Toolkit for Innovative and Eco-sustainable **Renovation Processes**

Abacus

Med-EcoSuRe

Mediterranean University as Catalyst for Eco-Sustainable Renovation

Integral part of the Med-EcoSure Toolkit for Innovative and Eco-Sustainable Renovation Processes, the Abacus of Retrofit Design Solutions has been developed in the framework of the Med-EcoSure project - Mediterranean University as catalyst for Eco-Sustainable Renovation, by the research group beXLab (building environmental eXperience) at the DIDA Department of Architecture of the University of Florence.

The Toolkit has been delivered as output of the Med-EcoSuRe project in **November 2022.**

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Introduction

The Abacus of Retrofit Design Solutions is an integral part of the 'Toolkit for an innovative and eco-sustainable renovation of university buildings', developed as output of the Med-EcoSure project - Mediterranean University as Catalyst of Eco-Sustainable Renovation (co-funded by ENI CBC MED program 2014-2020).

Within the Toolkit 5-phase renovation process, the Abacus is useful when the Analysis of Criticalities on the existing building has been carried out, and the Planning and Design of retrofit projects has to start.

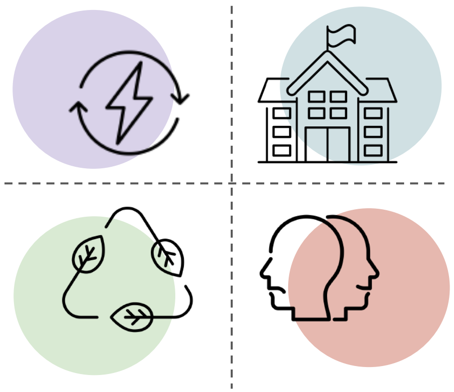
The Abacus is an organised and navigable selection of strategies for building retrofits in the Med socio-climatic context, correlated with appropriate technologies and materials. Firstly dedicated to high educational/university building, the Abacus can inform the pre-design phase of public buildings' renovation.

Contents have been selected and organised on the basis of an analysis of literature on building renovation in the Mediterranean area, and of best practices related to innovative energy efficiency projects related to university buildings (integral part of the Toolkit- see Best Practices).

Firstly dedicated to Living Lab contexts innovating building renovation processes, the Abacus is intended to stimulate an eco-sustainable, innovative, creative and collective design of retrofit projects, enabled by university/public building managers and involving the university/local community of stakeholders and users, as students/citizens.

Supporting innovative and eco-sustainable retrofit co-design processes [see Toolkit Phase 3 - Planning and Design], the Abacus is a tool to explore the most appropriated retrofit strategies, technologies and materials. For a best exploitation of the Abacus, it is important to consider the highly influencing pre and post design phases: the retrofit project needs to be appropriated to the specific existing building [see Toolkit Phase 1 - Knowledge Framework] in order to solve its criticalities [see Toolkit Phase 2 - Analysis of Criticalities] with a cost-effective interventions [see Toolkit Phase 4 - Intervention], also foreseeing the management of the future renovated building [see Toolkit Phase 5 - Post-management].

WHAT

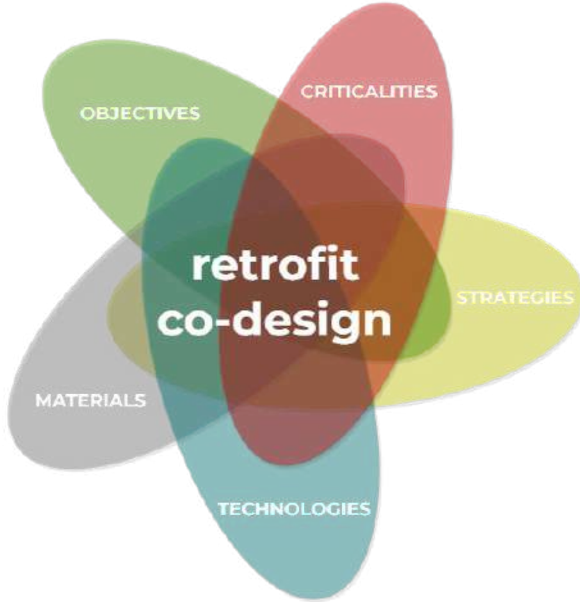


The Abacus of Retrofit Solutions is an easy-to-use tool to move the first steps in the Planning and Design of innovative and eco-sustainable renovation of Mediterranean University buildings, exploring the most appropriate strategies, technologies and materials to solve existing criticalities and reach ambitious renovation targets.

