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Building a climate-neutral future together

Sino-Swiss Cooperation on Zero Emissions Building

Technical Report

Zero Emissions Building Design with Greenery and Photovoltaics

Experiences from Switzerland

ENGLISH VERSION

AUGUST 2024

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Building a climate-neutral future together

This report has been produced within the framework Sino-Swiss Zero Emissions Building Project; an international collaboration funded by the Swiss Agency for Development and Cooperation in partnership with the Chinese Ministry of Housing and Urban-Rural Development.

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The Sino-Swiss Zero Emissions Building Project is an international collaboration funded by the Swiss Agency for Development Cooperation in partnership with the Chinese Ministry of Housing and Urban-Rural Development. The project aims to reduce greenhouse gas emissions and enable carbon neural development of the building sector in China by sharing Swiss know-how on sustainable and zero emission building.

Implementation partners:

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Contents

1. PROJECT BACKGROUND

About Sino-Swiss ZEB Project

In order to jointly address global climate change and to strengthen cooperation between China and Switzerland in the field of emission reduction in the construction industry, the Ministry of Housing and Urban-Rural Development of the People's Republic of China and the Swiss Federal Ministry of Foreign Affairs signed a Memorandum of Understanding (MoU) on 24 November 2020. The Memorandum is about the development of cooperation in the field of building energy efficiency. Within the framework of this MoU, the Swiss Agency for Development Cooperation (SDC) initiated and funded the Sino-Swiss Zero Emission Building Project. The project aims to support China in formulating the technical standard of zero carbon buildings and long-term roadmaps for reducing carbon emissions in the construction industry. Switzerland contributes by sharing know-how and use cases of zero emission building demonstration projects in different climate zones, while carrying out various forms of capacity building activities, so as to ultimately promote the carbon-neutral development of China's construction industry.

Project purpose

- Upgrading existing building energy efficiency standards to Zero Carbon technical Standards
- Implementing demo projects in 4 typical climate zones for testing the new ZEB standards and finding optimization potentials
- ZEB capacity building and knowledge dissemination

Project duration

- Phase I: 15. Mar. 2021 – 28. Feb. 2025

Project impact on climate protection

- Reduce CO2 Emission in building sector

2. GREEN FACADES AND PV - BUILDING ENVELOPE POTENTIAL

2.1. Summary

The key findings in brief:

- Greening and PV on the façade only compete with each other in rare cases. In most cases, the systems can achieve their greatest added value in completely different areas of the façade.
- PV should primarily be installed on areas with high electricity generation potential, i.e. on south, east and west-facing façades without shadowing.
- Greening can achieve the greatest added value in areas close to people and can increase the quality of stay (e.g. reduction of noise and pollutant emissions, potential for heat reduction, attractiveness of outdoor spaces...), especially in urban areas.
- The decision in favour of a system depends on various factors:
- Local needs (noise, climate, biodiversity, air quality, energy (optimization of own consumption)...)
- Prioritization of qualitative and quantitative aspects
- Analysis of the conditions: Orientation, shading, stories, wind and seasonal differences
- System boundary of the analysis (socio-economic assessment of the benefits: who benefits directly and indirectly, in the short and long term from the systems?)
- A combination of the systems can unite the various qualitative and quantitative advantages of the systems. The combination can be both ecologically and economically recommendable.
- Regulations and funding (responsibility of the authorities) will be decisive for the acceptance and increased use of the systems. In particular, clarity with regard to fire protection will be crucial for both PV and greening systems.
- The systems make a significant contribution in connection with important future issues such as the winter electricity shortage and livable, densely populated cities. Good, replicable examples for the future are important now for building and propagating expertise.
- In an optimized holistic planning process, the use of greening and PV should also be evaluated on roofs and in the building’s surroundings in addition to the façade. The advantages of the various systems and synergies can be utilized most efficiently in this way.

2.2. PV-Systems

2.2.1. Advantages

Security of Supply

Solar energy can be produced and utilized directly on site. This makes the consumer less dependent on price fluctuations. Well-planned, self-consumption-optimised systems therefore offer a high level of security of supply. By producing electricity via façades, more autonomy can be achieved, especially in months with low hydropower production.

Figure 1: MFH Brütten © 3S Swiss Solat Solution

Sustainable Power Generation

PV façades can be used to promote the production of electricity from renewable energy sources. This utilises the available solar energy on site to generate electricity and thus makes a positive contribution to reducing environmentally harmful emissions.

The Energy Perspectives 2050+ have analysed the development of Switzerland’s energy system to ensure net-zero greenhouse gas emissions and a secure energy supply in 2050 and propose a rapid and massive expansion of renewable energies in Switzerland. PV façades should make an important contribution in this respect: the aim is to increase the installed capacity of PV by a factor of 13 over the next 30 years.

No additional Space Requirements

Another advantage of using PV is that no additional usable area is required. PV systems can be placed

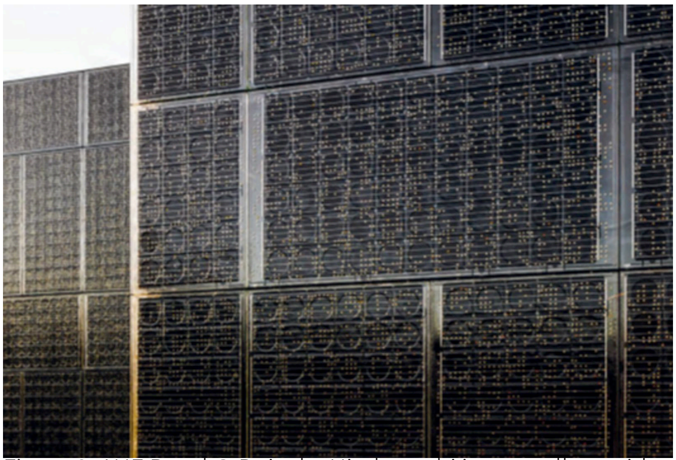


Figure 2: AUE Basel © Daisuke Hirabayashi jessenvollenweider

on roofs and façades and unused areas (undeveloped land) can be utilised for other purposes.

Long-Term Economic Advantages

PV systems are a sustainable investment that has the chance of amortisation. Savings through the use of solar power in operation (self-consumption) and remuneration for feeding into the grid mean that a PV system can pay off quickly. Energy costs are reduced immediately and the initial investment costs are amortised over the service life if the modules are used sensibly and have a good level of efficiency.

A PV system can also increase the value of a property and lead to better rentability and fewer vacancies.

Electricity Production without Noise and Emissions

PV systems enable electricity to be produced during operation without causing noise or pollutant emissions. This means that PV systems can also be used close to people without negatively affecting the quality of their stay.

Figure 3: Glaserhaus in Affoltern in Emmental © Christoph Heilig

Positive Ecobalance & Recyclability

A lot of embodied energy is generated for the construction of the PV modules, which should not be neglected. However, electricity is produced during operation, which leads to savings in the building' s energy consumption. Sensibly used PV modules with a good level of efficiency lead to a positive ecobalance over the life cycle.

PV modules also have a high recycling potential, as over 75 % can be reused. In Switzerland, the collection and processing of raw materials is guaranteed by an advance recycling fee (ARF).

Low Maintenance

As PV systems have no moving parts, they are very low-maintenance and have a long service life of 30-40 years. Only the inverter is considered a wearing part and must be replaced approximately every 15 years.

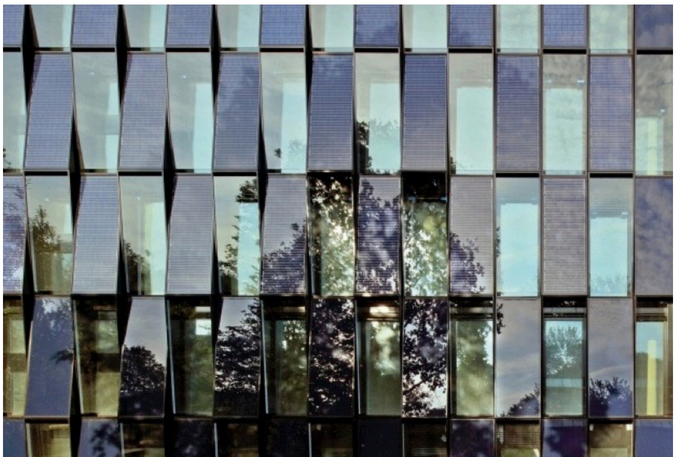


Figure 4: NEW Blauhaus © Robert Mehl / kadawittfeldarchitektur

Architectural Design Tools

PV modules are meanwhile available in a wide variety of designs (colours, textures, patterns, degree of transparency, etc.). This allows them to be used as an architectural design element.

Buildings play an important role in the cityscape and the design of outdoor spaces. PV systems therefore have great potential to create attractive outdoor spaces with a high quality of stay.

2.2.2. Obstacles

Fluctuations in the Energy Production

Energy production from PV systems is subject to fluc¬tuations depending on the time of day, the season and the weather. Long periods without sunlight make independence from the grid more difficult.

Figure 5: Shadowing of PV elements should be avoided © Kingsgate House, London / P. Bonomo

High Investment Costs

Despite falling prices for PV systems, the initial in-vest¬ment costs can be high. However, these costs can be amortised over time through the savings in operation.

Degradation

PV modules lose performance over time (degradation). The output decreases by approximately 0.4% per year , whereby the degradation values vary depending on the PV module.

Shadowing & Limited Space

Unfavorable orientation and shadowing by neighboring buildings or topographical elements cause a significant reduction in output and can even make an installation unprofitable. Not all building surfaces are therefore optimally suited for the utilization of PV. In addition, only a limited area is available on the roof:

Figure 6: Pollution can reduce the electricity output, regular cleaning is recommended © AdobeStock

Dependence on Feed-In Tariffs

If the surplus electricity is fed into the grid, the profi¬tability and amortisation period depend on the cur¬rent feed-in tariff. A high level of self-consumption should be aimed for.

Regular Cleaning

PV systems should be cleaned regularly (approx. once a year) to avoid reductions in output due to pollution.

2.2.3. System Comparison

Photovoltaic Roof

Positives:

- Higher annual electricity production
- Lower aesthetic requirements for roof systems, standard modules can be used without problems (lower costs, higher efficiency)
- Easy access to the system for flat roofs
- Combination of greenery and PV easier to realise than with façades
- Fire protection less problematic than with high façades

Negatives

- Risk of hail damage
- Horizontal or inclined systems become polluted more quickly (dust deposits, accumulation of black carbon)
- Limited space available, especially with tall buildings
- Roof surfaces offer a high quality of stay: if these are used for PV systems, other uses are not possi¬ble or only to a limited extent

Photovoltaic Façade

Positives

- Winter electricity production: a south-facing façade without shadowing can produce more electricity in the winter months than a flat roof-mounted system
- With a sensible arrangement of the modules, the electricity output can be more balanced in a daily and annual comparison than with roof systems
- Horizontal systems pollute less quickly and remain free of snow in winter
- Facades have a high level of previously unuti-

lised surface potential

- PV façades are usually installed as rear-ventilated façades, which means that the top facade layer can be dispensed with
- No additional usable space required

Negatives

- Lower annual electricity generation potential
- Generally higher investment costs
- Cleaning and maintenance: accessibility is particularly difficult with high facades and must be taken into account during planning (space for lifting platforms etc.)
- There is currently still a lack of overriding fire protection regulations for PV façades, which requires an individual fire protection concept for each property. Specialist experts should be involved

2.3. Greening

2.3.1. Advantages

Noise Reduction

Greenery has a high degree of sound absorption due to its structured surface. This means that only a certain proportion of the incoming sound is reflected into the surroundings and noise pollution can be reduced. Particularly in urban areas, added value can be realised here.

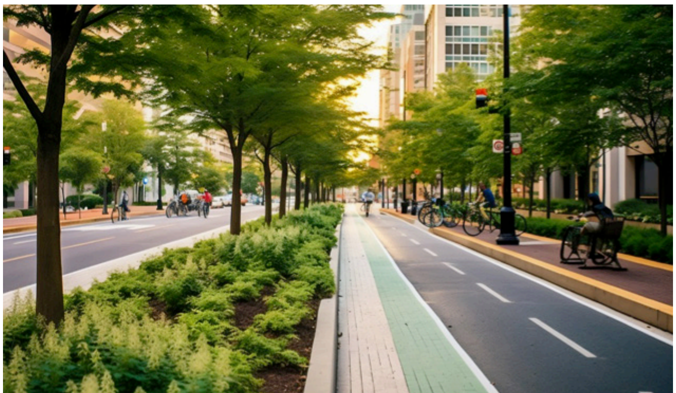


Figure 7: Green urban space © AdobeStock

Improvement of Air Quality

Greenery can make a positive contribution to impro¬ving air quality. This is particularly true in urban areas, where various sources of emissions (construction sites, traffic, etc.) can lead to higher levels of air pollu¬tion. Greenery can demonstrably help to reduce particu¬late matter, nitrogen dioxide and sulphur dioxide, bind CO2 and ozone and produce oxygen.

Promotion of Biodiversity

Greening creates new habitats and makes a positive contribution to biodiversity

Particular added value can be achieved when green spaces in cities are connected by green elements (e.g. green belts, green corridors) or serve as stepping stone biotopes.

Figure 8: Bosco Verticale © Claudia Luperto / Strut Architekten

Increasing the Quality of Stay

Green spaces are essential for the quality of life in cities. The positive effects can be both physical and psychological. Among other things, green spaces can reduce stress, promote health and increase pro¬ductivity and creativity. They also serve as social meeting places and promote sporting activities and exercise.

Rainwater Management

Greenery can absorb rainwater via the substrate layer (infiltration). This is then gradually released back into the atmosphere through evaporation. This not only has a cooling effect (evaporative cooling) on the envi¬ronment, but also helps to relieve the burden on the sewerage network.

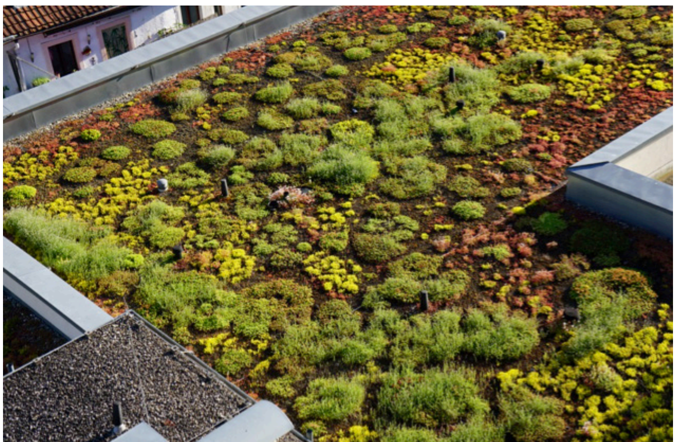


Figure 9: Green roof © AdobeStock

Thermal Insulation and Energy

Thermal insulation in summer is becoming increasingly important, especially in times of climate change. Greenery can be used as natural sun protection (shading effect of the plants). Deciduous plants also lose their leaves in winter, which means that solar heat gains are hardly restricted at this time of year.

