modules are installed directly on the structure that is connected on the building façades.

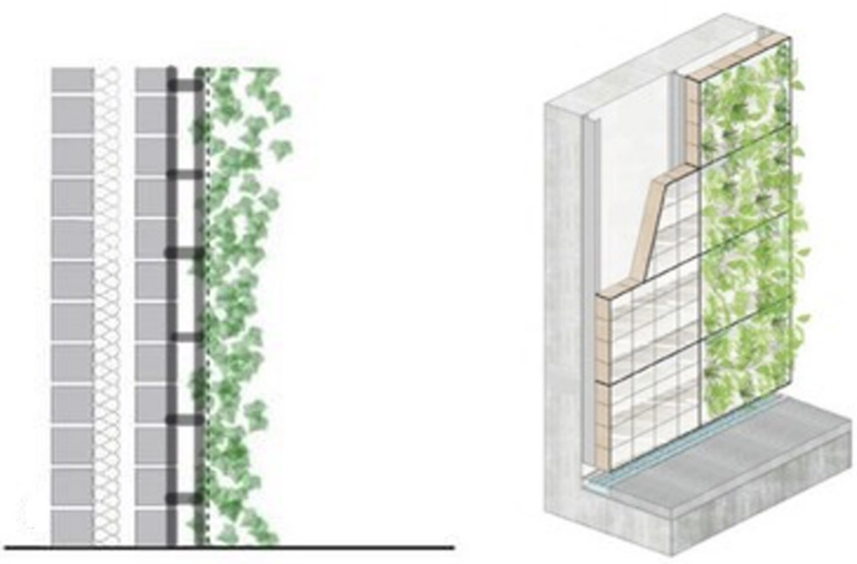


Figure 11 - - Structure of Modular green façades. Source [8], [9]

The installation is more flexible because it is easier and quicker the process. Another advantage is in the maintenance because this system allows an easy replacement of damaged parts, this came although with a higher cost of the double skin.

- ### Cassette plants walls

This system has some similarities in the structure of the living walls and the modular green walls, but the plants grow in pots or boxed integrated into the structure.

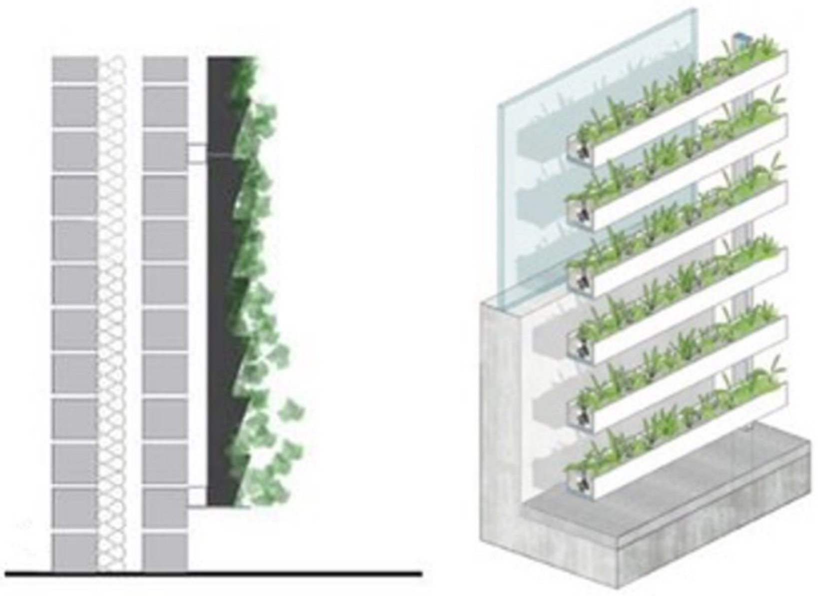


Figure 12 - - Structure of Cassette plants walls. Source [8], [9]

As the previous system its modularity and ease of installation is a feature of this solution, the cost could be contained respect the living walls, but it is a bulkier façade.

- ## Hydroponic systems

It differs from the previous technological system because the plants grow without soil, their roots are immersed in nutrient solutions. This solution enhances thermal proprieties and reduce maintenance.

There are different typologies of hydroponic systems:

Nutrient Film Technique (NFT): A thin layer of nutrient-rich water flows over plant roots.

Drip Irrigation System: Water and nutrients are delivered in controlled amounts. Aeroponics: Plants are suspended, and roots are misted with nutrients.

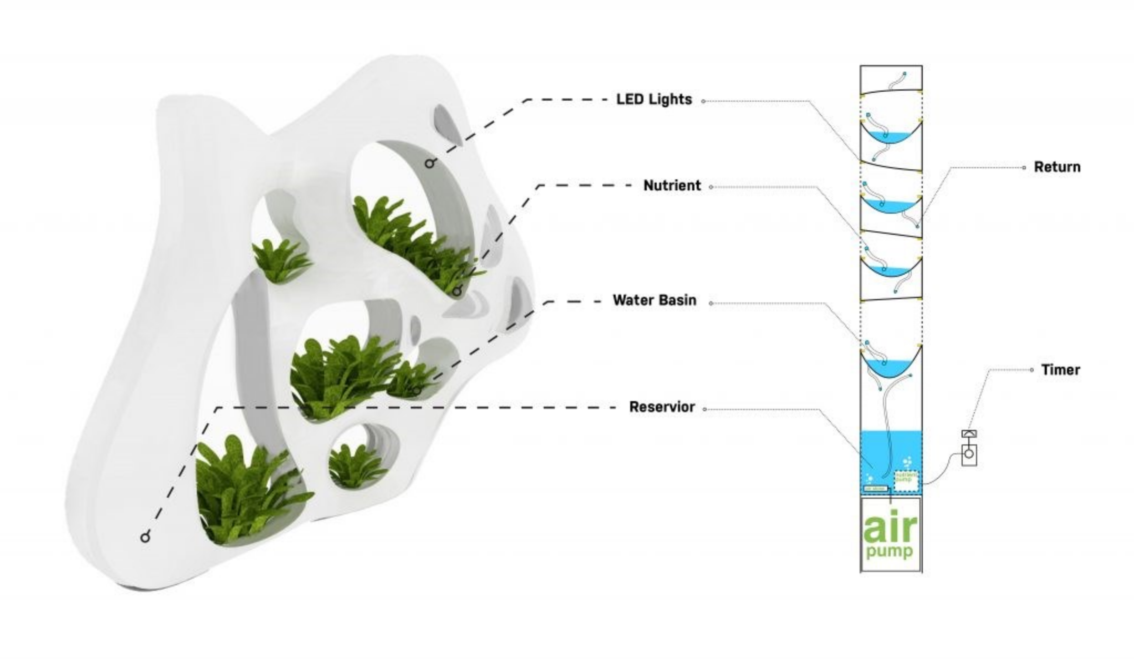


Figure 13 - example of an hydroponic system in the facade source[10]

4. SOIL-LESS SOLUTION

Soilless solutions for facades, such as hydroponic systems or bioreceptive green walls, offer several advantages over traditional systems that use soil.

Here are the main advantages of using this kind of solutions:

- **Less weight:** Soil-free green walls are often lighter, reducing the load on building structures. This is especially beneficial for existing buildings, where additional weight could be a problem.

- **Less maintenance**: Hydroponic and bioreceptive systems require less maintenance than traditional green walls with topsoil. Because there is no topsoil, the need to replace or regenerate the substrate is reduced and the risk of weed growth is minimized.

- **More control:** Hydroponic systems allow greater control over the supply of nutrients and water to plants. This can lead to more efficient growth and less waste of resources.

- **Efficient use of water:** Many soil-less systems, especially those with mosses or microalgae, require less water than systems that use soil. This makes them suitable for arid regions or where water is a scarce resource.

- **Sustainability:** Soil-free green walls can use recycled or low-cost materials for substrate. In addition, they can help purify the air and reduce the urban heat island effect.

- **Ease of installation:** Soil-free systems can be easier to install, especially those that are modular and mobile. This makes them more adaptable to different types of buildings, including prefabricated buildings.

- **Costs:** Implementing indirect green facades with planters range from €310.91/m² to €563.15/m². Systems with moss vary in cost between €210/m² and €590/m².

- **Environmental benefits:** Green facades can sequester carbon dioxide (CO2), with estimates ranging from 13.41 to 97.03 kg CO2eq per year for an area of 98 m². Mosses and algae help thermally insulate buildings and remove pollutants from the environment. Studies have found that the presence of plants can lower the surface temperature of buildings by up to 3.7°C.

In summary, soil-free solutions for facades offer a number of advantages in terms of weight, maintenance, control, water use and sustainability, making them a valid choice over traditional systems in many situations. [11], [12], [13], [14], [15], [16], [17], [18]

4.1. Technological system of Moss

In recent years, the growing focus on environmental sustainability and green architecture has led to an increase in the use of moss in building facades. This innovative solution is part of a broader trend toward the adoption of design strategies aimed at reducing the environmental impact of urban construction, improving the energy efficiency of buildings and creating healthier spaces for citizens. Due to its unique characteristics, moss is a viable alternative to traditional vertical gardens and green facades, offering advantages in terms of maintenance, durability and ecological performance.

The use of moss in building which falls under the umbrella of Nature-Based Solutions, is distinguished by its ability to combine aesthetics, functionality and respect for the environment. Interest in the use of moss in facades stems from its peculiar bio-receptivity and remarkable water retention capacity, characteristics that make it an ideal element for creating “living” facade systems.

Unlike the vascular plants used in conventional green facades, moss is a nonvascular plant that absorbs water and nutrients directly from atmospheric moisture, eliminating the need for complex irrigation systems and significantly reducing maintenance. In addition, its ability to capture atmospheric particulate matter and absorb carbon dioxide helps improve urban air quality, making it a particularly beneficial choice for cities with high levels of pollution.

Facades employing moss, often made with bio-receptive panels, are not just decorative elements, but true active systems that contribute to the well-being of the building and its surroundings. These systems can promote thermal insulation, improve air quality and reduce the environmental impact of buildings, demonstrating how architecture can integrate with nature to create healthier and more sustainable environments. The bio-receptivity of moss, or its ability to adhere and grow on building materials, is a key factor in this context.

Architecturally, the use of moss in facades allows natural elements to be integrated into buildings without adding significant structural loads, due to its light weight compared to traditional soil substrates. This makes it ideal for application on vertical surfaces and for creating modular systems and prefabricated panels that can be easily installed and replaced. In addition, moss has excellent thermal and acoustic insulation properties, contributing to the reduction of energy consumption in buildings and improving living comfort.

A key aspect for the success of these facades is the water retention of the substrate on which moss grows. Increased water retention, in fact, provides plants with constant access to nutrients, accelerating their development. This characteristic, combined with moss's ability to absorb moisture from the air, makes it particularly suitable even for hot, arid climates where water scarcity is often an obstacle to the growth of other forms of vegetation.

The implementation of moss facades is not limited to a simple aesthetic choice but represents a real technological innovation in the field of bio architecture. The most advanced systems integrate sensors for monitoring humidity and temperature, as well as automatic maintenance mechanisms that ensure their durability over time. Thanks to these developments, moss facades are finding more and more applications not only in residential buildings, but also in commercial facilities, offices, and public spaces.

Research in this field focuses not only on identifying the most suitable moss species for façades, but also on the most effective construction materials and techniques to promote their growth and survival. The porosity and roughness of the materials used, for example, are key determinants of water and nutrient retention, directly influencing moss development.

However, despite its many advantages, the use of moss in architecture also presents some challenges, such as the need for favorable environmental conditions for its optimal growth. Factors such as air humidity, exposure to sunlight, and air quality directly affect the ability of moss to thrive in an urban setting. Therefore, careful design and the adoption of innovative technologies is essential to ensure the long-term sustainability of these installations.

In summary, the use of moss in facades represents an innovative and multifunctional solution that:

- Promotes environmental sustainability by integrating nature into the built environment.
- Improves the energy efficiency of buildings through thermal insulation.
- Contributes to urban well-being through air purification and increased greenery.
- Provides low-impact solutions that require reduced maintenance and use of water resources.
- Introduces a new aesthetic value in architecture, creating dynamic and evolving facades.

As new technologies and materials continue to develop, moss facades could become an increasingly common component of tomorrow's buildings, contributing to greener, healthier and more efficient cities. The exploration and implementation of this technology promises to be an important step toward creating cities that are more sustainable, resilient and in harmony with nature.

5. USE OF GREY WATER

One of the most critical parts of a green façades is the water requirement for irrigation which is strictly related to the plant species types and secondly is related with the climatic zone of the site.

In the study of "Green perspectives for Italian buildings façades"[19] was estimated the water consumption making the hypothesis of a similar requirement of a square meter of lawn in Piedmont which is in spring and summer between 1050 and 2000 millimeters of water [20]. It was highlighted in the study that is not always to satisfy the water demand with rainwater, partially because in existing building is not always possible to install a system with a storage tank big enough, partially because rainwater is a variable quite aleatory, which lead to the use of aqueduct water to satisfy the water demand of the green façades.

This lead to conclude that the major challenge remains to satisfy the water requirement since the use of the aqueduct not only is an expensive solution but is a waist of a precious resource.

In Italy especially the aqueduct system is far behind the state of the art.

ISTAT released periodically the data related to the use of water in Italy which state that currently even if the tendency is slightly in reduction "*Italy has reconfirmed, for more than two decades, in first place in the European Union for the amount, in absolute value, of fresh water withdrawn for potable use from surface or groundwater bodies*" [21]

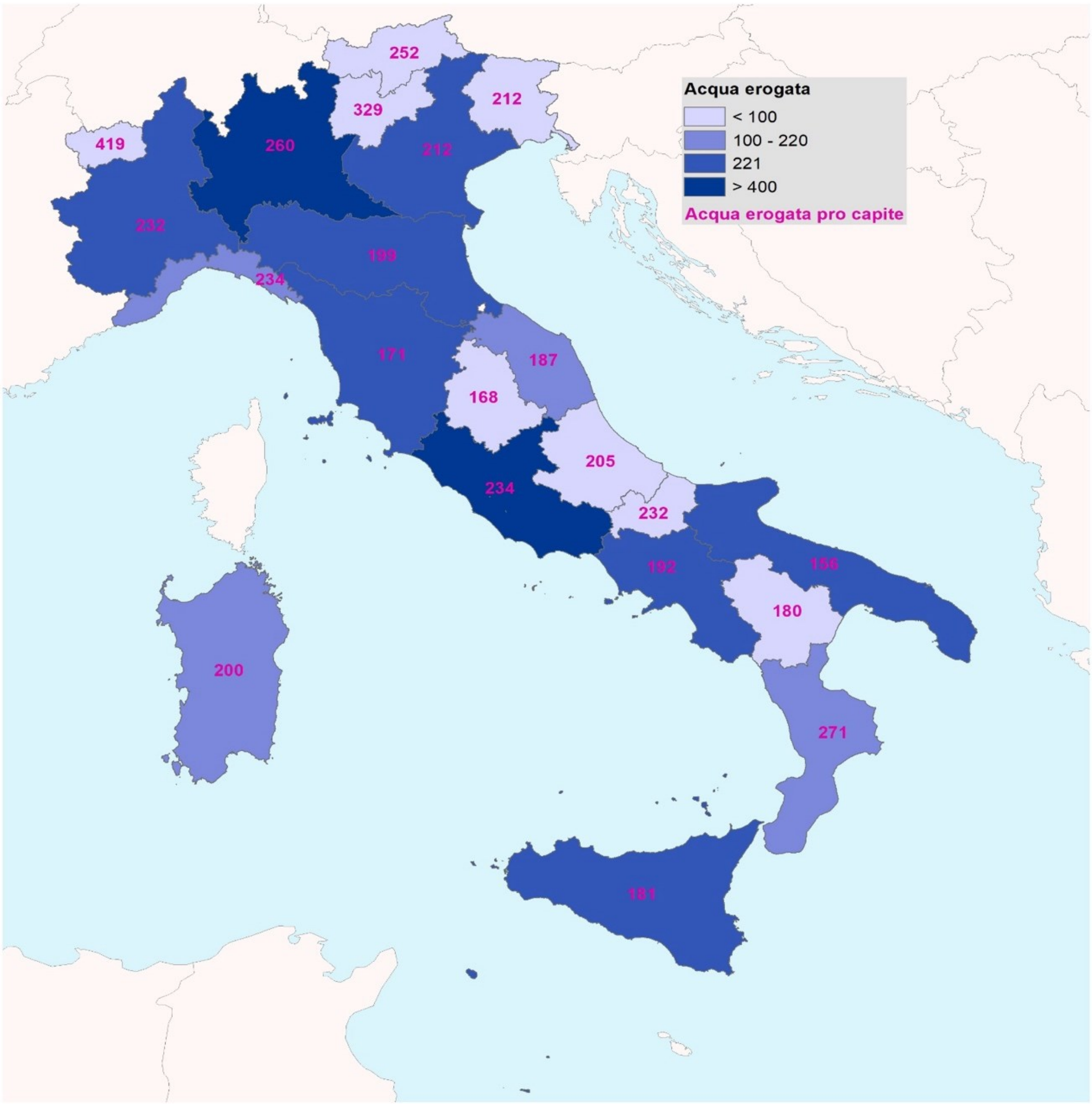


Figure 14 - Water delivered for authorized uses in municipal drinking water distribution networks by region. Year 2022, volumes in millions of cubic meters and per capita in liters per inhabitant per day. Source [21]

This led us to avoid the solution of using aqueduct for irrigation and offer us two different choices:

- Find plant species types that require low amount of water
- Use for irrigation other source: grey water.

5.1. Key points

The use of greywater in green façade systems is specifically studied here in Politecnico di Torino by Elisa Costamagna [22] and published in different articles, it represents an innovative and sustainable strategy for managing water resources and promoting greener urban environments. Greywater, defined as domestic wastewater excluding that from toilets, is particularly suitable for on-site reuse, reducing potable water consumption and relieving pressure on natural water resources.

Here is a detailed overview of greywater use in green façade systems, based on information in sources:

• Definition and characteristics of greywater

Greywater includes water from sinks, showers, washing machines, and dishwashers, excluding toilet flushes. This water accounts for a significant portion of domestic wastewater, about 70% in Europe.

Compared to black water, greywater has a lower concentration of pollutants and is produced in larger volumes. The production of greywater varies seasonally and depends on users' habits.

Greywater can be divided into “light GW” (from sinks and showers) and “dark GW” (from laundries and kitchens), with the former having a lower pollutant load.

• Green façade systems for greywater treatment

Green facades, or green walls, are vertical systems that integrate vegetation and growth substrates, offering a solution for greywater treatment in urban environments with limited space.

Green wall systems mimic the natural processes of artificial wetlands (constructed wetlands) by using a porous medium for plant growth through which greywater flows.

Greywater is supplied to the top of the green wall and percolates vertically through the substrate, feeding the plants and being treated.

Excess water, collected at the base of the system, is purified and reusable for non-potable purposes.

• Types of green façade systems for greywater

Vertical flow systems are among the most proven systems for greywater treatment. In these systems, greywater flows through vertically arranged vessels or panels.

Semi-horizontal flow systems involve water flowing horizontally within the vessels before moving to the lower level.

Modular systems with prefabricated pots or panels are common, and the fill materials used vary from sand to expanded clay, coconut fiber, perlite, and others.

Hydroponic systems use modular containers or panels with water-holding materials, without substrates, and are distinguished by the absence of structural decomposition of the growing material.

• Benefits of using greywater in green façades

Reduced potable water consumption: reuse of greywater for green façade irrigation reduces the need to use potable water for this purpose.

On-site wastewater treatment: green façades provide greywater treatment directly on-site, obviating the need for traditional wastewater treatment systems.

Improved water quality: green façades contribute to greywater purification through processes of filtration, sedimentation, adsorption, microbial degradation, and absorption by plants.

Environmental benefits: green façade systems improve air quality, provide thermal insulation, reduce the urban heat island effect, and promote biodiversity.

Reduced environmental impact: The use of greywater in green façade systems decreases freshwater demand and the environmental impact associated with wastewater treatment.

Sustainability: Green facades contribute to the United Nations Sustainable Development Goals (SDGs), particularly Goal 6 (clean water and sanitation) and Goal 11 (sustainable cities and communities).

• Efficiency and operational considerations

Pollutant removal efficiency varies with system configuration, environmental conditions, and type of filter material.

Green facades can achieve removals of 7-99% for total nitrogen, 25-99% for BOD5, 28-97% for COD, and 32-100% for Escherichia coli.

The choice of plant species is crucial, opting for plants that can withstand high water volumes and low pollutant loads, with appropriate aesthetic value.

The presence of plants promotes the development of microorganisms that contribute to water purification.

Medium- and long-term performance monitoring is essential, considering the possibility of clogging or reduced hydraulic performance.

• Examples and case studies

Several studies have demonstrated the effectiveness of green walls in greywater treatment, with varying but generally high pollutant removal rates.

The “vertECO” system has demonstrated more than 90 percent effectiveness in pollutant removal and produces water suitable for reuse for irrigation and toilet flushing[16].

The choice of plants and fill materials affects the efficiency of the system, and the addition of coconut fiber or sand to expanded clay (LECA) can improve performance.

Studies have shown that some plants, such as Mentha, are more effective in water removal than others.

• Additional considerations

To ensure safety and compliance with quality standards for reuse, additional disinfection treatment may be required for some applications.

The design of a green façade system for greywater treatment must take into account the local microclimate, water flow rate, and available materials.

The choice of fill materials with good water retention, porosity, and roughness is essential for plant growth and water purification.

Irrigation management, including intermittent feeding cycles, is critical to promote aerobic and anaerobic conditions that optimize purification.

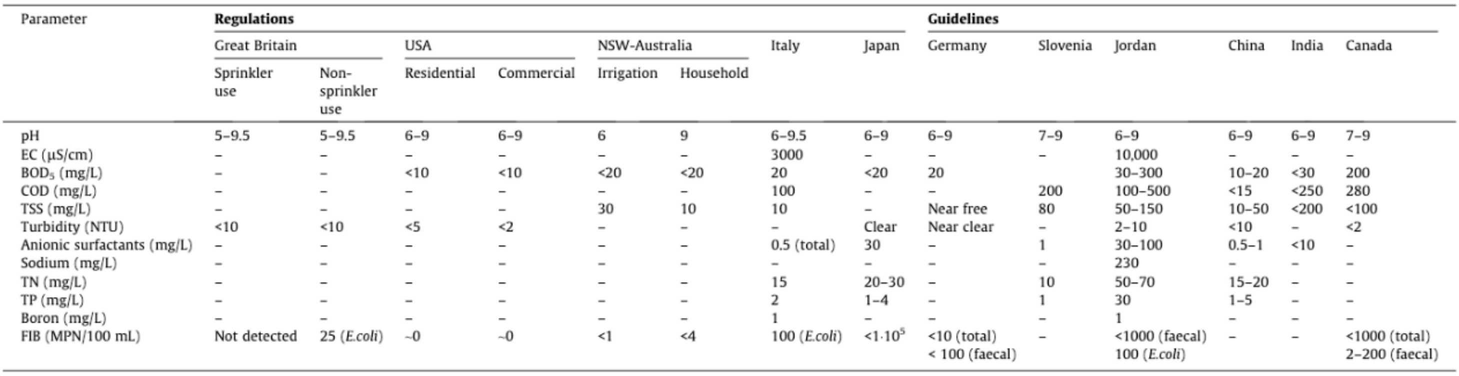
In summary, the use of greywater in green façade systems represents a real opportunity to promote environmental sustainability, reduce potable water consumption, and create healthier and more livable urban environments. Understanding the treatment mechanisms and operational dynamics is critical to the effective design and implementation of these systems.

Regulations

The regulations for grey water reuse have different requirement among different countries. It will not be the focus of this research an evaluation of this regulation.

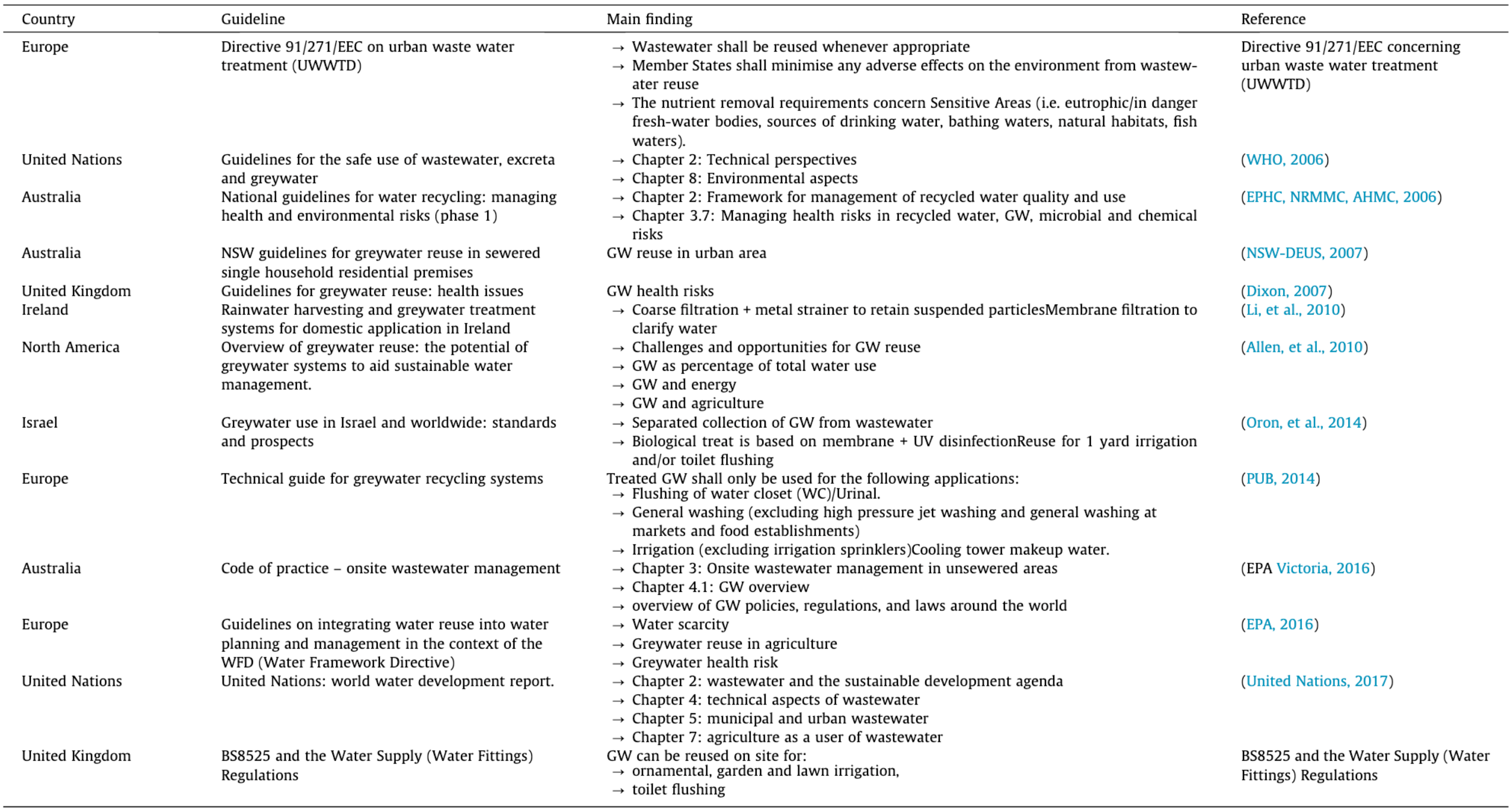
It will be sufficient to say that based on the methodology of the current state of grey water system, they are in line with many countries regulation and guidelines. For some of the most restrictive standards it will be necessary an additional level of treatment to comply with the regulation.

In this study it will be considered satisfied with the regulation the characteristics of treated grey water, thus not considering another level of wastewater purification.



Parameter	**Regulations**								**Guidelines**					
	Great Britain		USA		NSW-Australia		Italy	Japan	Germany	Slovenia	Jordan	China	India	Canada
	Sprinkler use	Non-sprinkler use	Residential	Commercial	Irrigation	Household								
pH	5–9.5	5–9.5	6–9	6–9	6	9	6–9.5	6–9	6–9	7–9	6–9	6–9	6–9	7–9
EC (μS/cm)	–	–	–	–	–	–	3000	–	–	–	10,000	–	–	–
BOD_5 (mg/L)	–	–	<10	<10	<20	<20	20	<20	20		30–300	10–20	<30	200
COD (mg/L)	–	–	–	–	–	–	100	–	–	200	100–500	<15	<250	280
TSS (mg/L)	–	–	–	–	30	10	10	–	Near free	80	50–150	10–50	<200	<100
Turbidity (NTU)	<10	<10	<5	<2	–	–	–	Clear	Near clear	–	2–10	<10	–	<2
Anionic surfactants (mg/L)	–	–	–	–	–	–	0.5 (total)	30	–	1	30–100	0.5–1	<10	–
Sodium (mg/L)	–	–	–	–	–	–	–	–	–	–	230	–	–	–
TN (mg/L)	–	–	–	–	–	–	15	20–30	–	10	50–70	15–20	–	–
TP (mg/L)	–	–	–	–	–	–	2	1–4	–	1	30	1–5	–	–
Boron (mg/L)	–	–	–	–	–	–	1	–	–	–	1	–	–	–
FIB (MPN/100 mL)	Not detected	25 (*E.coli*)	~0	~0	<1	<4	100 (*E.coli*)	$<1\cdot10^5$	<10 (total) < 100 (faecal)	–	<1000 (faecal) 100 (*E.coli*)	–	–	<1000 (total) 2–200 (faecal)

Figure 15 – Overview of regulations and guidelines for GW reuse. source [23]



Country	Guideline	Main finding	Reference
Europe	Directive 91/271/EEC on urban waste water treatment (UWWTD)	→ Wastewater shall be reused whenever appropriate → Member States shall minimise any adverse effects on the environment from wastewater reuse → The nutrient removal requirements concern Sensitive Areas (i.e. eutrophic/in danger fresh-water bodies, sources of drinking water, bathing waters, natural habitats, fish waters).	Directive 91/271/EEC concerning urban waste water treatment (UWWTD)
United Nations	Guidelines for the safe use of wastewater, excreta and greywater	→ Chapter 2: Technical perspectives → Chapter 8: Environmental aspects	(WHO, 2006)
Australia	National guidelines for water recycling: managing health and environmental risks (phase 1)	→ Chapter 2: Framework for management of recycled water quality and use → Chapter 3.7: Managing health risks in recycled water, GW, microbial and chemical risks	(EPHC, NRMMC, AHMC, 2006)
Australia	NSW guidelines for greywater reuse in sewered single household residential premises	GW reuse in urban area	(NSW-DEUS, 2007)
United Kingdom	Guidelines for greywater reuse: health issues	GW health risks	(Dixon, 2007)
Ireland	Rainwater harvesting and greywater treatment systems for domestic application in Ireland	→ Coarse filtration + metal strainer to retain suspended particlesMembrane filtration to clarify water	(Li, et al., 2010)
North America	Overview of greywater reuse: the potential of greywater systems to aid sustainable water management.	→ Challenges and opportunities for GW reuse → GW as percentage of total water use → GW and energy → GW and agriculture	(Allen, et al., 2010)
Israel	Greywater use in Israel and worldwide: standards and prospects	→ Separated collection of GW from wastewater → Biological treat is based on membrane + UV disinfectionReuse for 1 yard irrigation and/or toilet flushing	(Oron, et al., 2014)
Europe	Technical guide for greywater recycling systems	Treated GW shall only be used for the following applications: → Flushing of water closet (WC)/Urinal. → General washing (excluding high pressure jet washing and general washing at markets and food establishments) → Irrigation (excluding irrigation sprinklers)Cooling tower makeup water.	(PUB, 2014)
Australia	Code of practice – onsite wastewater management	→ Chapter 3: Onsite wastewater management in unsewered areas → Chapter 4.1: GW overview → overview of GW policies, regulations, and laws around the world	(EPA Victoria, 2016)
Europe	Guidelines on integrating water reuse into water planning and management in the context of the WFD (Water Framework Directive)	→ Water scarcity → Greywater reuse in agriculture → Greywater health risk	(EPA, 2016)
United Nations	United Nations: world water development report.	→ Chapter 2: wastewater and the sustainable development agenda → Chapter 4: technical aspects of wastewater → Chapter 5: municipal and urban wastewater → Chapter 7: agriculture as a user of wastewater	(United Nations, 2017)
United Kingdom	BS8525 and the Water Supply (Water Fittings) Regulations	GW can be reused on site for: → ornamental, garden and lawn irrigation, → toilet flushing	BS8525 and the Water Supply (Water Fittings) Regulations

Figure 16 – Proposed guidelines and reports for GW reuse (no standards or limits are available). source [23]

6. CASE STUDY

6.1. Project

The project is located in the North part of the metropolitan city of Turin, included between Corso Regio Parco, Piazza Abba, Via Gabriele Rossetti, the Po River and street at the Manifattura Tabacchi; the context, included between the historic Borgata del Regio Parco and the Po River, turns out to be of great urban significance with strong environmental values (Location: 45.08818N 7.71496E).

The EX-Manifattura Tabacchi, is an industrial building that was once an industry of Tobacco but from the mid-fifties the decline of the factory began which first closed some departments and then, in 1996, ceased its activity.