WHO

The Abacus is dedicated to building managers and technicians in charge of the management of the university/public buildings' stock who, well-knowing building and energy criticalities, are called to plan and design renovation actions. Also in the case of external contracting of retrofit projects (to professional architects, engineers, ESCOs), the Abacus can drive the definition of needs and requirements to inform an eco-sustainable and innovative retrofit project (e.g. . by setting the design phase (definition of the requirements for the architectural projects). For this reason, the Abacus is also useful to architects and engineers to align with the innovative and eco-sustainable retrofit objectives guiding the renovation of the university/public building.

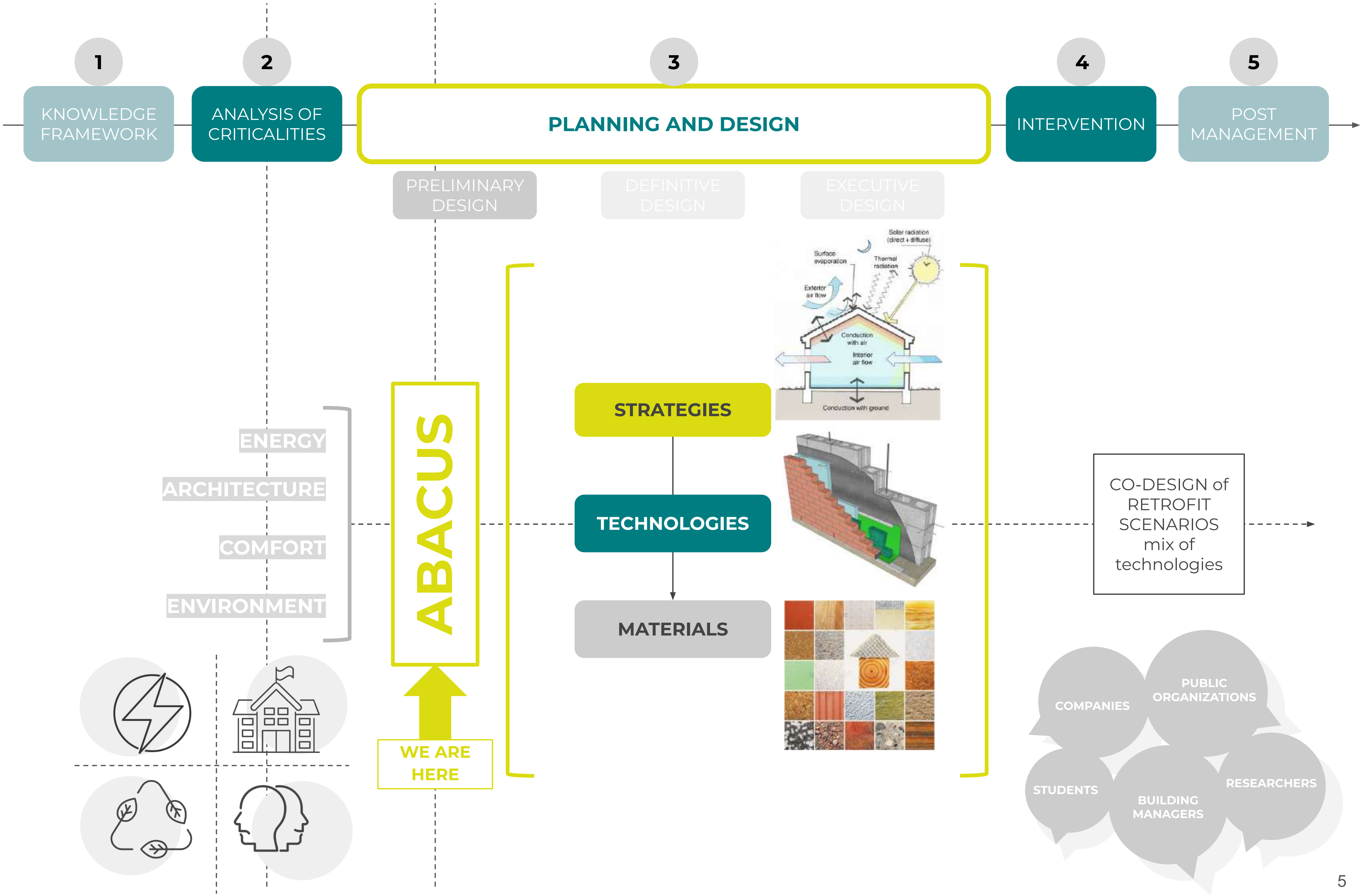
HOW



Dedicated to inspire the first phases of co-design, the Abacus is organised in five levels of exploration.

Starting from the recognition of renovation objectives/targets and of the criticalities of the existing building [see the Toolkit], the Abacus guides the co-design of bioclimatic and passive strategies for the Mediterranean socio-climatic area, towards the choice of the best technologies and the selection of traditional /innovative sustainable materials for the definition of cost-effective retrofit scenario.