Figure 10: Greenery requires regular maintenance © AdobeStock (links), newhome, Jürg Zulliger (rechts)

Cooling through Evaporation

Greenery has a cooling effect as it releases the absor¬bed water back into the environment through evapora¬tion. These aspects not only improve the microclimate, but also have a positive effect on reducing the urban heat island effect. A good ambient climate supports efficient night-time cooling of the interior spaces.

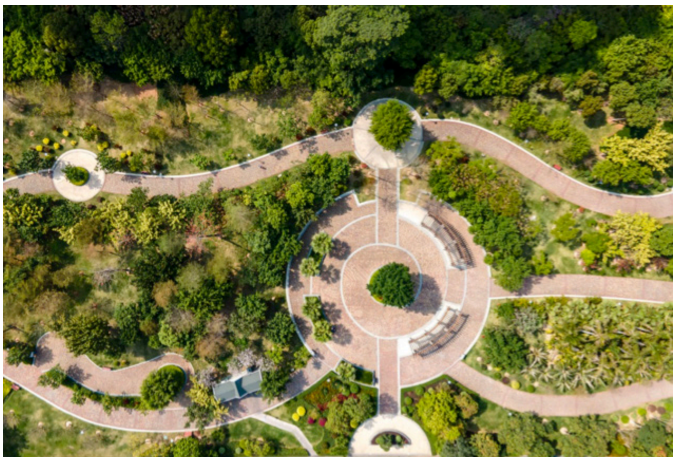


Figure 11: City-park © AdobeStock

Long-Term Economic Advantage

Green roofs, façades and outdoor areas can not only make a significant contribution to sustainability in times of climate change, but can also significantly increase the attractiveness of a property. A green place to work and live attracts the interest of employees and tenants. The results are good lettability and long-term tenancies. This leads to economic benefits in the long term.

2.3.2. Obstacles

Regular Maintenance

Greening requires regular maintenance to ensure its appearance and safety. In the case of façade greenery, for example, overgrowth of fire protection sections must be avoided in order to prevent the spread of flames in the event of a fire. In the case of urban trees, it must be ensured, among other things, that no branches fall on people.

The Growing Season Influences the Potential of Greening

Plants need time to develop. This means that greening can only realise its full potential after a certain amount of time. Depending on the system and plant species, this can take several years to decades. Existing green elements, such as trees or green spaces, should therefore be preserved as much as possible in construction projects.

2.3.3. System Comparison

Roof Greening

Positives

- Due to a high substrate volume, rainwater can be absorbed well
- Additional insulating effect (lower U-values)
- Protection against weather influences and lower thermal fluctuations have a positive effect on the service life of the roof structure
- Equalisation of natural space: buildings block parts of the natural topography; this can be made available again by greening the roof surface
- Good accessibility for care and maintenance on flat roofs
- A combination of green roofs and PV is easy to implement on roofs (utilise synergies)

Negatives

- Higher investment costs than a standard roof (costs vary depending on the roof greening)
- The additional ballast may require structural veri¬fication or structural reinforcements when retrofitting (grey CO2 emissions)
- Intensive roof greening may require additional irrigation; this is generally not necessary for extensive roof greening
- Roof greening is susceptible to invasive neophytes, especially at the beginning, and woody plants can also accumulate. Regular maintenance can prevent unwanted colonisation and damage
- Rooting can cause damage to the roof waterproofing and expensive repair work may be required. Regular inspections can prevent this.

Façade Greening

Positives

- Low space requirement
- No ground connection is required for wall-mounted greenery
- Additional insulating effect (lower U-values)
- Protection against weather influences and lower thermal fluctuations have a positive effect on the service life of the façade construction
- Façade greening can be used as an architectural element (diverse design options, effect on the building and urban space)

Negatives

- Wall-mounted greening in particular can lead to high investment costs
- Care and maintenance can be costly for tall buildings; sufficient space, e.g. for lifting platforms, must be planned for
- Structural reinforcements may be necessary (grey CO2 emissions)
- High water and nutrient requirements for wall-bound systems
- Rooting through ground-bound greenery can cause damage to the façade (regular maintenance and monitoring)
- Not yet widespread, lack of experience and uncertainties with the systems (planning, imple¬mentation, maintenance)

Greening in outdoor Spaces (Trees and Green Spaces)

Positives

- Accessible green spaces, such as city parks, serve as local recreation areas
- Combination of trees, hedges and shrub planting as well as meadow areas create a high level of habitat diversity
- High ecosystem services: trees provide shade and unsealed surfaces allow water to seep away
- Generally good accessibility, which facilitates care and maintenance
- Generally, no additional irrigation necessary

Negatives

- High space requirements, which can be a challenge, especially in urban areas
- Exposure to harmful environmental influences such as salt and dog urine

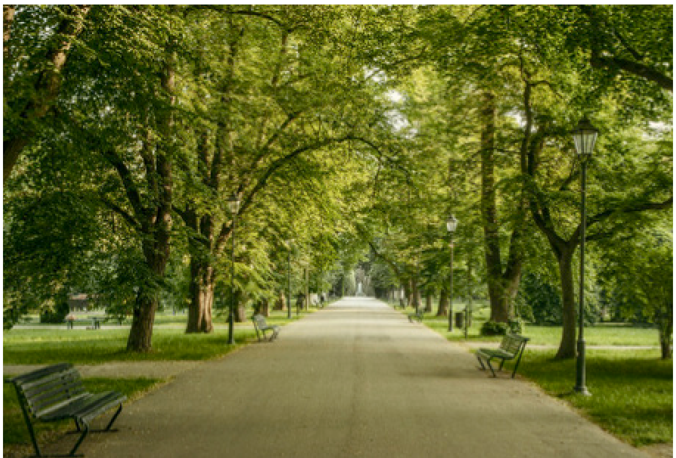


Figure 12: Green spaces and elements are essential for the quality of life in urban areas © AdobeStock

2.4. Recommendations on the Choice of System

2.4.1. Location as a Central Factor

The location is generally a component that cannot be directly influenced. The façade design must therefore be adapted to the existing context, as this is essential for the efficiency of the systems. When analysing the location, the potential of the fa¬çade surfaces must be evaluated. Various aspects must be taken into account, including shadowing, noise situation, climate, existing green spaces, etc.). For new construction projects, a property-specific and optimised façade design can be achieved using opaque, transparent, greened and PV surfaces. For refur-bishments, the focus should be on the existing surface potential.

2.4.2. Experts involved at an Early Stage

Experts in façade greening and PV façades should be consulted in the early planning phases and involved in the decision-making process. In this way, important information on efficiency, statics, fire protection, main¬tenance and care, space requirements and accessibility etc. can be obtained and the possibility of implementing the systems clarified. Specialist experts can also provide support in the selection of a suitable façade system, taking into account the :The early involvement of technical experts is also a key factor for cost planning and economic efficiency (e.g. using standard sizes for PV panels, as this has a major impact on the price, or the right choice of plants for façade greening). Furthermore, possible interfaces with other trades must be considered and coordinated from the outset, e.g. sanitary installations must be able to provide sufficient water for greenery.

2.4.3. Project Goals clearly defined

At the start of a project, the objectives should be clearly defined together with the client. Clients should first be shown the advantages of the various façade systems (sensitisation). The added value of greening and PV in terms of society, the economy and the environment should be discussed and a joint decision made on the choice of system. It is also essential to weigh up the use of greenery and PV on the roof and in the surrounding area (what makes sense on the façade/roof/environment?). Here too, it is important to consider the advantages and disadvantages and to define a sustainable overall concept (ecological, economic and social).

2.4.4. Floor and Façade-Specific Planning

Every context has different requirements. The surroundings (e.g. neighboring buildings, mountains, trees…) are decisive for the use of PV elements, as these can lead to shadowing of the modules and thus have a negative impact on efficiency. PV modules should therefore primarily be used on façade surfaces without shadowing. But even for façade greening, where sha¬dowing hardly plays a role, planning by storey and façade is essential in order to achieve the highest added value:

- Reduction of noise: proximity to the noise source is crucial, particularly relevant in urban areas (traffic noise, construction noise, etc.)
- Improving air quality: proximity to the source of emissions is crucial, highest potential on the lower floors (⩽ height of 4.5 m)
- Heat reduction: the cooling effect (evaporative co¬oling) of greenery can be enhanced by a high volume of greenery
- Rainwater retention: Consideration of the weather side, highest potential in Switzerland generally in the west.
- Promotion of biodiversity: green spaces are often partially arranged, especially in urban areas, façade greening can serve as a connecting element (“green belt, green corridor”), highest potential in this respect generally on the lower floors
- Increasing the quality of stay: highest potential in urban areas where densification is increasing and there are few green spaces. Greatest added value on the lower floors, as they are close to people.

2.4.5. Low-Tech and High-Tech

When planning façades, both low-tech and high-tech concepts can be taken into account and be effective. Low-tech solutions are generally characterised by greater adaptability and durability as well as lower susceptibility to faults. They are less demanding in terms of maintenance and operation. They are also generally less material-intensive and therefore lead to a better overall system life cycle assessment. Low-tech approaches tend to lead to economic and ecological advantages. Due to all these advantages, the use of low-tech solutions should be favoured in the first instance. However, the combination with high-tech components in the field of automation and energy management (storage, load management…) can lead to a significant optimisation of the overall system. When planning, it is important to consider which systems make sense where.

2.4.6. Combination of the Systems

If greening and PV are combined, synergies and advantages can be utilised. For example, the cooling effect of greenery (evaporative cooling) can be used to increase the efficiency of the PV modules. Furthermore, the combination of the systems offers many design advantages and can have a positive influence on the aesthetics of the building and the outdoor space.

2.4.7. Using PV Modules sensibly

For ecological and economic reasons, PV modules should be used sensibly. This allows the installation costs (embodied energy and embodied greenhouse gas emissions) and the initial investment costs to be amortised quickly. Decisive aspects here are in particular the orientation (south, east and west façade) and the shadowing of façade areas. Furthermore, the utilisation times of the building and future developments (e.g. future higher consumption due to electromobility, heat pumps, etc.) can be taken into account when planning a PV façade.

The following aspects should also be included in the planning:

- Aesthetic aspects
- Cost-benefit ratio
- Planning and dimensioning of the system based on the project objectives (winter electricity, overall balance, optimisation of self-consumption, etc.)

2.4.8. Greenings: Increase Potential

When planning façade greenings, the choice of plants and substrates in particular can make an important contribution to increasing the positive effect with regard to various aspects and the longevity of the systems.

The following should be noted:

- Consider future climatic conditions at the location (heat resistance, weather extremes, etc.)
- Different plant species promote species diversity (biodiversity)
- Aim for a high volume of greenery and a high plant density. This promotes the absorption of air pollutants, evaporative cooling and noise absorption
- A high substrate volume promotes rainwater management (infiltration), water cycles are positively influenced and the sewer network is relieved
- Greenings near the street/lower storeys creates new green spaces, improves the microclimate and enhances people' s well-being and health
- The choice of plants and systems also offers great design potential, as greening can change over time and also seasonally
- An exchange with experts is recommended.

2.5. Influence of the Systems

2.5.1. Qualitative & Quantitative Aspects

This section shows the influence of the various façade systems on qualitative and quantitative aspects. The overview table at the beginning summarises all the findings of the qualitative and quantitative analyses. The following pages go into more detail on the individual aspects and also provi¬de an assessment specific to each storey and orientation.

Qualitative Aspects

- Noise in cities
- Air quality
- Biodiversity.
- Rainwater retention
- Attractiveness of outdoor spaces

To assess the qualitative aspects, a literature research was first carried out and the most important principles from various studies were compiled.

Quantitative Aspects

- Thermal comfort indoors: temperature and overheating hours
- Operation of the building: Heating, cooling and electricity consumption
- Electricity production of the PV façade, solar potential and seasonal consideration
- Producing and operating: holistic life cycle assessment
- Economic consideration: initial and life cycle costs
- Microclimate: temperature on the façade and influence on the ambient climate

Simulations, calculations and measurements were carried out to assess the quantitative aspects. The most important findings are summarised for each aspect. Where simulation or calculation results are presented, these relate to the new eight-storey building under the assumptions made in the study.