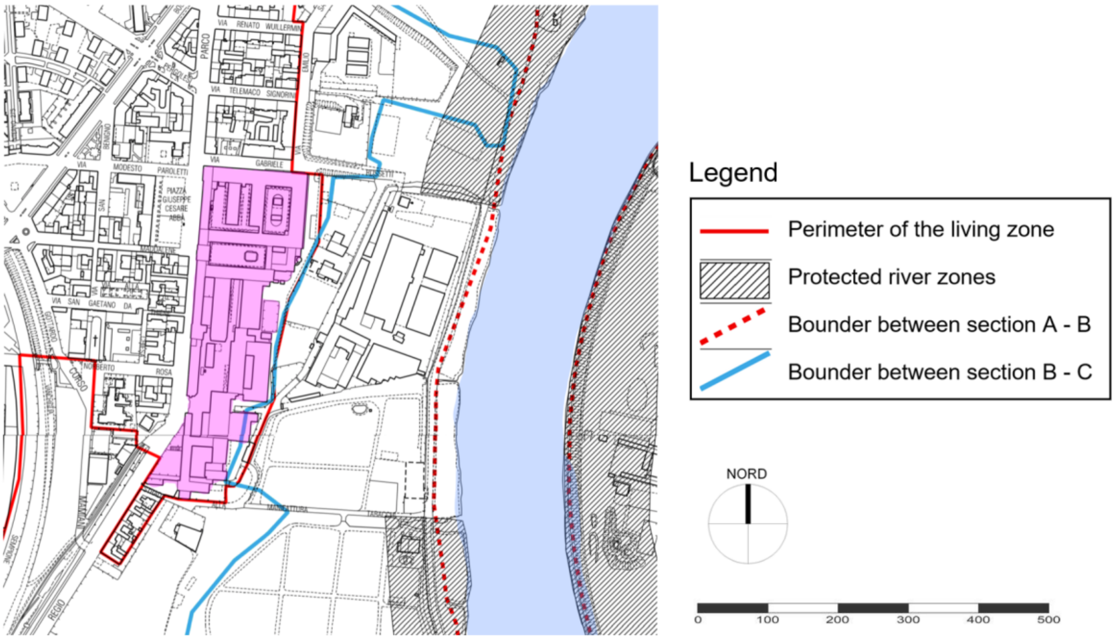


Figure 17 - Extract from PRG of Turin source[24]

The Manifattura tabacchi has a winning project for renovation that will reuse partially the old building and will expand in the green areas behind.

Architectural project managers Eutropia Architecture + Pinifarina Architecture together with Weber Architects and a large group-interdisciplinary

The project will have different branch under the cultural point.

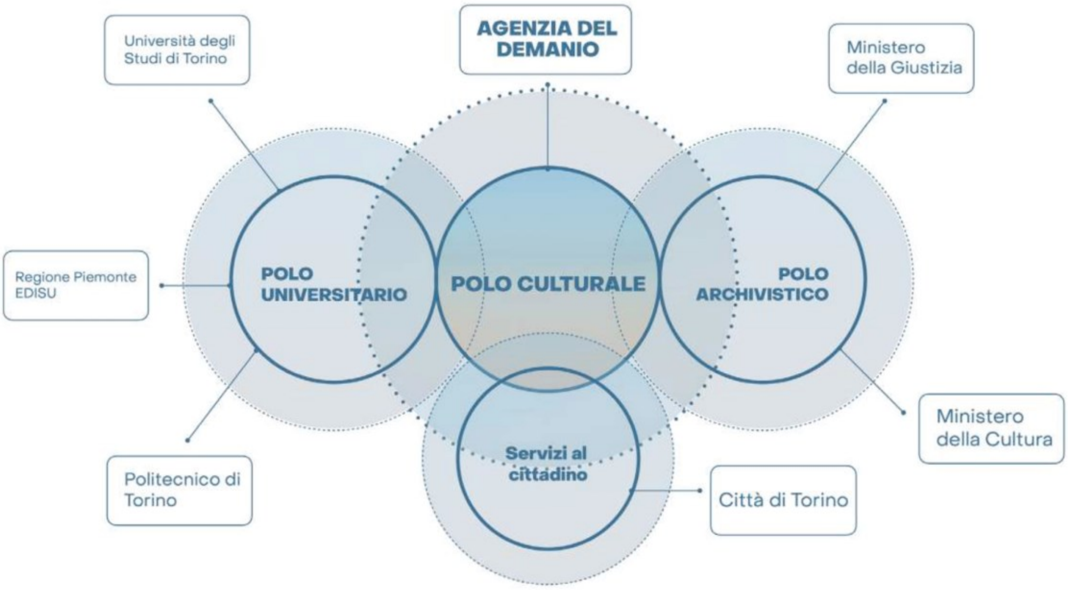


Figure 18 - Schema of the project function source[25]

The project aims to create a bond between culture, history and innovation.

Figure 19 - rendering of the new Manifattura tabacchi source[25]

The portion that is taken in examination is the section constructed by Pier Luigi Nervi after World War II. It's a portion of the building that develops from West to East, having the North facades that face Via Gabriele Rossetti and the south façade (the one in examination) that face an inner courtyard.

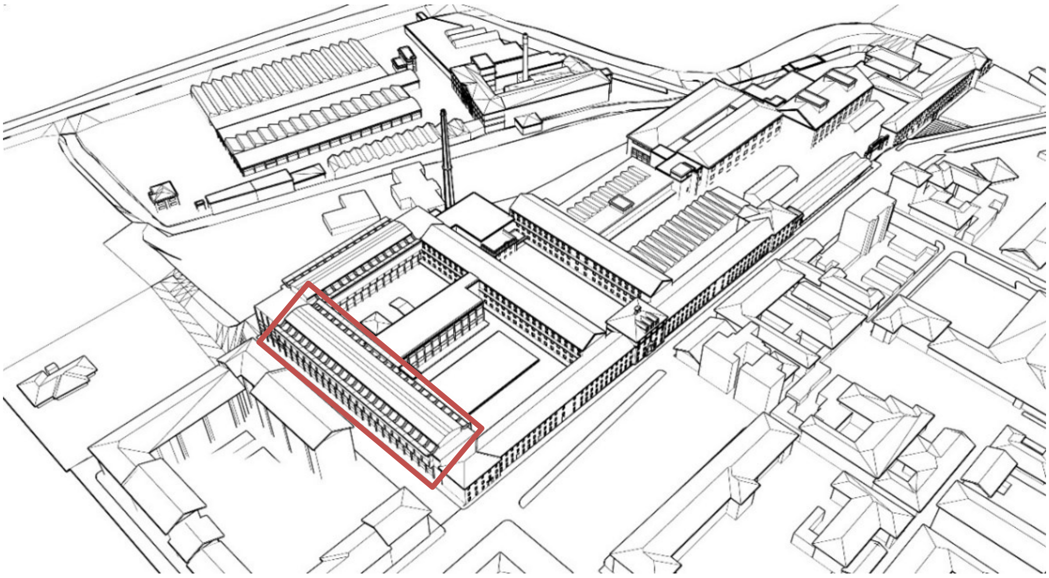


Figure 20 - 3D view of the Manifattura tabacchi with the designated building source [26]

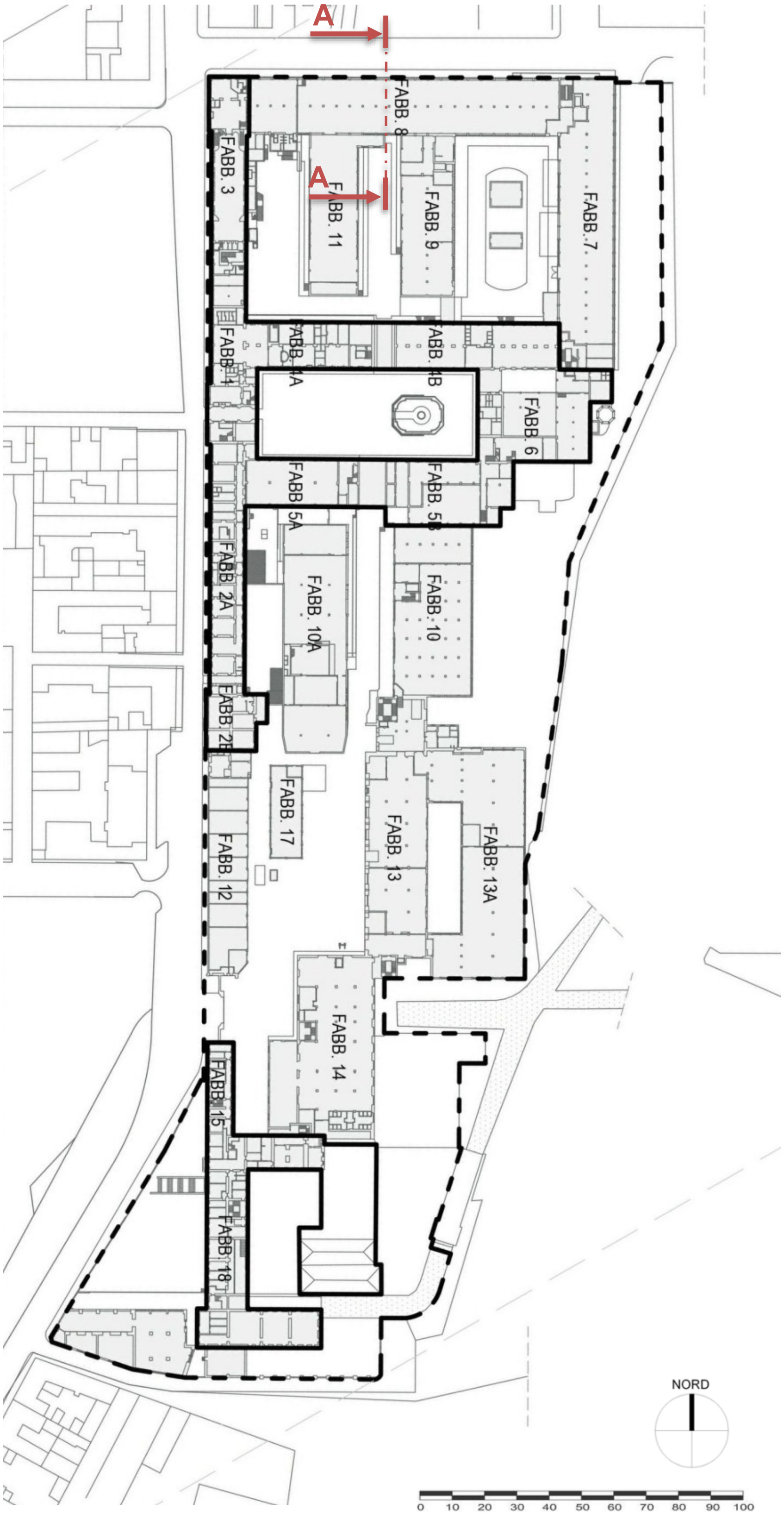


Figure 21 - Planimetric view of the ground floor with the section highlighted

6.2. Green facades

There will be the development of three different solutions for the façade in order to have a comparison of the impact and cost of the solutions.

- Traditional double skin facades
- Green facades with grey water treatment
- Green facades with soil-less solution with moss

In the following picture there will be highlighted the portion of the south facades that will be developed in scale 1:50 and then 1:10 for the detail.

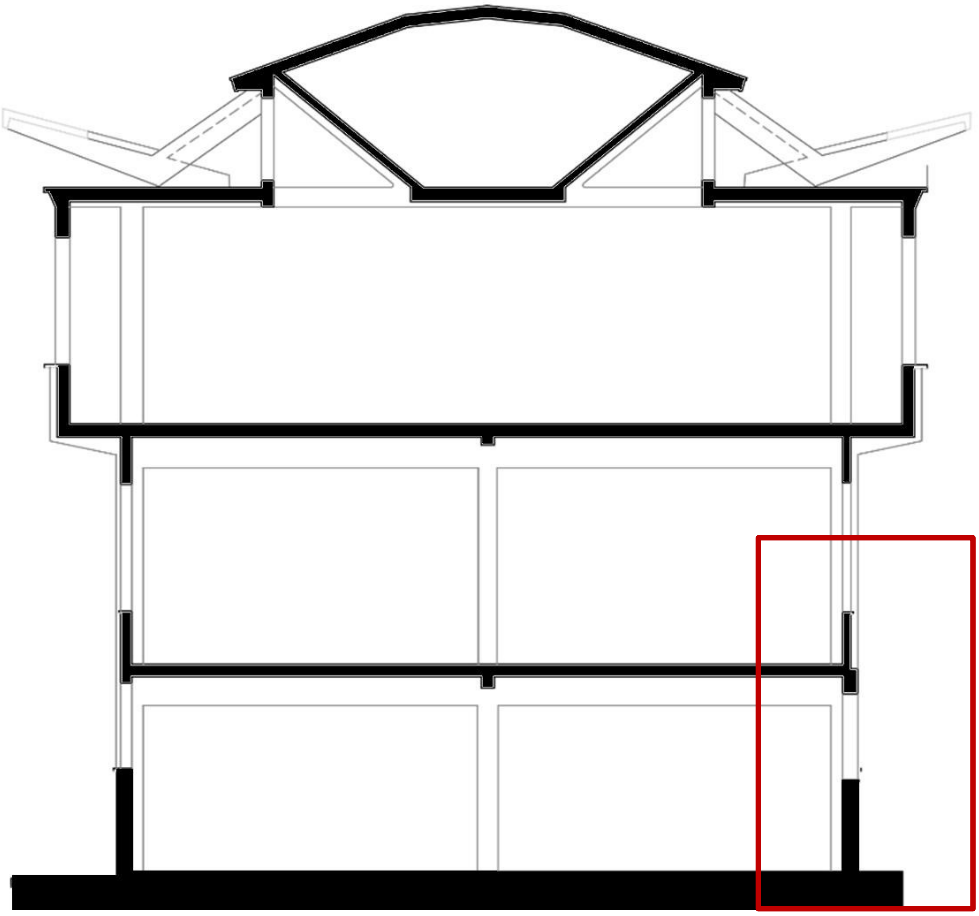
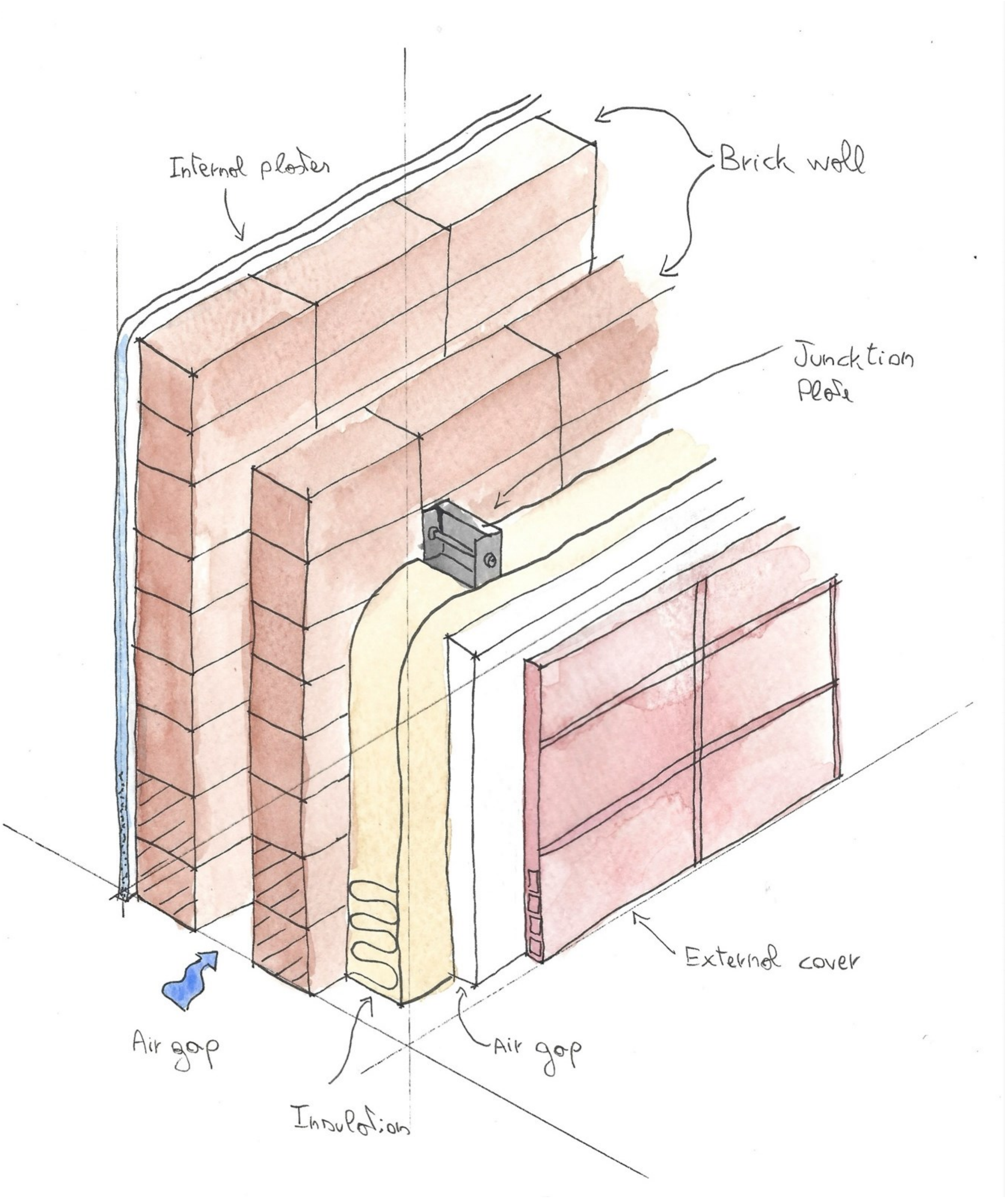
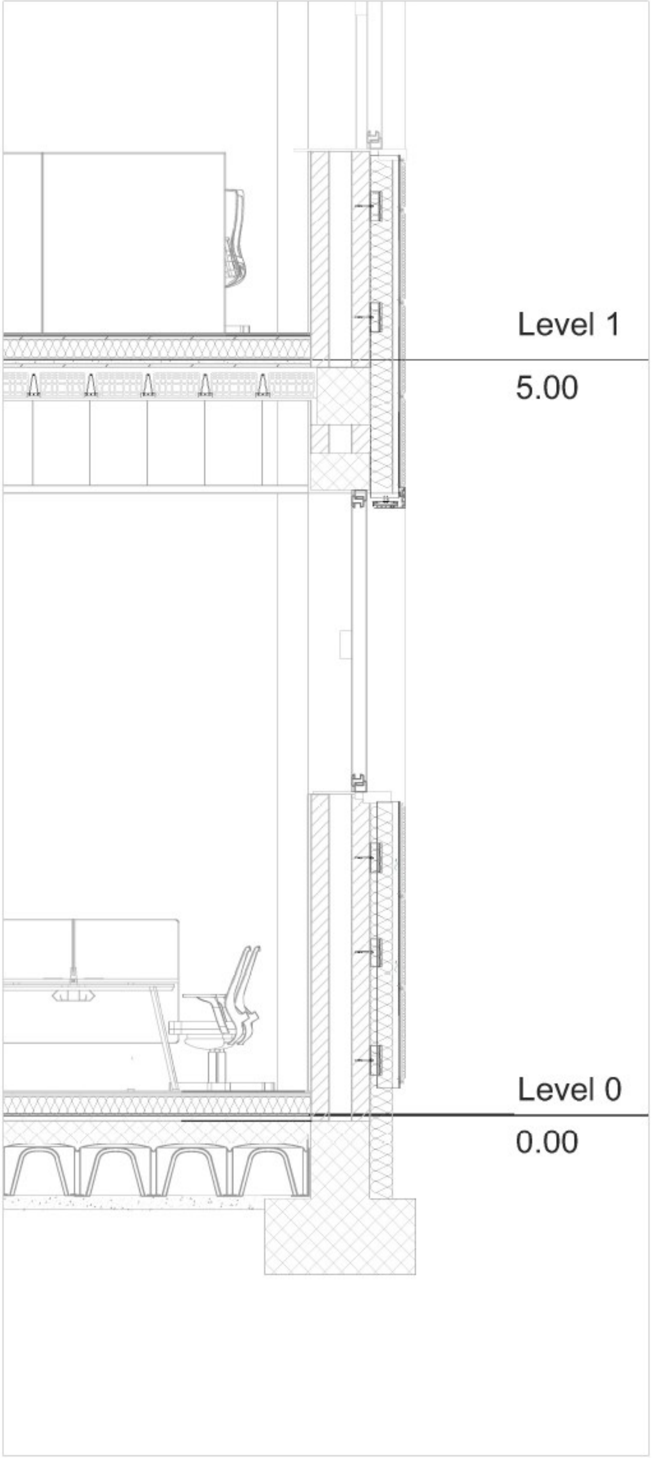


Figure 22 - Section of the building case study (not in scale)

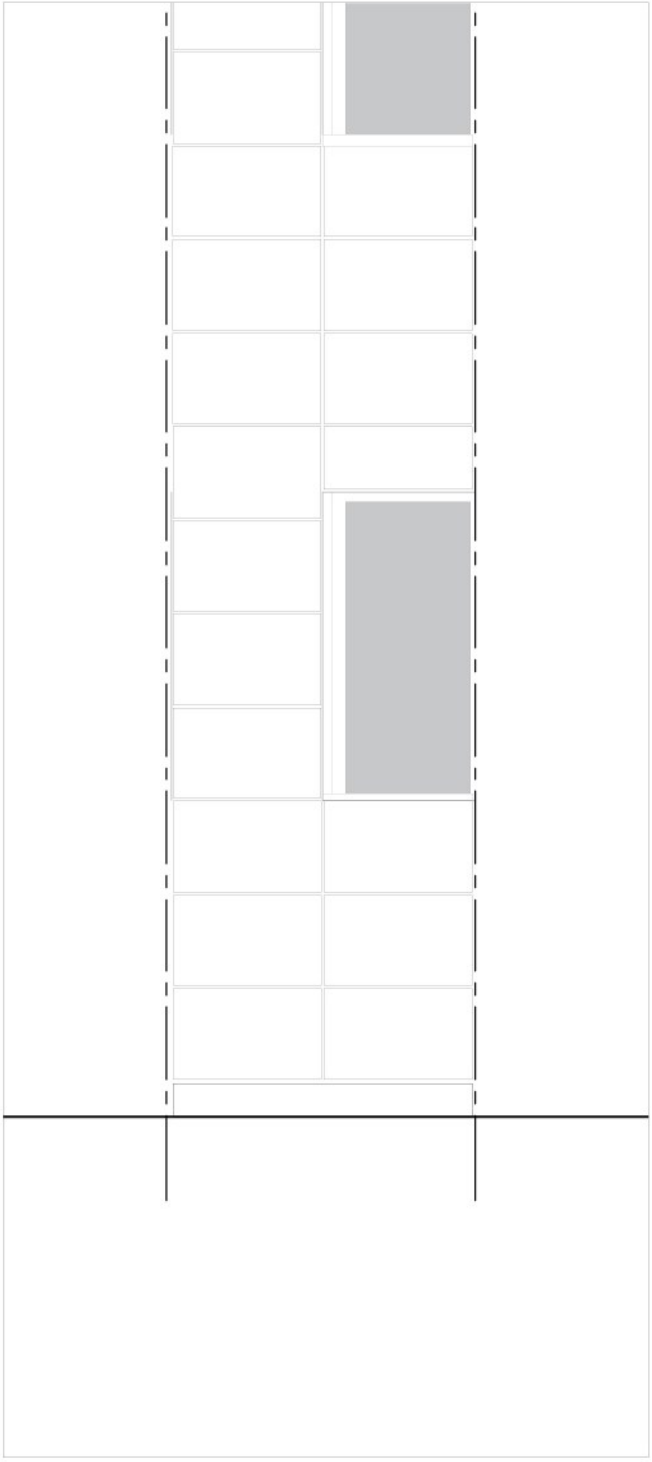
Concept of the double skin façade



Section of the Double skin

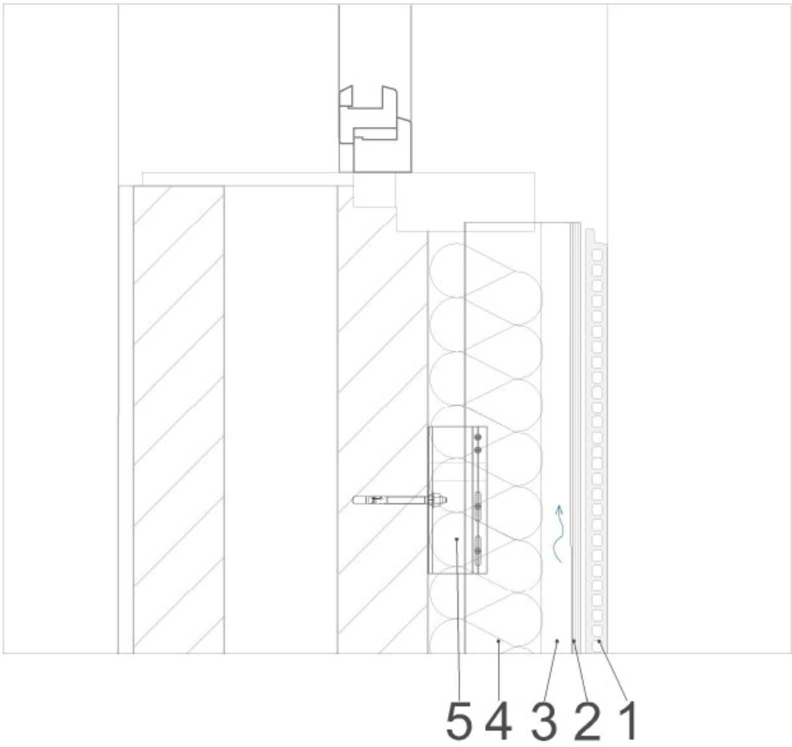


Prospect of the Double skin

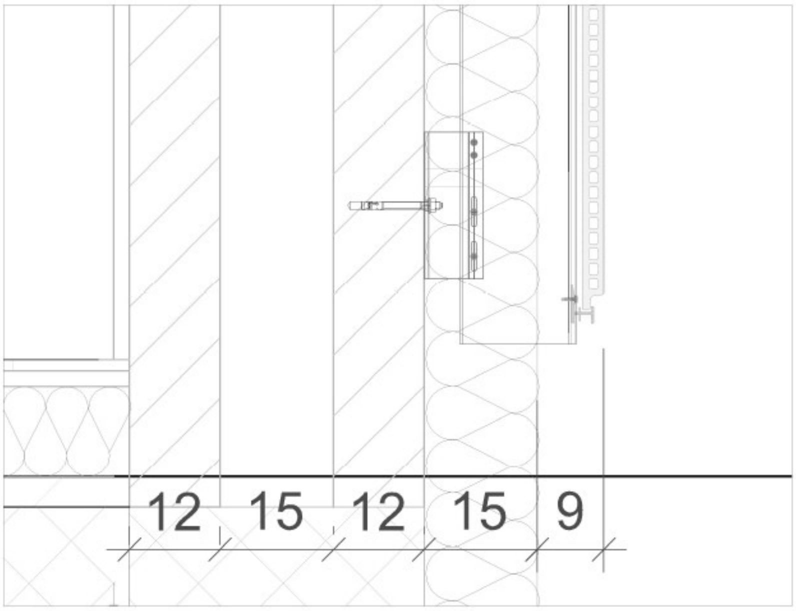


Scala 1:50

Detail of the upper attachment



Detail of the bottom attachment

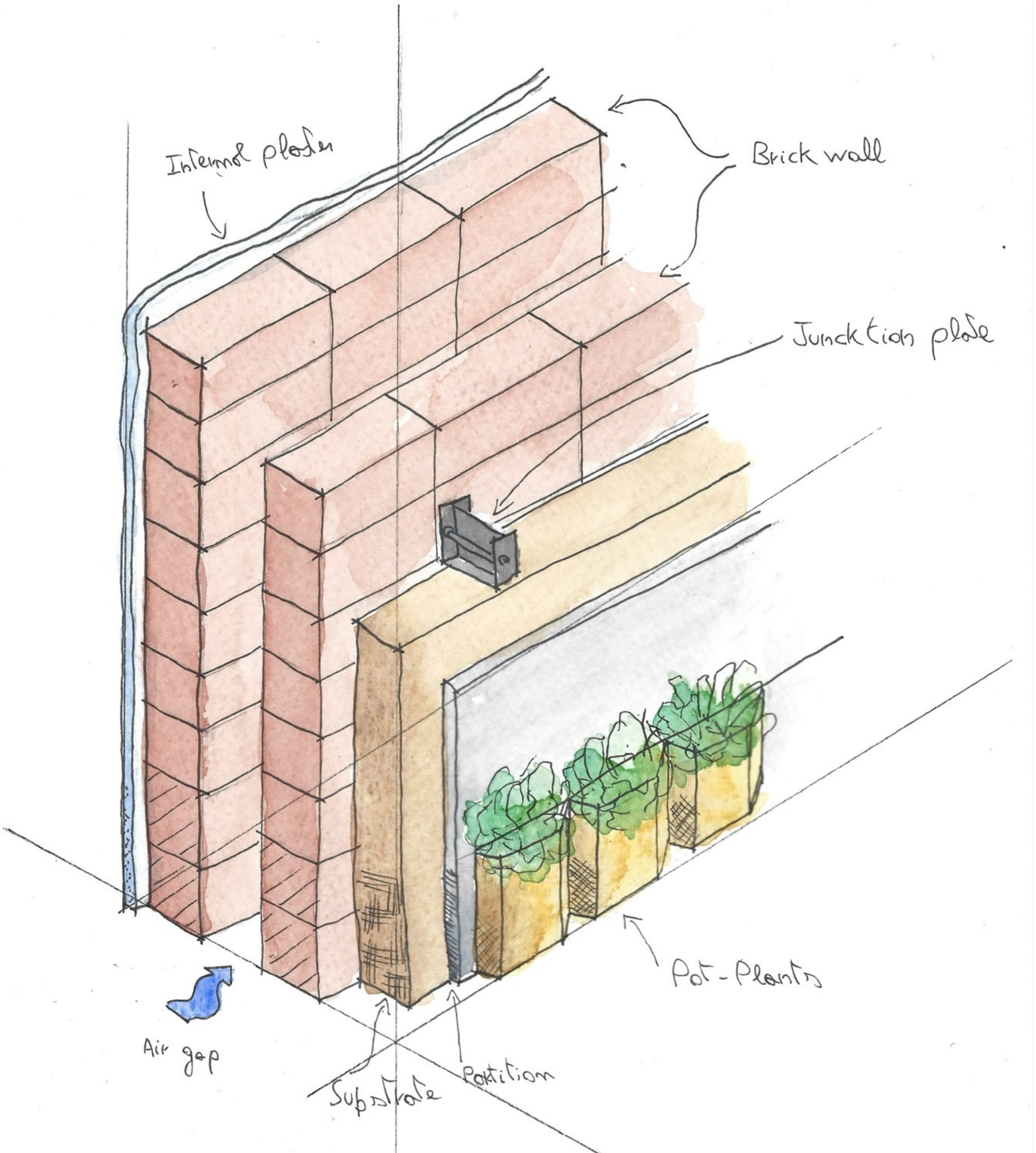


Legend

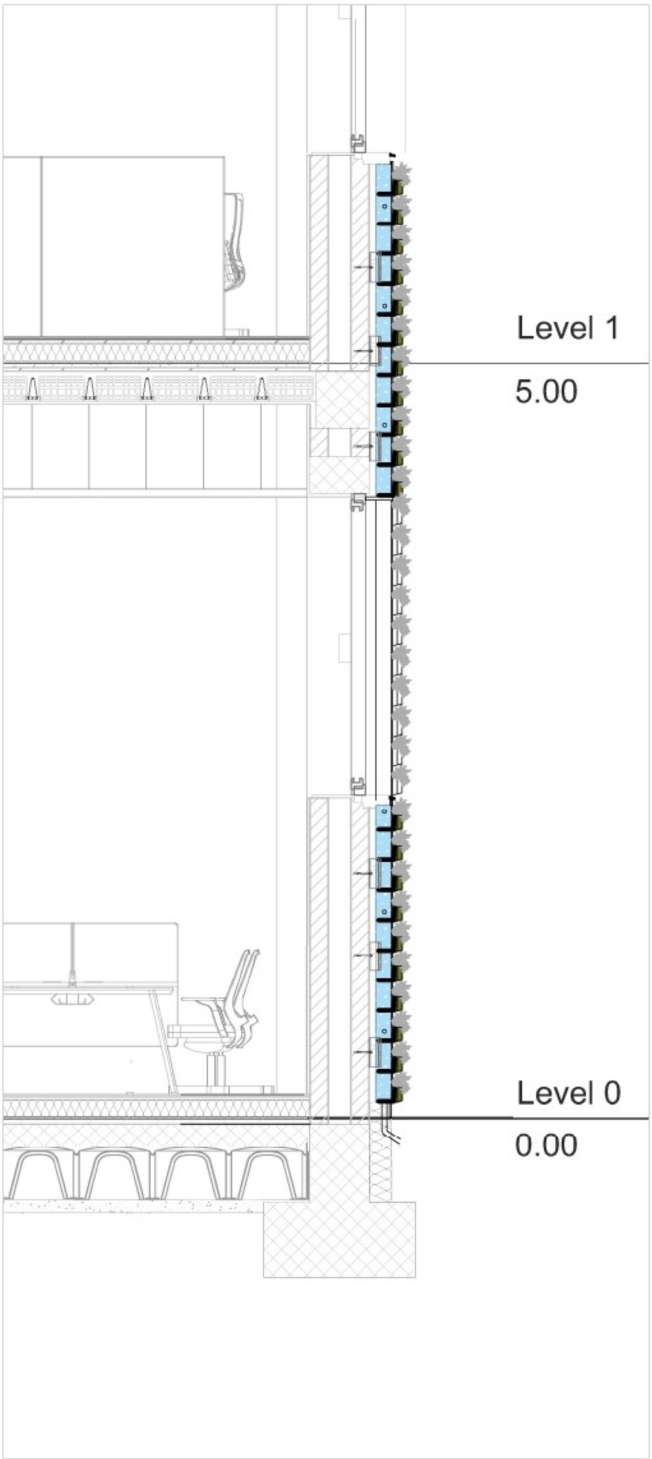
1. External cover
2. Metal stud cladding
3. Air gap
4. EPS insulation
5. Attachement brackets