The document is navigable: search and click links in the pages to move across the five levels of exploration


1
KNOWLEDGE FRAMEWORK
2
ANALYSIS OF CRITICALITIES
3
PLANNING AND DESIGN
4
INTERVENTION
5
POST MANAGEMENT
PRELIMINARY DESIGN
DEFINITIVE DESIGN
EXECUTIVE DESIGN
Solar radiation (direct + diffuse)
Surface evaporation
Thermal radiation
Exterior air flow
Conduction with air
Interior air flow
Conduction with ground
ENERGY
ARCHITECTURE
COMFORT
ENVIRONMENT
ABACUS
WE ARE HERE
STRATEGIES
TECHNOLOGIES
MATERIALS
CO-DESIGN of RETROFIT SCENARIOS mix of technologies
COMPANIES
PUBLIC ORGANIZATIONS
STUDENTS
BUILDING MANAGERS
RESEARCHERS

ABACUS
of Retrofit Design Solutions

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RETROFIT OBJECTIVES

A successful retrofit project addresses four interrelated objectives:

Reduction of ENERGY demand

-

Retrofits require at first instance the reduction of the building's energy demand, so that the low energy need can be fully satisfied by an integrated renewable energy production.

Improvement of ARCHITECTURAL QUALITY

+

Retrofits are an occasion for the aesthetical requalification of the university building, contributing to the definition of the green image of the university