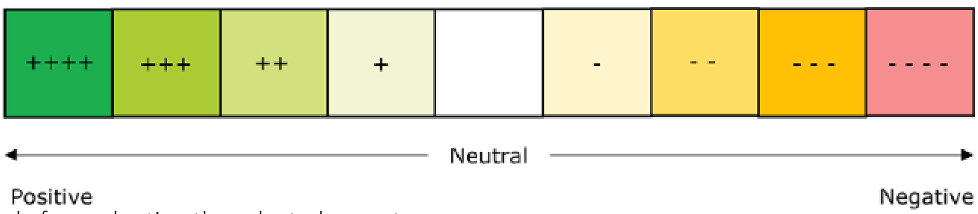


Figure 13: Colour scale for evaluating the selected aspects

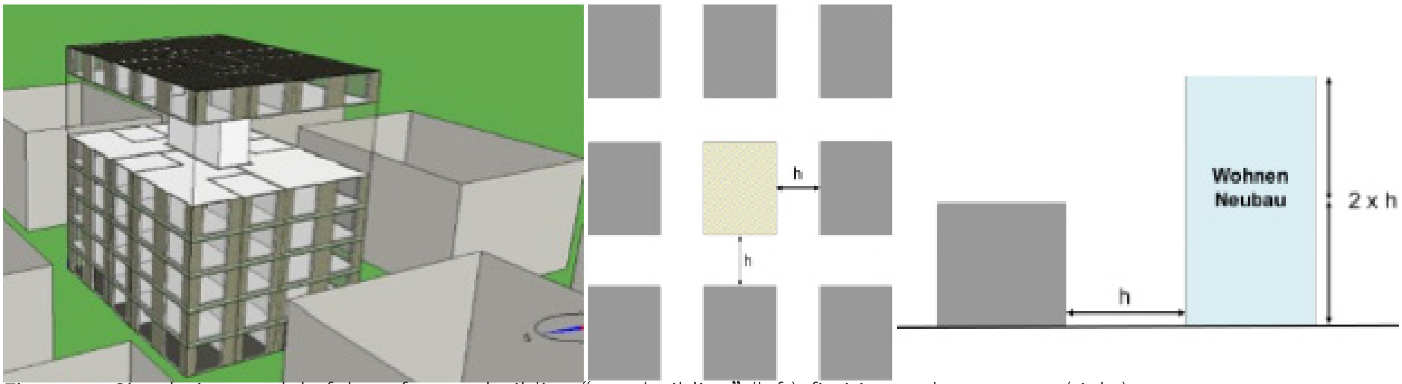


Figure 14: Simulation model of the reference building "new building" (left), fictitious urban context (right)

2.5.2. Evaluation

Qualitative Aspects Evaluation in comparison to the reference façade (ventilated fibre cement panels)	**Facade greening**		**PV façade**	
	ground-bound (deciduous, growth height up to 3 storeys)	**wall-bound** (evergreen, modular system, entire façade)	**opaque**	**transparent**
Noise in cities – the potential was assessed in a narrow street canyon with heavy road traffic (~ 80 dB, very loud)				
GROUND FLOOR	+ + +	+ + + +	–	–
1ST FLOOR	+ + +	+ + + +	–	–
2ND FLOOR	+ + +	+ + + +	–	–
3RD FLOOR	+ +	+ + +	*neutral*	*neutral*
≥ 4TH FLOOR	*neutral*	+ +	*neutral*	*neutral*
Air quality – The potential in a narrow street canyon with heavy road traffic was assessed.				
GROUND FLOOR	+ + +	+ + + +	*neutral*	*neutral*
1ST FLOOR	+ +	+ + +	*neutral*	*neutral*
2ND FLOOR	+	+	*neutral*	*neutral*
3RD FLOOR	+	+	*neutral*	*neutral*
≥ 4TH FLOOR	*neutral*	*neutral*	*neutral*	*neutral*
Biodiversity – The potential for promoting new habitats and biodiversity is shown; the risk of reflections was taken into account for the PV façades				
GROUND FLOOR	+ + +	+ + + +	–	–
1ST FLOOR	+ + +	+ + + +	–	–
2ND FLOOR	+ + +	+ + + +	–	–
3RD FLOOR	+ + +	+ + + +	–	–
≥ 4TH FLOOR	*neutral*	+ + + +	–	–
Rainwater retention – the potential for greening is greatest on the north/north-west/west weather sides				
GROUND FLOOR	+ + + +	+ + + +	*neutral*	*neutral*
1ST FLOOR	+ + +	+ + + +	*neutral*	*neutral*
2ND FLOOR	+ + +	+ + + +	*neutral*	*neutral*
3RD FLOOR	+ + +	+ + + +	*neutral*	*neutral*
≥ 4TH FLOOR	*neutral*	+ + + +	*neutral*	*neutral*
Attractiveness of outdoor spaces – The design potential of the façade systems was evaluated in terms of colour, pattern, degree of transparency, flowering times, etc.				
GROUND FLOOR	+ + +	+ + + +	*neutral*	+
1ST FLOOR	+ + +	+ + + +	*neutral*	+
2ND FLOOR	+ +	+ + +	*neutral*	+
3RD FLOOR	+ +	+ + +	*neutral*	+
≥ 4TH FLOOR	*neutral*	+ +	*neutral*	+

Legend:

+ low influence + + medium influence + + + high influence + + + + very high influence

+ + + + positive influence - - - - negative influence

Quantitative Aspects Evaluation in comparison to the reference façade (ventilated fibre cement panel)	**Facade greening**				**PV façade**			
	ground-bound		**wall-bound**		**opaque modules**		**transparent modules**	
	shadowed	not shadowed	shadowed	not shadowed	shadowed	not shadowed	shadowed	not shadowed
Thermal comfort in the interior: temperatures and overheating hours - the assessment was based on new buildings; the influence may be greater in old buildings with a poorly insulated building envelope.								
North	+	+	+	+	*neutral*	*neutral*	*neutral*	*neutral*
East	+	+	+	+ +	*neutral*	*neutral*	*neutral*	*neutral*
South	+	+	+	+ +	*neutral*	*neutral*	*neutral*	*neutral*
West	+	+	+	+ +	*neutral*	*neutral*	*neutral*	*neutral*
Operation of the building: heating, cooling and electricity consumption–maximum potential on the east > south > west > north façade.								
North	+	+	+	+	*neutral*	*neutral*	*neutral*	*neutral*
East	+	+	+	+	*neutral*	*neutral*	*neutral*	*neutral*
South	+	+	+	+	*neutral*	*neutral*	*neutral*	*neutral*
West	+	+	+	+	*neutral*	*neutral*	*neutral*	*neutral*
Annual electricity generation potential – maximum potential on the roof > on the south > east > west > north façade.								
North	*neutral*	*neutral*	*neutral*	*neutral*	+ +	+ +	+	+
East	*neutral*	*neutral*	*neutral*	*neutral*	+ +	+ + +	+	+ +
South	*neutral*	*neutral*	*neutral*	*neutral*	+ +	+ + + +	+	+ + +
West	*neutral*	*neutral*	*neutral*	*neutral*	+ +	+ + +	+	+ +
Winter electricity – maximum potential on the south façade > on the roof > on the east / west > north façade.								
North	*neutral*	*neutral*	*neutral*	*neutral*	+	+	+	+
East	*neutral*	*neutral*	*neutral*	*neutral*	+	+ +	+	+ +
South	*neutral*	*neutral*	*neutral*	*neutral*	+	+ + + +	+	+ + + +
West	*neutral*	*neutral*	*neutral*	*neutral*	+	+ +	+	+ +
Production: grey greenhouse gas emissions (GHG) – Compared to the reference façade, additional material is required for a ground-based green façade and the other systems are more emission-intensive than a fibre cement panel.								
North	–	–	– –	– –	– – – –	– – – –	– – – –	– – – –
East	–	–	– –	– –	– – – –	– – – –	– – – –	– – – –
South	–	–	– –	– –	– – – –	– – – –	– – – –	– – – –
West	–	–	– –	– –	– – – –	– – – –	– – – –	– – – –

Legend:

+ low influence   + + medium influence   + + + high influence   + + + + very high influence

+ + + + positive influence   - - - - negative influence

Quantitative Aspects Evaluation in comparison to the reference façade (ventilated fibre cement board)	**Facade greening**				**PV façade**			
	ground-bound		**wall-bound**		**opaque modules**		**transparent modules**	
	shadowed	not shadowed	shadowed	not shadowed	shadowed	not shadowed	shadowed	not shadowed
Production and operation: holistic life cycle assessment (LCC) – in relation to GHG with a 30-year amortisation period.								
North	–	–	– –	– –	– –	+	– – –	*neutral*
East	–	–	– –	– –	+ +	+ + + +	+ +	+ + +
South	–	–	– –	– –	+ + +	+ + + +	+ +	+ + + +
West	–	–	– –	– –	+ +	+ + + +	+	+ + +
Investment costs - of the different systems in comparison, all façade systems lead to higher investment costs compared to the reference façade								
North	–	–	– – – –	– – – –	– – –	– – –	– – –	– – –
East	–	–	– – – –	– – – –	– – –	– – –	– – –	– – –
South	–	–	– – – –	– – – –	– – –	– – –	– – –	– – –
West	–	–	– – – –	– – – –	– – –	– – –	– – –	– – –
Life cycle costs (LCC) – Investment, maintenance and operating costs including residual value with a 30-year observation period...								
North	– –	– –	– – – –	– – – –	*neutral*	*neutral*	– –	– –
East	– –	– –	– – – –	– – – –	*neutral*	+	– –	–
South	– –	– –	– – – –	– – – –	*neutral*	+	– –	–
West	– –	– –	– – – –	– – – –	*neutral*	+	– –	–
Temperature on the façade (summer case, south-facing) – in relation to the maximum deviations on a mild, sunny day (measurement results, only carried out with southern exposure)								
South	*not measured*	+ + +	*not measured*	+ + +	*not measured*	– –	*not measured*	–
Influence on the ambient climate (summer case) - related to the PET differences on a heat day (QKM simulation)								
North	+	+	+ +	+ +	+	+	*neutral*	*neutral*
East	+	+ +	+ +	+ + +	+	+	*neutral*	+
South	+	+ +	+ +	+ + ++	+	+ +	*neutral*	+
West	+	+ +	+ +	+ + +	+	+	*neutral*	+

Legend:

+	low influence	+ +	medium influence	+ + +	high influence	+ + + +	very high influence
+ + + +	positive influence	- - - -	negative influence				

For all qualitative and quantitative aspects, the façade systems were evaluated in comparison to the reference façade (rear-ventilated façade with fibre cement panels). This evaluation is presented graphically for each aspect using the example of the reference building “new building” (Figure 13) in order to be able to quickly assess the potential of the systems in the various orientations and storeys. The influence of the systems is shown using the colour scale in Figure 14.

2.6. Overview Table

2.7. Qualitative Aspects in Detail

2.7.1. Noise in Cities

Evaluation of the façade systems

The following diagram shows the influence of the various façade systems on the aspect of “Noise in Cities” in comparison to the reference façade, illustrated using the example of a narrow street canyon.

Summary “Noise in Cities”

- Façade greening can make a positive contribution to reducing noise in cities.
- PV modules have an acoustically hard, smooth surface, which is why sound waves are reflected to a large extent.
- The proximity to the emission source is decisive: the positive effect of greening is greater directly at the emission source (usually on the lower storeys), while the negative reflection effect of PV modules is smaller at a greater distance from the noise (usually on the upper storeys).
- Plant species that are used for ground-based systems are generally deciduous, which is why the positive effect is less pronounced in the winter months.
- If evergreen plant species are chosen for façade greening (usually for wall-mounted systems), the positive effect lasts all year round.

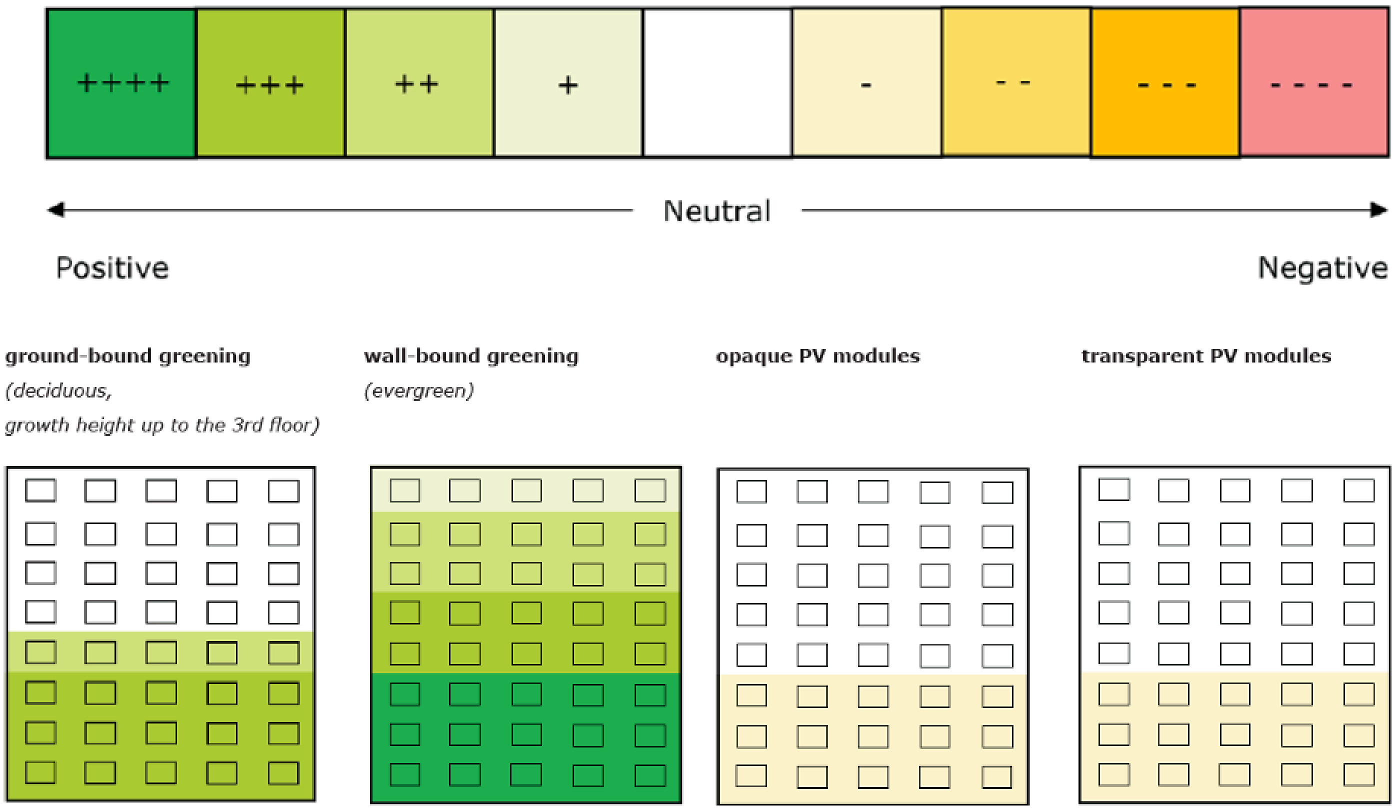


Figure 15: Influence of greening and PV façades on noise in cities.

2.7.2. Air Quality

Evaluation of the façade systems

The following diagram shows the influence of the various façade systems on the aspect of "Air Quality" in comparison to the reference façade, illustrated using the example of a narrow street canyon.

Figure 17: Influence of greening and PV façades on the aspect of air quality

Summary "Air Quality"

- Façade greening can make a positive contribution to improving air quality
- PV modules cannot make a direct contribution to improving air quality. However, CO_2 emissions can be avoided through the use of solar energy (indirect positive influence).
- The proximity to the emission source is decisive: the positive influence of greening can be achieved in street canyons, especially up to a height of ≤ 4.5 meters.
- In narrow street cross-sections, dense tree structures can lead to a build-up of air pollutants below the tree canopy (air circulation is restricted). Facade greening can be more effective in such a context.
- Deciduous plants only have a seasonal effect, whereas evergreen plant species (usually in wall-mounted systems) have an effect all year round.