Scala 1:10

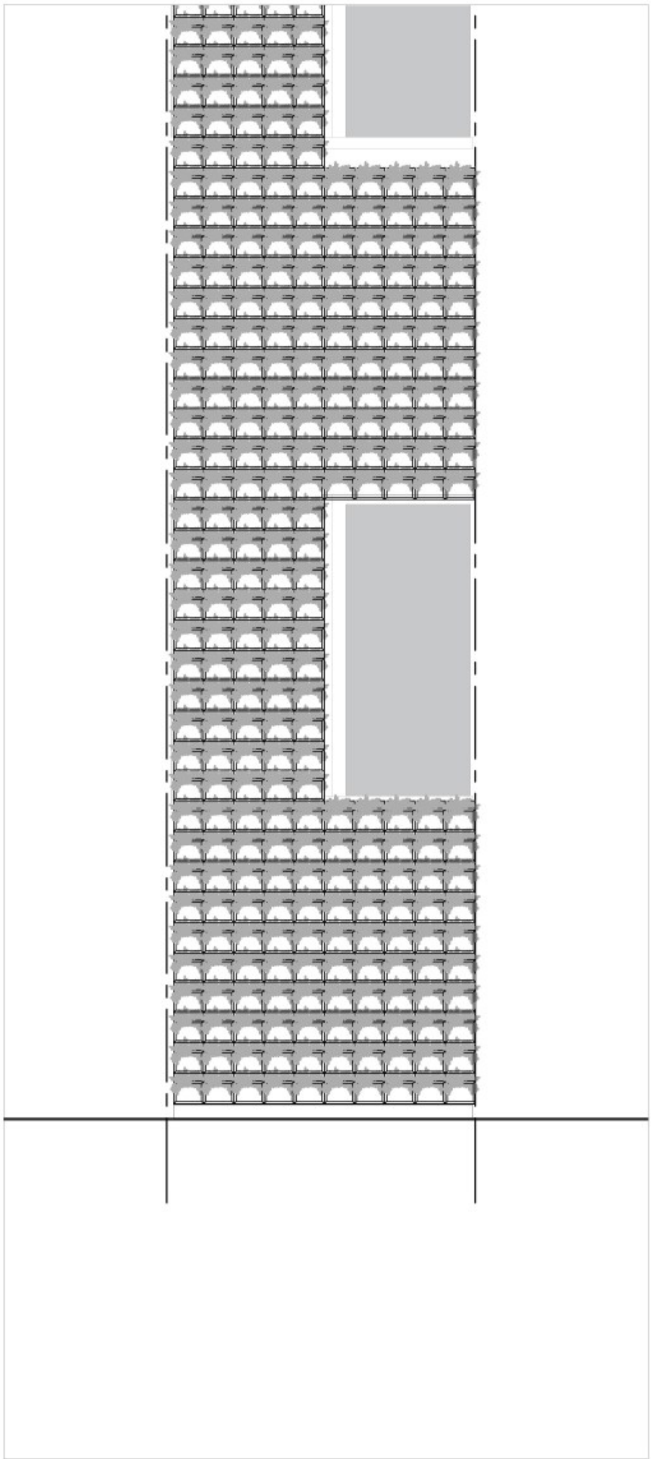
Concept of the double skin façade



Section of the GW facade



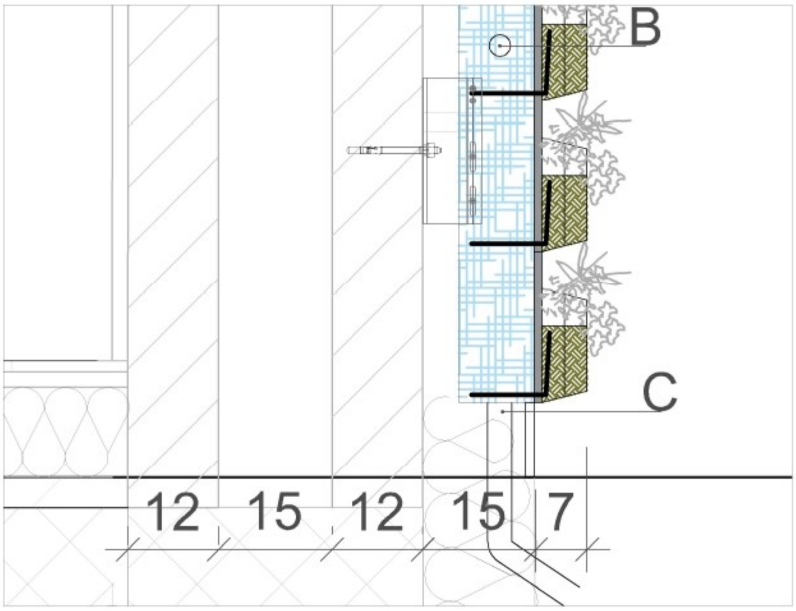
Prospect of the GW facade



Scala 1:50

Detail of the upper attachment

Detail of the bottom attachment



Legend

1. Pot - plants
2. Watertight partition panel
3. Water conduction capillary
4. Filling substrate of cleaning section
5. Attachement brackets

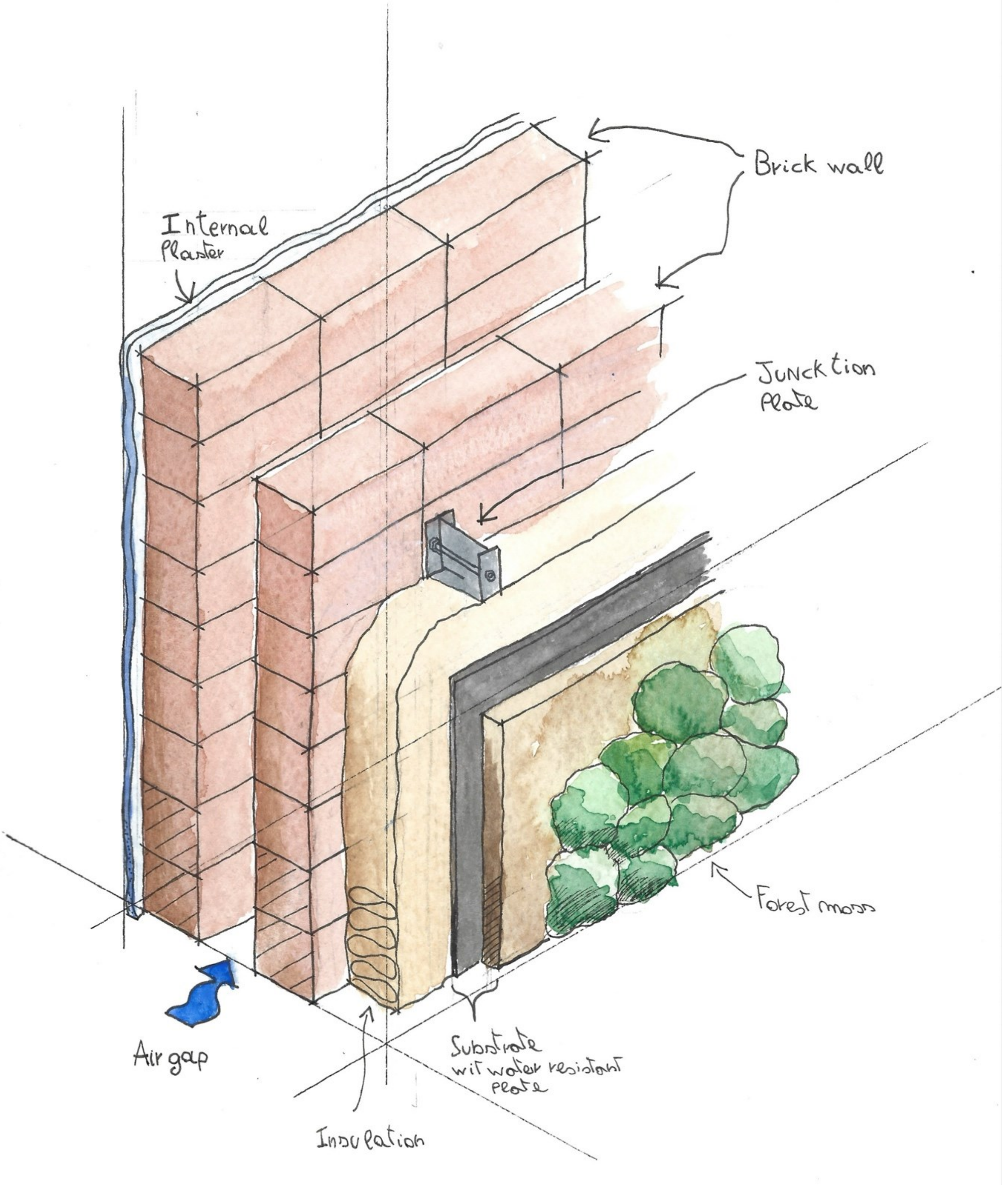
A. Drip edge

B. Horizontal piping

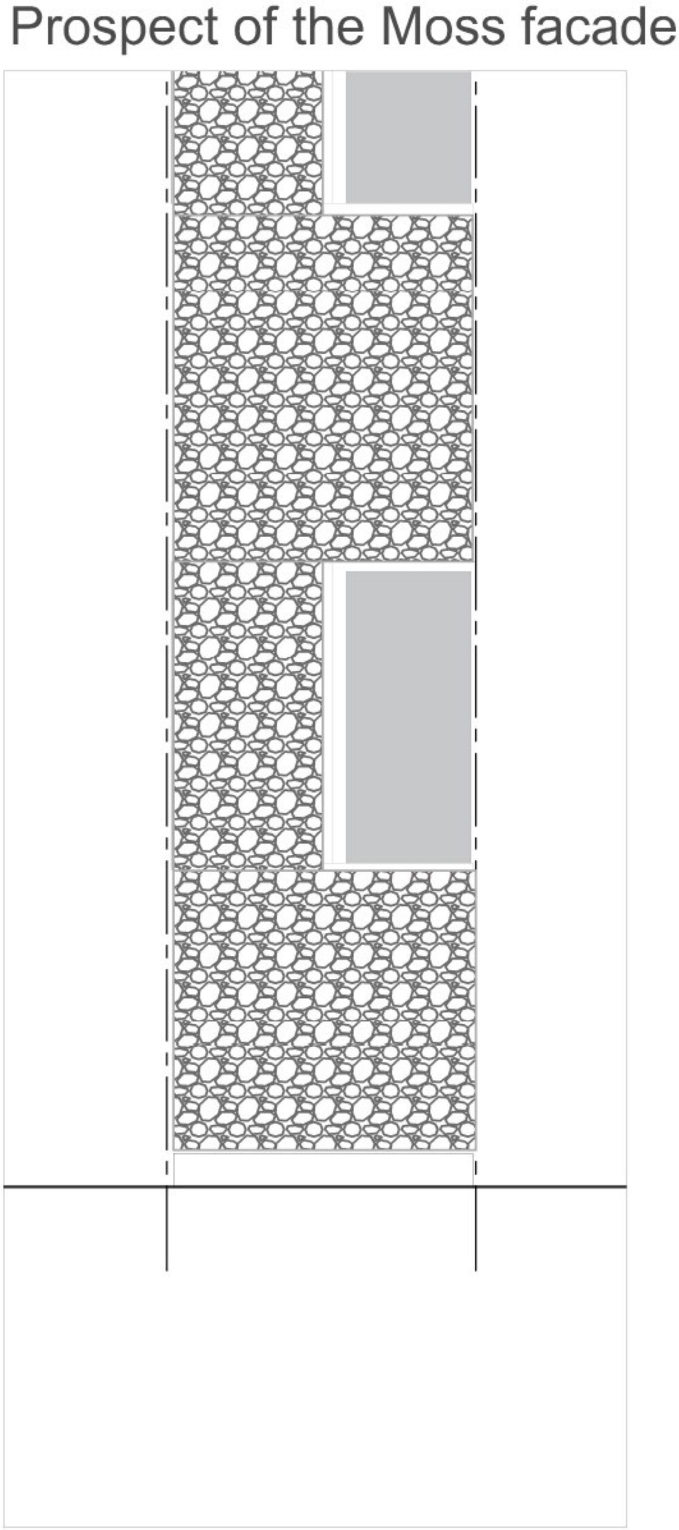
C. Vertical piping

Scala 1:10

Concept of the double skin façade

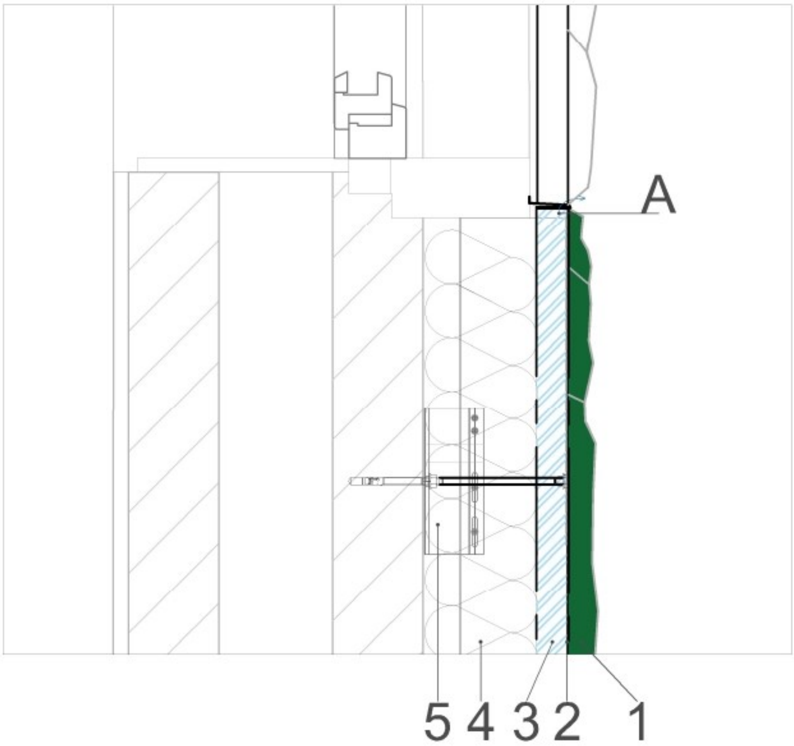



Section of the Moss facade

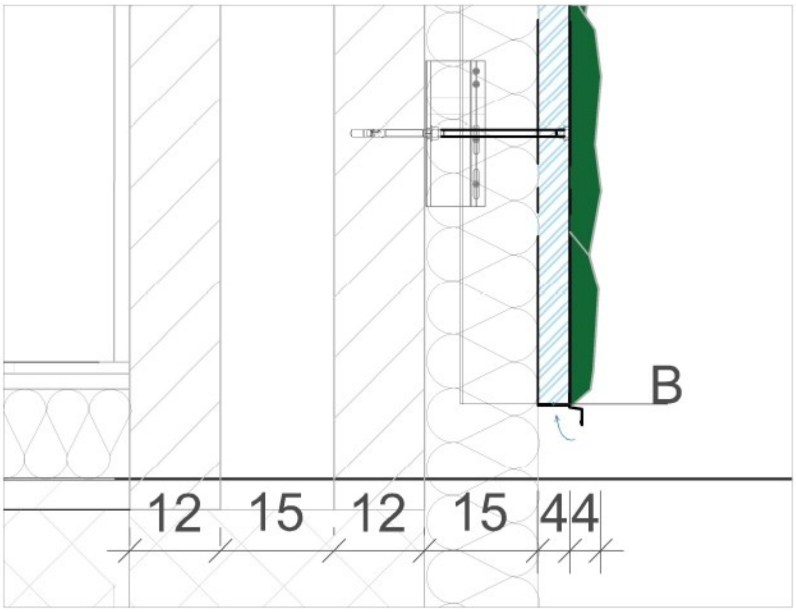

Prospect of the Moss facade

Scala 1:50

Detail of the upper attachment



Detail of the bottom attachment



Legend

1. Forest moss
2. Water-resistent plate
3. Substructure in KVH40
4. Thermal insulation
5. Attachement Brackets

A. Dripping cover

B. Ventilation grill

Scala 1:10

7. Financial analysis

In this paragraph it will be evaluated all the different aspect that practically in economic terms will discriminate one solution to the other.

this evaluation will be done through cost-benefit analysis, which is a methodological approach that aims to systematically assess the cost-effectiveness of a project or decision by examining and comparing all the costs and benefits associated with it over time.

It involves quantifying, if possible, in monetary terms, both the initial expenditures and investments and the future benefits, which may be direct, such as revenues or operational savings, or indirect, such as positive effects on the environment, society, or the local economy.

This method takes into account the fact that money has a different value over time, thus applying discount factors to bring all cash flows to present value. In this way, cost-benefit analysis not only helps determine whether an initiative is cost-effective, but also allows for the comparison of different alternatives, facilitating more informed and transparent decisions.

- ## Input data

- **Relation facades-surface:** Some of the input data is based on the planimetric square meter although we are considering the parameters for one square meter of facades, in order to assess this relation, it is considered a section of the building of 1 meter that as the south facades of 16.4 m2 and a total floor area of 54.6 m2. Dividing the floor area on the surface of the facades is obtained that 1 m2 of façade affect **3.33 m2** of floor area (number which will be multiplied in the calculation).

  It's important to say that for this calculation it is considered a section of the building with the boundaries entirely opaque, so a section of the building without the windows. The calculation is made for a section of the façade with the depth of 1 meter, this could be made of smaller modules that are not multiple of 1 meter, to simplify the calculation it is consider that the façade made out of modules are multiple of 1 meter, thus having no excess or waste cost due to cut out.

- **Cost of heating**: based in Turin, the cost of gas for heating, hot water and cooking is roughly 4141 € for an apartment of 110 m2 with 4-5 people, class G. [27] The case study (in base configuration) follow under the same class G since it has a demand of 141 kW/m2 of heating, assuming that 70% of this price is just for the heating is possible to obtain that the price of heating of a square meter is 26.35€ for one year (26.35 * 3.33 = **88.25€/year**).

- **Cost of cooling**: In order to evaluate the cost of cooling some considerations are needed: for the size of the case study 54.4 m2 is sufficient a cooling power of 12000BTU [28] which corresponds to 1.05 kWh [29] this energy is assumed (since it has a very variable cost) to be 0.15 €/kWh [30]. Considering the use of the cooling only in the hottest period which is July and August for Turin [31] with an usage of 6 hours a day the total cost of cooling for one square meter is: 1.04 €/m2*year (1.04*3.33 = **3.47€**).

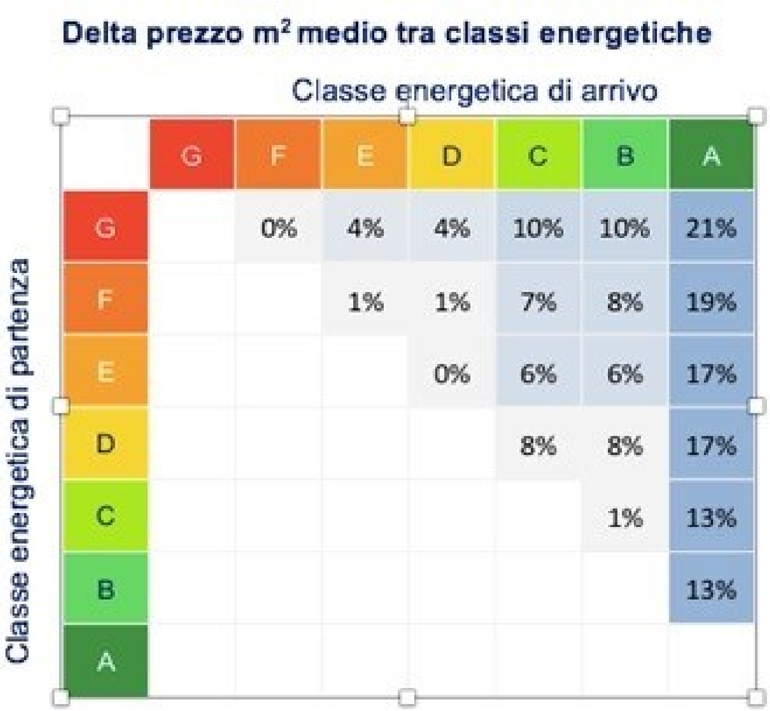
- **Property value rent**: The property value of this building was found with the website "*agenzia delle entrate*", in the year of 2024, selecting the city (Turin), the district (D14/Periferica/CIMITERO MONUMENTALE – BOTTICELLI), and the destinated use (Terziario – uffici). The result obtained indicated a monthly value between 4.2€ and 8.4€ for one square meter. Considering an average of 6.3€/m2*month extending the period for the full year is obtained: 75.6€/m2*year (75.6*3.33 = **251.7€/year**).

- **Property value:** The same procedure can be done to the real value of the property, the website indicated that for the same parameters the price is between 680€ and 1350€ for one square meter, assuming an average of 1015€/m2 (1015*3.33 = **3379.9€**).

- **Water consumption:** It was calculated that for the office use and for the density of the persons the average consumption of domestic water is 0.05m3/m2 assuming that 70% of the total is greywater, the average cost of is 2.62€/m3 the cost for the case study will be 0.09€/m2 (0.09*3.33 = **0.3€)**

- **Lifespan:** The lifespan considered for this kind of system is assumed to be of **50 years**, after this period is possible that regular maintenance is no longer sufficient, but it could be necessary a full refurbishment thus leading to the end of the previous system. In this scenario is present the installation, maintenance and the disposal of the double skin facades.

- **Rent value of building:** A study has been conducted by "*Maiora Solutions*" [33] about the value of the house in Milan related to his energetic class it has been assumed to have the same validity for the city of Turin. With an increase of value for the case study of 15% with a construction of double skin façade – green façade.



Delta prezzo m^2 medio tra classi energetiche

Classe energetica di arrivo

Classe energetica di partenza

	G	F	E	D	C	B	A
G		0%	4%	4%	10%	10%	21%
F			1%	1%	7%	8%	19%
E				0%	6%	6%	17%
D					8%	8%	17%
C						1%	13%
B							13%
A							

Figure 23 - percental raise of the value [33]

Notes for the table:

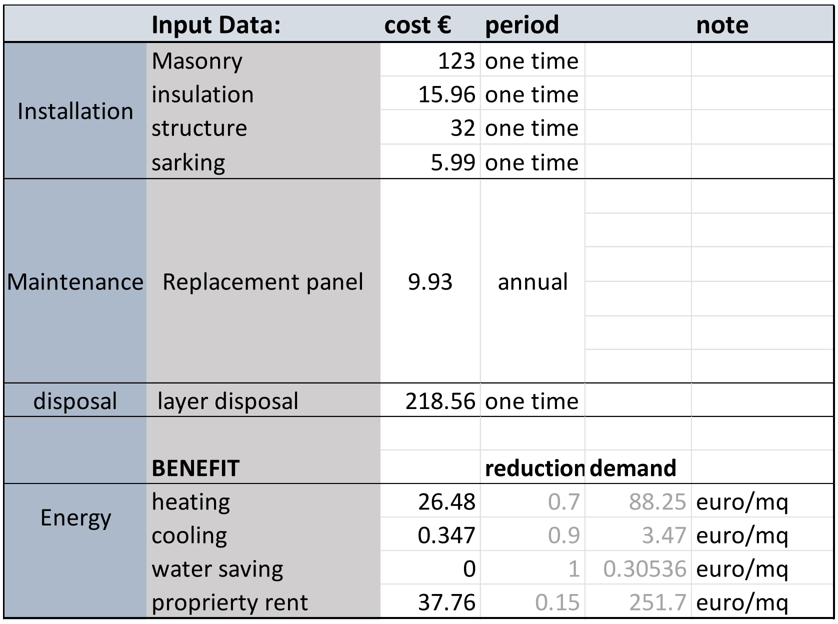
- **Installation cost:** Inside the installation cost it is embedded labor costs and business profit

- **Maintenance:** Inside the maintenance cost it is embedded labor costs and business profit, the maintenance consists of ordinary if needed and extraordinary.

- **Benefit:** the demand column is the cost that the building requires by design the reduction is the factor of improvement form the façade and then the cost is obtained. A saving for heating, cooling and water and an increase in the propriety rent.

Double skin facades

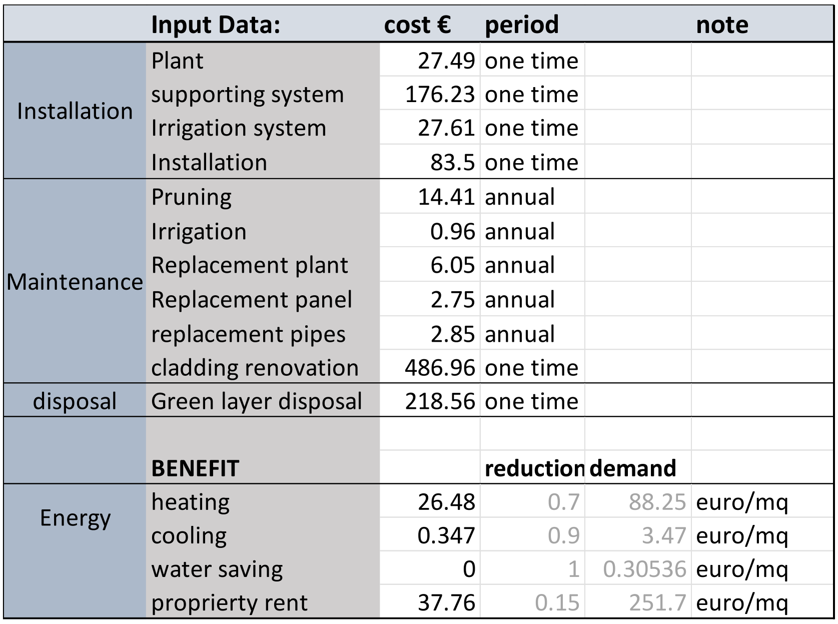
This solution is based on the data collected by “*Cost Implication of Implementing External Facade Systems for Commercial Buildings*”[34] assuming to have the same cost of disposal as the green facades. This data has been chosen because it is the mean value between different prices and has also the data for the maintenance.



	Input Data:	cost €	period		note
Installation	Masonry	123	one time		
	insulation	15.96	one time		
	structure	32	one time		
	sarking	5.99	one time		
Maintenance	Replacement panel	9.93	annual		
disposal	layer disposal	218.56	one time		
	BENEFIT		**reduction**	**demand**	
Energy	heating	26.48	0.7	88.25	euro/mq
	cooling	0.347	0.9	3.47	euro/mq
	water saving	0	1	0.30536	euro/mq
	proprierty rent	37.76	0.15	251.7	euro/mq

Green façade - Traditional

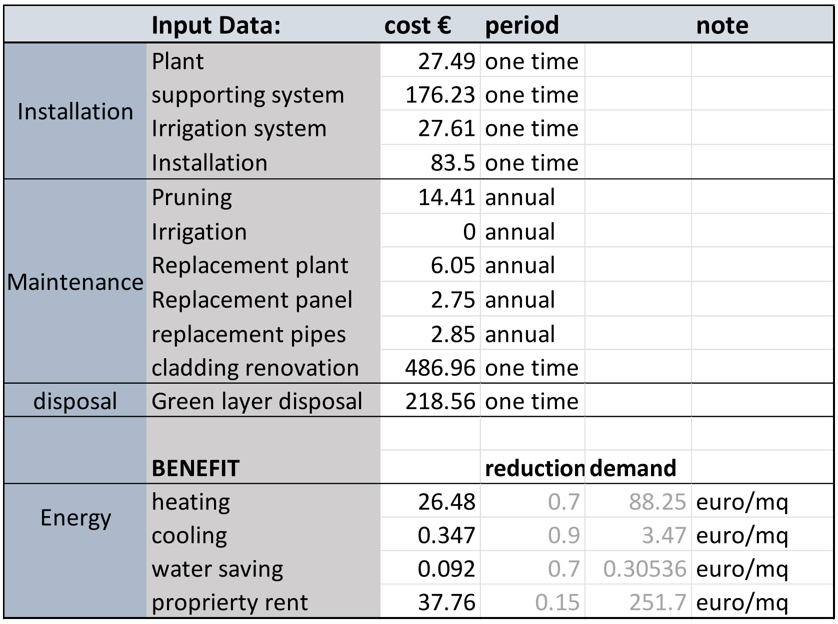
This solution is based on the cost of the installation, maintenance and disposal of a living wall system. [35]



	Input Data:	cost €	period		note
Installation	Plant	27.49	one time		
	supporting system	176.23	one time		
	Irrigation system	27.61	one time		
	Installation	83.5	one time		
Maintenance	Pruning	14.41	annual		
	Irrigation	0.96	annual		
	Replacement plant	6.05	annual		
	Replacement panel	2.75	annual		
	replacement pipes	2.85	annual		
	cladding renovation	486.96	one time		
disposal	Green layer disposal	218.56	one time		
	BENEFIT		**reduction**	**demand**	
Energy	heating	26.48	0.7	88.25	euro/mq
	cooling	0.347	0.9	3.47	euro/mq
	water saving	0	1	0.30536	euro/mq
	proprierty rent	37.76	0.15	251.7	euro/mq

Green façade – Grey water

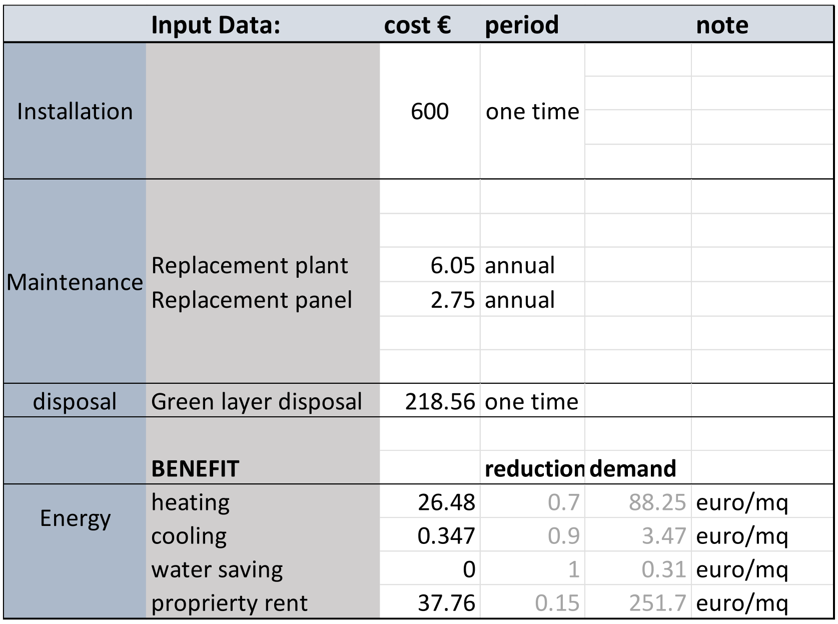
The system is very similar in his core to the previous system, so it has been chosen to evaluate the system keeping the same costs of installation, only the maintenance will change since irrigation is no longer a cost, because instead of using aqueduct water it is used wasted water.



	Input Data:	cost €	period		note
Installation	Plant	27.49	one time		
	supporting system	176.23	one time		
	Irrigation system	27.61	one time		
	Installation	83.5	one time		
Maintenance	Pruning	14.41	annual		
	Irrigation	0	annual		
	Replacement plant	6.05	annual		
	Replacement panel	2.75	annual		
	replacement pipes	2.85	annual		
	cladding renovation	486.96	one time		
disposal	Green layer disposal	218.56	one time		
	BENEFIT		**reduction**	**demand**	
Energy	heating	26.48	0.7	88.25	euro/mq
	cooling	0.347	0.9	3.47	euro/mq
	water saving	0.092	0.7	0.30536	euro/mq
	proprierty rent	37.76	0.15	251.7	euro/mq

Green façade – Moss

The installation data cost is taken by “*Moss manufaktur”[36],* the maintenance it has been evaluated only for replacement items.



	Input Data:	**cost €**	**period**		**note**
Installation		600	one time		
Maintenance	Replacement plant	6.05	annual		
	Replacement panel	2.75	annual		
disposal	Green layer disposal	218.56	one time		
	BENEFIT		**reduction**	**demand**	
Energy	heating	26.48	0.7	88.25	euro/mq
	cooling	0.347	0.9	3.47	euro/mq
	water saving	0	1	0.31	euro/mq
	proprierty rent	37.76	0.15	251.7	euro/mq

7.1. Net present value – NPV

Net Present Value (NPV) is a financial metric used to evaluate the profitability of an investment or project. It is a technique for discounted cash flow (DCF) analysis, which considers the time value of money. The fundamental idea behind NPV is to assess whether an investment will generate a positive or negative return after accounting for the time value of money

Formula:

$$NPV = \sum_{1}^{n} \frac{CF_n}{(1+r)^n}$$

Where:

- CFn is the cash flow for the n year
- r is the interest rate
- n is the number of years

Consideration about the result of NPV:

- If the NPV is positive, it indicates that the investment is expected to generate a profit, and the project is potentially worthwhile.
- If the NPV is negative, it suggests that the investment may not be a good idea, as it is expected to result in a loss.
- A higher positive NPV is generally preferred, as it implies a more significant potential for profitability.

Notes for the table:

- Since it is not exactly a cost benefit analysis the interest rate cannot be place equal to 4% (the one given by the European regulation [32]) this is a financial analysis so the interest rate has been chosen equal to a btp of comparable duration in years [37] of **2.15%**

- In the table below there is a column (period) that represent the number of years of the project, an inflow of the money saved or gained, an outflow of the costs of installation and then maintenance. The difference between the two column is the cashflow and from this the nvp is calculated.