Improvement of COMFORT and WELLBEING

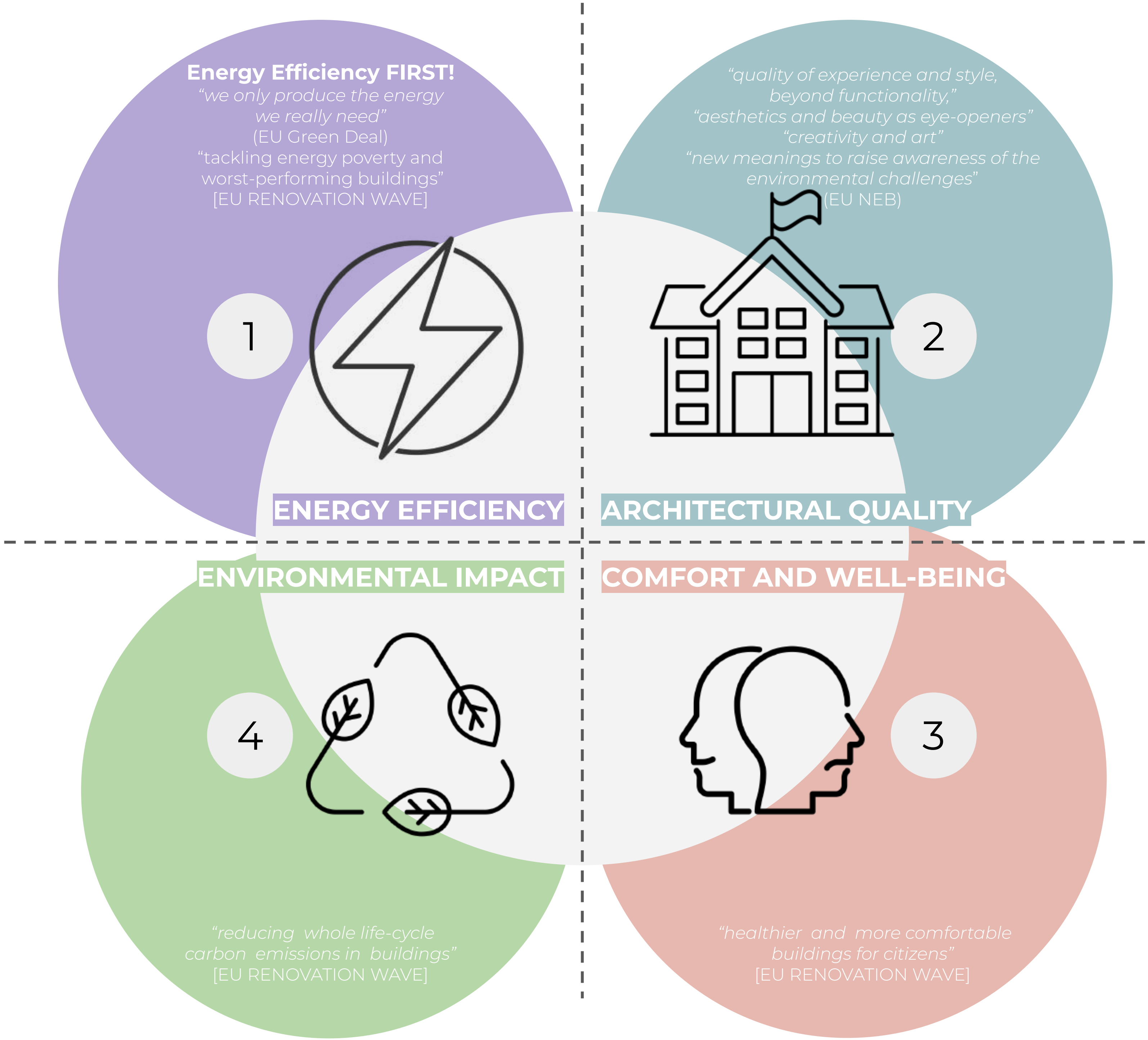
+

Retrofits can improve the indoor environmental conditions of university spaces in order to guarantee health, comfort and well-being for buildings' occupants, sustaining better didactic, working and social activities.