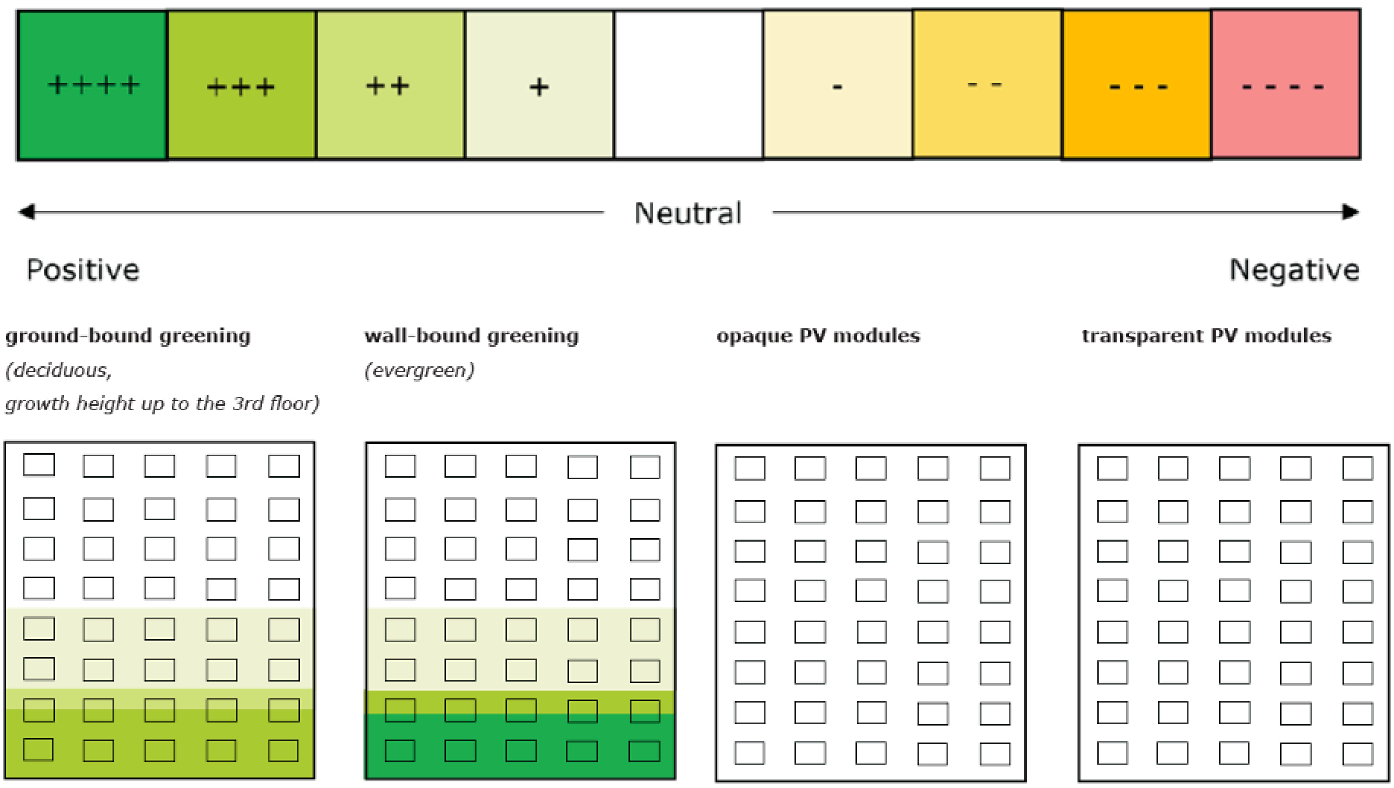


Figure 16: Influence of greening and PV façades on the aspect of air quality

2.7.3. Biodiversity

Evaluation of the façade systems

The following graphic shows the influence of the different façade systems compared to the reference façade on the aspect of "Biodiversity"

Summary "Biodiversity"

- Façade greening can make a positive contribution to promoting biodiversity, and there is great potential for this in urban areas in particular.
- PV façades harbour the risk of glare, which can be negative for birds, for example.
- In combination with greening, however, PV modules can help to create habitats with different mi¬croclimates.
- Deciduous plants only have a seasonal effect, whereas evergreen plant species (usually in wall-mounted systems) have an effect all year round.
- Ground-bound systems are limited in their growth height, while wall-bound systems can generally be used at various heights.

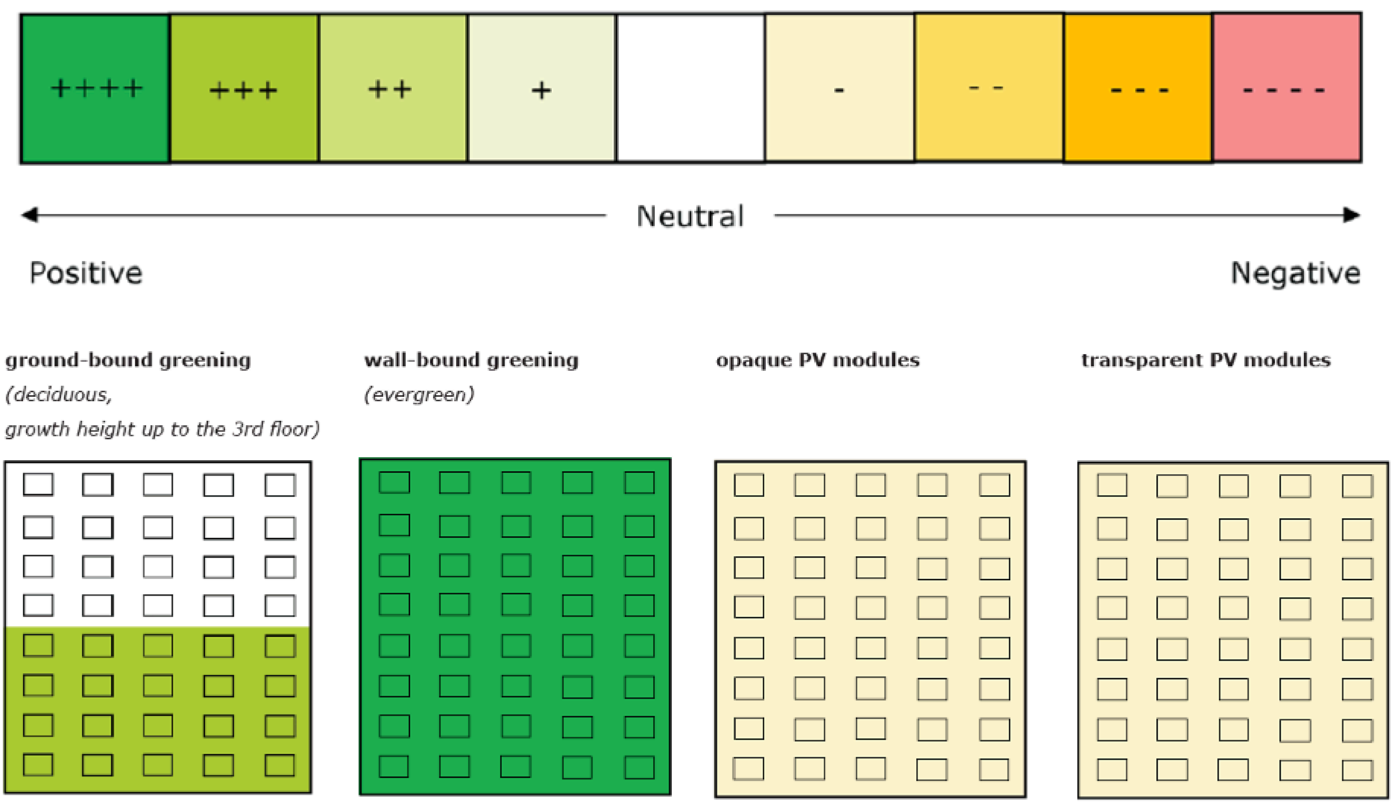


Figure 17: Influence of greening and PV façades on biodiversity

2.7.4. Rainwater Retention

Evaluation of the façade systems

The following diagram shows the influence of the different façade systems compared to the reference façade on the aspect of “Rainwater Retention”.

Summary “Rainwater Retention”

- Façade greenings can make a positive contribution to the infiltration of rainwater. The greatest potential arises on the weather sides (Switzerland: north/north-west).
- While wall-bound systems can achieve the same effect on the entire façade, the grea¬test potential for infiltration with ground-bound systems lies close to the ground (substrate layer is decisive for infiltration).
- PV façades cannot provide any added value in this respect.

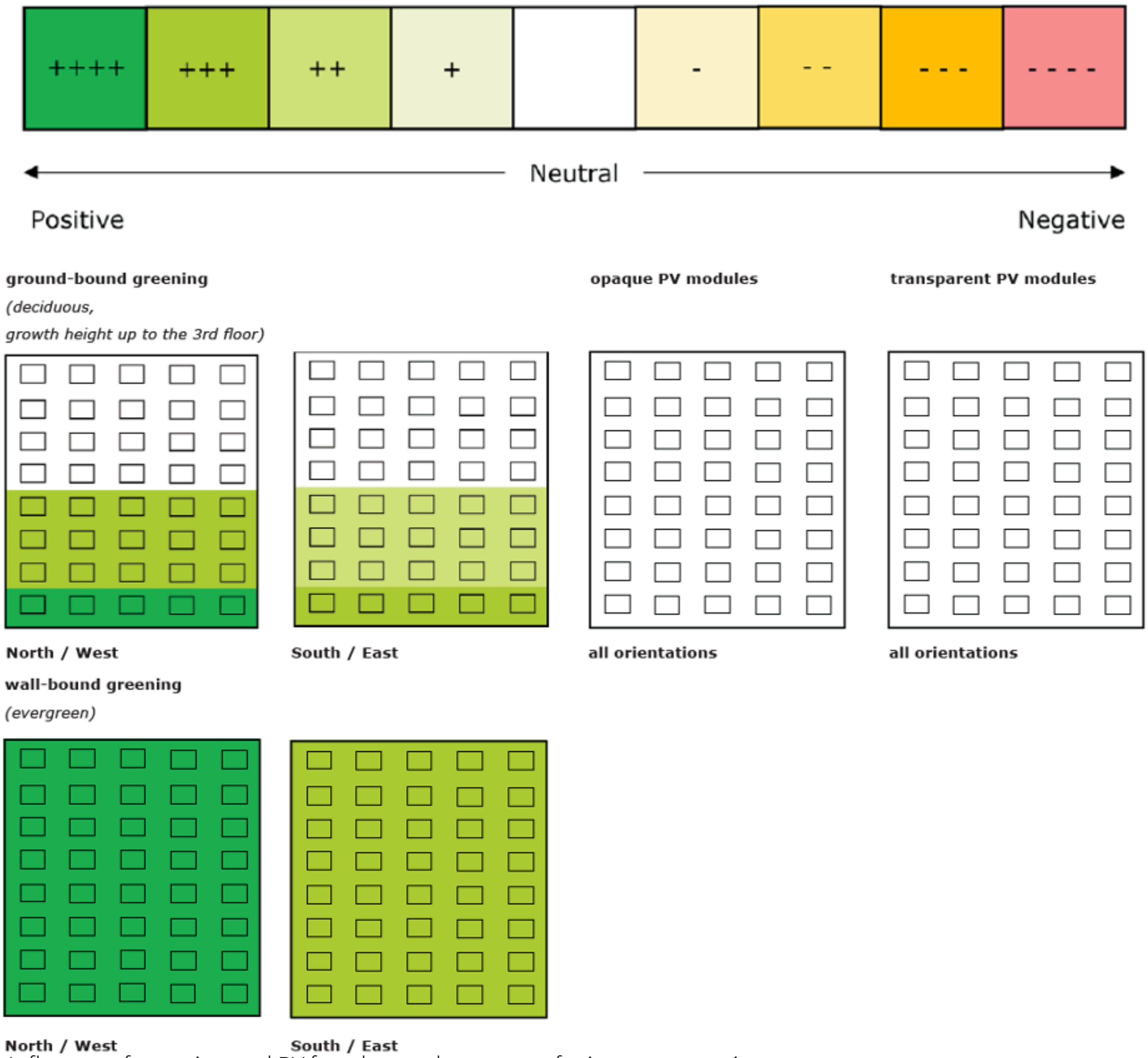


Figure 18: Influence of greening and PV façades on the aspect of rainwater retention

2.7.5. Attractiveness of outdoor Spaces

Evaluation of the façade systems

The following diagram shows the influence of the various façade systems on the aspect of “Attractiveness of out¬door Spaces” in comparison to the reference façade.

Summary “Attractiveness of outdoor Spaces”

- Façade greening has great potential for creating attractive and liveable outdoor spaces.
- Greening has the greatest potential in areas that are close to people (usually on the lower floors). On the façade, green areas can be used in a targeted manner and provide added design value on various levels (urban space, building structure, changing façade appearance, etc.)
- PV modules can be used in particular as an architectural design element. Various colours and patterns are available for opaque modules. Compared to the reference (fibre cement panel), similar possibilities are available here. Transparent modules have an additional design aspect here (degree of transparency).
- Deciduous plants change greatly with the seasons and lose their leaves in the winter months. Evergreen plants retain their foliage throughout the year (façade appearance remains largely unchanged). Ground-bound systems are also limited in their growth height.

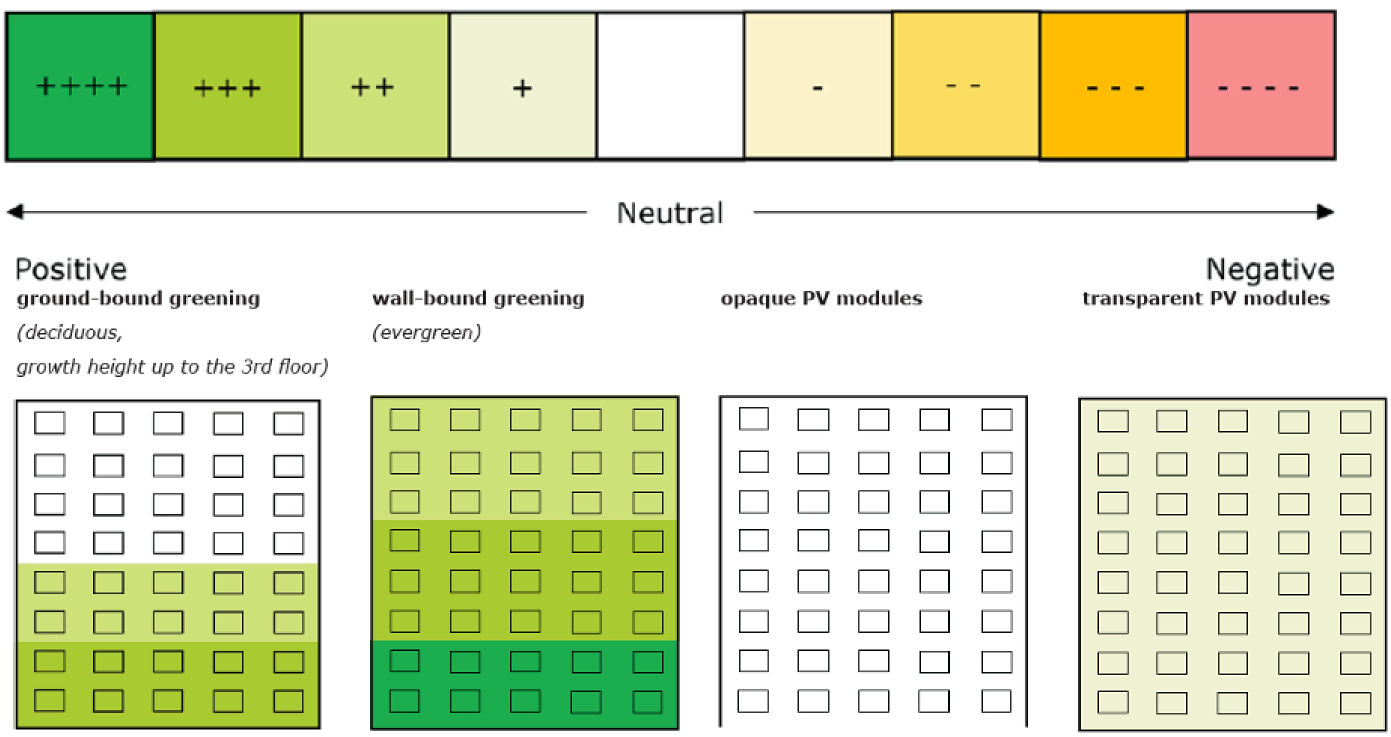


Figure 19: Influence of greening and PV façades on the attractiveness of outdoor spaces

2.8. Quantitative Aspects in Detail

2.8.1. Thermal Comfort in the Interior: Temperatures and overheating Hours

Evaluation of the façade systems

The following diagram shows the influence of the different façade systems on the aspect "Thermal Comfort in the Interior: Temperatures and overheating Hours" in comparison to the reference façade.