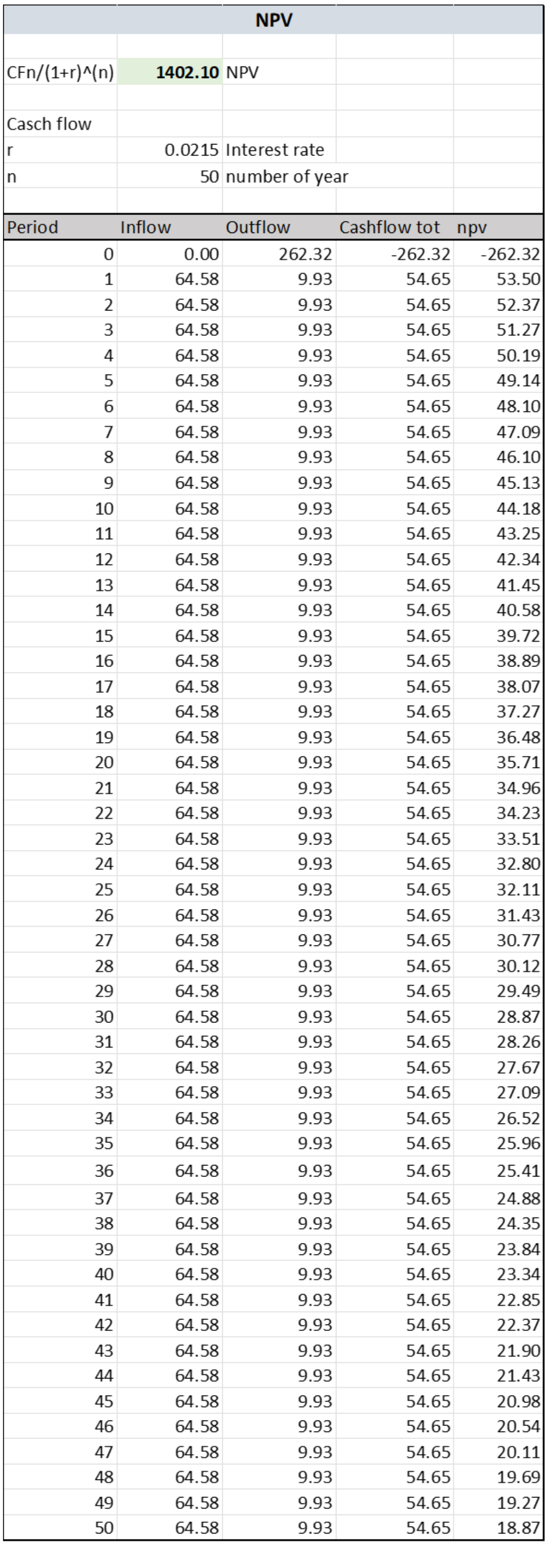
- It's essential to notice that the costs related to extraordinary maintenance and disposal has been embedded in the beginning in order to have first all the negative value than the positive one (otherwise the calculation is not operated correctly). It has been done actualizing the price of the expense to the date selected using the formula of the compound interest because the period is longer than a year.

$$K = \frac{M}{(1+i)^t} = M(1+i)^{-t}$$

Where:

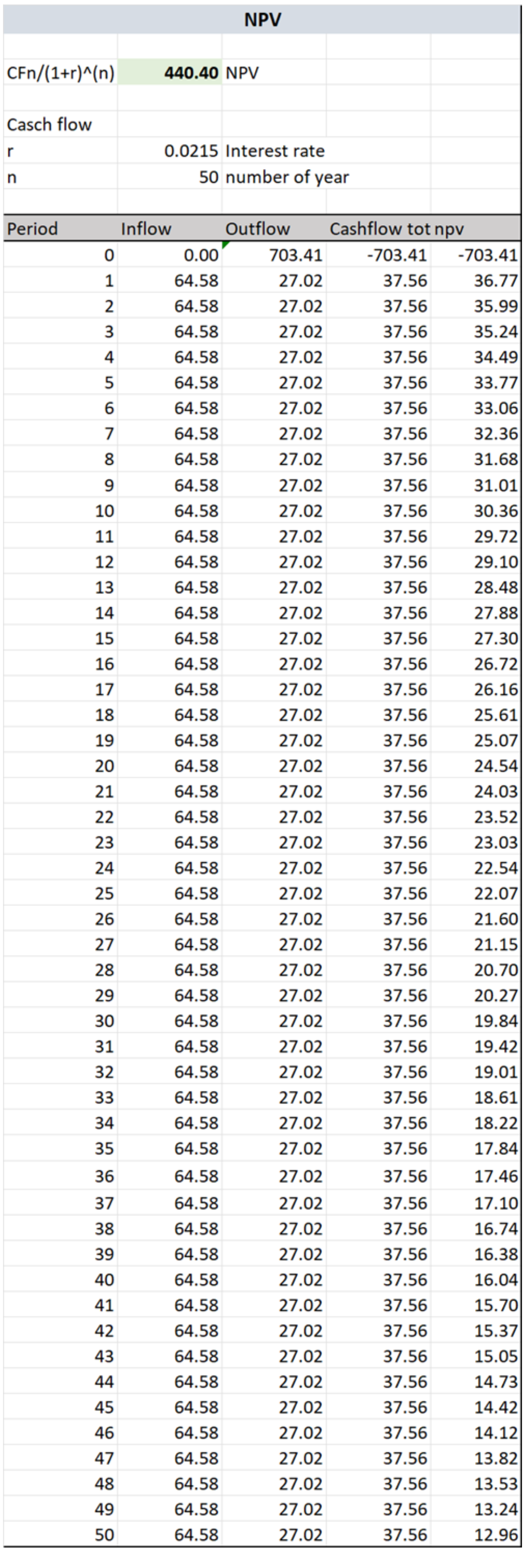
- K is the cost actualized
- M is the real cost
- i is the interest
- t is the number of years

Double skin facades



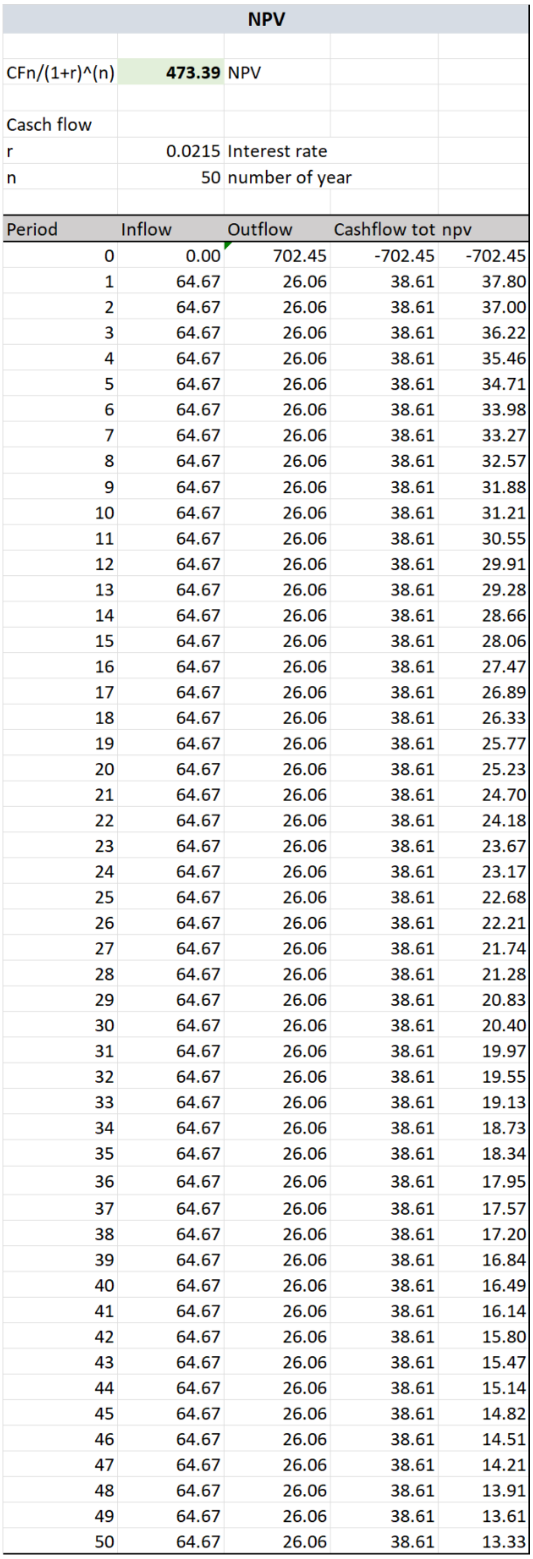
		NPV		
CFn/(1+r)^(n)	1402.10	NPV		
Casch flow				
r	0.0215	Interest rate		
n	50	number of year		
Period	Inflow	Outflow	Cashflow tot	npv
0	0.00	262.32	-262.32	-262.32
1	64.58	9.93	54.65	53.50
2	64.58	9.93	54.65	52.37
3	64.58	9.93	54.65	51.27
4	64.58	9.93	54.65	50.19
5	64.58	9.93	54.65	49.14
6	64.58	9.93	54.65	48.10
7	64.58	9.93	54.65	47.09
8	64.58	9.93	54.65	46.10
9	64.58	9.93	54.65	45.13
10	64.58	9.93	54.65	44.18
11	64.58	9.93	54.65	43.25
12	64.58	9.93	54.65	42.34
13	64.58	9.93	54.65	41.45
14	64.58	9.93	54.65	40.58
15	64.58	9.93	54.65	39.72
16	64.58	9.93	54.65	38.89
17	64.58	9.93	54.65	38.07
18	64.58	9.93	54.65	37.27
19	64.58	9.93	54.65	36.48
20	64.58	9.93	54.65	35.71
21	64.58	9.93	54.65	34.96
22	64.58	9.93	54.65	34.23
23	64.58	9.93	54.65	33.51
24	64.58	9.93	54.65	32.80
25	64.58	9.93	54.65	32.11
26	64.58	9.93	54.65	31.43
27	64.58	9.93	54.65	30.77
28	64.58	9.93	54.65	30.12
29	64.58	9.93	54.65	29.49
30	64.58	9.93	54.65	28.87
31	64.58	9.93	54.65	28.26
32	64.58	9.93	54.65	27.67
33	64.58	9.93	54.65	27.09
34	64.58	9.93	54.65	26.52
35	64.58	9.93	54.65	25.96
36	64.58	9.93	54.65	25.41
37	64.58	9.93	54.65	24.88
38	64.58	9.93	54.65	24.35
39	64.58	9.93	54.65	23.84
40	64.58	9.93	54.65	23.34
41	64.58	9.93	54.65	22.85
42	64.58	9.93	54.65	22.37
43	64.58	9.93	54.65	21.90
44	64.58	9.93	54.65	21.43
45	64.58	9.93	54.65	20.98
46	64.58	9.93	54.65	20.54
47	64.58	9.93	54.65	20.11
48	64.58	9.93	54.65	19.69
49	64.58	9.93	54.65	19.27
50	64.58	9.93	54.65	18.87

Green façade – Traditional



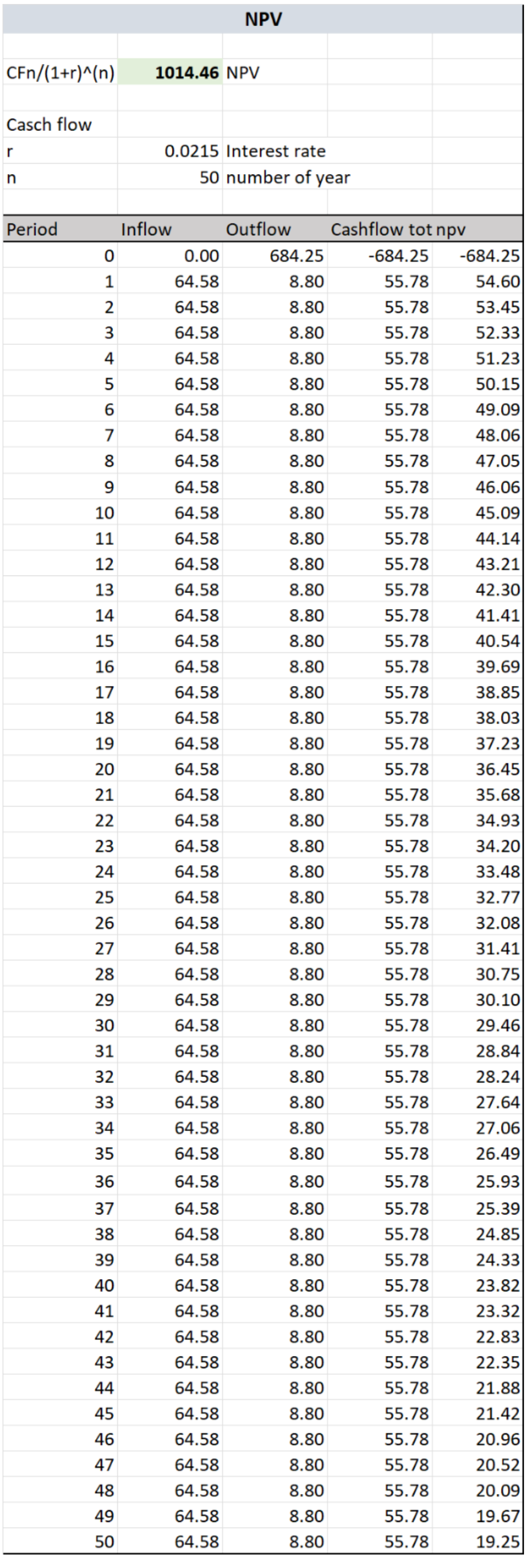
		NPV		
CFn/(1+r)^(n)	440.40	NPV		
Casch flow				
r	0.0215	Interest rate		
n	50	number of year		
Period	Inflow	Outflow	Cashflow tot	npv
0	0.00	703.41	-703.41	-703.41
1	64.58	27.02	37.56	36.77
2	64.58	27.02	37.56	35.99
3	64.58	27.02	37.56	35.24
4	64.58	27.02	37.56	34.49
5	64.58	27.02	37.56	33.77
6	64.58	27.02	37.56	33.06
7	64.58	27.02	37.56	32.36
8	64.58	27.02	37.56	31.68
9	64.58	27.02	37.56	31.01
10	64.58	27.02	37.56	30.36
11	64.58	27.02	37.56	29.72
12	64.58	27.02	37.56	29.10
13	64.58	27.02	37.56	28.48
14	64.58	27.02	37.56	27.88
15	64.58	27.02	37.56	27.30
16	64.58	27.02	37.56	26.72
17	64.58	27.02	37.56	26.16
18	64.58	27.02	37.56	25.61
19	64.58	27.02	37.56	25.07
20	64.58	27.02	37.56	24.54
21	64.58	27.02	37.56	24.03
22	64.58	27.02	37.56	23.52
23	64.58	27.02	37.56	23.03
24	64.58	27.02	37.56	22.54
25	64.58	27.02	37.56	22.07
26	64.58	27.02	37.56	21.60
27	64.58	27.02	37.56	21.15
28	64.58	27.02	37.56	20.70
29	64.58	27.02	37.56	20.27
30	64.58	27.02	37.56	19.84
31	64.58	27.02	37.56	19.42
32	64.58	27.02	37.56	19.01
33	64.58	27.02	37.56	18.61
34	64.58	27.02	37.56	18.22
35	64.58	27.02	37.56	17.84
36	64.58	27.02	37.56	17.46
37	64.58	27.02	37.56	17.10
38	64.58	27.02	37.56	16.74
39	64.58	27.02	37.56	16.38
40	64.58	27.02	37.56	16.04
41	64.58	27.02	37.56	15.70
42	64.58	27.02	37.56	15.37
43	64.58	27.02	37.56	15.05
44	64.58	27.02	37.56	14.73
45	64.58	27.02	37.56	14.42
46	64.58	27.02	37.56	14.12
47	64.58	27.02	37.56	13.82
48	64.58	27.02	37.56	13.53
49	64.58	27.02	37.56	13.24
50	64.58	27.02	37.56	12.96

Green façade – Grey water



		NPV		
CFn/(1+r)^(n)	**473.39**	NPV		
Casch flow				
r	0.0215	Interest rate		
n	50	number of year		
Period	Inflow	Outflow	Cashflow tot	npv
0	0.00	702.45	-702.45	-702.45
1	64.67	26.06	38.61	37.80
2	64.67	26.06	38.61	37.00
3	64.67	26.06	38.61	36.22
4	64.67	26.06	38.61	35.46
5	64.67	26.06	38.61	34.71
6	64.67	26.06	38.61	33.98
7	64.67	26.06	38.61	33.27
8	64.67	26.06	38.61	32.57
9	64.67	26.06	38.61	31.88
10	64.67	26.06	38.61	31.21
11	64.67	26.06	38.61	30.55
12	64.67	26.06	38.61	29.91
13	64.67	26.06	38.61	29.28
14	64.67	26.06	38.61	28.66
15	64.67	26.06	38.61	28.06
16	64.67	26.06	38.61	27.47
17	64.67	26.06	38.61	26.89
18	64.67	26.06	38.61	26.33
19	64.67	26.06	38.61	25.77
20	64.67	26.06	38.61	25.23
21	64.67	26.06	38.61	24.70
22	64.67	26.06	38.61	24.18
23	64.67	26.06	38.61	23.67
24	64.67	26.06	38.61	23.17
25	64.67	26.06	38.61	22.68
26	64.67	26.06	38.61	22.21
27	64.67	26.06	38.61	21.74
28	64.67	26.06	38.61	21.28
29	64.67	26.06	38.61	20.83
30	64.67	26.06	38.61	20.40
31	64.67	26.06	38.61	19.97
32	64.67	26.06	38.61	19.55
33	64.67	26.06	38.61	19.13
34	64.67	26.06	38.61	18.73
35	64.67	26.06	38.61	18.34
36	64.67	26.06	38.61	17.95
37	64.67	26.06	38.61	17.57
38	64.67	26.06	38.61	17.20
39	64.67	26.06	38.61	16.84
40	64.67	26.06	38.61	16.49
41	64.67	26.06	38.61	16.14
42	64.67	26.06	38.61	15.80
43	64.67	26.06	38.61	15.47
44	64.67	26.06	38.61	15.14
45	64.67	26.06	38.61	14.82
46	64.67	26.06	38.61	14.51
47	64.67	26.06	38.61	14.21
48	64.67	26.06	38.61	13.91
49	64.67	26.06	38.61	13.61
50	64.67	26.06	38.61	13.33

Green façade – Moss



		NPV		
CFn/(1+r)^(n)	**1014.46**	NPV		
Casch flow				
r	0.0215	Interest rate		
n	50	number of year		
Period	Inflow	Outflow	Cashflow tot	npv
0	0.00	684.25	-684.25	-684.25
1	64.58	8.80	55.78	54.60
2	64.58	8.80	55.78	53.45
3	64.58	8.80	55.78	52.33
4	64.58	8.80	55.78	51.23
5	64.58	8.80	55.78	50.15
6	64.58	8.80	55.78	49.09
7	64.58	8.80	55.78	48.06
8	64.58	8.80	55.78	47.05
9	64.58	8.80	55.78	46.06
10	64.58	8.80	55.78	45.09
11	64.58	8.80	55.78	44.14
12	64.58	8.80	55.78	43.21
13	64.58	8.80	55.78	42.30
14	64.58	8.80	55.78	41.41
15	64.58	8.80	55.78	40.54
16	64.58	8.80	55.78	39.69
17	64.58	8.80	55.78	38.85
18	64.58	8.80	55.78	38.03
19	64.58	8.80	55.78	37.23
20	64.58	8.80	55.78	36.45
21	64.58	8.80	55.78	35.68
22	64.58	8.80	55.78	34.93
23	64.58	8.80	55.78	34.20
24	64.58	8.80	55.78	33.48
25	64.58	8.80	55.78	32.77
26	64.58	8.80	55.78	32.08
27	64.58	8.80	55.78	31.41
28	64.58	8.80	55.78	30.75
29	64.58	8.80	55.78	30.10
30	64.58	8.80	55.78	29.46
31	64.58	8.80	55.78	28.84
32	64.58	8.80	55.78	28.24
33	64.58	8.80	55.78	27.64
34	64.58	8.80	55.78	27.06
35	64.58	8.80	55.78	26.49
36	64.58	8.80	55.78	25.93
37	64.58	8.80	55.78	25.39
38	64.58	8.80	55.78	24.85
39	64.58	8.80	55.78	24.33
40	64.58	8.80	55.78	23.82
41	64.58	8.80	55.78	23.32
42	64.58	8.80	55.78	22.83
43	64.58	8.80	55.78	22.35
44	64.58	8.80	55.78	21.88
45	64.58	8.80	55.78	21.42
46	64.58	8.80	55.78	20.96
47	64.58	8.80	55.78	20.52
48	64.58	8.80	55.78	20.09
49	64.58	8.80	55.78	19.67
50	64.58	8.80	55.78	19.25

In those tables is found a column with the year, followed by the inflow, (which is zero first year since it is the one where the system is installed, so it doesn’t produce yet income, but it has only the installation cost), the outflow, the total cash flow and the NVP related to that year, the sum of which creates the total NVP.

The table for the NVP show that among the 4 solution the double skin facades has the highest score 1402.10, followed by the Moss façade with quite a gap, because it has 1014.46.

The solution with the traditional green façade and the one with grey water are comparable.

This means that it is relevant that double skin façade as it has been designed has the highest chance of be profitable.

7.2. Internal rate of return – IRR

Similar to Net Present Value (NPV), IRR helps assess the profitability of an investment by considering the time value of money. However, instead of focusing on the net present value of cash flows, IRR identifies the discount rate at which the present value of the cash inflows equals the present value of the cash outflows.

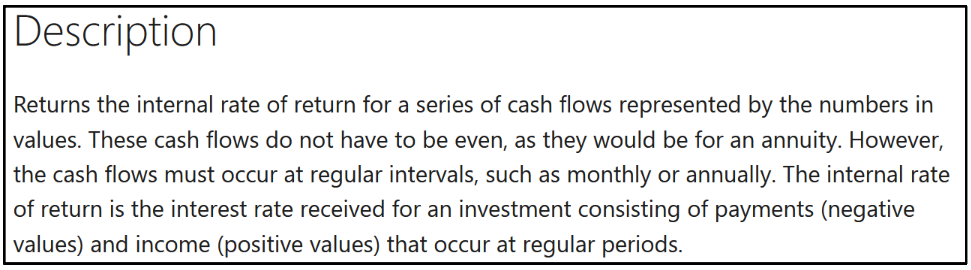
The formula for the IRR is the following one:

$$0 = NPV = \sum_{n=0}^{N} \frac{CFn}{(1+IRR)^{n}}$$

The difficult part about this calculation is that there is not a straightforward way to solve for IRR, the possible way to solve it Is either using an iterative method or a financial calculator. For the project the function IRR (TIR.cost in Italian) has been used.

Consideration about the result of IRR:

- If the IRR is greater than the required rate of return or cost of capital, the investment is considered attractive.
- If the IRR is less than the required rate of return, the investment may be less appealing.

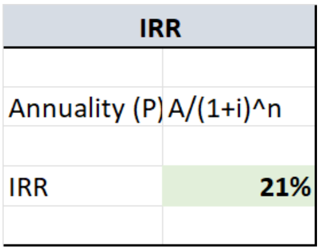


Description

Returns the internal rate of return for a series of cash flows represented by the numbers in values. These cash flows do not have to be even, as they would be for an annuity. However, the cash flows must occur at regular intervals, such as monthly or annually. The internal rate of return is the interest rate received for an investment consisting of payments (negative values) and income (positive values) that occur at regular periods.

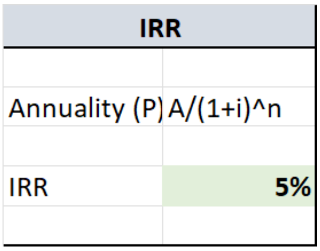
Figure 24 - description of the function used source[38]

Double skin façade



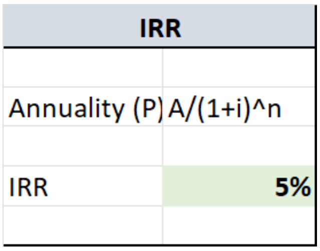
IRR	
Annuality (P)	A/(1+i)^n
IRR	**21%**

Green façade - Traditional



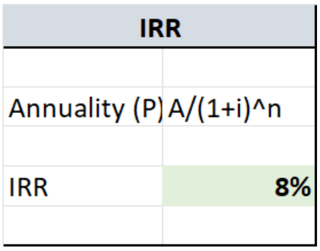
IRR	
Annuality (P)	A/(1+i)^n
IRR	**5%**

Green façade – Grey water



IRR	
Annuality (P)	A/(1+i)^n
IRR	**5%**

Green façade – Moss



IRR	
Annuality (P)	A/(1+i)^n
IRR	**8%**

The highest IRR correspond to the double skin façade with 21% the other IRR are all comparable.

7.3. Payback period – PBP

The **payback period** is a simple financial metric used to evaluate the time it takes for an investment to generate cash inflows sufficient to recover its initial cost or investment outlay. It is a basic measure of liquidity and risk, indicating how quickly an investor can recover their initial investment.

Payback Period = Annual Cash Inflow / Initial Investment

Consideration about the result of PP:

- The shorter the payback period, the more attractive the investment is considered. A shorter payback period implies a quicker return of the initial investment, which is generally preferred.

The **discounted payback period** is an extension of the traditional payback period, taking into account the time value of money by discounting future cash flows. While the traditional payback period simply divides the initial investment by the annual cash inflow, the discounted payback period considers the present value of these cash flows.

$$DPP = \sum_{1}^{n} \frac{CF_n}{(1+r)^n}$$

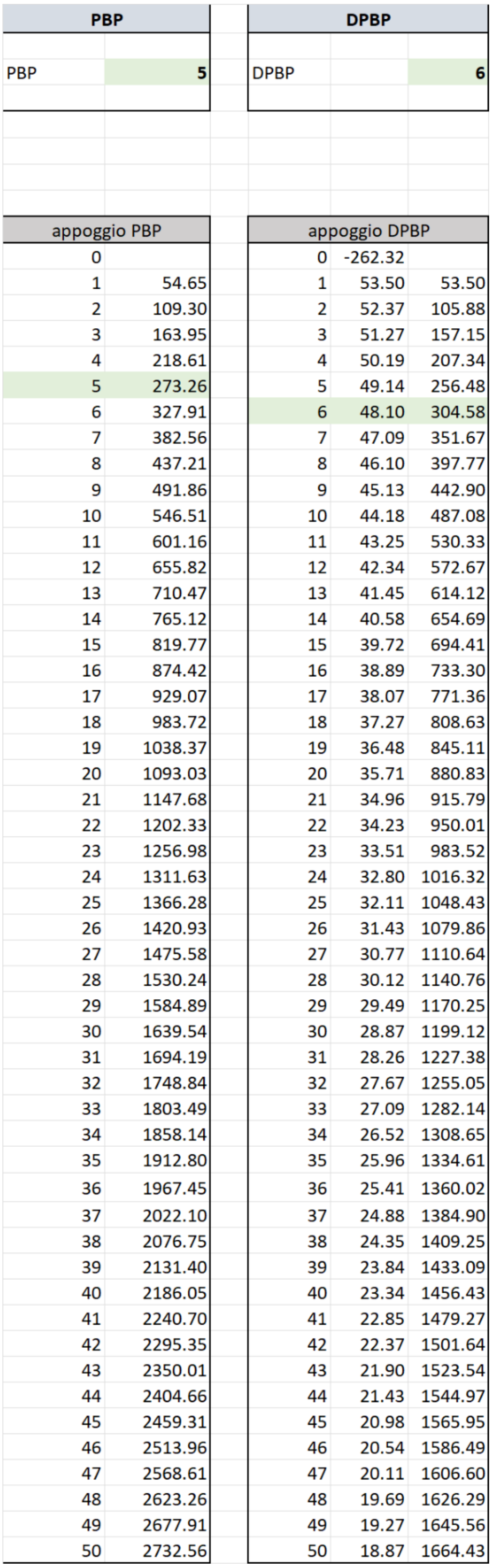
Where:

- CFn is the cash flow for the n year
- r is the new interest rate
- n is the number of years

Consideration about the result of DPP:

- Unlike the traditional payback period, the discounted payback period recognizes that a dollar received in the future is worth less than a dollar received today. It applies a discount rate to adjust future cash flows to their present value.
- Similar to the traditional payback period, a shorter discounted payback period is generally considered more favorable. It indicates how quickly the project can recover the initial investment, accounting for the time value of money.

Double skin façade



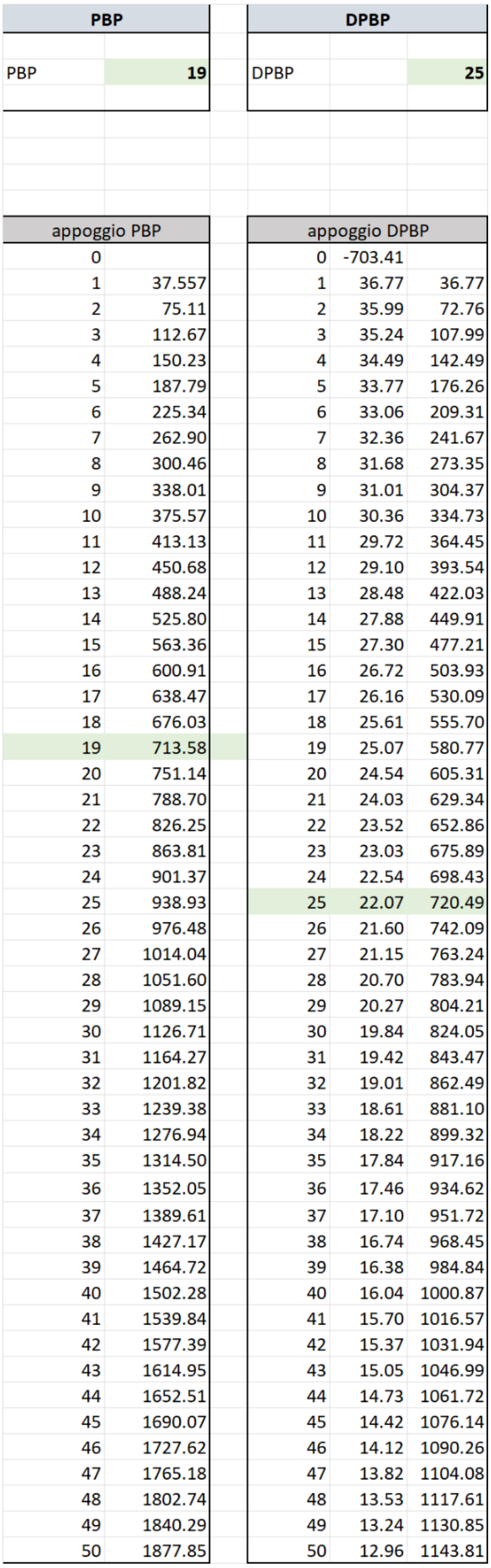
PBP	
PBP	5

DPBP	
DPBP	6

appoggio PBP	
0	
1	54.65
2	109.30
3	163.95
4	218.61
5	273.26
6	327.91
7	382.56
8	437.21
9	491.86
10	546.51
11	601.16
12	655.82
13	710.47
14	765.12
15	819.77
16	874.42
17	929.07
18	983.72
19	1038.37
20	1093.03
21	1147.68
22	1202.33
23	1256.98
24	1311.63
25	1366.28
26	1420.93
27	1475.58
28	1530.24
29	1584.89
30	1639.54
31	1694.19
32	1748.84
33	1803.49
34	1858.14
35	1912.80
36	1967.45
37	2022.10
38	2076.75
39	2131.40
40	2186.05
41	2240.70
42	2295.35
43	2350.01
44	2404.66
45	2459.31
46	2513.96
47	2568.61
48	2623.26
49	2677.91
50	2732.56

appoggio DPBP		
0	-262.32	
1	53.50	53.50
2	52.37	105.88
3	51.27	157.15
4	50.19	207.34
5	49.14	256.48
6	48.10	304.58
7	47.09	351.67
8	46.10	397.77
9	45.13	442.90
10	44.18	487.08
11	43.25	530.33
12	42.34	572.67
13	41.45	614.12
14	40.58	654.69
15	39.72	694.41
16	38.89	733.30
17	38.07	771.36
18	37.27	808.63
19	36.48	845.11
20	35.71	880.83
21	34.96	915.79
22	34.23	950.01
23	33.51	983.52
24	32.80	1016.32
25	32.11	1048.43
26	31.43	1079.86
27	30.77	1110.64
28	30.12	1140.76
29	29.49	1170.25
30	28.87	1199.12
31	28.26	1227.38
32	27.67	1255.05
33	27.09	1282.14
34	26.52	1308.65
35	25.96	1334.61
36	25.41	1360.02
37	24.88	1384.90
38	24.35	1409.25
39	23.84	1433.09
40	23.34	1456.43
41	22.85	1479.27
42	22.37	1501.64
43	21.90	1523.54
44	21.43	1544.97
45	20.98	1565.95
46	20.54	1586.49
47	20.11	1606.60
48	19.69	1626.29
49	19.27	1645.56
50	18.87	1664.43

Green façade – Traditional



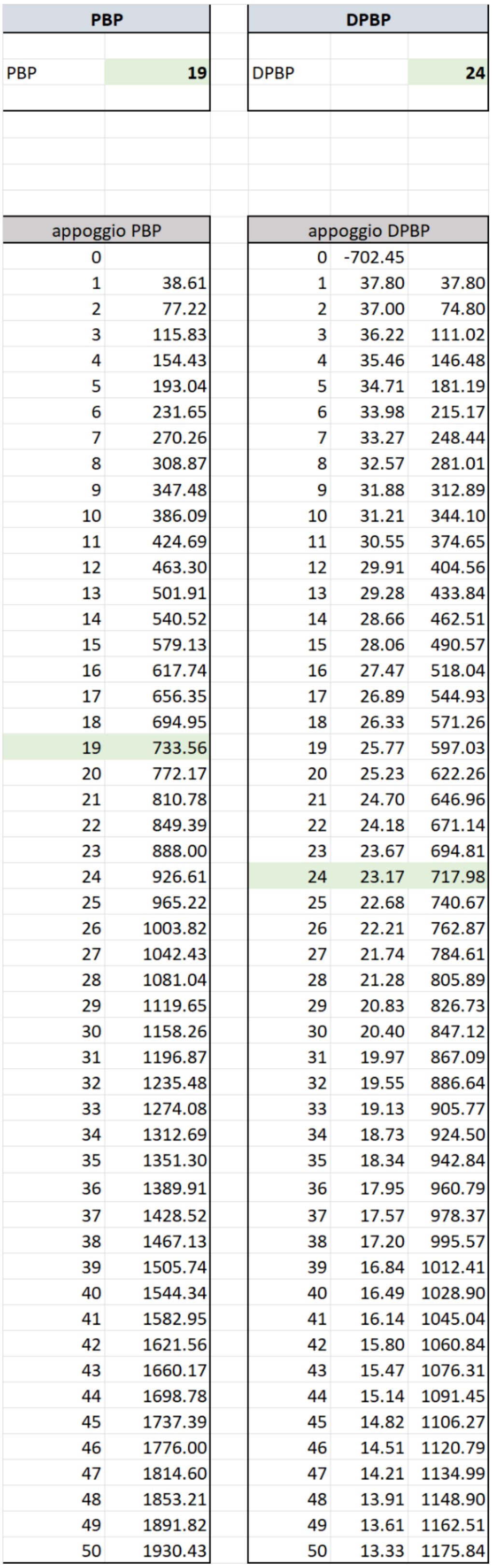
PBP	
PBP	19

DPBP	
DPBP	25

appoggio PBP	
0	
1	37.557
2	75.11
3	112.67
4	150.23
5	187.79
6	225.34
7	262.90
8	300.46
9	338.01
10	375.57
11	413.13
12	450.68
13	488.24
14	525.80
15	563.36
16	600.91
17	638.47
18	676.03
19	713.58
20	751.14
21	788.70
22	826.25
23	863.81
24	901.37
25	938.93
26	976.48
27	1014.04
28	1051.60
29	1089.15
30	1126.71
31	1164.27
32	1201.82
33	1239.38
34	1276.94
35	1314.50
36	1352.05
37	1389.61
38	1427.17
39	1464.72
40	1502.28
41	1539.84
42	1577.39
43	1614.95
44	1652.51
45	1690.07
46	1727.62
47	1765.18
48	1802.74
49	1840.29
50	1877.85

appoggio DPBP		
0	-703.41	
1	36.77	36.77
2	35.99	72.76
3	35.24	107.99
4	34.49	142.49
5	33.77	176.26
6	33.06	209.31
7	32.36	241.67
8	31.68	273.35
9	31.01	304.37
10	30.36	334.73
11	29.72	364.45
12	29.10	393.54
13	28.48	422.03
14	27.88	449.91
15	27.30	477.21
16	26.72	503.93
17	26.16	530.09
18	25.61	555.70
19	25.07	580.77
20	24.54	605.31
21	24.03	629.34
22	23.52	652.86
23	23.03	675.89
24	22.54	698.43
25	22.07	720.49
26	21.60	742.09
27	21.15	763.24
28	20.70	783.94
29	20.27	804.21
30	19.84	824.05
31	19.42	843.47
32	19.01	862.49
33	18.61	881.10
34	18.22	899.32
35	17.84	917.16
36	17.46	934.62
37	17.10	951.72
38	16.74	968.45
39	16.38	984.84
40	16.04	1000.87
41	15.70	1016.57
42	15.37	1031.94
43	15.05	1046.99
44	14.73	1061.72
45	14.42	1076.14
46	14.12	1090.26
47	13.82	1104.08
48	13.53	1117.61
49	13.24	1130.85
50	12.96	1143.81