Reduction of ENVIRONMENTAL IMPACT

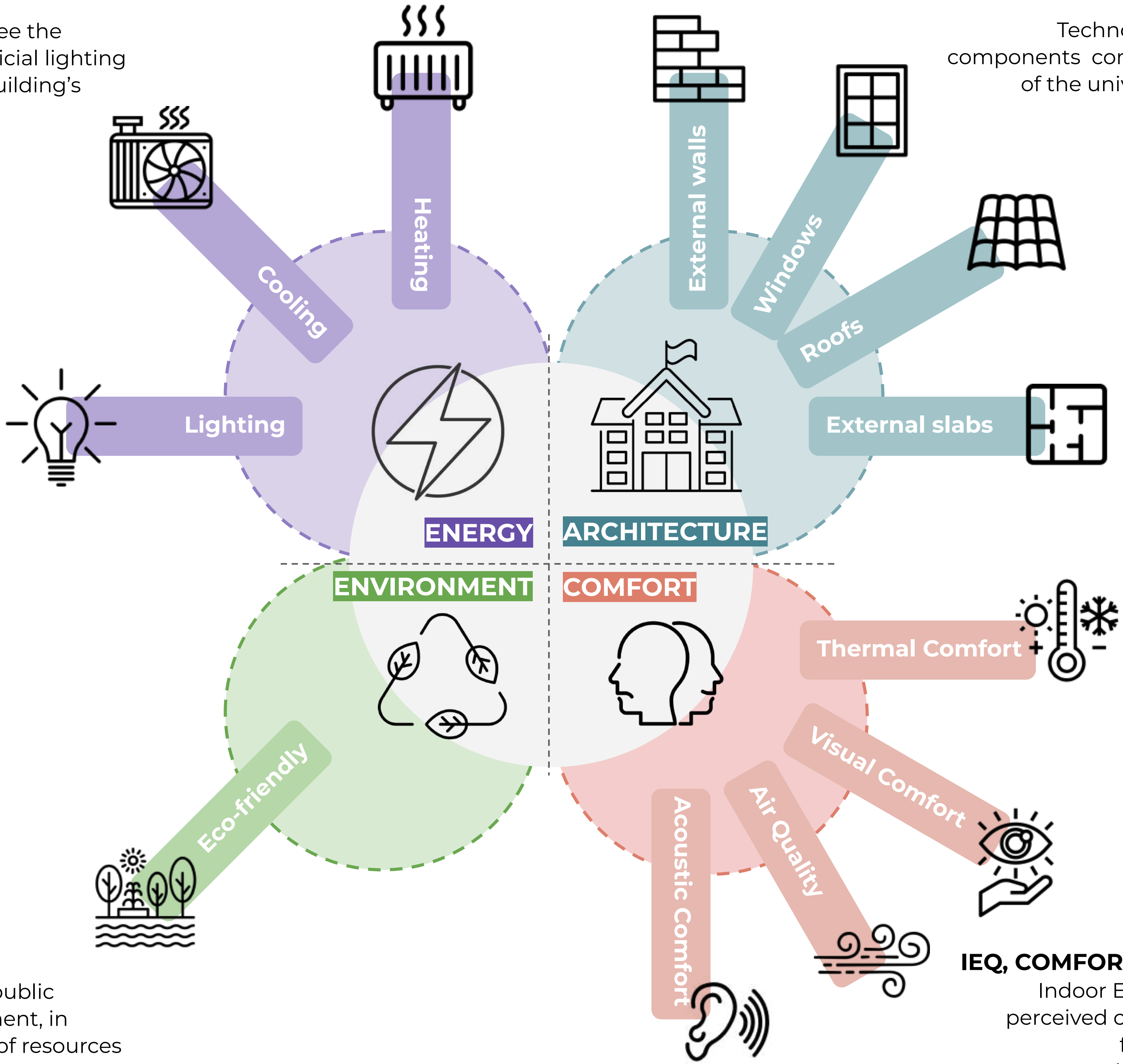
-

Ambitious retrofits can also reduce the environmental impact of the University, in terms of use of renewable resources and carbon-neutral solutions, contributing to the university strategies for sustainability.


Energy Efficiency FIRST!
"we only produce the energy we really need"
(EU Green Deal)
"tackling energy poverty and worst-performing buildings"
[EU RENOVATION WAVE]
"quality of experience and style, beyond functionality,"
"aesthetics and beauty as eye-openers"
"creativity and art"
"new meanings to raise awareness of the environmental challenges"
(EU NEB)
1
2
ENERGY EFFICIENCY
ARCHITECTURAL QUALITY
ENVIRONMENTAL IMPACT
COMFORT AND WELL-BEING
4
3
"reducing whole life-cycle carbon emissions in buildings"
[EU RENOVATION WAVE]
"healthier and more comfortable buildings for citizens"
[EU RENOVATION WAVE]

ENERGY
Plant systems to guarantee the heating, cooling and artificial lighting of the university/public building's living spaces

ARCHITECTURE
Technological elements and components composing the envelope of the university/public building



ENVIRONMENT
Impact of the university/public building on the environment, in terms of sustainable use of resources (renewable energies, circular materials) for low carbon emissions