Summary "Thermal Comfort in the Interior: Temperatures and overheating Hours"

- Façade greenings have a positive effect on the indoor temperature and the number of hours of overheating. In a new building with a well-insulated façade, however, this effect can be categorised as minor.
- Wall-bound façade greening is generally more effecti¬ve than ground-bound planting. The effect is greatest in the east, south and west orientations from the 2nd floor upwards, as there is less shadowing from neighboring buildings and therefore more solar radiation reaches the façades.
- The PV façades were not analysed in detail. Although the temperature at the modules may be higher, this has hardly any effect on indoor comfort, especially if the building is of a good standard.

Note:

However, if the thermal properties of the building are to be improved, it should be kept in mind that (additional) insulation of the outer shell is more effective than a façade greening and should be favoured accordingly.

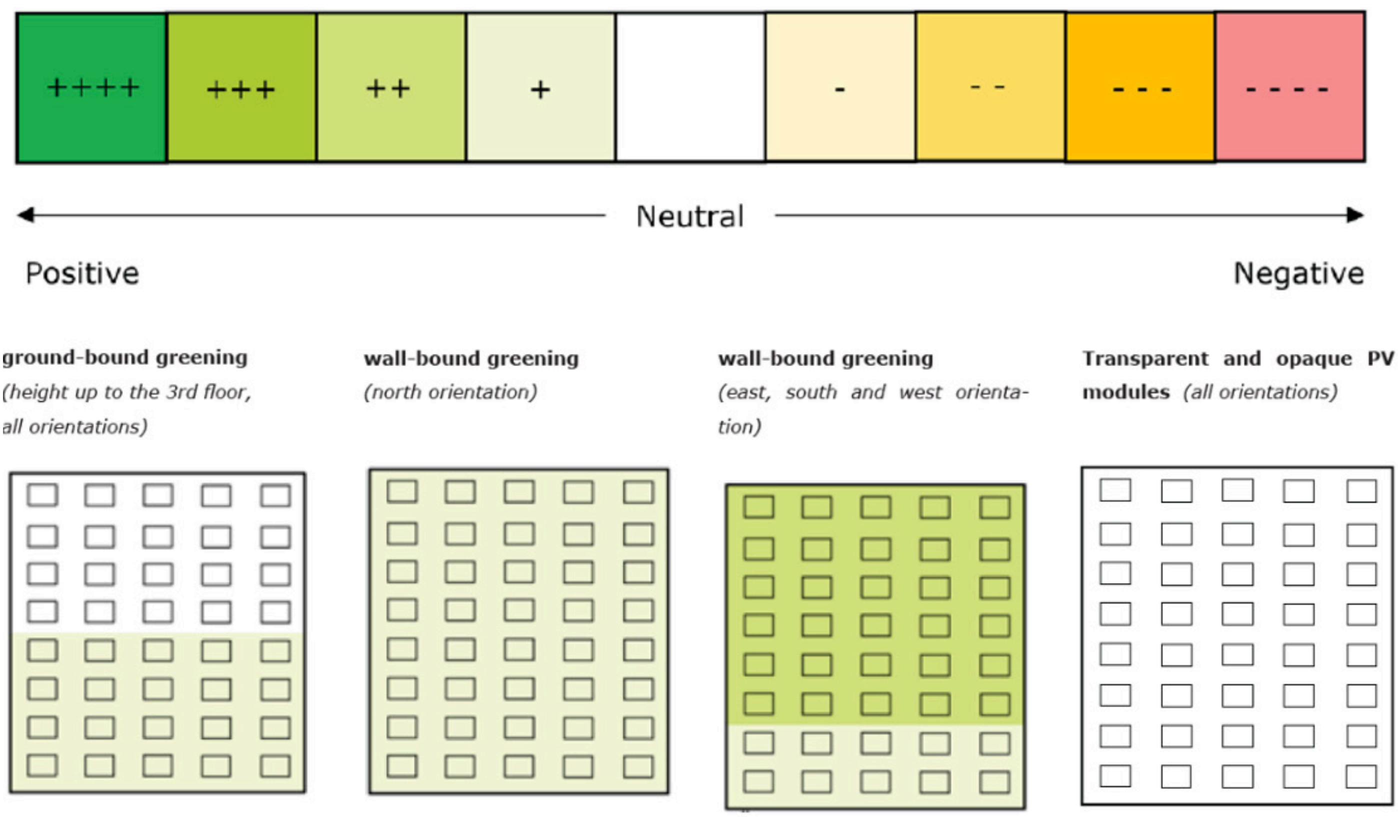


Figure 20: Influence of greening and PV façades on the indoor climate

2.8.2. Operating of the Building: Heating, Cooling and Electricity Consumption

Evaluation of the façade systems

The following diagram shows the influence of the different façade systems on the aspect "Operation of the Building: Heating, Cooling and Electricity Consumption" compared to the reference façade.

Summary "Operation of the Building: Heating, Cooling and Electricity Consumption"

- The influence of façade greening is very low due to the good thermal envelope, especially in the case of ground-based greening.
- Both greenings lead to a reduction in energy and power requirements in summer for the new building under consideration, but to an increase in winter. Overall, however, the effect over the year is slightly positive, as cooling will be more important in future.
- Due to the low effect of the greening, no colour gradation was applied to the storeys and orientations. However, the positive effect will be greatest on façade surfaces with direct sunlight.
- The influence of the PV façades can be assessed as neutral compared to the reference façade (rear-ventilated façade with fibre cement panels).

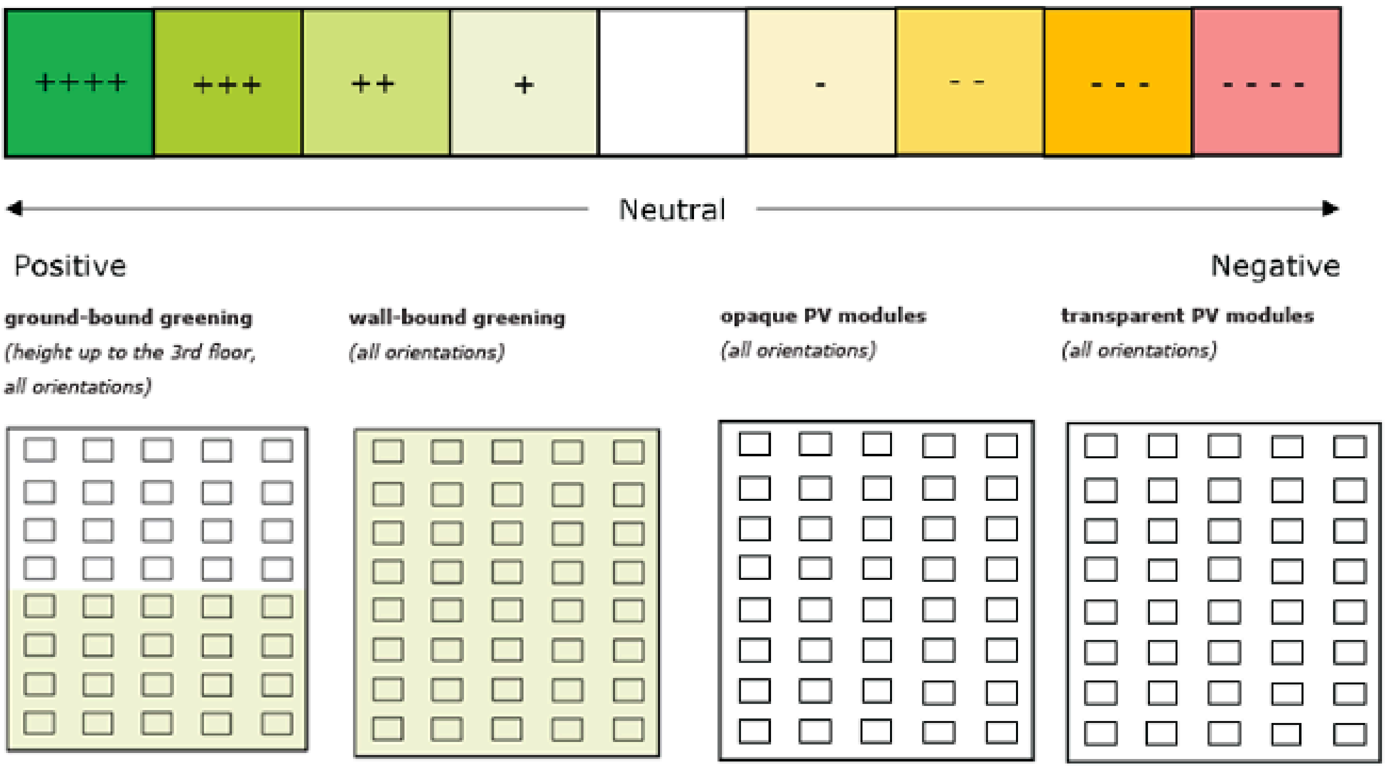


Figure 21: Influence of greening and PV façades on energy demand and power requirements

2.8.3. Electricity Production of the PV Façade, Solar Potential and Seasonal View

Evaluation of the façade systems

The following diagram shows the electricity generation potential of a PV façade (20% efficiency) over the year and in the winter months compared to the reference façade. The assessment was based on the calculation results for annual electricity generation and for winter electricity.

Summary "Electricity Production of the PV Façade, Solar Potential and Seasonal View"

- 1. Highest potential in the orientations south, then east, then west (in that order) and on non-shadowed areas of the façade.
- 2. Yields can also be achieved on a north-facing façade and on shadowed areas of the façade (lower storeys), but these are significantly lower.

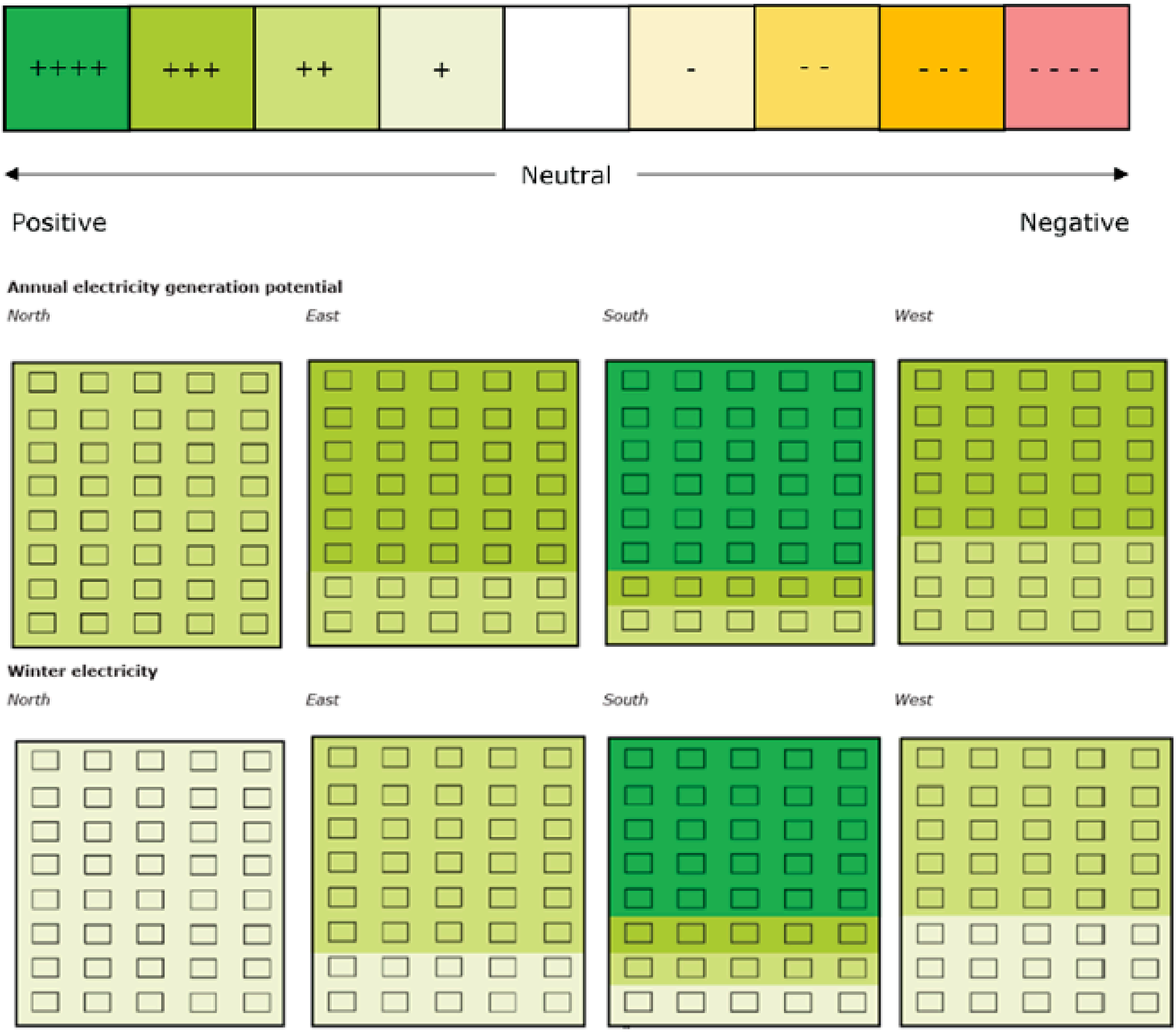


Figure 22: Annual electricity generation potential and winter electricity from PV façades in different orientations and stories

2.8.4. Production and Operation: Holistic Life Cycle Assessment (LCA)

Evaluation of the façade systems

The following diagram shows the influence of the various façade systems on the “overall Life Cycle Assessment” aspect compared to the reference façade. The impact is shown in relation to the GHG for production, maintenance and operation.