Green façade – Grey water



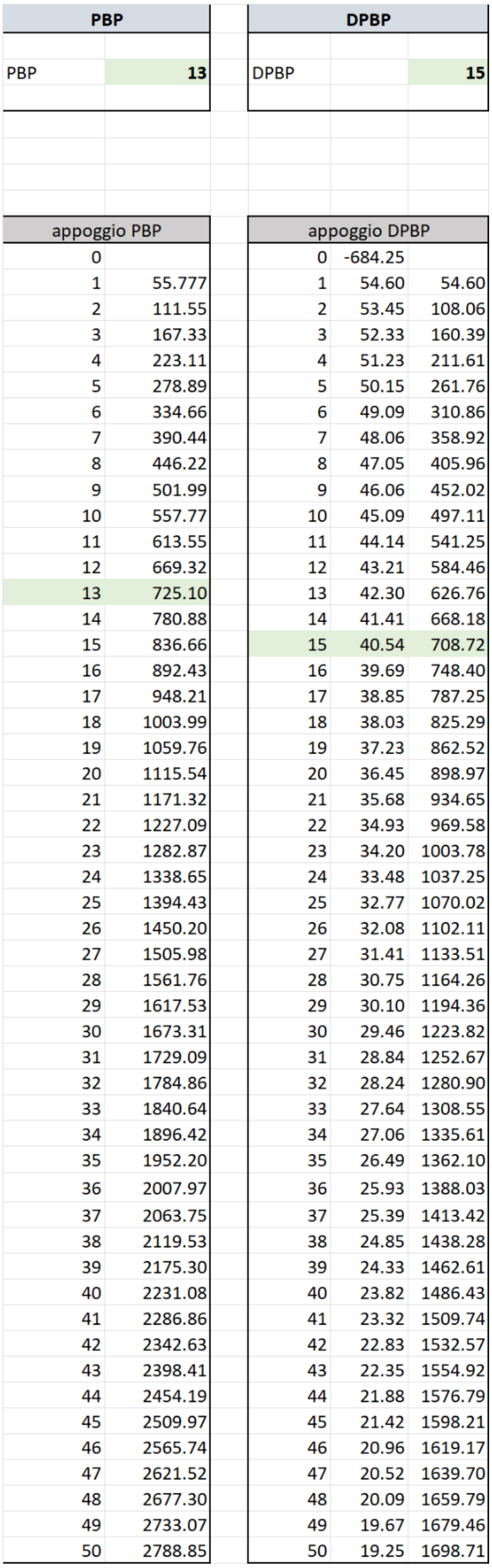
PBP	
PBP	19

DPBP	
DPBP	24

appoggio PBP	
0	
1	38.61
2	77.22
3	115.83
4	154.43
5	193.04
6	231.65
7	270.26
8	308.87
9	347.48
10	386.09
11	424.69
12	463.30
13	501.91
14	540.52
15	579.13
16	617.74
17	656.35
18	694.95
19	733.56
20	772.17
21	810.78
22	849.39
23	888.00
24	926.61
25	965.22
26	1003.82
27	1042.43
28	1081.04
29	1119.65
30	1158.26
31	1196.87
32	1235.48
33	1274.08
34	1312.69
35	1351.30
36	1389.91
37	1428.52
38	1467.13
39	1505.74
40	1544.34
41	1582.95
42	1621.56
43	1660.17
44	1698.78
45	1737.39
46	1776.00
47	1814.60
48	1853.21
49	1891.82
50	1930.43

appoggio DPBP		
0	-702.45	
1	37.80	37.80
2	37.00	74.80
3	36.22	111.02
4	35.46	146.48
5	34.71	181.19
6	33.98	215.17
7	33.27	248.44
8	32.57	281.01
9	31.88	312.89
10	31.21	344.10
11	30.55	374.65
12	29.91	404.56
13	29.28	433.84
14	28.66	462.51
15	28.06	490.57
16	27.47	518.04
17	26.89	544.93
18	26.33	571.26
19	25.77	597.03
20	25.23	622.26
21	24.70	646.96
22	24.18	671.14
23	23.67	694.81
24	23.17	717.98
25	22.68	740.67
26	22.21	762.87
27	21.74	784.61
28	21.28	805.89
29	20.83	826.73
30	20.40	847.12
31	19.97	867.09
32	19.55	886.64
33	19.13	905.77
34	18.73	924.50
35	18.34	942.84
36	17.95	960.79
37	17.57	978.37
38	17.20	995.57
39	16.84	1012.41
40	16.49	1028.90
41	16.14	1045.04
42	15.80	1060.84
43	15.47	1076.31
44	15.14	1091.45
45	14.82	1106.27
46	14.51	1120.79
47	14.21	1134.99
48	13.91	1148.90
49	13.61	1162.51
50	13.33	1175.84

Green façade – Moss



PBP	
PBP	13

DPBP	
DPBP	15

appoggio PBP	
0	
1	55.777
2	111.55
3	167.33
4	223.11
5	278.89
6	334.66
7	390.44
8	446.22
9	501.99
10	557.77
11	613.55
12	669.32
13	725.10
14	780.88
15	836.66
16	892.43
17	948.21
18	1003.99
19	1059.76
20	1115.54
21	1171.32
22	1227.09
23	1282.87
24	1338.65
25	1394.43
26	1450.20
27	1505.98
28	1561.76
29	1617.53
30	1673.31
31	1729.09
32	1784.86
33	1840.64
34	1896.42
35	1952.20
36	2007.97
37	2063.75
38	2119.53
39	2175.30
40	2231.08
41	2286.86
42	2342.63
43	2398.41
44	2454.19
45	2509.97
46	2565.74
47	2621.52
48	2677.30
49	2733.07
50	2788.85

appoggio DPBP		
0	-684.25	
1	54.60	54.60
2	53.45	108.06
3	52.33	160.39
4	51.23	211.61
5	50.15	261.76
6	49.09	310.86
7	48.06	358.92
8	47.05	405.96
9	46.06	452.02
10	45.09	497.11
11	44.14	541.25
12	43.21	584.46
13	42.30	626.76
14	41.41	668.18
15	40.54	708.72
16	39.69	748.40
17	38.85	787.25
18	38.03	825.29
19	37.23	862.52
20	36.45	898.97
21	35.68	934.65
22	34.93	969.58
23	34.20	1003.78
24	33.48	1037.25
25	32.77	1070.02
26	32.08	1102.11
27	31.41	1133.51
28	30.75	1164.26
29	30.10	1194.36
30	29.46	1223.82
31	28.84	1252.67
32	28.24	1280.90
33	27.64	1308.55
34	27.06	1335.61
35	26.49	1362.10
36	25.93	1388.03
37	25.39	1413.42
38	24.85	1438.28
39	24.33	1462.61
40	23.82	1486.43
41	23.32	1509.74
42	22.83	1532.57
43	22.35	1554.92
44	21.88	1576.79
45	21.42	1598.21
46	20.96	1619.17
47	20.52	1639.70
48	20.09	1659.79
49	19.67	1679.46
50	19.25	1698.71

The most representative data is the discounted payback period because it would be not realistic considering time value of money.

This is clear if the results are compared, the most effective one is the double skin façade, that has a PBP of 5 year and the period for the DPB is 6 years this is a close gap because the period is not long enough to experience a real difference in value over time.

If the results of the green façade traditional are compared the two indicators vary in a significant way, because in one is 19 years and the other is 25 years, this is a period long enough where the value of money need to be related to the time.

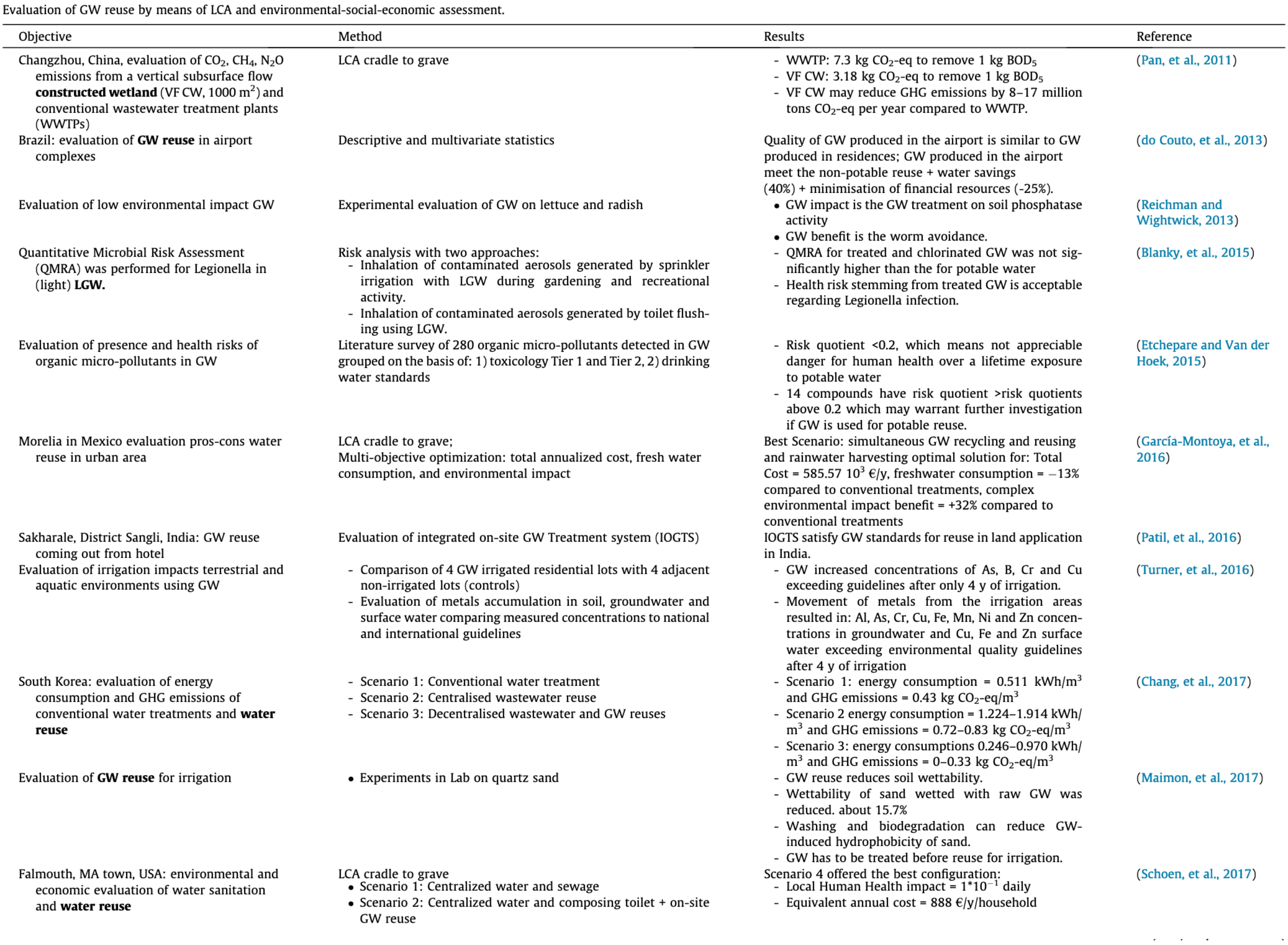
7.4. Sensitivity analysis

Sensitivity analysis is a financial modeling technique used to assess how changes in the input variables of a model impact the output. It helps identify the sensitivity of a project or investment to variations in specific factors, providing insights into the potential impact of different scenarios.

• Impact of greywater treatment

Greywater reuse is a hot topic in the current studies and different methodologies, hypothesis or primary data led to different outcome.

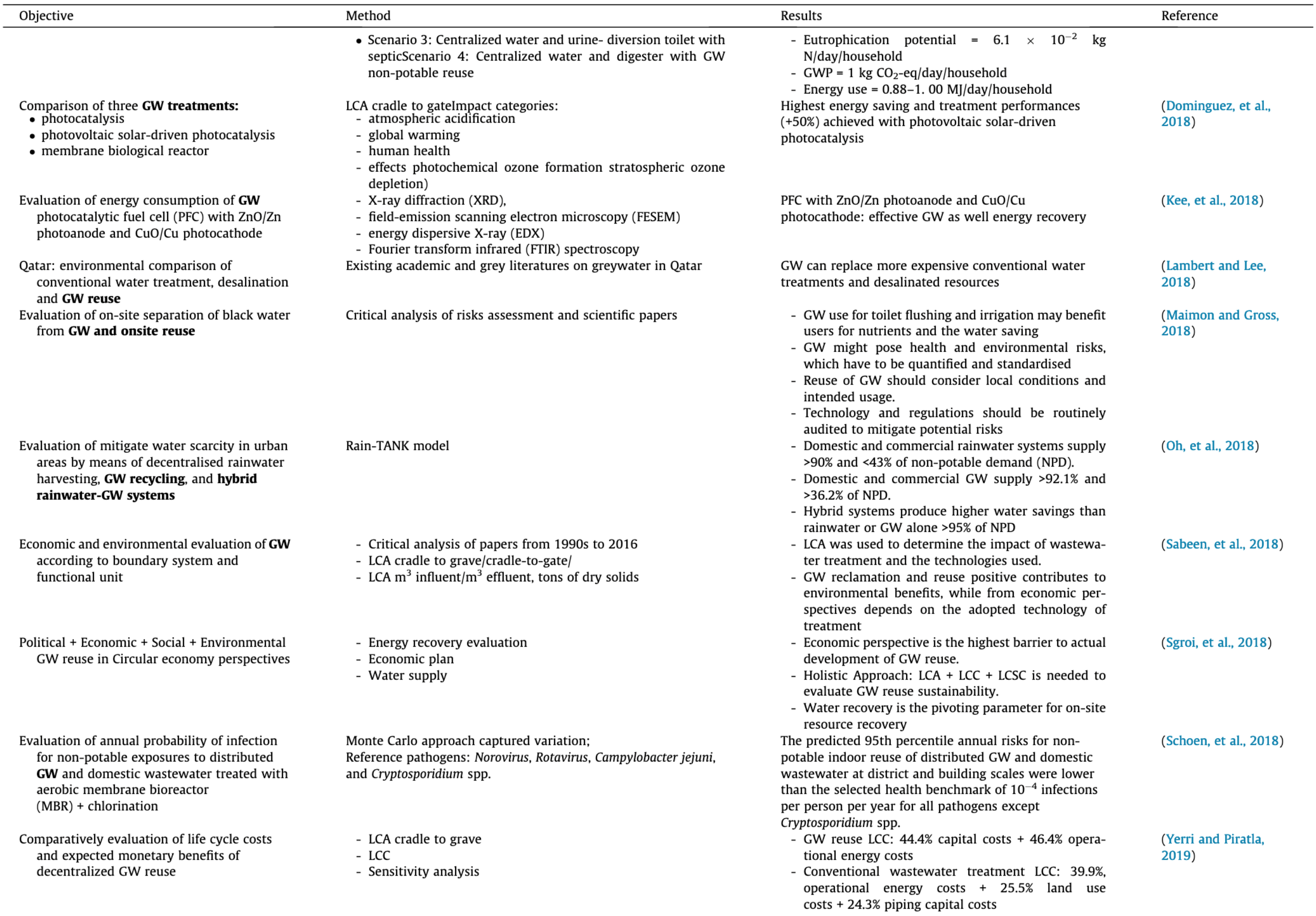
In the study "*A review of nature-based solutions for greywater treatment: Applications, hydraulic design, and environmental benefits*" [23] it has been summarized the Life Cycle Analyses of 30 different studies done in the past years to summarize the pros and cons.



Evaluation of GW reuse by means of LCA and environmental-social-economic assessment.

Objective	Method	Results	Reference
Changzhou, China, evaluation of CO_2, CH_4, N_2O emissions from a vertical subsurface flow **constructed wetland** (VF CW, 1000 m^2) and conventional wastewater treatment plants (WWTPs)	LCA cradle to grave	- WWTP: 7.3 kg CO_2-eq to remove 1 kg BOD_5 - VF CW: 3.18 kg CO_2-eq to remove 1 kg BOD_5 - VF CW may reduce GHG emissions by 8–17 million tons CO_2-eq per year compared to WWTP.	(Pan, et al., 2011)
Brazil: evaluation of **GW reuse** in airport complexes	Descriptive and multivariate statistics	Quality of GW produced in the airport is similar to GW produced in residences; GW produced in the airport meet the non-potable reuse + water savings (40%) + minimisation of financial resources (-25%).	(do Couto, et al., 2013)
Evaluation of low environmental impact GW	Experimental evaluation of GW on lettuce and radish	• GW impact is the GW treatment on soil phosphatase activity • GW benefit is the worm avoidance.	(Reichman and Wightwick, 2013)
Quantitative Microbial Risk Assessment (QMRA) was performed for Legionella in (light) **LGW.**	Risk analysis with two approaches: - Inhalation of contaminated aerosols generated by sprinkler irrigation with LGW during gardening and recreational activity. - Inhalation of contaminated aerosols generated by toilet flushing using LGW.	- QMRA for treated and chlorinated GW was not significantly higher than the for potable water - Health risk stemming from treated GW is acceptable regarding Legionella infection.	(Blanky, et al., 2015)
Evaluation of presence and health risks of organic micro-pollutants in GW	Literature survey of 280 organic micro-pollutants detected in GW grouped on the basis of: 1) toxicology Tier 1 and Tier 2, 2) drinking water standards	- Risk quotient <0.2, which means not appreciable danger for human health over a lifetime exposure to potable water - 14 compounds have risk quotient >risk quotients above 0.2 which may warrant further investigation if GW is used for potable reuse.	(Etchepare and Van der Hoek, 2015)
Morelia in Mexico evaluation pros-cons water reuse in urban area	LCA cradle to grave; Multi-objective optimization: total annualized cost, fresh water consumption, and environmental impact	Best Scenario: simultaneous GW recycling and reusing and rainwater harvesting optimal solution for: Total Cost = 585.57 10^3 €/y, freshwater consumption = −13% compared to conventional treatments, complex environmental impact benefit = +32% compared to conventional treatments	(García-Montoya, et al., 2016)
Sakharale, District Sangli, India: GW reuse coming out from hotel	Evaluation of integrated on-site GW Treatment system (IOGTS)	IOGTS satisfy GW standards for reuse in land application in India.	(Patil, et al., 2016)
Evaluation of irrigation impacts terrestrial and aquatic environments using GW	- Comparison of 4 GW irrigated residential lots with 4 adjacent non-irrigated lots (controls) - Evaluation of metals accumulation in soil, groundwater and surface water comparing measured concentrations to national and international guidelines	- GW increased concentrations of As, B, Cr and Cu exceeding guidelines after only 4 y of irrigation. - Movement of metals from the irrigation areas resulted in: Al, As, Cr, Cu, Fe, Mn, Ni and Zn concentrations in groundwater and Cu, Fe and Zn surface water exceeding environmental quality guidelines after 4 y of irrigation	(Turner, et al., 2016)
South Korea: evaluation of energy consumption and GHG emissions of conventional water treatments and **water reuse**	- Scenario 1: Conventional water treatment - Scenario 2: Centralised wastewater reuse - Scenario 3: Decentralised wastewater and GW reuses	- Scenario 1: energy consumption = 0.511 kWh/m^3 and GHG emissions = 0.43 kg CO_2-eq/m^3 - Scenario 2 energy consumption = 1.224–1.914 kWh/m^3 and GHG emissions = 0.72–0.83 kg CO_2-eq/m^3 - Scenario 3: energy consumptions 0.246–0.970 kWh/m^3 and GHG emissions = 0–0.33 kg CO_2-eq/m^3	(Chang, et al., 2017)
Evaluation of **GW reuse** for irrigation	• Experiments in Lab on quartz sand	- GW reuse reduces soil wettability. - Wettability of sand wetted with raw GW was reduced. about 15.7% - Washing and biodegradation can reduce GW-induced hydrophobicity of sand. - GW has to be treated before reuse for irrigation.	(Maimon, et al., 2017)
Falmouth, MA town, USA: environmental and economic evaluation of water sanitation and **water reuse**	LCA cradle to grave • Scenario 1: Centralized water and sewage • Scenario 2: Centralized water and composing toilet + on-site GW reuse	Scenario 4 offered the best configuration: - Local Human Health impact = $1*10^{-1}$ daily - Equivalent annual cost = 888 €/y/household	(Schoen, et al., 2017)

Figure 25 - Evaluation of GW reuse by means of LCA and environmental-social-economic assessment. Part 1 – source [23]



Objective	Method	Results	Reference
	• Scenario 3: Centralized water and urine- diversion toilet with septicScenario 4: Centralized water and digester with GW non-potable reuse	- Eutrophication potential = 6.1 × 10^{-2} kg N/day/household - GWP = 1 kg CO_2-eq/day/household - Energy use = 0.88–1. 00 MJ/day/household	
Comparison of three **GW treatments:** • photocatalysis • photovoltaic solar-driven photocatalysis • membrane biological reactor	LCA cradle to gateImpact categories: - atmospheric acidification - global warming - human health - effects photochemical ozone formation stratospheric ozone depletion	Highest energy saving and treatment performances (+50%) achieved with photovoltaic solar-driven photocatalysis	(Dominguez, et al., 2018)
Evaluation of energy consumption of **GW** photocatalytic fuel cell (PFC) with ZnO/Zn photoanode and CuO/Cu photocathode	- X-ray diffraction (XRD), - field-emission scanning electron microscopy (FESEM) - energy dispersive X-ray (EDX) - Fourier transform infrared (FTIR) spectroscopy	PFC with ZnO/Zn photoanode and CuO/Cu photocathode: effective GW as well energy recovery	(Kee, et al., 2018)
Qatar: environmental comparison of conventional water treatment, desalination and **GW reuse**	Existing academic and grey literatures on greywater in Qatar	GW can replace more expensive conventional water treatments and desalinated resources	(Lambert and Lee, 2018)
Evaluation of on-site separation of black water from **GW and onsite reuse**	Critical analysis of risks assessment and scientific papers	- GW use for toilet flushing and irrigation may benefit users for nutrients and the water saving - GW might pose health and environmental risks, which have to be quantified and standardised - Reuse of GW should consider local conditions and intended usage. - Technology and regulations should be routinely audited to mitigate potential risks	(Maimon and Gross, 2018)
Evaluation of mitigate water scarcity in urban areas by means of decentralised rainwater harvesting, **GW recycling**, and **hybrid rainwater-GW systems**	Rain-TANK model	- Domestic and commercial rainwater systems supply >90% and <43% of non-potable demand (NPD). - Domestic and commercial GW supply >92.1% and >36.2% of NPD. - Hybrid systems produce higher water savings than rainwater or GW alone >95% of NPD	(Oh, et al., 2018)
Economic and environmental evaluation of **GW** according to boundary system and functional unit	- Critical analysis of papers from 1990s to 2016 - LCA cradle to grave/cradle-to-gate/ - LCA m^3 influent/m^3 effluent, tons of dry solids	- LCA was used to determine the impact of wastewater treatment and the technologies used. - GW reclamation and reuse positive contributes to environmental benefits, while from economic perspectives depends on the adopted technology of treatment	(Sabeen, et al., 2018)
Political + Economic + Social + Environmental GW reuse in Circular economy perspectives	- Energy recovery evaluation - Economic plan - Water supply	- Economic perspective is the highest barrier to actual development of GW reuse. - Holistic Approach: LCA + LCC + LCSC is needed to evaluate GW reuse sustainability. - Water recovery is the pivoting parameter for on-site resource recovery	(Sgroi, et al., 2018)
Evaluation of annual probability of infection for non-potable exposures to distributed **GW** and domestic wastewater treated with aerobic membrane bioreactor (MBR) + chlorination	Monte Carlo approach captured variation; Reference pathogens: *Norovirus*, *Rotavirus*, *Campylobacter jejuni*, and *Cryptosporidium* spp.	The predicted 95th percentile annual risks for non-potable indoor reuse of distributed GW and domestic wastewater at district and building scales were lower than the selected health benchmark of 10^{-4} infections per person per year for all pathogens except *Cryptosporidium* spp.	(Schoen, et al., 2018)
Comparatively evaluation of life cycle costs and expected monetary benefits of decentralized GW reuse	- LCA cradle to grave - LCC - Sensitivity analysis	- GW reuse LCC: 44.4% capital costs + 46.4% operational energy costs - Conventional wastewater treatment LCC: 39.9%, operational energy costs + 25.5% land use costs + 24.3% piping capital costs	(Yerri and Piratla, 2019)

Figure 26 - Evaluation of GW reuse by means of LCA and environmental-social-economic assessment. Part 2 Source [23]

- Greywater reuse in urban areas can decrease of about **30%** water consumption in buildings [39]
- Greywater reuse in multi-story buildings in Israel may save **150 Mm3/y** of freshwater use [40].
- Reduction of about **50%** in greenhouse emissions compared to traditional wastewater treatment plants [41].
- This improvement for vertical flow CW is distributed among transportation stage (up to ~19 kg CO2-eq/PE/y less), treatment stage (up to ~40 kg CO2-eq/PE/y less), and sludge handling.
- An indirect effect of greywater system is the decentralization of the treatment thus leading to an energy saving form traditional (centralized): 1.224–1.914 kWh/ m3 to the one in situ 0.2460.970 kWh/m3 which means a reduction up to **~80%** [42]

A general analysis shows that although results may vary by site-especially in terms of net economic benefits-most studies indicate that greywater treatment with decentralized approaches is more beneficial than conventional methods, both in terms of net energy consumption and economic costs.

- Material price

Since the project is based on a building located in the North of Italy, is possible to look at report of ISTAT "Istituto Nazionale di Statistica", an Italian institution that periodically review the prices of construction.

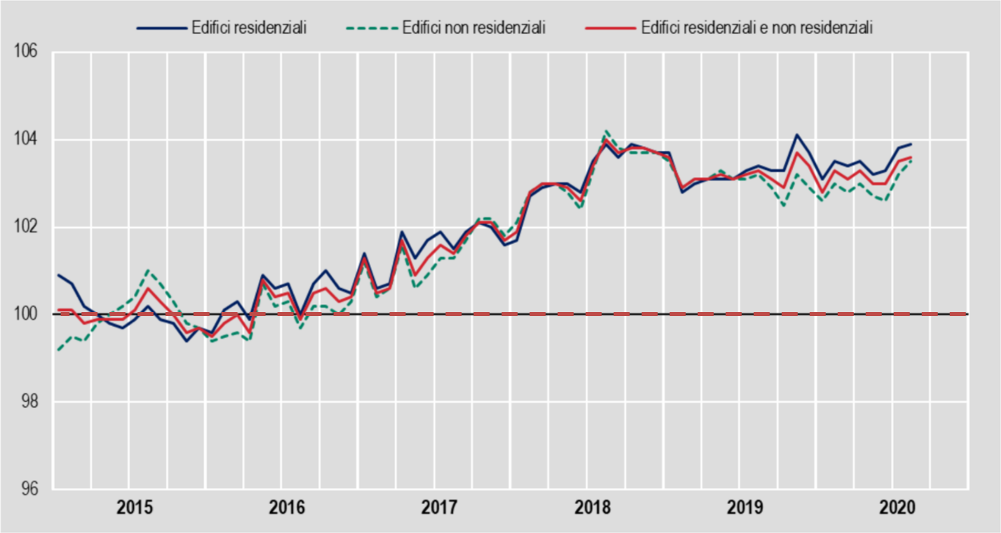


Figure 27 - Construction output price index numbers. residential and non-residential buildings source [43]

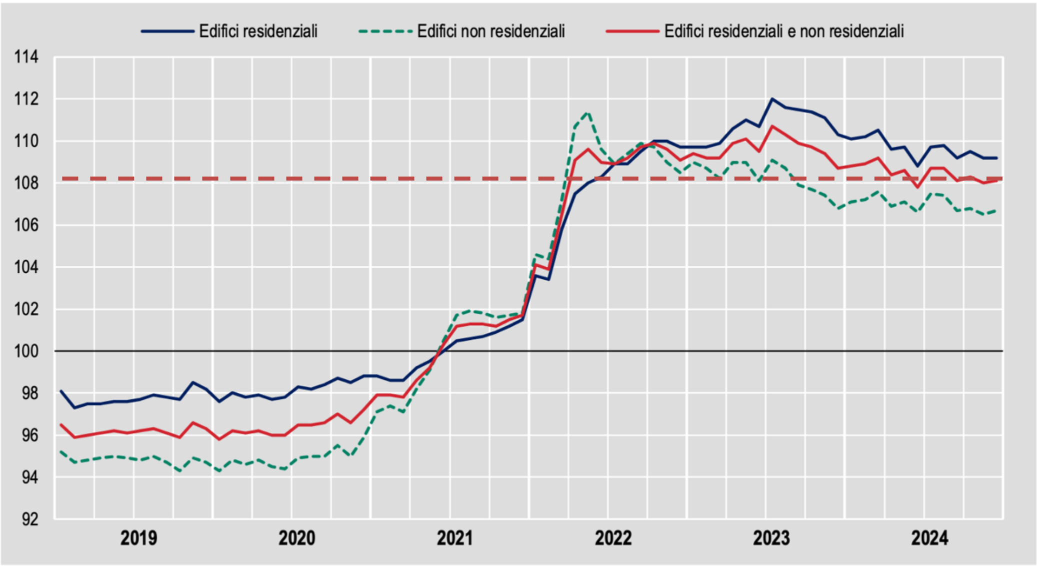


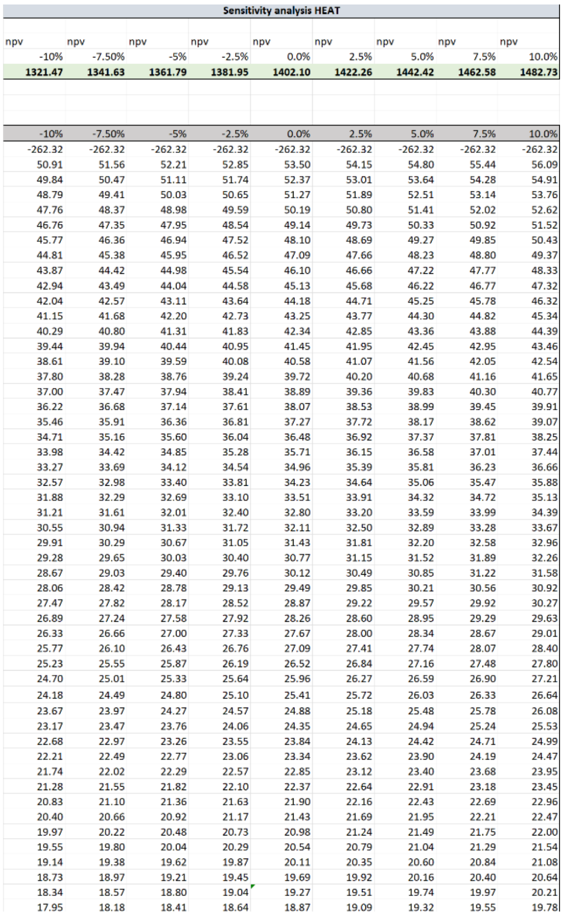
Figure 28 - Construction output price index numbers. residential and non-residential buildings source [44]

As is possible to evaluate, the price increased drastically in the past years. It could be a good approximation that the price increased statistically of 17% in less than 10 years for construction cost of residential and non-residential building.

The Italy state took notice of the rising price of the materials and partially refund the building site that were in the middle of the construction facing costs that are no longer close to the original.

Even if the price of the material has seen a big fluctuation it will be took into account the same range of -10% +10% because this rise that happened was for the major part due to the pandemic which is an anomalous event. The common fluctuation does not experience gap this big.