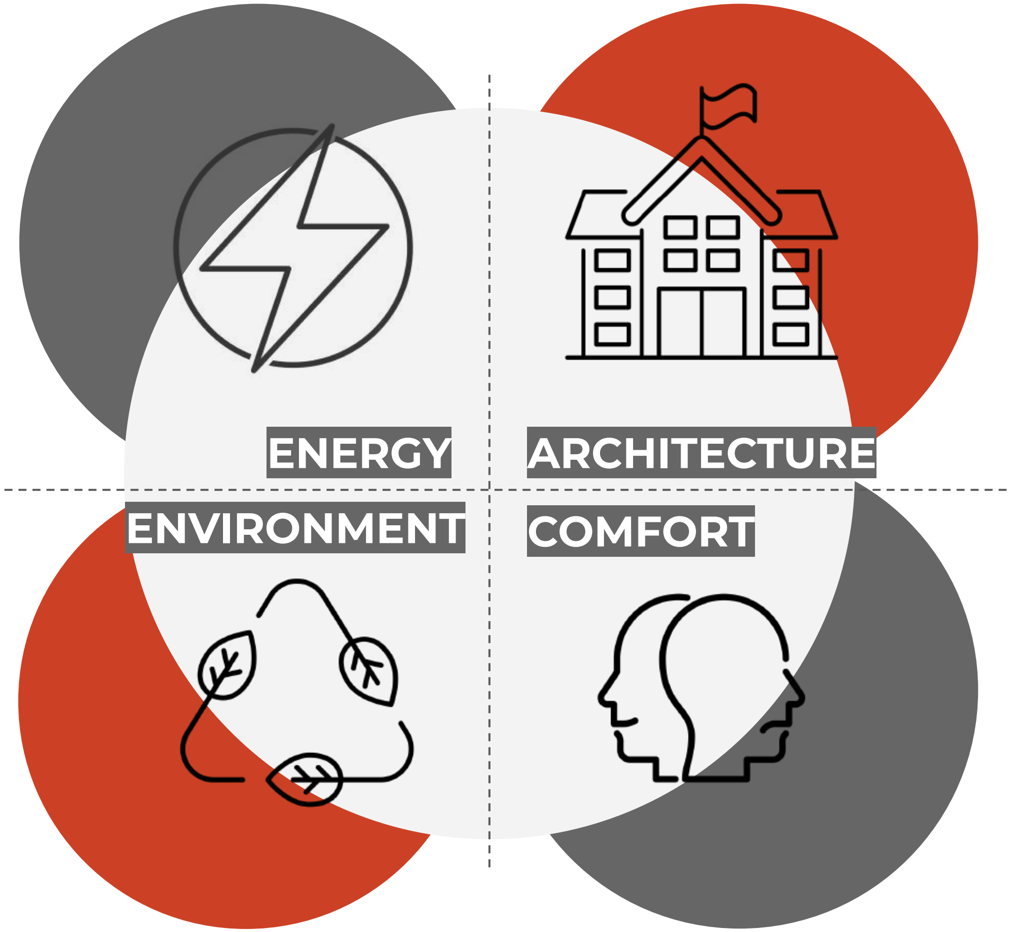
IEQ, COMFORT AND WELLBEING
Indoor Environmental Quality, perceived comfort and wellbeing from occupants of the university/public building