Summary “Production and Operation: Holistic Life Cycle Assessment (LCA)”

- Ground-bound greening only leads to slightly higher GHGs than the reference façade (slightly higher material costs for the system).
- Wall-bound greening requires more construction work than the ground-bound system and therefore leads to slightly higher GHG.
- With PV systems, the environmental impact of opaque modules is amortised more quickly than transparent modules (higher efficiency).
- A targeted arrangement is crucial for amortisation: the higher the electricity output during operation, the better.

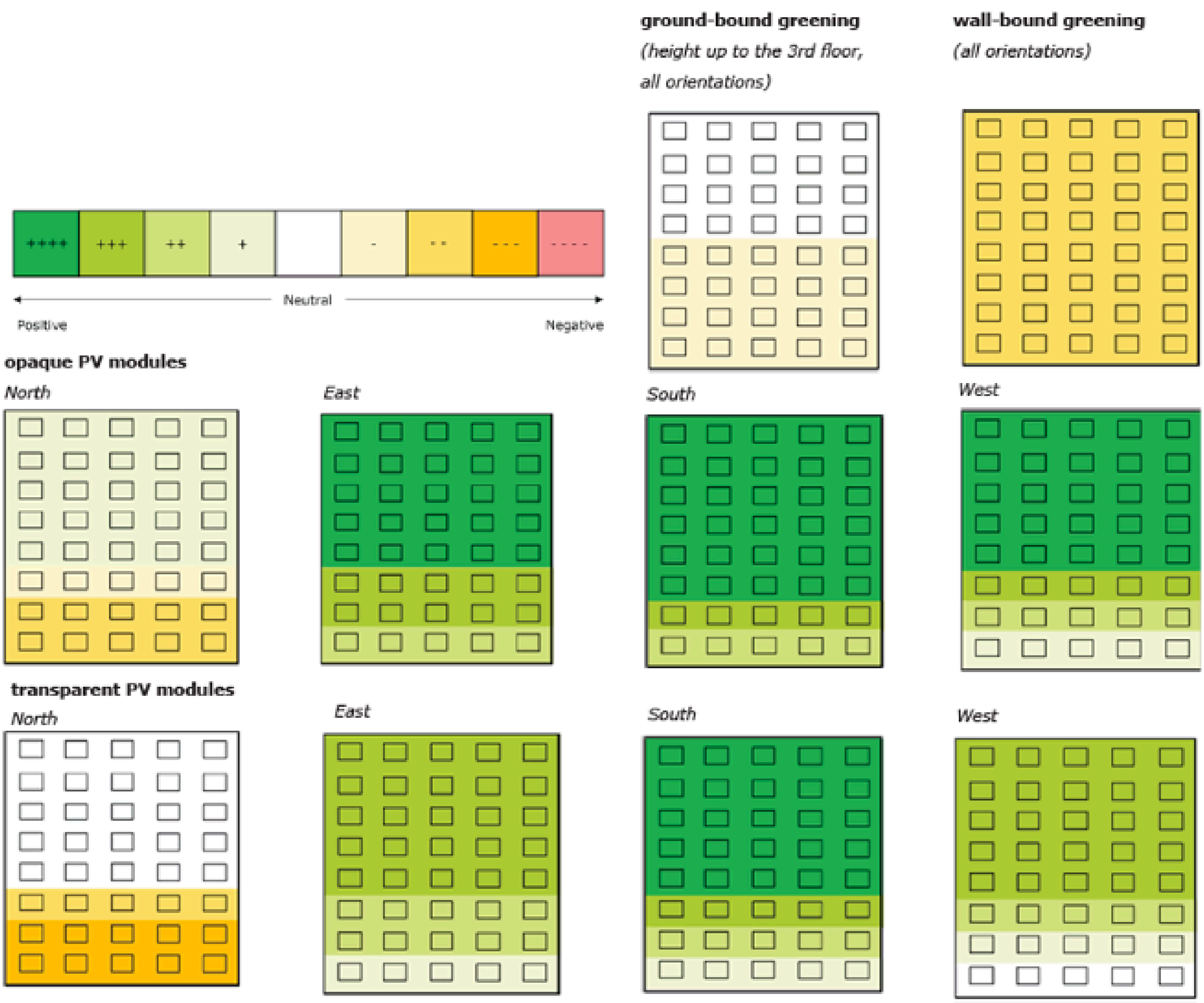


Figure 23: GHG for the construction, maintenance and operation of the four façade systems

2.8.5. Economic Consideration: Initial and Life Cycle Costs (LCC)

Evaluation of the façade systems

The diagram below shows the influence of the various façade systems on Life Cycle Costs (LCC) compared to the reference façade.

Summary "Economic Consideration: Initial and Life Cycle Costs (LCC)"

- Ground-bound greening only leads to slightly higher investment costs, but there are also ongoing mainte¬nance costs compared to the reference façade.
- Wall-bound greening is the most cost-intensive of the systems considered.
- The opaque PV façade can amortise the initially high costs over the life cycle if the modules are arranged on surfaces with high solar potential.
- The transparent modules lead to slightly higher costs over the life cycle than the reference, especially on surfaces with low solar potential.

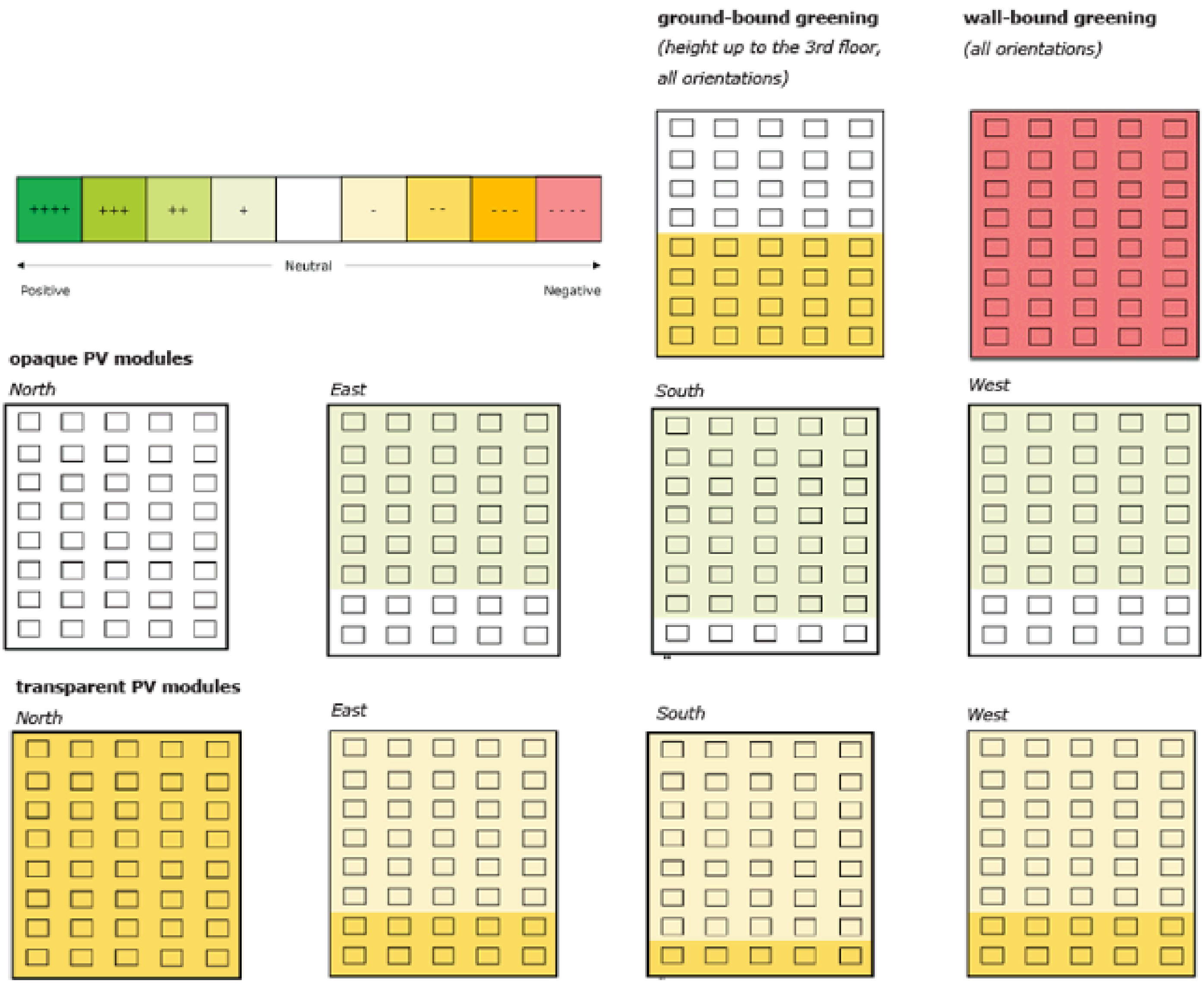


Figure 24: Investment and life cycle costs of the various façade systems compared to the reference façade

2.9. Combination Greening & PV

2.9.1. Findings of the qualitative and quantitative analysis

Greening and PV offer various advantages on the façade. In particular, greening can provide qualitative added value in outdoor spaces, including a better quality of stay, greater biodiversity and better rainwater management. There is also the potential for heat reduction, which will become increasingly important in cities in particular in view of climate change. However, electricity generation via PV façades will also become increasingly important in the future and represent a relevant measure for a sustainable energy supply in Switzerland. A combination of PV and greening on the façade could combine the advantages of both systems. As a rule, the two systems do not compete with each other: façade greening achieves the greatest effect when positioned close to people, i.e. in most cases these are the lower areas/storeys of the building. PV modules, on the other hand, should be arranged on façade areas with high electricity generation potential, i.e. on south, east and west façades without shadowing. This usually applies to the upper floors of the building, as the lower floors are usually shadowed by neighboring buildings.

2.9.2. System combinations

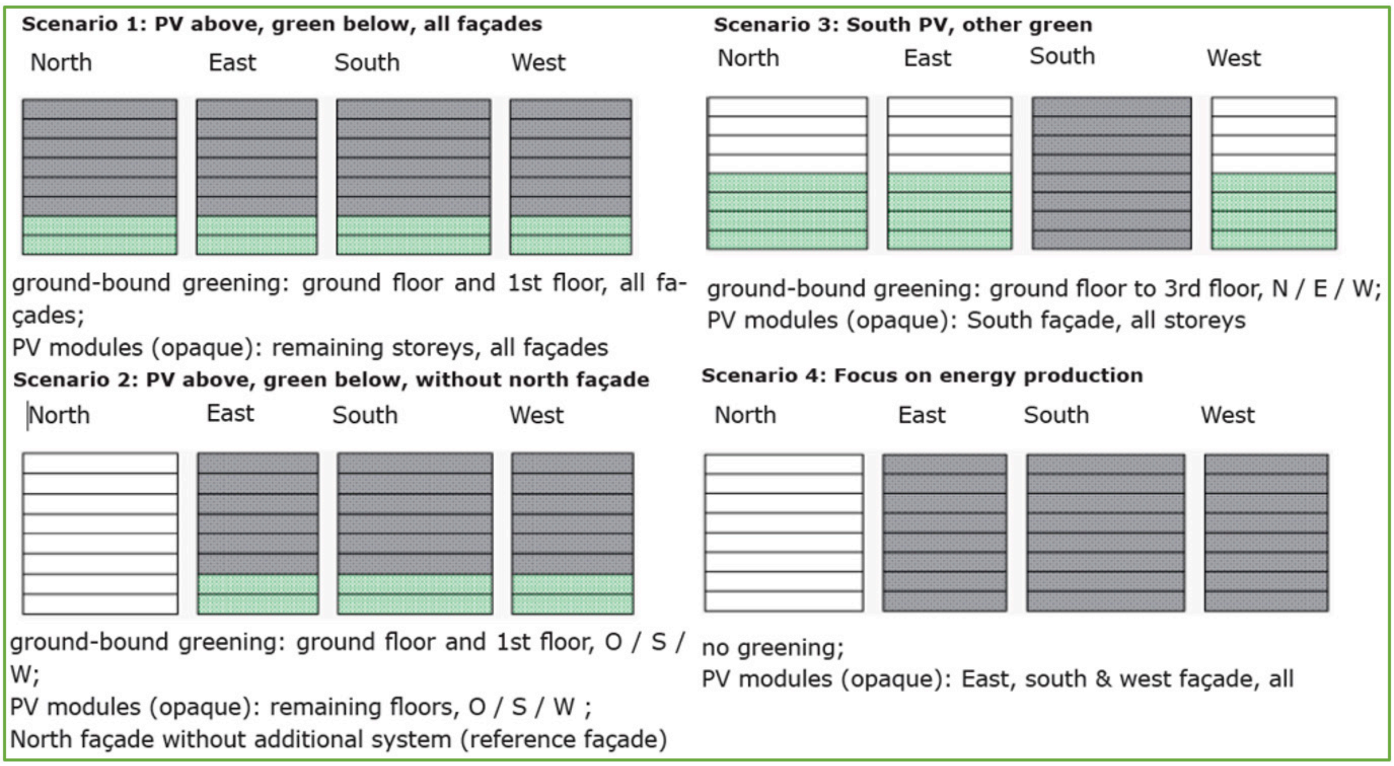
Based on these findings, the combination of different sys¬tems on the building was also analysed as part of the study. On the right are the various scenarios that specifically combine greening and PV on the façade (scenarios 1 to 3) or optimise the arrangement of PV modules (scenario 4). In each case, a ground-bound system was assumed for the wall-bound façade greening, as this has a lower environmental impact and is more cost-effective than a wall-bound system. For the PV façade, opaque modules were chosen as they also offer ecological and economic advantages due to their higher efficiency.