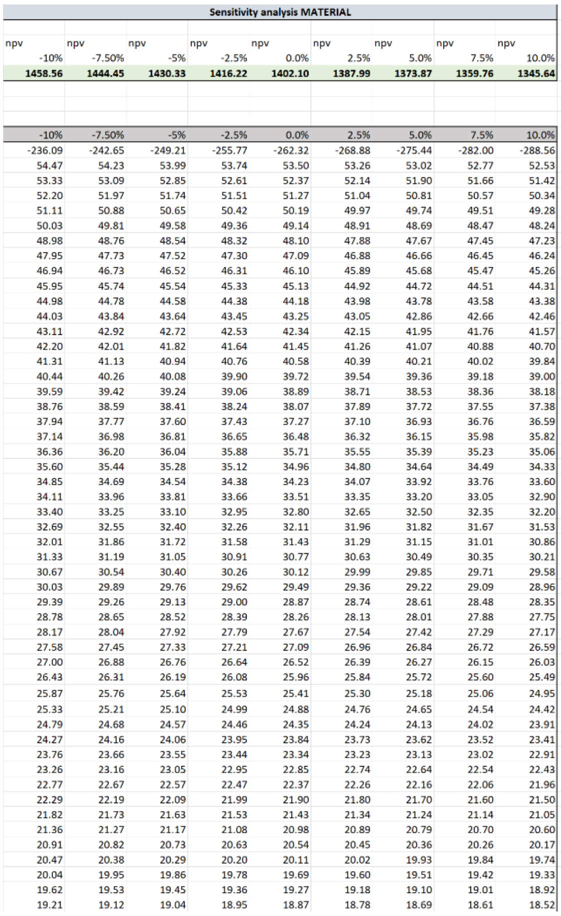
Double skin façade



Sensitivity analysis HEAT

npv	npv	npv	npv	npv	npv	npv	npv	npv
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
1321.47	**1341.63**	**1361.79**	**1381.95**	**1402.10**	**1422.26**	**1442.42**	**1462.58**	**1482.73**

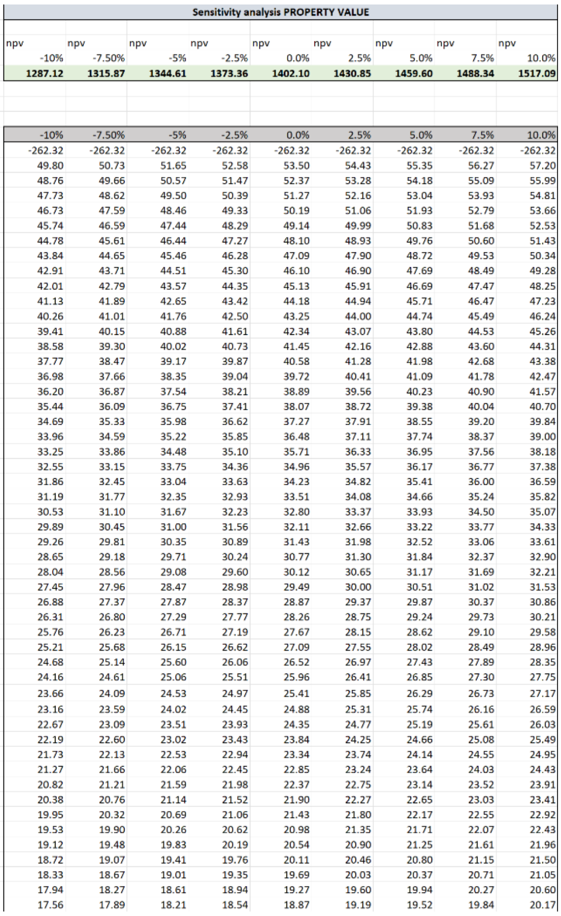
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
-262.32	-262.32	-262.32	-262.32	-262.32	-262.32	-262.32	-262.32	-262.32
50.91	51.56	52.21	52.85	53.50	54.15	54.80	55.44	56.09
49.84	50.47	51.11	51.74	52.37	53.01	53.64	54.28	54.91
48.79	49.41	50.03	50.65	51.27	51.89	52.51	53.14	53.76
47.76	48.37	48.98	49.59	50.19	50.80	51.41	52.02	52.62
46.76	47.35	47.95	48.54	49.14	49.73	50.33	50.92	51.52
45.77	46.36	46.94	47.52	48.10	48.69	49.27	49.85	50.43
44.81	45.38	45.95	46.52	47.09	47.66	48.23	48.80	49.37
43.87	44.42	44.98	45.54	46.10	46.66	47.22	47.77	48.33
42.94	43.49	44.04	44.58	45.13	45.68	46.22	46.77	47.32
42.04	42.57	43.11	43.64	44.18	44.71	45.25	45.78	46.32
41.15	41.68	42.20	42.73	43.25	43.77	44.30	44.82	45.34
40.29	40.80	41.31	41.83	42.34	42.85	43.36	43.88	44.39
39.44	39.94	40.44	40.95	41.45	41.95	42.45	42.95	43.46
38.61	39.10	39.59	40.08	40.58	41.07	41.56	42.05	42.54
37.80	38.28	38.76	39.24	39.72	40.20	40.68	41.16	41.65
37.00	37.47	37.94	38.41	38.89	39.36	39.83	40.30	40.77
36.22	36.68	37.14	37.61	38.07	38.53	38.99	39.45	39.91
35.46	35.91	36.36	36.81	37.27	37.72	38.17	38.62	39.07
34.71	35.16	35.60	36.04	36.48	36.92	37.37	37.81	38.25
33.98	34.42	34.85	35.28	35.71	36.15	36.58	37.01	37.44
33.27	33.69	34.12	34.54	34.96	35.39	35.81	36.23	36.66
32.57	32.98	33.40	33.81	34.23	34.64	35.06	35.47	35.88
31.88	32.29	32.69	33.10	33.51	33.91	34.32	34.72	35.13
31.21	31.61	32.01	32.40	32.80	33.20	33.59	33.99	34.39
30.55	30.94	31.33	31.72	32.11	32.50	32.89	33.28	33.67
29.91	30.29	30.67	31.05	31.43	31.81	32.20	32.58	32.96
29.28	29.65	30.03	30.40	30.77	31.15	31.52	31.89	32.26
28.67	29.03	29.40	29.76	30.12	30.49	30.85	31.22	31.58
28.06	28.42	28.78	29.13	29.49	29.85	30.21	30.56	30.92
27.47	27.82	28.17	28.52	28.87	29.22	29.57	29.92	30.27
26.89	27.24	27.58	27.92	28.26	28.60	28.95	29.29	29.63
26.33	26.66	27.00	27.33	27.67	28.00	28.34	28.67	29.01
25.77	26.10	26.43	26.76	27.09	27.41	27.74	28.07	28.40
25.23	25.55	25.87	26.19	26.52	26.84	27.16	27.48	27.80
24.70	25.01	25.33	25.64	25.96	26.27	26.59	26.90	27.21
24.18	24.49	24.80	25.10	25.41	25.72	26.03	26.33	26.64
23.67	23.97	24.27	24.57	24.88	25.18	25.48	25.78	26.08
23.17	23.47	23.76	24.06	24.35	24.65	24.94	25.24	25.53
22.68	22.97	23.26	23.55	23.84	24.13	24.42	24.71	24.99
22.21	22.49	22.77	23.06	23.34	23.62	23.90	24.19	24.47
21.74	22.02	22.29	22.57	22.85	23.12	23.40	23.68	23.95
21.28	21.55	21.82	22.10	22.37	22.64	22.91	23.18	23.45
20.83	21.10	21.36	21.63	21.90	22.16	22.43	22.69	22.96
20.40	20.66	20.92	21.17	21.43	21.69	21.95	22.21	22.47
19.97	20.22	20.48	20.73	20.98	21.24	21.49	21.75	22.00
19.55	19.80	20.04	20.29	20.54	20.79	21.04	21.29	21.54
19.14	19.38	19.62	19.87	20.11	20.35	20.60	20.84	21.08
18.73	18.97	19.21	19.45	19.69	19.92	20.16	20.40	20.64
18.34	18.57	18.80	19.04	19.27	19.51	19.74	19.97	20.21
17.95	18.18	18.41	18.64	18.87	19.09	19.32	19.55	19.78



Sensitivity analysis MATERIAL

npv	npv	npv	npv	npv	npv	npv	npv	npv
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
1458.56	**1444.45**	**1430.33**	**1416.22**	**1402.10**	**1387.99**	**1373.87**	**1359.76**	**1345.64**

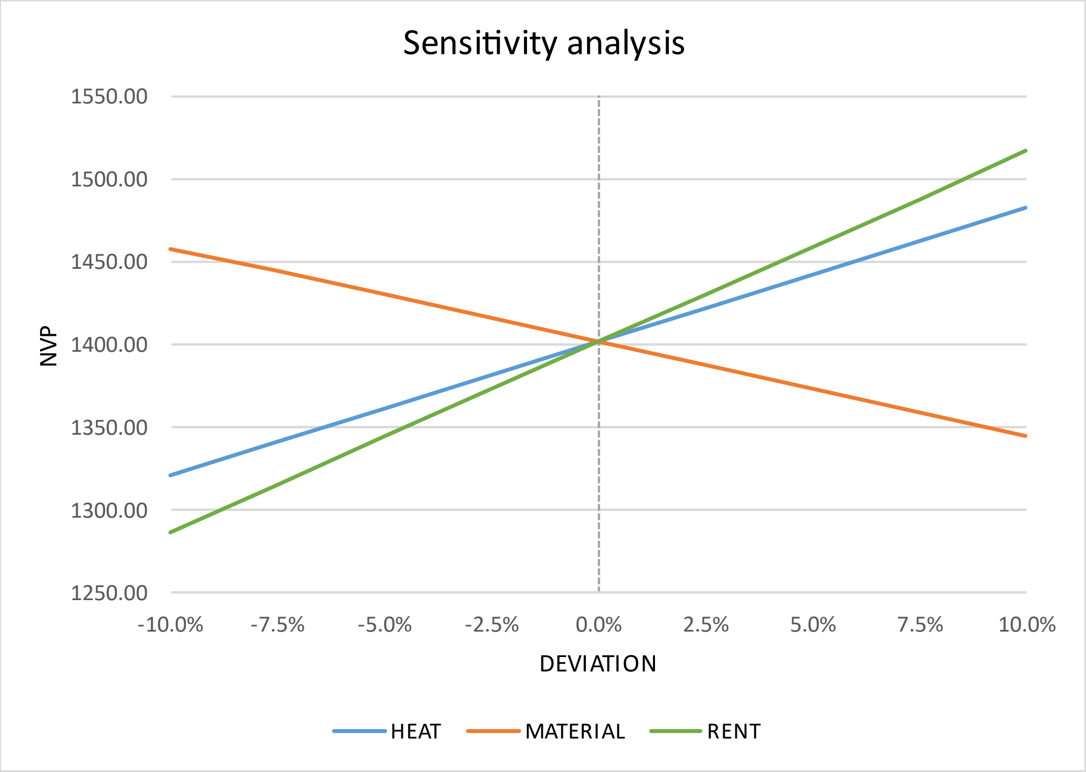
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
-236.09	-242.65	-249.21	-255.77	-262.32	-268.88	-275.44	-282.00	-288.56
54.47	54.23	53.99	53.74	53.50	53.26	53.02	52.77	52.53
53.33	53.09	52.85	52.61	52.37	52.14	51.90	51.66	51.42
52.20	51.97	51.74	51.51	51.27	51.04	50.81	50.57	50.34
51.11	50.88	50.65	50.42	50.19	49.97	49.74	49.51	49.28
50.03	49.81	49.58	49.36	49.14	48.91	48.69	48.47	48.24
48.98	48.76	48.54	48.32	48.10	47.88	47.67	47.45	47.23
47.95	47.73	47.52	47.30	47.09	46.88	46.66	46.45	46.24
46.94	46.73	46.52	46.31	46.10	45.89	45.68	45.47	45.26
45.95	45.74	45.54	45.33	45.13	44.92	44.72	44.51	44.31
44.98	44.78	44.58	44.38	44.18	43.98	43.78	43.58	43.38
44.03	43.84	43.64	43.45	43.25	43.05	42.86	42.66	42.46
43.11	42.92	42.72	42.53	42.34	42.15	41.95	41.76	41.57
42.20	42.01	41.82	41.64	41.45	41.26	41.07	40.88	40.70
41.31	41.13	40.94	40.76	40.58	40.39	40.21	40.02	39.84
40.44	40.26	40.08	39.90	39.72	39.54	39.36	39.18	39.00
39.59	39.42	39.24	39.06	38.89	38.71	38.53	38.36	38.18
38.76	38.59	38.41	38.24	38.07	37.89	37.72	37.55	37.38
37.94	37.77	37.60	37.43	37.27	37.10	36.93	36.76	36.59
37.14	36.98	36.81	36.65	36.48	36.32	36.15	35.98	35.82
36.36	36.20	36.04	35.88	35.71	35.55	35.39	35.23	35.06
35.60	35.44	35.28	35.12	34.96	34.80	34.64	34.49	34.33
34.85	34.69	34.54	34.38	34.23	34.07	33.92	33.76	33.60
34.11	33.96	33.81	33.66	33.51	33.35	33.20	33.05	32.90
33.40	33.25	33.10	32.95	32.80	32.65	32.50	32.35	32.20
32.69	32.55	32.40	32.26	32.11	31.96	31.82	31.67	31.53
32.01	31.86	31.72	31.58	31.43	31.29	31.15	31.01	30.86
31.33	31.19	31.05	30.91	30.77	30.63	30.49	30.35	30.21
30.67	30.54	30.40	30.26	30.12	29.99	29.85	29.71	29.58
30.03	29.89	29.76	29.62	29.49	29.36	29.22	29.09	28.96
29.39	29.26	29.13	29.00	28.87	28.74	28.61	28.48	28.35
28.78	28.65	28.52	28.39	28.26	28.13	28.01	27.88	27.75
28.17	28.04	27.92	27.79	27.67	27.54	27.42	27.29	27.17
27.58	27.45	27.33	27.21	27.09	26.96	26.84	26.72	26.59
27.00	26.88	26.76	26.64	26.52	26.39	26.27	26.15	26.03
26.43	26.31	26.19	26.08	25.96	25.84	25.72	25.60	25.49
25.87	25.76	25.64	25.53	25.41	25.30	25.18	25.06	24.95
25.33	25.21	25.10	24.99	24.88	24.76	24.65	24.54	24.42
24.79	24.68	24.57	24.46	24.35	24.24	24.13	24.02	23.91
24.27	24.16	24.06	23.95	23.84	23.73	23.62	23.52	23.41
23.76	23.66	23.55	23.44	23.34	23.23	23.13	23.02	22.91
23.26	23.16	23.05	22.95	22.85	22.74	22.64	22.54	22.43
22.77	22.67	22.57	22.47	22.37	22.26	22.16	22.06	21.96
22.29	22.19	22.09	21.99	21.90	21.80	21.70	21.60	21.50
21.82	21.73	21.63	21.53	21.43	21.34	21.24	21.14	21.05
21.36	21.27	21.17	21.08	20.98	20.89	20.79	20.70	20.60
20.91	20.82	20.73	20.63	20.54	20.45	20.36	20.26	20.17
20.47	20.38	20.29	20.20	20.11	20.02	19.93	19.84	19.74
20.04	19.95	19.86	19.78	19.69	19.60	19.51	19.42	19.33
19.62	19.53	19.45	19.36	19.27	19.18	19.10	19.01	18.92
19.21	19.12	19.04	18.95	18.87	18.78	18.69	18.61	18.52



Sensitivity analysis PROPERTY VALUE

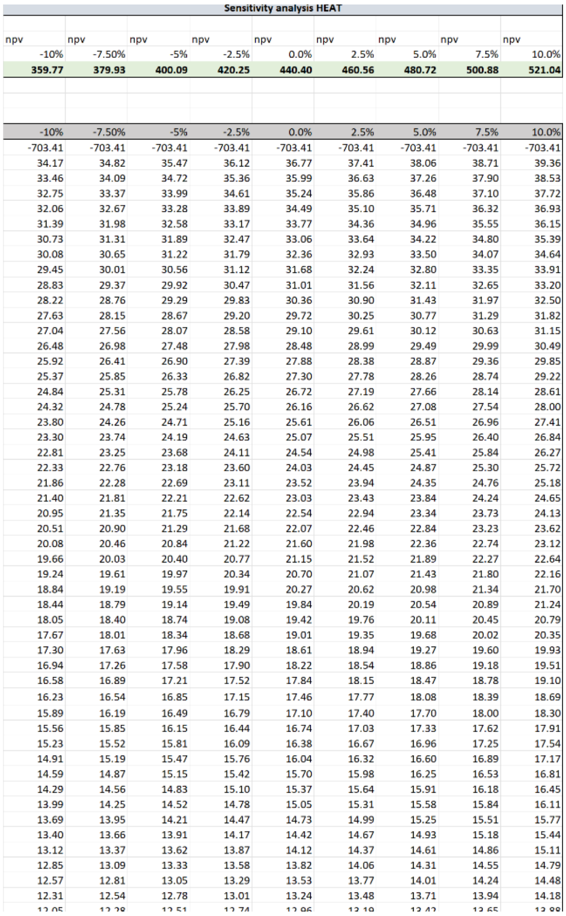
npv	npv	npv	npv	npv	npv	npv	npv	npv
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
1287.12	**1315.87**	**1344.61**	**1373.36**	**1402.10**	**1430.85**	**1459.60**	**1488.34**	**1517.09**

-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
-262.32	-262.32	-262.32	-262.32	-262.32	-262.32	-262.32	-262.32	-262.32
49.80	50.73	51.65	52.58	53.50	54.43	55.35	56.27	57.20
48.76	49.66	50.57	51.47	52.37	53.28	54.18	55.09	55.99
47.73	48.62	49.50	50.39	51.27	52.16	53.04	53.93	54.81
46.73	47.59	48.46	49.33	50.19	51.06	51.93	52.79	53.66
45.74	46.59	47.44	48.29	49.14	49.99	50.83	51.68	52.53
44.78	45.61	46.44	47.27	48.10	48.93	49.76	50.60	51.43
43.84	44.65	45.46	46.28	47.09	47.90	48.72	49.53	50.34
42.91	43.71	44.51	45.30	46.10	46.90	47.69	48.49	49.28
42.01	42.79	43.57	44.35	45.13	45.91	46.69	47.47	48.25
41.13	41.89	42.65	43.42	44.18	44.94	45.71	46.47	47.23
40.26	41.01	41.76	42.50	43.25	44.00	44.74	45.49	46.24
39.41	40.15	40.88	41.61	42.34	43.07	43.80	44.53	45.26
38.58	39.30	40.02	40.73	41.45	42.16	42.88	43.60	44.31
37.77	38.47	39.17	39.87	40.58	41.28	41.98	42.68	43.38
36.98	37.66	38.35	39.04	39.72	40.41	41.09	41.78	42.47
36.20	36.87	37.54	38.21	38.89	39.56	40.23	40.90	41.57
35.44	36.09	36.75	37.41	38.07	38.72	39.38	40.04	40.70
34.69	35.33	35.98	36.62	37.27	37.91	38.55	39.20	39.84
33.96	34.59	35.22	35.85	36.48	37.11	37.74	38.37	39.00
33.25	33.86	34.48	35.10	35.71	36.33	36.95	37.56	38.18
32.55	33.15	33.75	34.36	34.96	35.57	36.17	36.77	37.38
31.86	32.45	33.04	33.63	34.23	34.82	35.41	36.00	36.59
31.19	31.77	32.35	32.93	33.51	34.08	34.66	35.24	35.82
30.53	31.10	31.67	32.23	32.80	33.37	33.93	34.50	35.07
29.89	30.45	31.00	31.56	32.11	32.66	33.22	33.77	34.33
29.26	29.81	30.35	30.89	31.43	31.98	32.52	33.06	33.61
28.65	29.18	29.71	30.24	30.77	31.30	31.84	32.37	32.90
28.04	28.56	29.08	29.60	30.12	30.65	31.17	31.69	32.21
27.45	27.96	28.47	28.98	29.49	30.00	30.51	31.02	31.53
26.88	27.37	27.87	28.37	28.87	29.37	29.87	30.37	30.86
26.31	26.80	27.29	27.77	28.26	28.75	29.24	29.73	30.21
25.76	26.23	26.71	27.19	27.67	28.15	28.62	29.10	29.58
25.21	25.68	26.15	26.62	27.09	27.55	28.02	28.49	28.96
24.68	25.14	25.60	26.06	26.52	26.97	27.43	27.89	28.35
24.16	24.61	25.06	25.51	25.96	26.41	26.85	27.30	27.75
23.66	24.09	24.53	24.97	25.41	25.85	26.29	26.73	27.17
23.16	23.59	24.02	24.45	24.88	25.31	25.74	26.16	26.59
22.67	23.09	23.51	23.93	24.35	24.77	25.19	25.61	26.03
22.19	22.60	23.02	23.43	23.84	24.25	24.66	25.08	25.49
21.73	22.13	22.53	22.94	23.34	23.74	24.14	24.55	24.95
21.27	21.66	22.06	22.45	22.85	23.24	23.64	24.03	24.43
20.82	21.21	21.59	21.98	22.37	22.75	23.14	23.52	23.91
20.38	20.76	21.14	21.52	21.90	22.27	22.65	23.03	23.41
19.95	20.32	20.69	21.06	21.43	21.80	22.17	22.55	22.92
19.53	19.90	20.26	20.62	20.98	21.35	21.71	22.07	22.43
19.12	19.48	19.83	20.19	20.54	20.90	21.25	21.61	21.96
18.72	19.07	19.41	19.76	20.11	20.46	20.80	21.15	21.50
18.33	18.67	19.01	19.35	19.69	20.03	20.37	20.71	21.05
17.94	18.27	18.61	18.94	19.27	19.60	19.94	20.27	20.60
17.56	17.89	18.21	18.54	18.87	19.19	19.52	19.84	20.17



Making a comparison of the tree variable that were evaluated it is clear to see that rent has the most impact on the same deviation, because it has the steepest line.

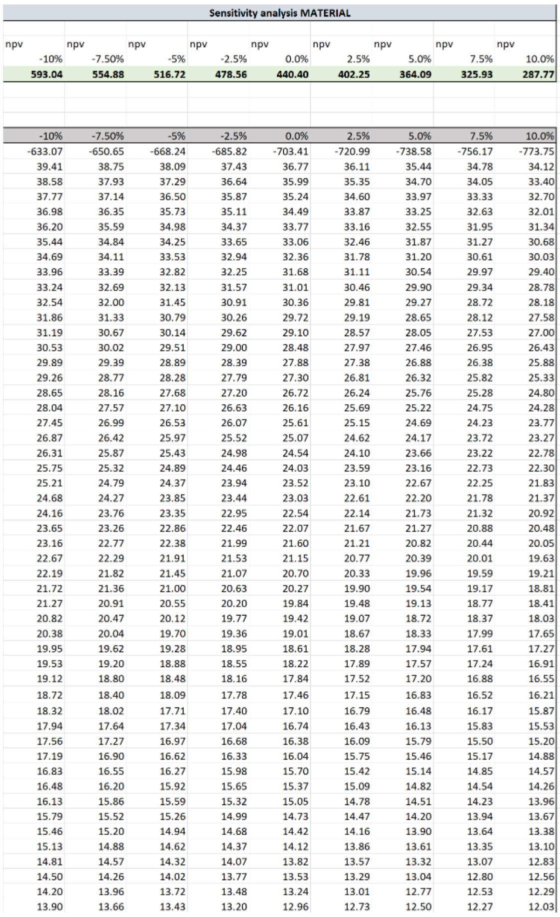
Green façade - Traditional



Sensitivity analysis HEAT

npv	npv	npv	npv	npv	npv	npv	npv	npv
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
359.77	**379.93**	**400.09**	**420.25**	**440.40**	**460.56**	**480.72**	**500.88**	**521.04**

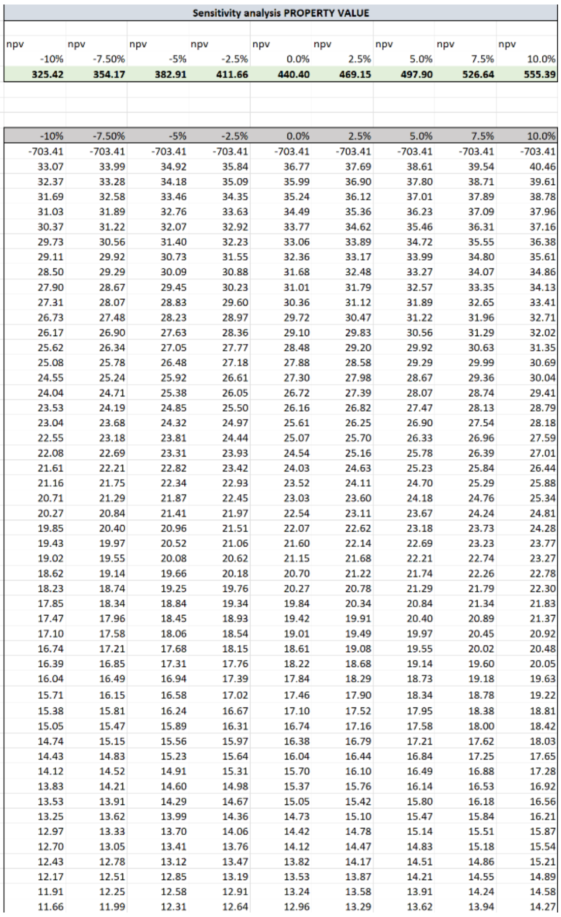
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
-703.41	-703.41	-703.41	-703.41	-703.41	-703.41	-703.41	-703.41	-703.41
34.17	34.82	35.47	36.12	36.77	37.41	38.06	38.71	39.36
33.46	34.09	34.72	35.36	35.99	36.63	37.26	37.90	38.53
32.75	33.37	33.99	34.61	35.24	35.86	36.48	37.10	37.72
32.06	32.67	33.28	33.89	34.49	35.10	35.71	36.32	36.93
31.39	31.98	32.58	33.17	33.77	34.36	34.96	35.55	36.15
30.73	31.31	31.89	32.47	33.06	33.64	34.22	34.80	35.39
30.08	30.65	31.22	31.79	32.36	32.93	33.50	34.07	34.64
29.45	30.01	30.56	31.12	31.68	32.24	32.80	33.35	33.91
28.83	29.37	29.92	30.47	31.01	31.56	32.11	32.65	33.20
28.22	28.76	29.29	29.83	30.36	30.90	31.43	31.97	32.50
27.63	28.15	28.67	29.20	29.72	30.25	30.77	31.29	31.82
27.04	27.56	28.07	28.58	29.10	29.61	30.12	30.63	31.15
26.48	26.98	27.48	27.98	28.48	28.99	29.49	29.99	30.49
25.92	26.41	26.90	27.39	27.88	28.38	28.87	29.36	29.85
25.37	25.85	26.33	26.82	27.30	27.78	28.26	28.74	29.22
24.84	25.31	25.78	26.25	26.72	27.19	27.66	28.14	28.61
24.32	24.78	25.24	25.70	26.16	26.62	27.08	27.54	28.00
23.80	24.26	24.71	25.16	25.61	26.06	26.51	26.96	27.41
23.30	23.74	24.19	24.63	25.07	25.51	25.95	26.40	26.84
22.81	23.25	23.68	24.11	24.54	24.98	25.41	25.84	26.27
22.33	22.76	23.18	23.60	24.03	24.45	24.87	25.30	25.72
21.86	22.28	22.69	23.11	23.52	23.94	24.35	24.76	25.18
21.40	21.81	22.21	22.62	23.03	23.43	23.84	24.24	24.65
20.95	21.35	21.75	22.14	22.54	22.94	23.34	23.73	24.13
20.51	20.90	21.29	21.68	22.07	22.46	22.84	23.23	23.62
20.08	20.46	20.84	21.22	21.60	21.98	22.36	22.74	23.12
19.66	20.03	20.40	20.77	21.15	21.52	21.89	22.27	22.64
19.24	19.61	19.97	20.34	20.70	21.07	21.43	21.80	22.16
18.84	19.19	19.55	19.91	20.27	20.62	20.98	21.34	21.70
18.44	18.79	19.14	19.49	19.84	20.19	20.54	20.89	21.24
18.05	18.40	18.74	19.08	19.42	19.76	20.11	20.45	20.79
17.67	18.01	18.34	18.68	19.01	19.35	19.68	20.02	20.35
17.30	17.63	17.96	18.29	18.61	18.94	19.27	19.60	19.93
16.94	17.26	17.58	17.90	18.22	18.54	18.86	19.18	19.51
16.58	16.89	17.21	17.52	17.84	18.15	18.47	18.78	19.10
16.23	16.54	16.85	17.15	17.46	17.77	18.08	18.39	18.69
15.89	16.19	16.49	16.79	17.10	17.40	17.70	18.00	18.30
15.56	15.85	16.15	16.44	16.74	17.03	17.33	17.62	17.91
15.23	15.52	15.81	16.09	16.38	16.67	16.96	17.25	17.54
14.91	15.19	15.47	15.76	16.04	16.32	16.60	16.89	17.17
14.59	14.87	15.15	15.42	15.70	15.98	16.25	16.53	16.81
14.29	14.56	14.83	15.10	15.37	15.64	15.91	16.18	16.45
13.99	14.25	14.52	14.78	15.05	15.31	15.58	15.84	16.11
13.69	13.95	14.21	14.47	14.73	14.99	15.25	15.51	15.77
13.40	13.66	13.91	14.17	14.42	14.67	14.93	15.18	15.44
13.12	13.37	13.62	13.87	14.12	14.37	14.61	14.86	15.11
12.85	13.09	13.33	13.58	13.82	14.06	14.31	14.55	14.79
12.57	12.81	13.05	13.29	13.53	13.77	14.01	14.24	14.48
12.31	12.54	12.78	13.01	13.24	13.48	13.71	13.94	14.18



Sensitivity analysis MATERIAL

npv	npv	npv	npv	npv	npv	npv	npv	npv
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
593.04	**554.88**	**516.72**	**478.56**	**440.40**	**402.25**	**364.09**	**325.93**	**287.77**

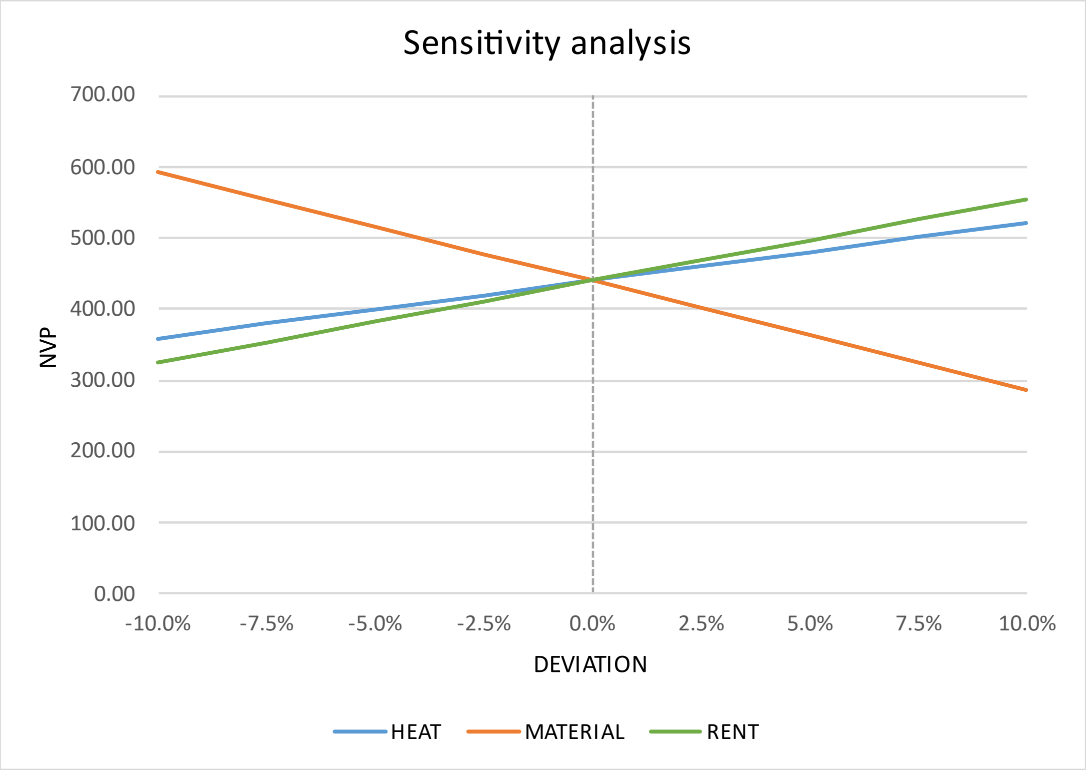
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
-633.07	-650.65	-668.24	-685.82	-703.41	-720.99	-738.58	-756.17	-773.75
39.41	38.75	38.09	37.43	36.77	36.11	35.44	34.78	34.12
38.58	37.93	37.29	36.64	35.99	35.35	34.70	34.05	33.40
37.77	37.14	36.50	35.87	35.24	34.60	33.97	33.33	32.70
36.98	36.35	35.73	35.11	34.49	33.87	33.25	32.63	32.01
36.20	35.59	34.98	34.37	33.77	33.16	32.55	31.95	31.34
35.44	34.84	34.25	33.65	33.06	32.46	31.87	31.27	30.68
34.69	34.11	33.53	32.94	32.36	31.78	31.20	30.61	30.03
33.96	33.39	32.82	32.25	31.68	31.11	30.54	29.97	29.40
33.24	32.69	32.13	31.57	31.01	30.46	29.90	29.34	28.78
32.54	32.00	31.45	30.91	30.36	29.81	29.27	28.72	28.18
31.86	31.33	30.79	30.26	29.72	29.19	28.65	28.12	27.58
31.19	30.67	30.14	29.62	29.10	28.57	28.05	27.53	27.00
30.53	30.02	29.51	29.00	28.48	27.97	27.46	26.95	26.43
29.89	29.39	28.89	28.39	27.88	27.38	26.88	26.38	25.88
29.26	28.77	28.28	27.79	27.30	26.81	26.32	25.82	25.33
28.65	28.16	27.68	27.20	26.72	26.24	25.76	25.28	24.80
28.04	27.57	27.10	26.63	26.16	25.69	25.22	24.75	24.28
27.45	26.99	26.53	26.07	25.61	25.15	24.69	24.23	23.77
26.87	26.42	25.97	25.52	25.07	24.62	24.17	23.72	23.27
26.31	25.87	25.43	24.98	24.54	24.10	23.66	23.22	22.78
25.75	25.32	24.89	24.46	24.03	23.59	23.16	22.73	22.30
25.21	24.79	24.37	23.94	23.52	23.10	22.67	22.25	21.83
24.68	24.27	23.85	23.44	23.03	22.61	22.20	21.78	21.37
24.16	23.76	23.35	22.95	22.54	22.14	21.73	21.32	20.92
23.65	23.26	22.86	22.46	22.07	21.67	21.27	20.88	20.48
23.16	22.77	22.38	21.99	21.60	21.21	20.82	20.44	20.05
22.67	22.29	21.91	21.53	21.15	20.77	20.39	20.01	19.63
22.19	21.82	21.45	21.07	20.70	20.33	19.96	19.59	19.21
21.72	21.36	21.00	20.63	20.27	19.90	19.54	19.17	18.81
21.27	20.91	20.55	20.20	19.84	19.48	19.13	18.77	18.41
20.82	20.47	20.12	19.77	19.42	19.07	18.72	18.37	18.03
20.38	20.04	19.70	19.36	19.01	18.67	18.33	17.99	17.65
19.95	19.62	19.28	18.95	18.61	18.28	17.94	17.61	17.27
19.53	19.20	18.88	18.55	18.22	17.89	17.57	17.24	16.91
19.12	18.80	18.48	18.16	17.84	17.52	17.20	16.88	16.55
18.72	18.40	18.09	17.78	17.46	17.15	16.83	16.52	16.21
18.32	18.02	17.71	17.40	17.10	16.79	16.48	16.17	15.87
17.94	17.64	17.34	17.04	16.74	16.43	16.13	15.83	15.53
17.56	17.27	16.97	16.68	16.38	16.09	15.79	15.50	15.20
17.19	16.90	16.62	16.33	16.04	15.75	15.46	15.17	14.88
16.83	16.55	16.27	15.98	15.70	15.42	15.14	14.85	14.57
16.48	16.20	15.92	15.65	15.37	15.09	14.82	14.54	14.26
16.13	15.86	15.59	15.32	15.05	14.78	14.51	14.23	13.96
15.79	15.52	15.26	14.99	14.73	14.47	14.20	13.94	13.67
15.46	15.20	14.94	14.68	14.42	14.16	13.90	13.64	13.38
15.13	14.88	14.62	14.37	14.12	13.86	13.61	13.35	13.10
14.81	14.57	14.32	14.07	13.82	13.57	13.32	13.07	12.83
14.50	14.26	14.02	13.77	13.53	13.29	13.04	12.80	12.56
14.20	13.96	13.72	13.48	13.24	13.01	12.77	12.53	12.29
13.90	13.66	13.43	13.20	12.96	12.73	12.50	12.27	12.03



Sensitivity analysis PROPERTY VALUE

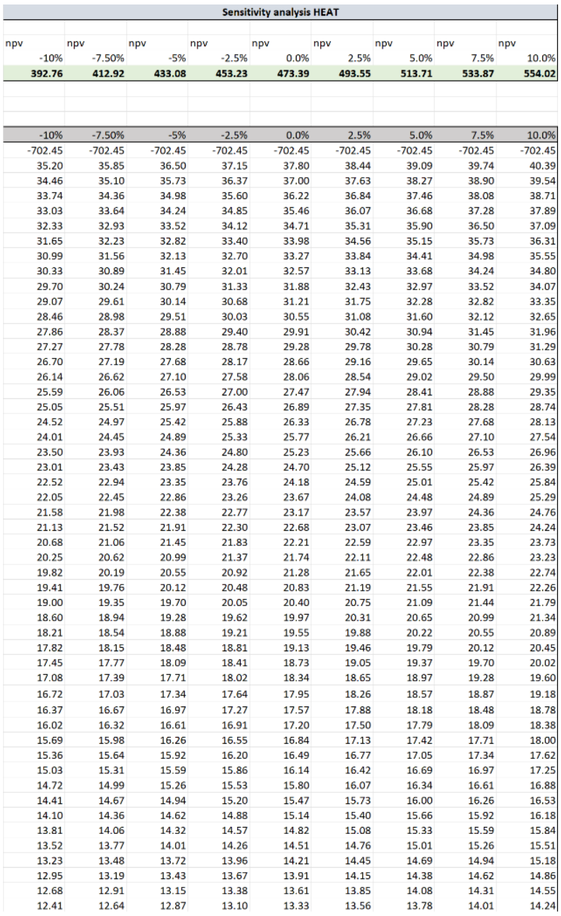
npv	npv	npv	npv	npv	npv	npv	npv	npv
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
325.42	**354.17**	**382.91**	**411.66**	**440.40**	**469.15**	**497.90**	**526.64**	**555.39**

-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
-703.41	-703.41	-703.41	-703.41	-703.41	-703.41	-703.41	-703.41	-703.41
33.07	33.99	34.92	35.84	36.77	37.69	38.61	39.54	40.46
32.37	33.28	34.18	35.09	35.99	36.90	37.80	38.71	39.61
31.69	32.58	33.46	34.35	35.24	36.12	37.01	37.89	38.78
31.03	31.89	32.76	33.63	34.49	35.36	36.23	37.09	37.96
30.37	31.22	32.07	32.92	33.77	34.62	35.46	36.31	37.16
29.73	30.56	31.40	32.23	33.06	33.89	34.72	35.55	36.38
29.11	29.92	30.73	31.55	32.36	33.17	33.99	34.80	35.61
28.50	29.29	30.09	30.88	31.68	32.48	33.27	34.07	34.86
27.90	28.67	29.45	30.23	31.01	31.79	32.57	33.35	34.13
27.31	28.07	28.83	29.60	30.36	31.12	31.89	32.65	33.41
26.73	27.48	28.23	28.97	29.72	30.47	31.22	31.96	32.71
26.17	26.90	27.63	28.36	29.10	29.83	30.56	31.29	32.02
25.62	26.34	27.05	27.77	28.48	29.20	29.92	30.63	31.35
25.08	25.78	26.48	27.18	27.88	28.58	29.29	29.99	30.69
24.55	25.24	25.92	26.61	27.30	27.98	28.67	29.36	30.04
24.04	24.71	25.38	26.05	26.72	27.39	28.07	28.74	29.41
23.53	24.19	24.85	25.50	26.16	26.82	27.47	28.13	28.79
23.04	23.68	24.32	24.97	25.61	26.25	26.90	27.54	28.18
22.55	23.18	23.81	24.44	25.07	25.70	26.33	26.96	27.59
22.08	22.69	23.31	23.93	24.54	25.16	25.78	26.39	27.01
21.61	22.21	22.82	23.42	24.03	24.63	25.23	25.84	26.44
21.16	21.75	22.34	22.93	23.52	24.11	24.70	25.29	25.88
20.71	21.29	21.87	22.45	23.03	23.60	24.18	24.76	25.34
20.27	20.84	21.41	21.97	22.54	23.11	23.67	24.24	24.81
19.85	20.40	20.96	21.51	22.07	22.62	23.18	23.73	24.28
19.43	19.97	20.52	21.06	21.60	22.14	22.69	23.23	23.77
19.02	19.55	20.08	20.62	21.15	21.68	22.21	22.74	23.27
18.62	19.14	19.66	20.18	20.70	21.22	21.74	22.26	22.78
18.23	18.74	19.25	19.76	20.27	20.78	21.29	21.79	22.30
17.85	18.34	18.84	19.34	19.84	20.34	20.84	21.34	21.83
17.47	17.96	18.45	18.93	19.42	19.91	20.40	20.89	21.37
17.10	17.58	18.06	18.54	19.01	19.49	19.97	20.45	20.92
16.74	17.21	17.68	18.15	18.61	19.08	19.55	20.02	20.48
16.39	16.85	17.31	17.76	18.22	18.68	19.14	19.60	20.05
16.04	16.49	16.94	17.39	17.84	18.29	18.73	19.18	19.63
15.71	16.15	16.58	17.02	17.46	17.90	18.34	18.78	19.22
15.38	15.81	16.24	16.67	17.10	17.52	17.95	18.38	18.81
15.05	15.47	15.89	16.31	16.74	17.16	17.58	18.00	18.42
14.74	15.15	15.56	15.97	16.38	16.79	17.21	17.62	18.03
14.43	14.83	15.23	15.64	16.04	16.44	16.84	17.25	17.65
14.12	14.52	14.91	15.31	15.70	16.10	16.49	16.88	17.28
13.83	14.21	14.60	14.98	15.37	15.76	16.14	16.53	16.92
13.53	13.91	14.29	14.67	15.05	15.42	15.80	16.18	16.56
13.25	13.62	13.99	14.36	14.73	15.10	15.47	15.84	16.21
12.97	13.33	13.70	14.06	14.42	14.78	15.14	15.51	15.87
12.70	13.05	13.41	13.76	14.12	14.47	14.83	15.18	15.54
12.43	12.78	13.12	13.47	13.82	14.17	14.51	14.86	15.21
12.17	12.51	12.85	13.19	13.53	13.87	14.21	14.55	14.89
11.91	12.25	12.58	12.91	13.24	13.58	13.91	14.24	14.58
11.66	11.99	12.31	12.64	12.96	13.29	13.62	13.94	14.27



Making a comparison of the tree variable that were evaluated it is clear to see that material has the most impact on the same deviation, because it has the steepest line.

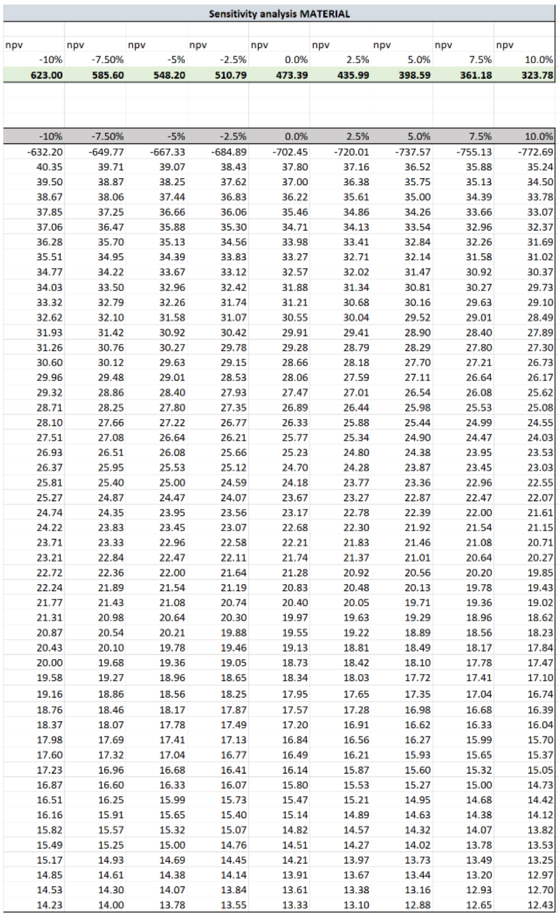
Green façade – Grey water



Sensitivity analysis HEAT

npv	npv	npv	npv	npv	npv	npv	npv	npv
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
392.76	**412.92**	**433.08**	**453.23**	**473.39**	**493.55**	**513.71**	**533.87**	**554.02**

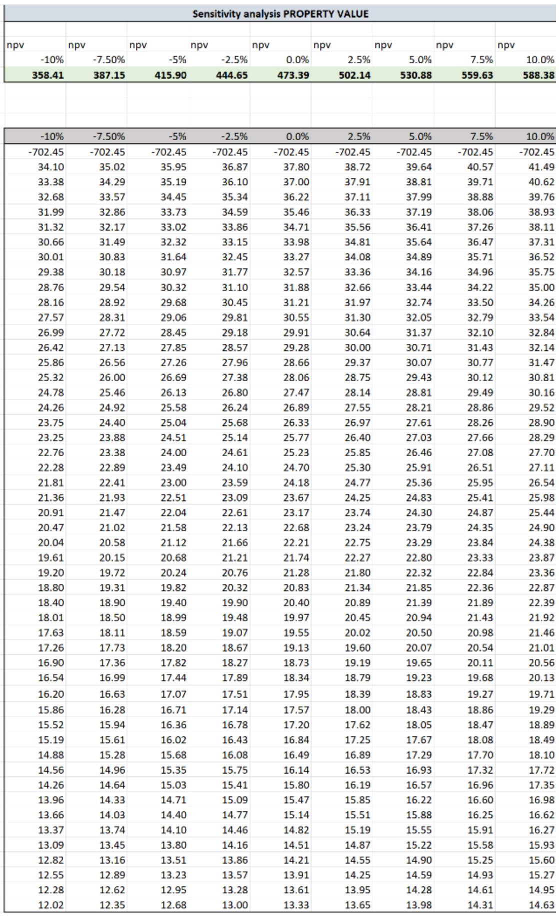
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
-702.45	-702.45	-702.45	-702.45	-702.45	-702.45	-702.45	-702.45	-702.45
35.20	35.85	36.50	37.15	37.80	38.44	39.09	39.74	40.39
34.46	35.10	35.73	36.37	37.00	37.63	38.27	38.90	39.54
33.74	34.36	34.98	35.60	36.22	36.84	37.46	38.08	38.71
33.03	33.64	34.24	34.85	35.46	36.07	36.68	37.28	37.89
32.33	32.93	33.52	34.12	34.71	35.31	35.90	36.50	37.09
31.65	32.23	32.82	33.40	33.98	34.56	35.15	35.73	36.31
30.99	31.56	32.13	32.70	33.27	33.84	34.41	34.98	35.55
30.33	30.89	31.45	32.01	32.57	33.13	33.68	34.24	34.80
29.70	30.24	30.79	31.33	31.88	32.43	32.97	33.52	34.07
29.07	29.61	30.14	30.68	31.21	31.75	32.28	32.82	33.35
28.46	28.98	29.51	30.03	30.55	31.08	31.60	32.12	32.65
27.86	28.37	28.88	29.40	29.91	30.42	30.94	31.45	31.96
27.27	27.78	28.28	28.78	29.28	29.78	30.28	30.79	31.29
26.70	27.19	27.68	28.17	28.66	29.16	29.65	30.14	30.63
26.14	26.62	27.10	27.58	28.06	28.54	29.02	29.50	29.99
25.59	26.06	26.53	27.00	27.47	27.94	28.41	28.88	29.35
25.05	25.51	25.97	26.43	26.89	27.35	27.81	28.28	28.74
24.52	24.97	25.42	25.88	26.33	26.78	27.23	27.68	28.13
24.01	24.45	24.89	25.33	25.77	26.21	26.66	27.10	27.54
23.50	23.93	24.36	24.80	25.23	25.66	26.10	26.53	26.96
23.01	23.43	23.85	24.28	24.70	25.12	25.55	25.97	26.39
22.52	22.94	23.35	23.76	24.18	24.59	25.01	25.42	25.84
22.05	22.45	22.86	23.26	23.67	24.08	24.48	24.89	25.29
21.58	21.98	22.38	22.77	23.17	23.57	23.97	24.36	24.76
21.13	21.52	21.91	22.30	22.68	23.07	23.46	23.85	24.24
20.68	21.06	21.45	21.83	22.21	22.59	22.97	23.35	23.73
20.25	20.62	20.99	21.37	21.74	22.11	22.48	22.86	23.23
19.82	20.19	20.55	20.92	21.28	21.65	22.01	22.38	22.74
19.41	19.76	20.12	20.48	20.83	21.19	21.55	21.91	22.26
19.00	19.35	19.70	20.05	20.40	20.75	21.09	21.44	21.79
18.60	18.94	19.28	19.62	19.97	20.31	20.65	20.99	21.34
18.21	18.54	18.88	19.21	19.55	19.88	20.22	20.55	20.89
17.82	18.15	18.48	18.81	19.13	19.46	19.79	20.12	20.45
17.45	17.77	18.09	18.41	18.73	19.05	19.37	19.70	20.02
17.08	17.39	17.71	18.02	18.34	18.65	18.97	19.28	19.60
16.72	17.03	17.34	17.64	17.95	18.26	18.57	18.87	19.18
16.37	16.67	16.97	17.27	17.57	17.88	18.18	18.48	18.78
16.02	16.32	16.61	16.91	17.20	17.50	17.79	18.09	18.38
15.69	15.98	16.26	16.55	16.84	17.13	17.42	17.71	18.00
15.36	15.64	15.92	16.20	16.49	16.77	17.05	17.34	17.62
15.03	15.31	15.59	15.86	16.14	16.42	16.69	16.97	17.25
14.72	14.99	15.26	15.53	15.80	16.07	16.34	16.61	16.88
14.41	14.67	14.94	15.20	15.47	15.73	16.00	16.26	16.53
14.10	14.36	14.62	14.88	15.14	15.40	15.66	15.92	16.18
13.81	14.06	14.32	14.57	14.82	15.08	15.33	15.59	15.84
13.52	13.77	14.01	14.26	14.51	14.76	15.01	15.26	15.51
13.23	13.48	13.72	13.96	14.21	14.45	14.69	14.94	15.18
12.95	13.19	13.43	13.67	13.91	14.15	14.38	14.62	14.86
12.68	12.91	13.15	13.38	13.61	13.85	14.08	14.31	14.55
12.41	12.64	12.87	13.10	13.33	13.56	13.78	14.01	14.24



Sensitivity analysis MATERIAL

npv	npv	npv	npv	npv	npv	npv	npv	npv
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
623.00	**585.60**	**548.20**	**510.79**	**473.39**	**435.99**	**398.59**	**361.18**	**323.78**

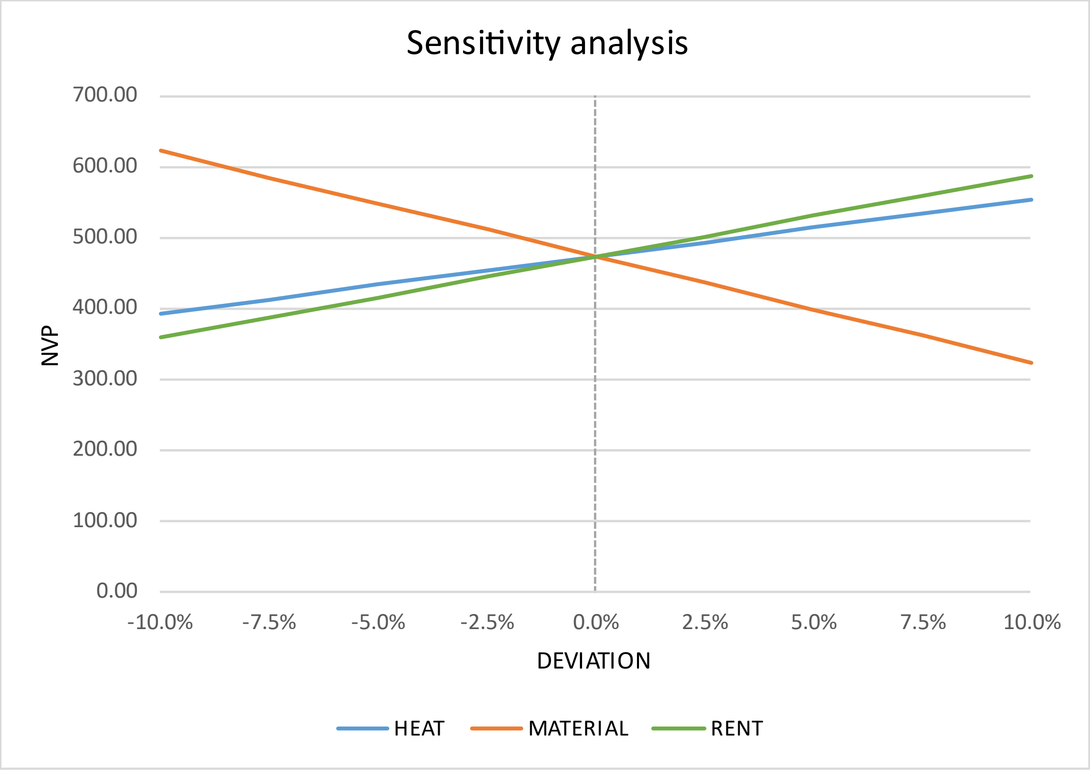
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
-632.20	-649.77	-667.33	-684.89	-702.45	-720.01	-737.57	-755.13	-772.69
40.35	39.71	39.07	38.43	37.80	37.16	36.52	35.88	35.24
39.50	38.87	38.25	37.62	37.00	36.38	35.75	35.13	34.50
38.67	38.06	37.44	36.83	36.22	35.61	35.00	34.39	33.78
37.85	37.25	36.66	36.06	35.46	34.86	34.26	33.66	33.07
37.06	36.47	35.88	35.30	34.71	34.13	33.54	32.96	32.37
36.28	35.70	35.13	34.56	33.98	33.41	32.84	32.26	31.69
35.51	34.95	34.39	33.83	33.27	32.71	32.14	31.58	31.02
34.77	34.22	33.67	33.12	32.57	32.02	31.47	30.92	30.37
34.03	33.50	32.96	32.42	31.88	31.34	30.81	30.27	29.73
33.32	32.79	32.26	31.74	31.21	30.68	30.16	29.63	29.10
32.62	32.10	31.58	31.07	30.55	30.04	29.52	29.01	28.49
31.93	31.42	30.92	30.42	29.91	29.41	28.90	28.40	27.89
31.26	30.76	30.27	29.78	29.28	28.79	28.29	27.80	27.30
30.60	30.12	29.63	29.15	28.66	28.18	27.70	27.21	26.73
29.96	29.48	29.01	28.53	28.06	27.59	27.11	26.64	26.17
29.32	28.86	28.40	27.93	27.47	27.01	26.54	26.08	25.62
28.71	28.25	27.80	27.35	26.89	26.44	25.98	25.53	25.08
28.10	27.66	27.22	26.77	26.33	25.88	25.44	24.99	24.55
27.51	27.08	26.64	26.21	25.77	25.34	24.90	24.47	24.03
26.93	26.51	26.08	25.66	25.23	24.80	24.38	23.95	23.53
26.37	25.95	25.53	25.12	24.70	24.28	23.87	23.45	23.03
25.81	25.40	25.00	24.59	24.18	23.77	23.36	22.96	22.55
25.27	24.87	24.47	24.07	23.67	23.27	22.87	22.47	22.07
24.74	24.35	23.95	23.56	23.17	22.78	22.39	22.00	21.61
24.22	23.83	23.45	23.07	22.68	22.30	21.92	21.54	21.15
23.71	23.33	22.96	22.58	22.21	21.83	21.46	21.08	20.71
23.21	22.84	22.47	22.11	21.74	21.37	21.01	20.64	20.27
22.72	22.36	22.00	21.64	21.28	20.92	20.56	20.20	19.85
22.24	21.89	21.54	21.19	20.83	20.48	20.13	19.78	19.43
21.77	21.43	21.08	20.74	20.40	20.05	19.71	19.36	19.02
21.31	20.98	20.64	20.30	19.97	19.63	19.29	18.96	18.62
20.87	20.54	20.21	19.88	19.55	19.22	18.89	18.56	18.23
20.43	20.10	19.78	19.46	19.13	18.81	18.49	18.17	17.84
20.00	19.68	19.36	19.05	18.73	18.42	18.10	17.78	17.47
19.58	19.27	18.96	18.65	18.34	18.03	17.72	17.41	17.10
19.16	18.86	18.56	18.25	17.95	17.65	17.35	17.04	16.74
18.76	18.46	18.17	17.87	17.57	17.28	16.98	16.68	16.39
18.37	18.07	17.78	17.49	17.20	16.91	16.62	16.33	16.04
17.98	17.69	17.41	17.13	16.84	16.56	16.27	15.99	15.70
17.60	17.32	17.04	16.77	16.49	16.21	15.93	15.65	15.37
17.23	16.96	16.68	16.41	16.14	15.87	15.60	15.32	15.05
16.87	16.60	16.33	16.07	15.80	15.53	15.27	15.00	14.73
16.51	16.25	15.99	15.73	15.47	15.21	14.95	14.68	14.42
16.16	15.91	15.65	15.40	15.14	14.89	14.63	14.38	14.12
15.82	15.57	15.32	15.07	14.82	14.57	14.32	14.07	13.82
15.49	15.25	15.00	14.76	14.51	14.27	14.02	13.78	13.53
15.17	14.93	14.69	14.45	14.21	13.97	13.73	13.49	13.25
14.85	14.61	14.38	14.14	13.91	13.67	13.44	13.20	12.97
14.53	14.30	14.07	13.84	13.61	13.38	13.16	12.93	12.70
14.23	14.00	13.78	13.55	13.33	13.10	12.88	12.65	12.43



Sensitivity analysis PROPERTY VALUE

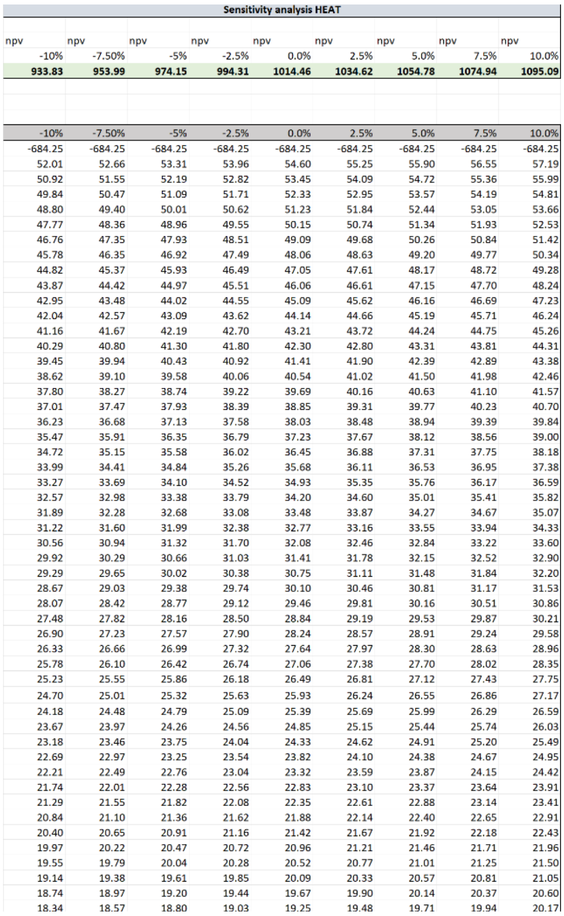
npv	npv	npv	npv	npv	npv	npv	npv	npv
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
358.41	**387.15**	**415.90**	**444.65**	**473.39**	**502.14**	**530.88**	**559.63**	**588.38**

-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
-702.45	-702.45	-702.45	-702.45	-702.45	-702.45	-702.45	-702.45	-702.45
34.10	35.02	35.95	36.87	37.80	38.72	39.64	40.57	41.49
33.38	34.29	35.19	36.10	37.00	37.91	38.81	39.71	40.62
32.68	33.57	34.45	35.34	36.22	37.11	37.99	38.88	39.76
31.99	32.86	33.73	34.59	35.46	36.33	37.19	38.06	38.93
31.32	32.17	33.02	33.86	34.71	35.56	36.41	37.26	38.11
30.66	31.49	32.32	33.15	33.98	34.81	35.64	36.47	37.31
30.01	30.83	31.64	32.45	33.27	34.08	34.89	35.71	36.52
29.38	30.18	30.97	31.77	32.57	33.36	34.16	34.96	35.75
28.76	29.54	30.32	31.10	31.88	32.66	33.44	34.22	35.00
28.16	28.92	29.68	30.45	31.21	31.97	32.74	33.50	34.26
27.57	28.31	29.06	29.81	30.55	31.30	32.05	32.79	33.54
26.99	27.72	28.45	29.18	29.91	30.64	31.37	32.10	32.84
26.42	27.13	27.85	28.57	29.28	30.00	30.71	31.43	32.14
25.86	26.56	27.26	27.96	28.66	29.37	30.07	30.77	31.47
25.32	26.00	26.69	27.38	28.06	28.75	29.43	30.12	30.81
24.78	25.46	26.13	26.80	27.47	28.14	28.81	29.49	30.16
24.26	24.92	25.58	26.24	26.89	27.55	28.21	28.86	29.52
23.75	24.40	25.04	25.68	26.33	26.97	27.61	28.26	28.90
23.25	23.88	24.51	25.14	25.77	26.40	27.03	27.66	28.29
22.76	23.38	24.00	24.61	25.23	25.85	26.46	27.08	27.70
22.28	22.89	23.49	24.10	24.70	25.30	25.91	26.51	27.11
21.81	22.41	23.00	23.59	24.18	24.77	25.36	25.95	26.54
21.36	21.93	22.51	23.09	23.67	24.25	24.83	25.41	25.98
20.91	21.47	22.04	22.61	23.17	23.74	24.30	24.87	25.44
20.47	21.02	21.58	22.13	22.68	23.24	23.79	24.35	24.90
20.04	20.58	21.12	21.66	22.21	22.75	23.29	23.84	24.38
19.61	20.15	20.68	21.21	21.74	22.27	22.80	23.33	23.87
19.20	19.72	20.24	20.76	21.28	21.80	22.32	22.84	23.36
18.80	19.31	19.82	20.32	20.83	21.34	21.85	22.36	22.87
18.40	18.90	19.40	19.90	20.40	20.89	21.39	21.89	22.39
18.01	18.50	18.99	19.48	19.97	20.45	20.94	21.43	21.92
17.63	18.11	18.59	19.07	19.55	20.02	20.50	20.98	21.46
17.26	17.73	18.20	18.67	19.13	19.60	20.07	20.54	21.01
16.90	17.36	17.82	18.27	18.73	19.19	19.65	20.11	20.56
16.54	16.99	17.44	17.89	18.34	18.79	19.23	19.68	20.13
16.20	16.63	17.07	17.51	17.95	18.39	18.83	19.27	19.71
15.86	16.28	16.71	17.14	17.57	18.00	18.43	18.86	19.29
15.52	15.94	16.36	16.78	17.20	17.62	18.05	18.47	18.89
15.19	15.61	16.02	16.43	16.84	17.25	17.67	18.08	18.49
14.88	15.28	15.68	16.08	16.49	16.89	17.29	17.70	18.10
14.56	14.96	15.35	15.75	16.14	16.53	16.93	17.32	17.72
14.26	14.64	15.03	15.41	15.80	16.19	16.57	16.96	17.35
13.96	14.33	14.71	15.09	15.47	15.85	16.22	16.60	16.98
13.66	14.03	14.40	14.77	15.14	15.51	15.88	16.25	16.62
13.37	13.74	14.10	14.46	14.82	15.19	15.55	15.91	16.27
13.09	13.45	13.80	14.16	14.51	14.87	15.22	15.58	15.93
12.82	13.16	13.51	13.86	14.21	14.55	14.90	15.25	15.60
12.55	12.89	13.23	13.57	13.91	14.25	14.59	14.93	15.27
12.28	12.62	12.95	13.28	13.61	13.95	14.28	14.61	14.95
12.02	12.35	12.68	13.00	13.33	13.65	13.98	14.31	14.63



Making a comparison of the tree variable that were evaluated it is clear to see that material has the most impact on the same deviation, because it has the steepest line.