2.9.3. Added economic value

- A selective arrangement of the PV modules leads to lower life cycle costs than if the entire façade is covered with PV.
- A specific combination of greening and PV only leads to a slight increase in life cycle costs compared to the reference façade.
- Decisions should also take into account non-quantifiable aspects, such as greater attractiveness of the property through greening and PV, better lettability and long-term tenancies (fewer vacancies).

2.9.4. Ecological benefits

A selective arrangement of the PV modules or the combination of greening and PV on the façade can reduce the GHG over the life cycle compared to the reference façade.



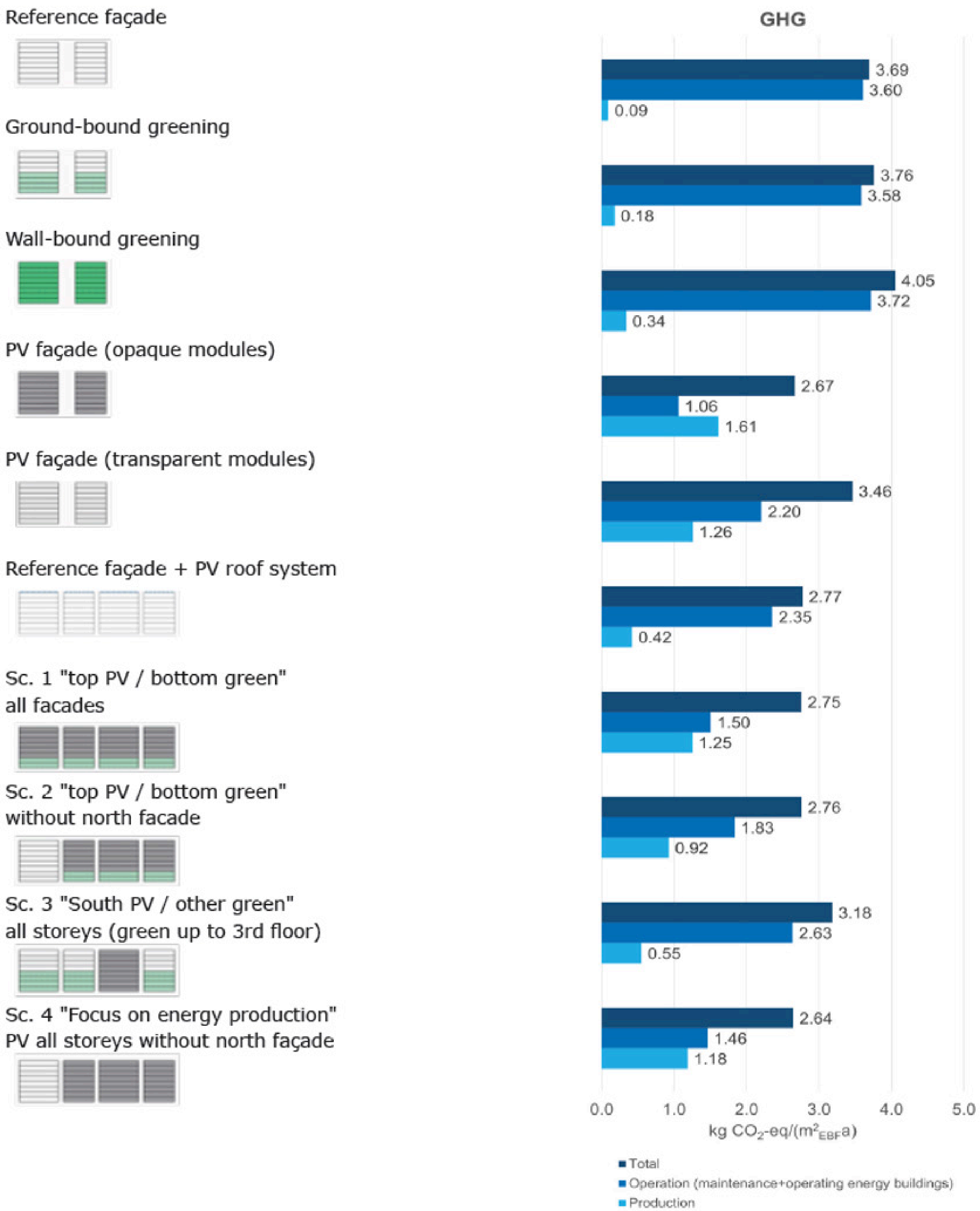


Figure 25: Greenhouse gas emissions of the reference façade (rear-ventilated façade with fibre cement panels), the various façade systems, the PV roof system including reference façade and the four scenarios. The results are shown for the reference building "new building".

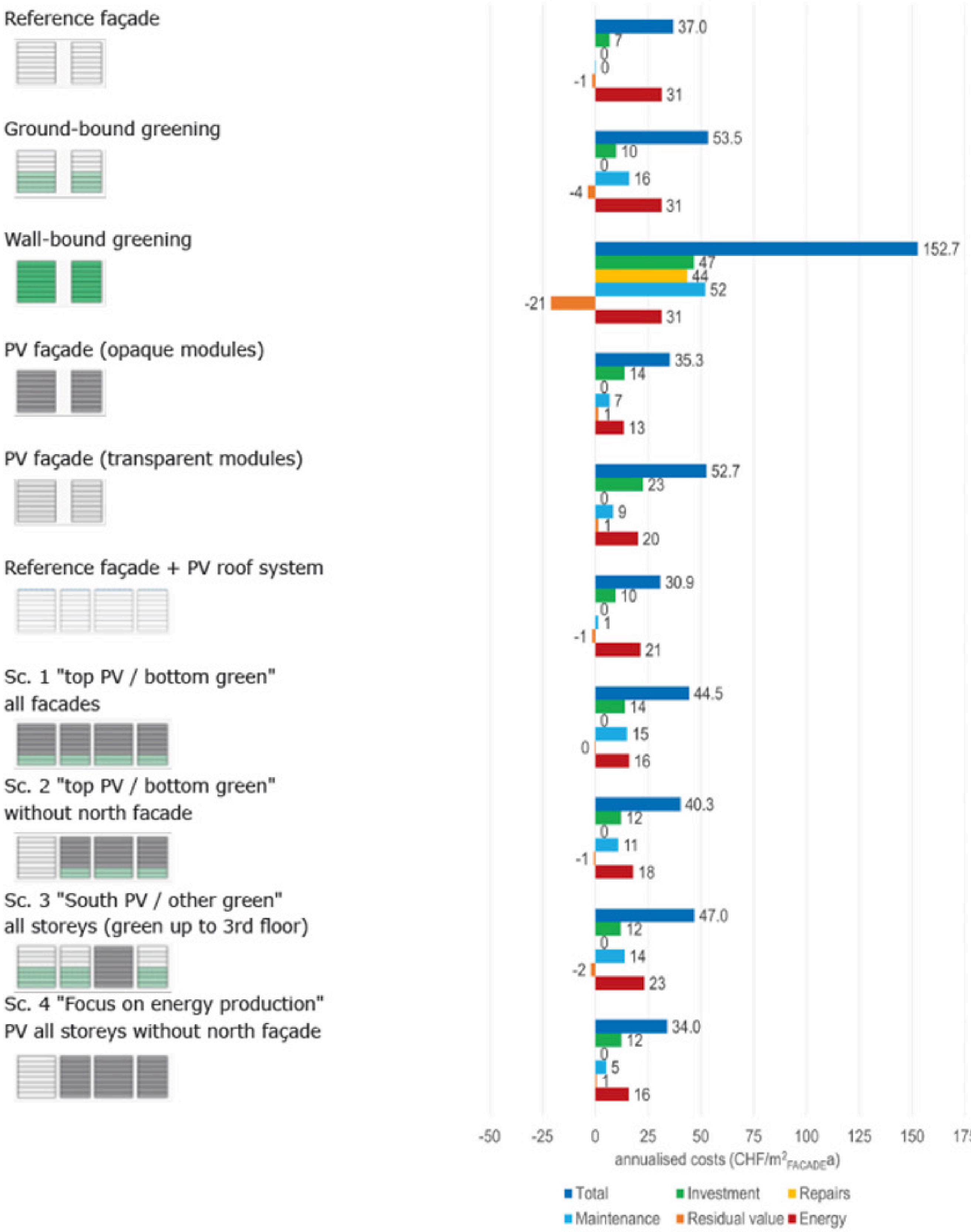


Figure 26: Annualised costs (present value) of the reference façade (rear-ventilated façade with fibre cement panels), the various façade systems, the PV roof system incl. reference façade and the four scenarios. The results are shown for an observation period of 30 years for the reference building "new building".

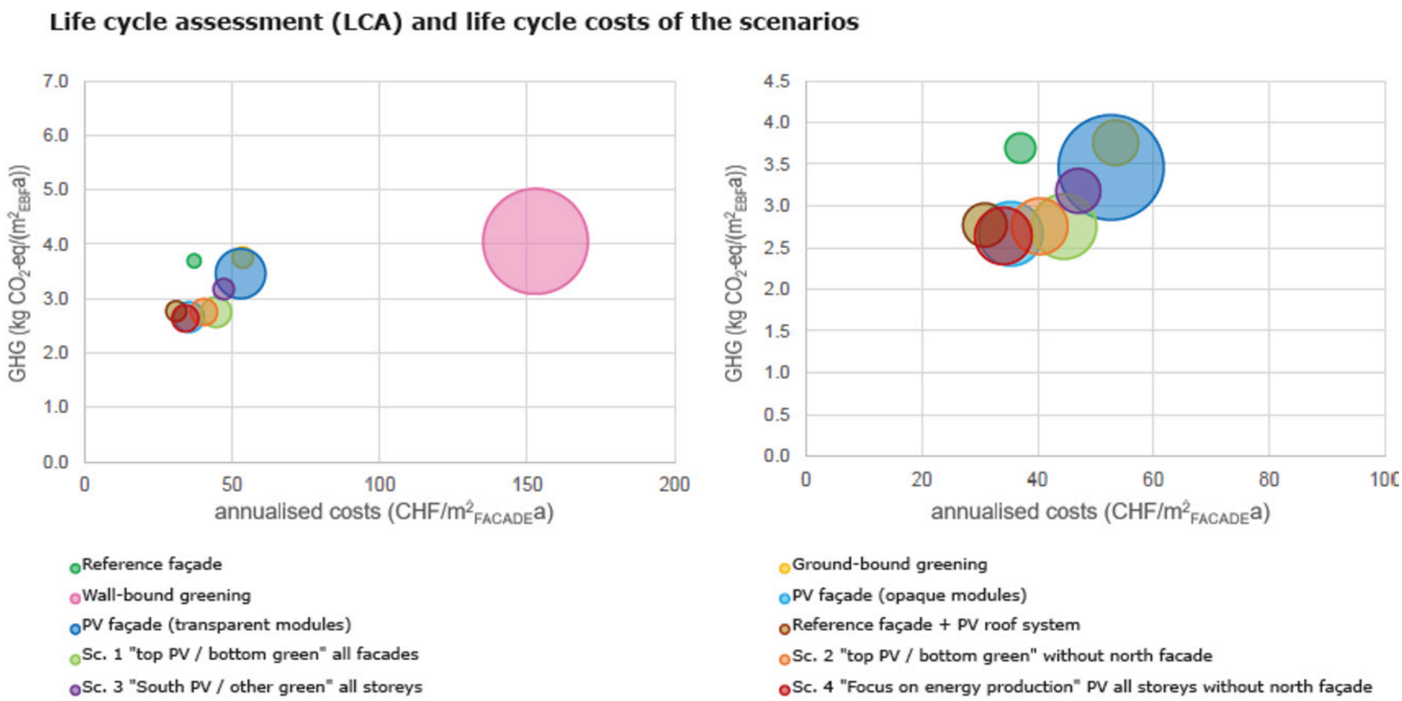


Figure 27: LCA and annualised costs during the 30-year observation period (left: all variants; right: enlarged representation without the wall-bound greening). The size of the circle shows the investment costs. The results are shown for the reference building “new building”.

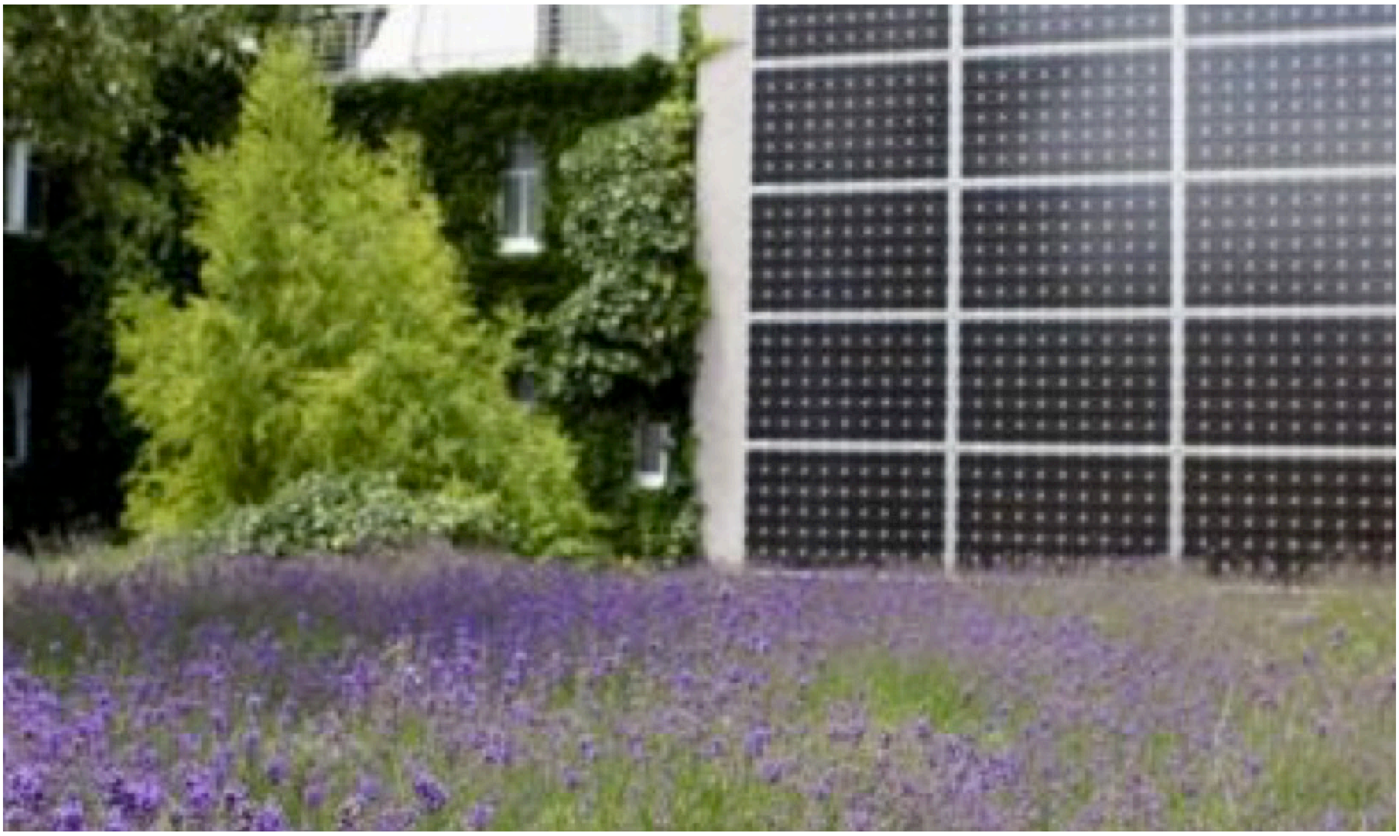


Figure 28: The combination of PV and greening is worthwhile in many respects (© Boutiquehotel Stadthalle Wien)