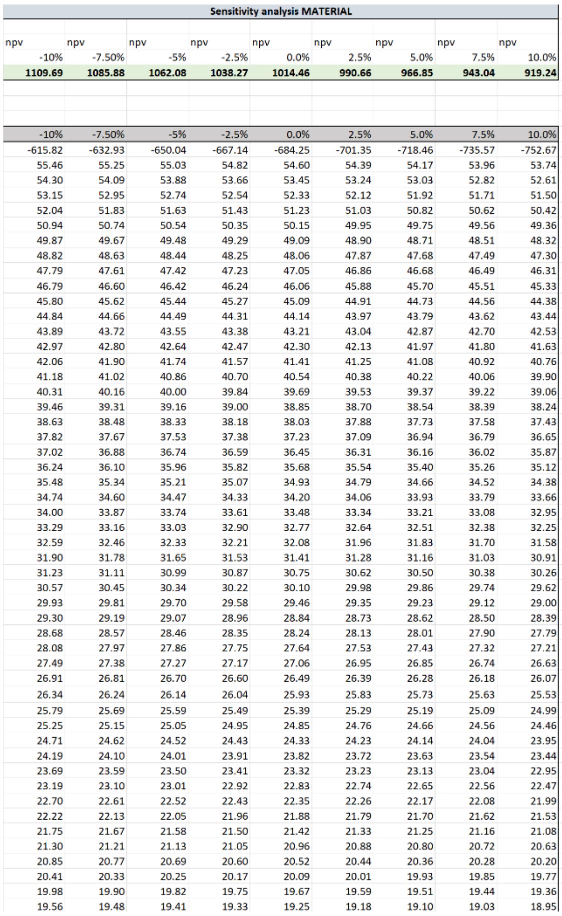
Green façade – Moss



Sensitivity analysis HEAT

npv	npv	npv	npv	npv	npv	npv	npv	npv
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
933.83	**953.99**	**974.15**	**994.31**	**1014.46**	**1034.62**	**1054.78**	**1074.94**	**1095.09**

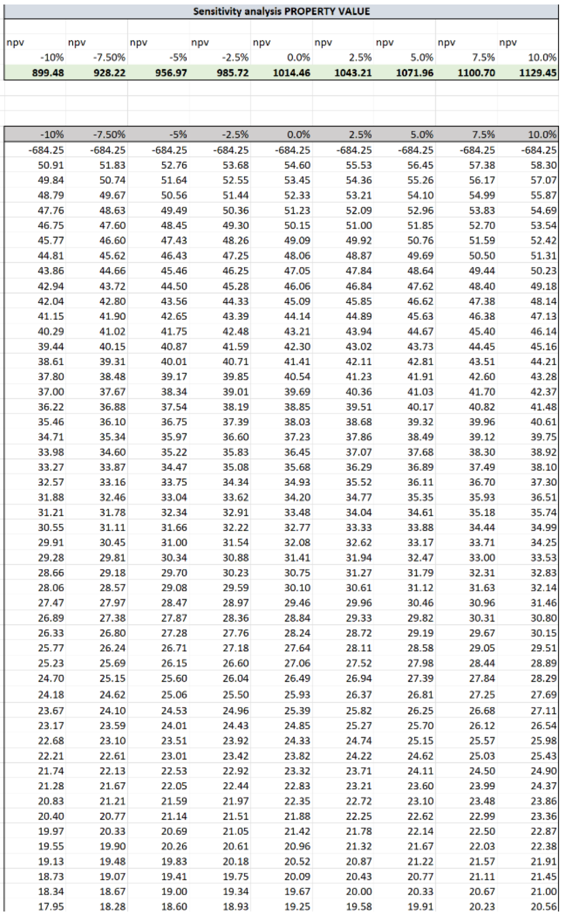
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
-684.25	-684.25	-684.25	-684.25	-684.25	-684.25	-684.25	-684.25	-684.25
52.01	52.66	53.31	53.96	54.60	55.25	55.90	56.55	57.19
50.92	51.55	52.19	52.82	53.45	54.09	54.72	55.36	55.99
49.84	50.47	51.09	51.71	52.33	52.95	53.57	54.19	54.81
48.80	49.40	50.01	50.62	51.23	51.84	52.44	53.05	53.66
47.77	48.36	48.96	49.55	50.15	50.74	51.34	51.93	52.53
46.76	47.35	47.93	48.51	49.09	49.68	50.26	50.84	51.42
45.78	46.35	46.92	47.49	48.06	48.63	49.20	49.77	50.34
44.82	45.37	45.93	46.49	47.05	47.61	48.17	48.72	49.28
43.87	44.42	44.97	45.51	46.06	46.61	47.15	47.70	48.24
42.95	43.48	44.02	44.55	45.09	45.62	46.16	46.69	47.23
42.04	42.57	43.09	43.62	44.14	44.66	45.19	45.71	46.24
41.16	41.67	42.19	42.70	43.21	43.72	44.24	44.75	45.26
40.29	40.80	41.30	41.80	42.30	42.80	43.31	43.81	44.31
39.45	39.94	40.43	40.92	41.41	41.90	42.39	42.89	43.38
38.62	39.10	39.58	40.06	40.54	41.02	41.50	41.98	42.46
37.80	38.27	38.74	39.22	39.69	40.16	40.63	41.10	41.57
37.01	37.47	37.93	38.39	38.85	39.31	39.77	40.23	40.70
36.23	36.68	37.13	37.58	38.03	38.48	38.94	39.39	39.84
35.47	35.91	36.35	36.79	37.23	37.67	38.12	38.56	39.00
34.72	35.15	35.58	36.02	36.45	36.88	37.31	37.75	38.18
33.99	34.41	34.84	35.26	35.68	36.11	36.53	36.95	37.38
33.27	33.69	34.10	34.52	34.93	35.35	35.76	36.17	36.59
32.57	32.98	33.38	33.79	34.20	34.60	35.01	35.41	35.82
31.89	32.28	32.68	33.08	33.48	33.87	34.27	34.67	35.07
31.22	31.60	31.99	32.38	32.77	33.16	33.55	33.94	34.33
30.56	30.94	31.32	31.70	32.08	32.46	32.84	33.22	33.60
29.92	30.29	30.66	31.03	31.41	31.78	32.15	32.52	32.90
29.29	29.65	30.02	30.38	30.75	31.11	31.48	31.84	32.20
28.67	29.03	29.38	29.74	30.10	30.46	30.81	31.17	31.53
28.07	28.42	28.77	29.12	29.46	29.81	30.16	30.51	30.86
27.48	27.82	28.16	28.50	28.84	29.19	29.53	29.87	30.21
26.90	27.23	27.57	27.90	28.24	28.57	28.91	29.24	29.58
26.33	26.66	26.99	27.32	27.64	27.97	28.30	28.63	28.96
25.78	26.10	26.42	26.74	27.06	27.38	27.70	28.02	28.35
25.23	25.55	25.86	26.18	26.49	26.81	27.12	27.43	27.75
24.70	25.01	25.32	25.63	25.93	26.24	26.55	26.86	27.17
24.18	24.48	24.79	25.09	25.39	25.69	25.99	26.29	26.59
23.67	23.97	24.26	24.56	24.85	25.15	25.44	25.74	26.03
23.18	23.46	23.75	24.04	24.33	24.62	24.91	25.20	25.49
22.69	22.97	23.25	23.54	23.82	24.10	24.38	24.67	24.95
22.21	22.49	22.76	23.04	23.32	23.59	23.87	24.15	24.42
21.74	22.01	22.28	22.56	22.83	23.10	23.37	23.64	23.91
21.29	21.55	21.82	22.08	22.35	22.61	22.88	23.14	23.41
20.84	21.10	21.36	21.62	21.88	22.14	22.40	22.65	22.91
20.40	20.65	20.91	21.16	21.42	21.67	21.92	22.18	22.43
19.97	20.22	20.47	20.72	20.96	21.21	21.46	21.71	21.96
19.55	19.79	20.04	20.28	20.52	20.77	21.01	21.25	21.50
19.14	19.38	19.61	19.85	20.09	20.33	20.57	20.81	21.05
18.74	18.97	19.20	19.44	19.67	19.90	20.14	20.37	20.60
18.34	18.57	18.80	19.03	19.25	19.48	19.71	19.94	20.17



Sensitivity analysis MATERIAL

npv	npv	npv	npv	npv	npv	npv	npv	npv
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
1109.69	**1085.88**	**1062.08**	**1038.27**	**1014.46**	**990.66**	**966.85**	**943.04**	**919.24**

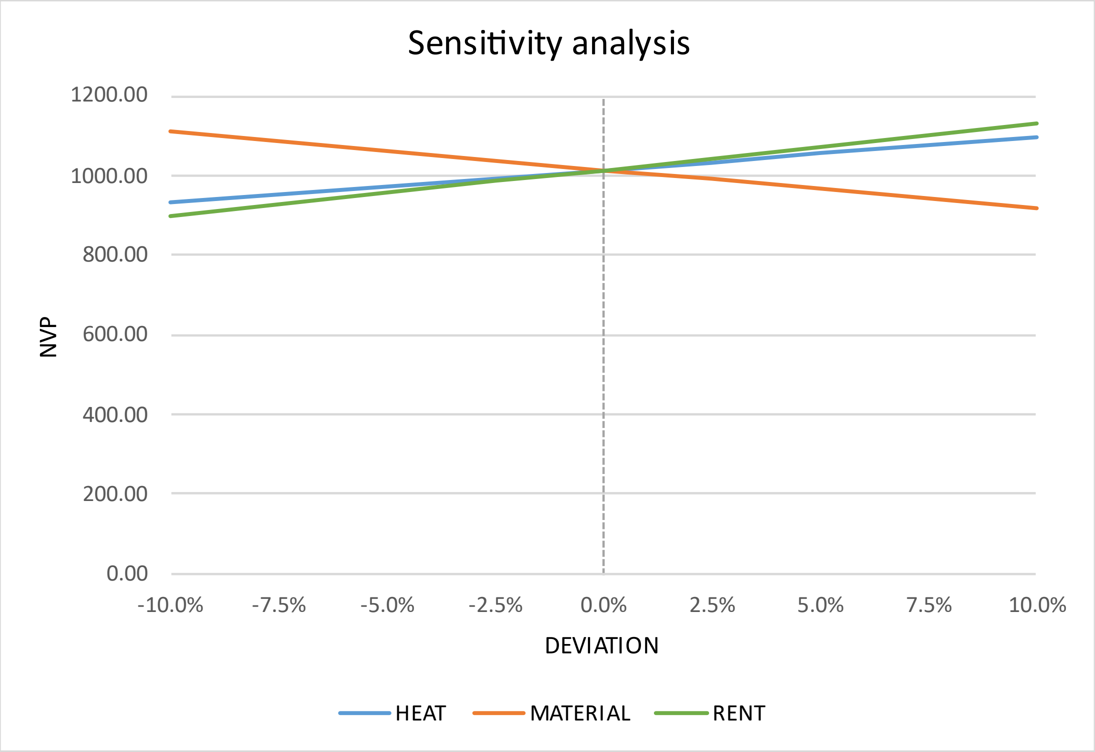
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
-615.82	-632.93	-650.04	-667.14	-684.25	-701.35	-718.46	-735.57	-752.67
55.46	55.25	55.03	54.82	54.60	54.39	54.17	53.96	53.74
54.30	54.09	53.88	53.66	53.45	53.24	53.03	52.82	52.61
53.15	52.95	52.74	52.54	52.33	52.12	51.92	51.71	51.50
52.04	51.83	51.63	51.43	51.23	51.03	50.82	50.62	50.42
50.94	50.74	50.54	50.35	50.15	49.95	49.75	49.56	49.36
49.87	49.67	49.48	49.29	49.09	48.90	48.71	48.51	48.32
48.82	48.63	48.44	48.25	48.06	47.87	47.68	47.49	47.30
47.79	47.61	47.42	47.23	47.05	46.86	46.68	46.49	46.31
46.79	46.60	46.42	46.24	46.06	45.88	45.70	45.51	45.33
45.80	45.62	45.44	45.27	45.09	44.91	44.73	44.56	44.38
44.84	44.66	44.49	44.31	44.14	43.97	43.79	43.62	43.44
43.89	43.72	43.55	43.38	43.21	43.04	42.87	42.70	42.53
42.97	42.80	42.64	42.47	42.30	42.13	41.97	41.80	41.63
42.06	41.90	41.74	41.57	41.41	41.25	41.08	40.92	40.76
41.18	41.02	40.86	40.70	40.54	40.38	40.22	40.06	39.90
40.31	40.16	40.00	39.84	39.69	39.53	39.37	39.22	39.06
39.46	39.31	39.16	39.00	38.85	38.70	38.54	38.39	38.24
38.63	38.48	38.33	38.18	38.03	37.88	37.73	37.58	37.43
37.82	37.67	37.53	37.38	37.23	37.09	36.94	36.79	36.65
37.02	36.88	36.74	36.59	36.45	36.31	36.16	36.02	35.87
36.24	36.10	35.96	35.82	35.68	35.54	35.40	35.26	35.12
35.48	35.34	35.21	35.07	34.93	34.79	34.66	34.52	34.38
34.74	34.60	34.47	34.33	34.20	34.06	33.93	33.79	33.66
34.00	33.87	33.74	33.61	33.48	33.34	33.21	33.08	32.95
33.29	33.16	33.03	32.90	32.77	32.64	32.51	32.38	32.25
32.59	32.46	32.33	32.21	32.08	31.96	31.83	31.70	31.58
31.90	31.78	31.65	31.53	31.41	31.28	31.16	31.03	30.91
31.23	31.11	30.99	30.87	30.75	30.62	30.50	30.38	30.26
30.57	30.45	30.34	30.22	30.10	29.98	29.86	29.74	29.62
29.93	29.81	29.70	29.58	29.46	29.35	29.23	29.12	29.00
29.30	29.19	29.07	28.96	28.84	28.73	28.62	28.50	28.39
28.68	28.57	28.46	28.35	28.24	28.13	28.01	27.90	27.79
28.08	27.97	27.86	27.75	27.64	27.53	27.43	27.32	27.21
27.49	27.38	27.27	27.17	27.06	26.95	26.85	26.74	26.63
26.91	26.81	26.70	26.60	26.49	26.39	26.28	26.18	26.07
26.34	26.24	26.14	26.04	25.93	25.83	25.73	25.63	25.53
25.79	25.69	25.59	25.49	25.39	25.29	25.19	25.09	24.99
25.25	25.15	25.05	24.95	24.85	24.76	24.66	24.56	24.46
24.71	24.62	24.52	24.43	24.33	24.23	24.14	24.04	23.95
24.19	24.10	24.01	23.91	23.82	23.72	23.63	23.54	23.44
23.69	23.59	23.50	23.41	23.32	23.23	23.13	23.04	22.95
23.19	23.10	23.01	22.92	22.83	22.74	22.65	22.56	22.47
22.70	22.61	22.52	22.43	22.35	22.26	22.17	22.08	21.99
22.22	22.13	22.05	21.96	21.88	21.79	21.70	21.62	21.53
21.75	21.67	21.58	21.50	21.42	21.33	21.25	21.16	21.08
21.30	21.21	21.13	21.05	20.96	20.88	20.80	20.72	20.63
20.85	20.77	20.69	20.60	20.52	20.44	20.36	20.28	20.20
20.41	20.33	20.25	20.17	20.09	20.01	19.93	19.85	19.77
19.98	19.90	19.82	19.75	19.67	19.59	19.51	19.44	19.36
19.56	19.48	19.41	19.33	19.25	19.18	19.10	19.03	18.95



Sensitivity analysis PROPERTY VALUE

npv	npv	npv	npv	npv	npv	npv	npv	npv
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
899.48	**928.22**	**956.97**	**985.72**	**1014.46**	**1043.21**	**1071.96**	**1100.70**	**1129.45**

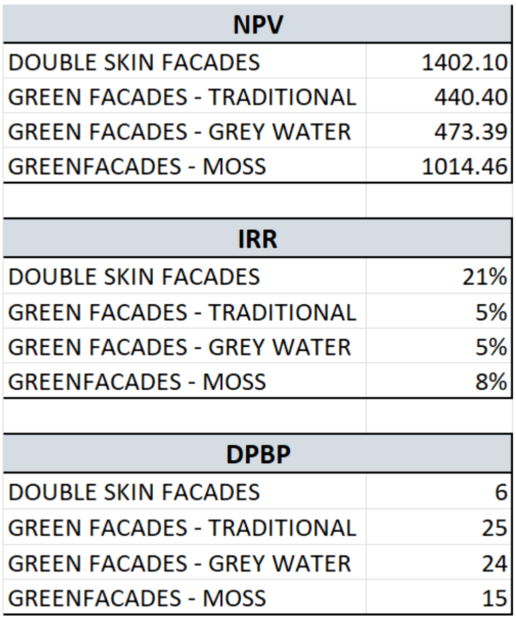
-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
-684.25	-684.25	-684.25	-684.25	-684.25	-684.25	-684.25	-684.25	-684.25
50.91	51.83	52.76	53.68	54.60	55.53	56.45	57.38	58.30
49.84	50.74	51.64	52.55	53.45	54.36	55.26	56.17	57.07
48.79	49.67	50.56	51.44	52.33	53.21	54.10	54.99	55.87
47.76	48.63	49.49	50.36	51.23	52.09	52.96	53.83	54.69
46.75	47.60	48.45	49.30	50.15	51.00	51.85	52.70	53.54
45.77	46.60	47.43	48.26	49.09	49.92	50.76	51.59	52.42
44.81	45.62	46.43	47.25	48.06	48.87	49.69	50.50	51.31
43.86	44.66	45.46	46.25	47.05	47.84	48.64	49.44	50.23
42.94	43.72	44.50	45.28	46.06	46.84	47.62	48.40	49.18
42.04	42.80	43.56	44.33	45.09	45.85	46.62	47.38	48.14
41.15	41.90	42.65	43.39	44.14	44.89	45.63	46.38	47.13
40.29	41.02	41.75	42.48	43.21	43.94	44.67	45.40	46.14
39.44	40.15	40.87	41.59	42.30	43.02	43.73	44.45	45.16
38.61	39.31	40.01	40.71	41.41	42.11	42.81	43.51	44.21
37.80	38.48	39.17	39.85	40.54	41.23	41.91	42.60	43.28
37.00	37.67	38.34	39.01	39.69	40.36	41.03	41.70	42.37
36.22	36.88	37.54	38.19	38.85	39.51	40.17	40.82	41.48
35.46	36.10	36.75	37.39	38.03	38.68	39.32	39.96	40.61
34.71	35.34	35.97	36.60	37.23	37.86	38.49	39.12	39.75
33.98	34.60	35.22	35.83	36.45	37.07	37.68	38.30	38.92
33.27	33.87	34.47	35.08	35.68	36.29	36.89	37.49	38.10
32.57	33.16	33.75	34.34	34.93	35.52	36.11	36.70	37.30
31.88	32.46	33.04	33.62	34.20	34.77	35.35	35.93	36.51
31.21	31.78	32.34	32.91	33.48	34.04	34.61	35.18	35.74
30.55	31.11	31.66	32.22	32.77	33.33	33.88	34.44	34.99
29.91	30.45	31.00	31.54	32.08	32.62	33.17	33.71	34.25
29.28	29.81	30.34	30.88	31.41	31.94	32.47	33.00	33.53
28.66	29.18	29.70	30.23	30.75	31.27	31.79	32.31	32.83
28.06	28.57	29.08	29.59	30.10	30.61	31.12	31.63	32.14
27.47	27.97	28.47	28.97	29.46	29.96	30.46	30.96	31.46
26.89	27.38	27.87	28.36	28.84	29.33	29.82	30.31	30.80
26.33	26.80	27.28	27.76	28.24	28.72	29.19	29.67	30.15
25.77	26.24	26.71	27.18	27.64	28.11	28.58	29.05	29.51
25.23	25.69	26.15	26.60	27.06	27.52	27.98	28.44	28.89
24.70	25.15	25.60	26.04	26.49	26.94	27.39	27.84	28.29
24.18	24.62	25.06	25.50	25.93	26.37	26.81	27.25	27.69
23.67	24.10	24.53	24.96	25.39	25.82	26.25	26.68	27.11
23.17	23.59	24.01	24.43	24.85	25.27	25.70	26.12	26.54
22.68	23.10	23.51	23.92	24.33	24.74	25.15	25.57	25.98
22.21	22.61	23.01	23.42	23.82	24.22	24.62	25.03	25.43
21.74	22.13	22.53	22.92	23.32	23.71	24.11	24.50	24.90
21.28	21.67	22.05	22.44	22.83	23.21	23.60	23.99	24.37
20.83	21.21	21.59	21.97	22.35	22.72	23.10	23.48	23.86
20.40	20.77	21.14	21.51	21.88	22.25	22.62	22.99	23.36
19.97	20.33	20.69	21.05	21.42	21.78	22.14	22.50	22.87
19.55	19.90	20.26	20.61	20.96	21.32	21.67	22.03	22.38
19.13	19.48	19.83	20.18	20.52	20.87	21.22	21.57	21.91
18.73	19.07	19.41	19.75	20.09	20.43	20.77	21.11	21.45
18.34	18.67	19.00	19.34	19.67	20.00	20.33	20.67	21.00
17.95	18.28	18.60	18.93	19.25	19.58	19.91	20.23	20.56



Making a comparison of the tree variable that were evaluated it is clear to see that material has the most impact on the same deviation, because it has the steepest line.

8. COMPARISON

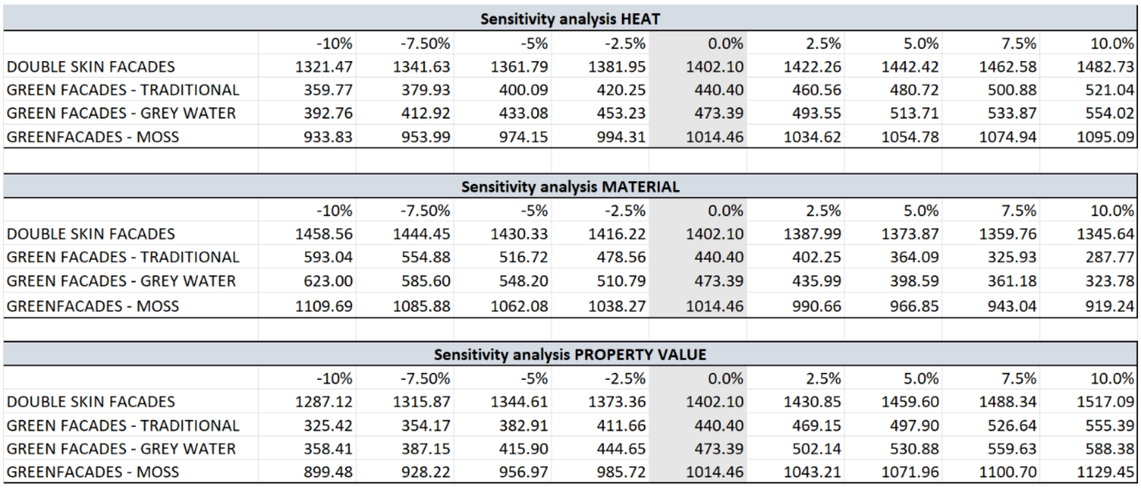
Here is summarize the indicators that were evaluated during the cost benefit analysis, with each solution.



NPV	
DOUBLE SKIN FACADES	1402.10
GREEN FACADES - TRADITIONAL	440.40
GREEN FACADES - GREY WATER	473.39
GREENFACADES - MOSS	1014.46

IRR	
DOUBLE SKIN FACADES	21%
GREEN FACADES - TRADITIONAL	5%
GREEN FACADES - GREY WATER	5%
GREENFACADES - MOSS	8%

DPBP	
DOUBLE SKIN FACADES	6
GREEN FACADES - TRADITIONAL	25
GREEN FACADES - GREY WATER	24
GREENFACADES - MOSS	15



Sensitivity analysis HEAT

	-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
DOUBLE SKIN FACADES	1321.47	1341.63	1361.79	1381.95	1402.10	1422.26	1442.42	1462.58	1482.73
GREEN FACADES - TRADITIONAL	359.77	379.93	400.09	420.25	440.40	460.56	480.72	500.88	521.04
GREEN FACADES - GREY WATER	392.76	412.92	433.08	453.23	473.39	493.55	513.71	533.87	554.02
GREENFACADES - MOSS	933.83	953.99	974.15	994.31	1014.46	1034.62	1054.78	1074.94	1095.09

Sensitivity analysis MATERIAL

	-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
DOUBLE SKIN FACADES	1458.56	1444.45	1430.33	1416.22	1402.10	1387.99	1373.87	1359.76	1345.64
GREEN FACADES - TRADITIONAL	593.04	554.88	516.72	478.56	440.40	402.25	364.09	325.93	287.77
GREEN FACADES - GREY WATER	623.00	585.60	548.20	510.79	473.39	435.99	398.59	361.18	323.78
GREENFACADES - MOSS	1109.69	1085.88	1062.08	1038.27	1014.46	990.66	966.85	943.04	919.24

Sensitivity analysis PROPERTY VALUE

	-10%	-7.50%	-5%	-2.5%	0.0%	2.5%	5.0%	7.5%	10.0%
DOUBLE SKIN FACADES	1287.12	1315.87	1344.61	1373.36	1402.10	1430.85	1459.60	1488.34	1517.09
GREEN FACADES - TRADITIONAL	325.42	354.17	382.91	411.66	440.40	469.15	497.90	526.64	555.39
GREEN FACADES - GREY WATER	358.41	387.15	415.90	444.65	473.39	502.14	530.88	559.63	588.38
GREENFACADES - MOSS	899.48	928.22	956.97	985.72	1014.46	1043.21	1071.96	1100.70	1129.45

Form this evaluation the double skin façade appears to be the economical best choice.

The evaluation is trying to represent the most useful and realistic case but is essential to understand that even if in this case study the double skin façade has an economical advantage it is not always true.

There are some key points that need to be enlighten in order to have a better comprehension:

- The double skin façade is the solution with the most kind of typologies, thus it’s easy to make significant impact in the results changing the stratigraphy.
- The green façade is a relative new façade, and it is not spread in the same measure that the traditional one especially the one with grey water treatment and soil less technology. This means that the availability is limited and that has a correlation to a highest price.

There are other kind of benefict from a green façade that are not represented by an economic indicator or that it would be difficult to quantify in other manner, but never the less they are present and should not be underestimated. The most important are:

- The architectural value, that is highly dependant by the context of the building because it could not have a particular appeal a green façade in a rural area surrounded by nature but it coul be inestimable if the building is contructed in a city where there is no green spaces and it is the only solution to add it.
- The life qualitiy, it is hard to evaluate the psycological aspects, contact with greenery is known to reduce stress and improve mood. Green facades can help create more relaxing and stimulating environments, promoting the general well-being of users.

- Improving air quality, plants absorb carbon dioxide and pollutants, releasing oxygen. This helps reduce the concentration of pollutants in the air, improving the health and well-being of residents.

- Reduction of noise pollution, the plant structure helps attenuate outside noise, creating a quieter and more comfortable environment, both for building occupants and the surrounding area.

Overall, all of these aspects are essential to take in consideration to. make the best choice in the design phase of a project.

9. APPLICATIONS

In this section there will be some consideration of the possible application of this solution of double skin, in other kind of context.

9.1. Different climatic zone

Climate zones significantly influence the performance of green facades. Climatic factors such as outdoor air temperature, outdoor relative humidity, wind speed and solar radiation intensity are critical determinants of the effectiveness of greening systems

Several studies have examined the impact of climate zones on green façade systems:

- **Tropical climates**: Green façade systems play an important role in improving the energy efficiency of buildings. In these climate zones, it is important to emphasize designs that emphasize cooling and moisture control.
- **Mediterranean climates**: In continental Mediterranean climates, Green façade can passively reduce building energy consumption by up to 59%. [15] In winter, it can lead to energy savings of 4.2%. Evergreen species offer year-round benefits.
- **Hot summer and cold winter climate zones**: Climatic characteristics have a significant impact on the energy-saving effect of Green façade. Long-term monitoring results show that the average monthly energy-saving rate in winter is only 3.6 percent, with the highest value being just 11.3 percent, and there are also many months without energy saving. In these areas, it is important to choose species that can withstand both hot and cold weather.
- **Arid climates**: Higher temperatures can lead to greater evapotranspiration and, if the reduction in flow is not accounted for, lead

to less mass removal, leading to an inaccurate representation of actual system performance [45]

Plant selection based on regional temperature and humidity conditions is critical to optimizing the performance of green façade systems

For example, tropical areas might prioritize species with high evapotranspiration rates. The fundamental mechanisms of green façade, such as shading, evapotranspiration, and insulation, remain unchanged, allowing knowledge gained from the Hot summer and cold winter climate zones context to be applied elsewhere with appropriate adaptations.

Here follows a map of the different climatic zone of the world.

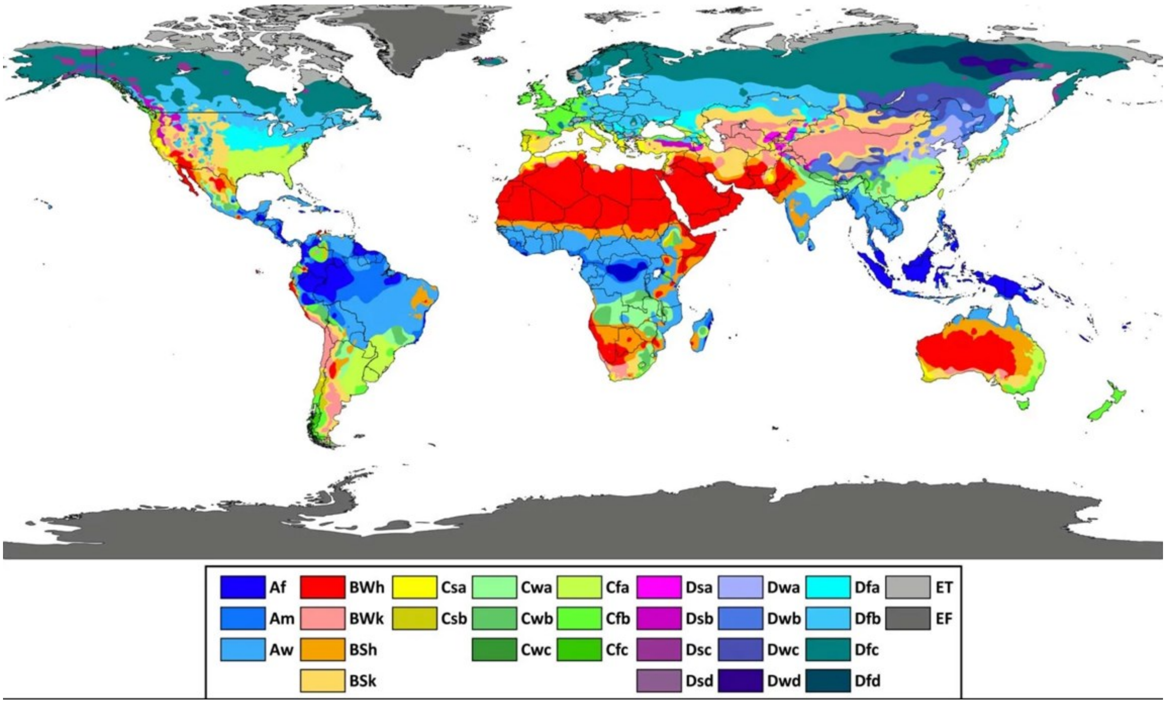


Figure 29 - K¨oppen-Geiger climate classification source [46]

This is a characterization of how much in a single state is possible to encounter different climate.

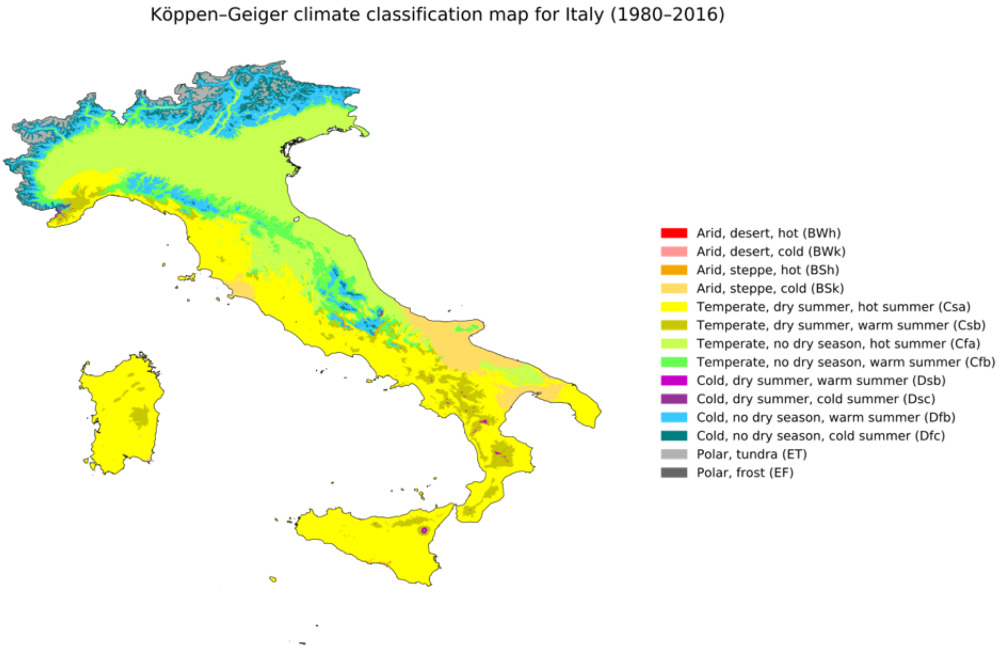


Figure 30 - K¨oppen-Geiger climate classification Italy source [47]

This is fundamental knowledge in order to design the best, in terms of performance, double skin façades, especially green facades, because not only different conditions affect the need to make a double skin façade, but it affects also the performance requirement and in case of a green facades it affect also the kind of plant species that is possible to have.

9.2. New vs renovation

Green facades can be classified as direct or indirect systems, with different implications for application on existing versus new buildings. [19]

Here are the main differences in application between the two types of buildings:

Existing buildings

Indirect systems are generally preferred. These systems use lightweight external structures, such as trellises, nets or cables, to support the growth of climbing plants.

Indirect systems can integrate planters into the exterior structure, even at different heights, which is useful when planting directly into the ground at the base of the wall is not possible.

Indirect green façade systems can be adapted to any type of façade, even on existing buildings. The configuration can be optimized according to solar exposure to provide shade without excessively obstructing the view from the inside.

Application of Vertical Greenery Systems on existing buildings is a strategy to reduce heat islands and absorb carbon dioxide.

New buildings

Both direct and indirect systems can be considered. Direct green facades have no support structures and plants climb directly on the wall. The project is easily designed to accommodate the use of greenery in the facades. Space can be provided for planting directly into the ground at the base of the wall.

The installation of Vertical Greenery Systems can lead to energy savings for cooling buildings and mitigate the urban heat island effect.

In summary, while in new buildings there is more flexibility in the choice of green façade system, in existing buildings it is often preferable to choose for indirect systems that are better suited to existing structural features.

Usually also the Existing building for this lack of predisposition of a double skin façade have higher cost respect a new building that has this structure by design.

9.3. Roof systems

It will not be the focus of this thesis but is important to mention the other areas of application of greenery, the main are green roof.

Green roof are vegetation-covered building roofs designed to improve the energy efficiency of buildings and promote urban sustainability. They can be extensive, with low-maintenance plants and low weight, or intensive, with more diverse vegetation and a roof garden-like structure.

• Pro of Green Roofs

- **Thermal insulation and energy savings:** Reduction of heat loss in winter and overheating in summer, resulting in savings in air conditioning costs.

- **Rainwater absorption:** Decrease water runoff, reducing the risk of urban flooding.

- **Pollution reduction and air quality improvement:** Plants absorb CO_2 and atmospheric particulate matter.

- **Increasing biodiversity:** They create habitats for insects and small animals, promoting the urban ecosystem.

- **Extended roof life:** They protect the underlying roof from weathering and UV rays, increasing the useful life of the structure.

- **Aesthetic benefits and psychological well-being:** They improve the urban landscape and visual comfort, contributing to the quality of life.

• Contrary to Green Roofs

- **High initial costs:** Installation requires specific materials, waterproofing, and an appropriate structure to support the additional weight.

- **Necessary maintenance:** Even extensive systems require minimal maintenance for plant health and water drainage.

- **Additional weight on the building:** May necessitate structural verification and, in some cases, reinforcement of the building to support the load.

- **Variable efficiency depending on climate:** In very dry areas, an irrigation system may be necessary, while in very rainy climates drainage management must be carefully designed.

Ultimately, green roofs are an effective solution for improving urban sustainability, but their implementation requires careful evaluation of cost, building structure, and climate context.

10. CONCLUSION

This paper presented the topic of green facades and in particular new technologies applied to them.

The environmental impact of construction on climate change was highlighted, we focused on how to reduce this impact through the use of double skin facades.

An excursus was made on how traditional facades are composed, what kind of limitations and problems they present, then the different types of green facades present were analyzed.

Soil-less technologies (through moss) and graywater reuse were analyzed, in particular what is involved in using these technologies and what are their merits and drawbacks.

Four technologies: Double skin façade (traditional), green façade (traditional), green face with grey water, moss facade, were compared directly in the case study of the EX-Manifattura Tabacchi, going on to design an example of a facade with its stratigraphy.

The main focus has been from the design of these facades to go to parametrically analysis of a square meter of facade by cost benefit analysis, net present value, internal rate of return, payback period and sensitivity analysis.

This returns a result that is representative only of this example, where from the purely economic aspect it appears that the double skin façade would seem to be the most beneficial solution.

This does not take into account some aspects, architectural, perceived quality, psychological that are not assessable in a parametric way but nevertheless remain essential to be taken into account at the design stage and can be determinant in other cases.

Finally, it was pointed out that the applicability of these solutions can be expanded from this context and condition, so it is possible to adopt them in other areas and building types as well.

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Per la mia personale visione non c’è traguardo che abbia significato se non si può condividerlo con le persone più care.

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LIST OF FIGURES

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