2.10. Positive Factors on the Effect of Greening and PV

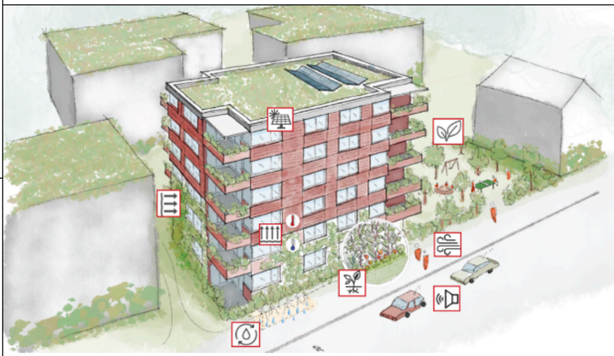
Below is an overview of the various positive factors on the effect of Greening and PV:

Noise in cities
+ High plant density
+ High green volume
+ Small leaf structures
+ Loosely stored substrates
+ Proximity to the emission source (usually on the lower floors)
+ Distance to the emission source (usually on the upper floors)
+ Combination with greening

Attractiveness of outdoor spaces
+ Different plant species
+ Flowering times and colours
+ Proximity to people and recreation areas (usually on the lower floors)
+ Design options: Patterns, colours, degrees of transparency...
+ Combination with greening

Rainwater retention
+ High substrate layer (infiltration)
+ High green volume (evaporation capacity)
+ Weather sides North/North-West

Air quality
+ High leaf density
+ High degree of coverage
+ Sufficient water supply
+ Proximity to the emission source (usually in the lower storeys)



Thermal comfort indoors & operation of the building (heating, cooling and electricity consumption)
+ High green volume / substrate volume
+ High degree of coverage
+ Avoid shadowing of windows in winter
+ greatest effect in unrenovated old buildings (high U-values)

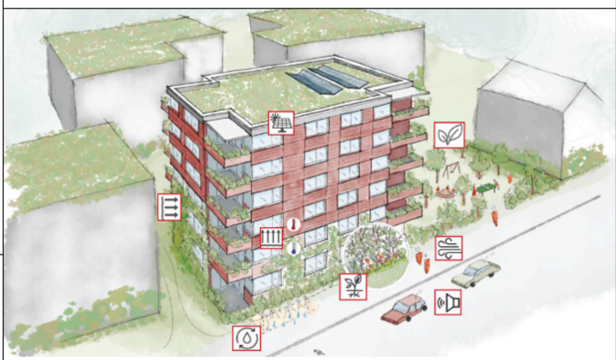
Temperature on the façade, influence on the ambient climate (summer)
+ High green volume / substrate volume
+ Sufficient water supply
+ Orientation: east, then south and west
+ Good air circulation
+ Combination with greening

Biodiversity
+ Favours native plant species
+ Use plants adapted to the location
+ Mixed cultures (different plant species) instead of monocultures with only one species
+ Use as a connecting element of green spaces ("green belt")
+ Combination with transparent PV elements (shadowing -> different microclimate)

Winter electricity
+ High efficiency
+ Steep to vertical arrangement
+ Avoid shadowing
+ Orientation: south, then east and west
+ Aim for longevity and efficient systems (maintenance and upkeep)

Production and operation: Holistic Life Cycle Assessment (LCA)
+ Less material-intensive systems, conscious choice of materials
+ High green volume
+ Rapid amortisation due to high efficiency
+ Avoid shadowing
+ Architecture with efficient arrangement, little shadowing
+ Orientation: south, then east and west
+ Combination with mobility & heat generation, possibly storage

Economic analysis: initial and life cycle costs (LCC)
+ Systems with low care and maintenance requirements
+ Robust plants and systems (long service life, reduced susceptibility)
+ Clarify possible subsidies
+ Use of standard modules
+ Simplicity of the system
+ Optimisation of yields
+ Robust systems with low susceptibility



Production (grey greenhouse gas emissions)
+ Use of reusable and renewable materials (e.g. steel, wood, etc.) for the substructure
+ Reduce construction costs, pay attention to additional costs for statics
+ Technical elements only where necessary
+ Favour local companies
+ Use reusable and renewable materials (e.g. steel, wood...) for the substructure
+ Compare product declarations / favour local products
+ Durable and robust systems (guarantee dis-mantlability and plan for replacement modules)

Annual electricity generation potential
+ Combination of greening + PV (evaporative cooling -> increased efficiency)
+ High efficiency
+ Avoid shadowing
+ Orientation: south, then east and west
+ Aim for longevity and efficient systems (maintenance and upkeep)

2.11. Focus Topics

2.11.1. Combination of Greening and PV

A combination of different façade systems can bring advantages with regard to various aspects (efficiency, design, etc.). In an urban context, low-lying areas of buildings are often shadowed, which is why the installation of PV modules is only worthwhile in rare cases. Modules on exposed surfaces have a shorter amortisation period. Shaded areas, such as the north façade, can be suitable for façade greening. Areas close to the street benefit in particular, as the quality of life there is enhanced and has a positive effect on the urban climate.

Figure 31: Hortus, Allschwil near Basel, movable, horizontal PV modules on the outer façade (left) produce electricity and serve as sun protection, in the inner courtyard (right) the façade was greened (© Herzog & de Meuron)

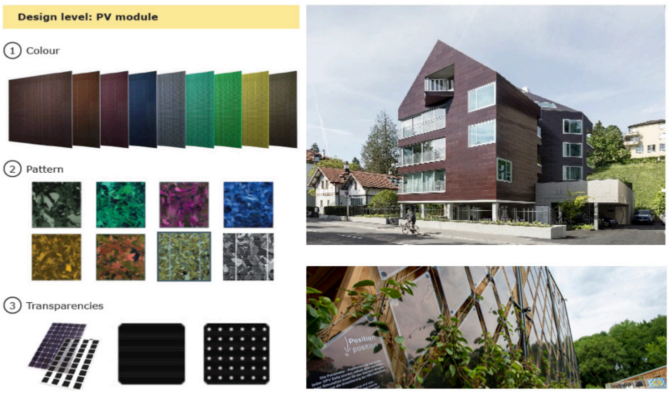


Figure 29: left: Design options at PV module level (© SI Module GmbH, ertex solartechnik GmbH, friSolar); top right: Residential building in Zurich, Solaris 416, opaque PV façade and roof, uniform choice of colours for the modules used (© Beat Bühler); bottom right: SolarDecathlon 21/22 input from CoLLab, the trellis on the façade is used for both PV modules and greening (© Lukas Fischer, HFT Stuttgart)

Figure 32: left: Residential building in Zurich, Höngg, opaque PV modules design the façade of the residential building (© Kämpfen Zinke + Partner AG); middle & right: Office for Environment and Energy in Basel, customized PV panels give the building its expression (© AUE)

Figure 30: left: Transparent, coloured PV modules design the façade of the SwissTech Convention Center in Lausanne (© Mediacom EPFL); right: SolarDecathlon 21/22 Entry from Local+. PV and greened areas were clearly separated from each other in the façade design (© team-localplus)

Figure 33: SolarDecathlon 21/22 input from CoLLab, the trellis on the façade is used for both PV modules and greening (© Lukas Fischer, HFT Stuttgart)

2.12. Checklist

Façade planning with greening and PV *Recommendations for the phases of SIA 112:2014*	*1 Strategic planning*	*2 Preliminary studies*	*3 Project planning*	*4 Invitation to tender*	*5 Realisation*	*6 Operation*
BASICS:						
Create and document references to overarching objectives, guiding principles or plans of the neighbourhood, municipality or canton, e.g. energy reference plans, climate change maps, guidelines on urban climate or green corridors						
Identify and take into account overall or neighbourhood concepts that are relevant for façade design with regard to the targeted promotion of energy and urban climate priorities and greening objectives						
Sensitising and informing the client about the advantages and disadvantages of the various façade systems. Ensure the flow of information to project decision-makers						
Clarification of legal conditions (restrictions and requirements) - Clarify authorisation procedure and eligibility in advance (critical points: Monument protection, appearance, fire protection, façade reflection, bird/animal protection...) - PV: Check conditions of potential grid operators (connection search)						
OBJECTIVE:						
Joint definition of objectives to be pursued with the façade (e.g. with regard to exterior and interior quality, energy generation, biodiversity, (rain)water management, social exchange, identification)						
Drawing up a building envelope energy concept, prioritising the following aspects: - Energy production (electricity or heat) and energy reduction (thermal insulation, movable / fixed or structural / natural sun protection, e.g. through greening) - PV: maximum annual solar power yield / maximum winter power yield - PV: self-consumption coverage: quantitative / temporal consistency - PV: Storage option (battery, combination with electromobility or heat pump)						
Drawing up a building envelope greening concept, prioritising the following aspects: - Compare options for surroundings, roof and façade - Façade: improving the outdoor climate, shading the façade or outdoor/indoor areas - Façade: design options (e.g. reference to nature, colour, seasonal changes)						
Establish a long-term view as the basis for the profitability analysis						

Façade planning with greening and PV *Recommendations for the phases of SIA 112:2014*	*1 Strategic planning*	*2 Preliminary studies*	*3 Project planning*	*4 Invitation to tender*	*5 Realisation*	*6 Operation*
LOCATION:						
Analysing the building plot today and with a view to the future Topics: Air quality, cityscape, climate, solar radiation, orientation, shadowing, building utilisation times depending on façade side and storey, relationship to surrounding buildings, supply options, need for recreational areas, meeting points...						
Assessing the need for and suitability of greening and PV systems						
BUILDING:						
Determination of space potential on the façade. Where is space generally available? Where are which systems suitable?						
Carrying out a variant test: - Options for façades and roof systems (costs / benefits) - Application of greening and PV systems in the façade (PV only, green only, combination) - Cost analysis/rough cost calculation compared to a conventional façade, taking into account the entire life cycle of the system, any local feed-in tariffs and subsidies						
Clarification of technical feasibility (façade properties, statics)						
Checking of the supply and maintenance requirements (space requirements, accessibility, need for lifting equipment, etc.)						
FAÇADE GREENING:						
Preliminary clarifications considering the desired façade appearance: - Ground or wall-mounted systems - Direct growth on the façade or climbing aids (corresponding verification of suitability for exterior walls) - Consideration of the growing season depending on the choice of system - Evergreen or deciduous plants (seasonal consideration, summer - greening as a shadowing element, winter - deciduous greening allows heat gains via transparent components, evergreen plants recommended for north façades)						
Determining of the static requirements depending on the system and, if necessary, taking measures to fulfil the load-bearing capacity. Prepare verifications						
Pre-selection of plants according to current and future site factors (water, light, heat, chemical and mechanical factors) in consultation with experts						

Include specific targets for climate-change-friendly construction in the general terms and conditions of tenders *Façade planning with greening and PV* *Recommendations for the phases of SIA 112:2014*	1 Strategic planning	2 Preliminary studies	3 Project planning	4 Invitation to tender	5 Realisation	6 Operation
COMMISSIONING:						
Fulfilment of the required tests (electricity, any irrigation systems)						
Notification of commissioning to authorities, fire brigade and the local grid operator						
Instruction of the client, FM officer or technical personnel						
MAINTENANCE AND SERVICING:						
Development of a concept for maintenance and servicing - Plan accessibility of the façade (e.g. lifting platform, façade lift...) - Check space requirements and floor load-bearing capacity for scaffolding and lifting platforms - Cooperation with specialised personnel (Façade cleaning specialists, Gardener)						
Development and safeguarding of the monitoring concept - Recording electricity production and financial flows - Systematic fault reports, periodic checks in accordance with NIV Reading and processing of data						
Consider management by specialised personnel and instruction of FM contractors - Maintenance contract - Regular cleaning - Repairs in the event of a fault (Inverter, Software updates, Irrigation system) - Replacement of system components (Holders, degraded PV modules (Repower), damaged plants)						
Transfer of the system to a recycling company in the event of dismantling						
DOCUMENTATION:						
Documentation of all aspects of the project planning and realisation phase: plans, reports, technical data sheets, maintenance plan.						
Documentation of maintenance appointments and all work carried out						

Façade planning with greening and PV *Recommendations for the phases of SIA 112:2014*	*1 Strategic planning*	*2 Preliminary studies*	*3 Project planning*	*4 Invitation to tender*	*5 Realisation*	*6 Operation*
FAÇADE GREENING:						
If necessary, develop a concept for irrigation - Clarification of irrigation requirements taking into account climate change (temperature peaks, possible temporary shortages) - Use of rainwater and/or grey water - Evaluation of sensor-based, demand-led control (especially for wall-mounted systems)						
PV FAÇADE:						
Preliminary clarification taking into account the desired façade appearance - Design with opaque, transparent, inclined elements - Evaluation of PV elements as fixed sun shading - Integration in the overall colour concept						
Clarification of the dimensions of standard modules in the planning stage (cost reduction)						
Define and draw system layout. Create a project description						
Clarify detailed questions for current and future requirements (statics, mounting system, inverters, cable routing, feed-in concept, measurement and billing concept, interfaces with roofers, plumbers, building services engineering, electromobility)						
FIRE PROTECTION:						
Development of a fire protection concept - Observing the applicable standards and guidelines at cantonal and federal level - Create a customised protection concept in consultation with experts - Discussion and approval of the concept by the responsible authority						
Ensuring correct operation: If necessary, regular watering and maintenance (removal of dead wood) to ensure fire protection and an attractive façade appearance						
Ensuring correct operation: Regular inspection of the components / system						
IMPLEMENTATION:						
Material and plant selection taking into account the ecological impact (e.g. life cycle assessment of the system components, influence on the environment, water and nutrient supply)						
Definition of technical details taking into account circularity (e.g. dismantlability, recyclability, reusability)						

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