- Objectives
- Criticalities
- Strategies
- Technologies
- Materials

CRITICALITIES

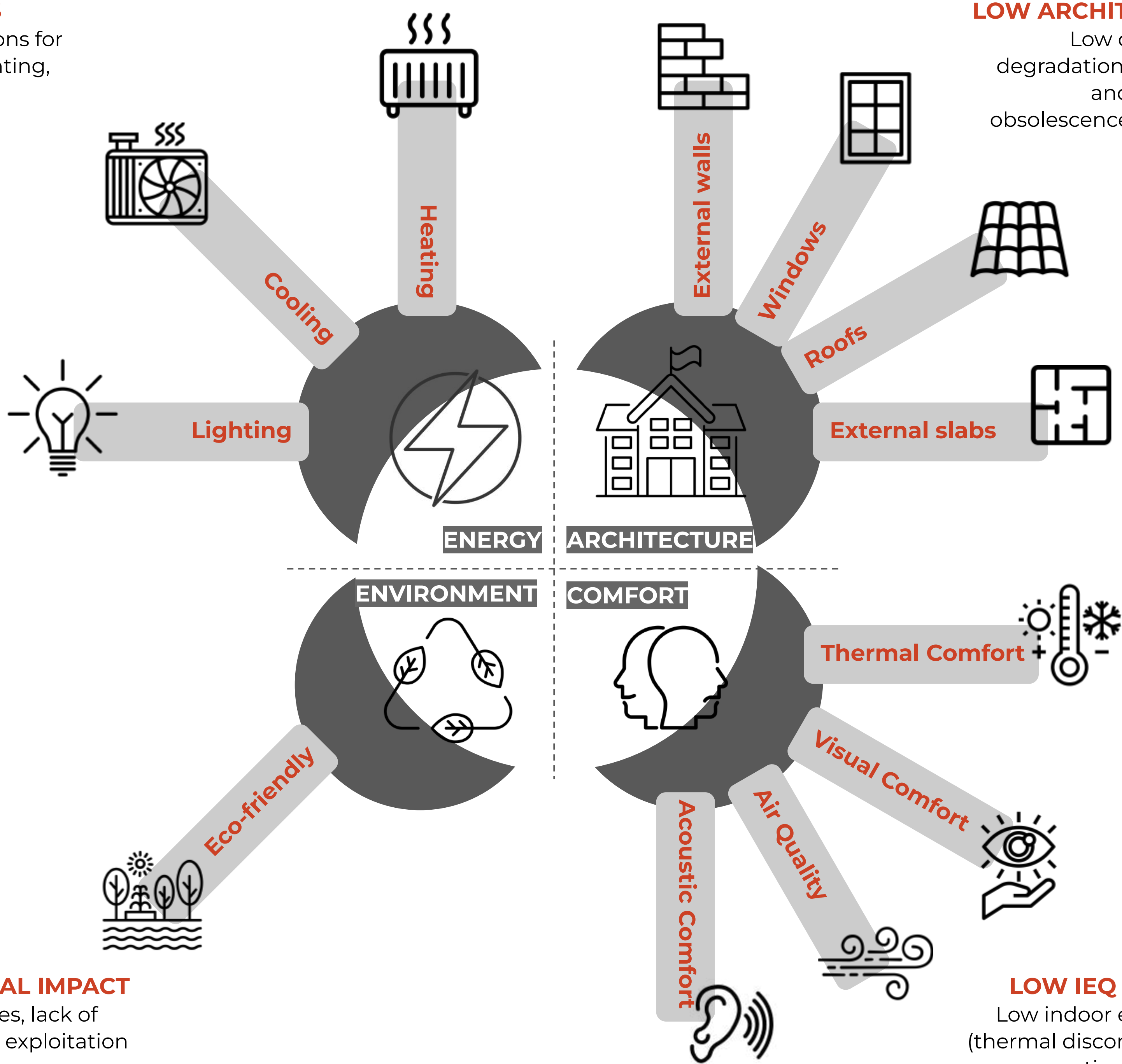
The selection of the most appropriate strategies, technologies and materials to retrofit the university/public building has to fix its specific criticalities [see phase 1 and 2 of the TOOLKIT]

Which are the main criticalities of the university/public building to renovate?



HIGH ENERGY NEEDS
High energy consumptions for heating, cooling and lighting, revealed by high costs

LOW ARCHITECTURAL QUALITY
Low quality of the building, degradation of the internal spaces and/or outdoor envelope, obsolescence of building elements



HIGH ENVIRONMENTAL IMPACT
Energy from fossil sources, lack of renewable energies and exploitation of natural resources

LOW IEQ AND DISCOMFORT
Low indoor environmental quality (thermal discomfort, scarce daylight, acoustic disturbances, stale air)

STRATEGIES

PASSIVE

- >> Valorise daylight 1
- >> Allow natural ventilation 2
- >> Integrate shading devices 3
- >> Upgrade the opaque envelope 4
- >> Replace fixtures 5
- >> Insert green elements 6
- >> Regulate outdoor microclimate 7

ACTIVE

- >> Integrate renewable energies 8
- >> Consider efficient plant systems 9
- >> Digitalize management 10

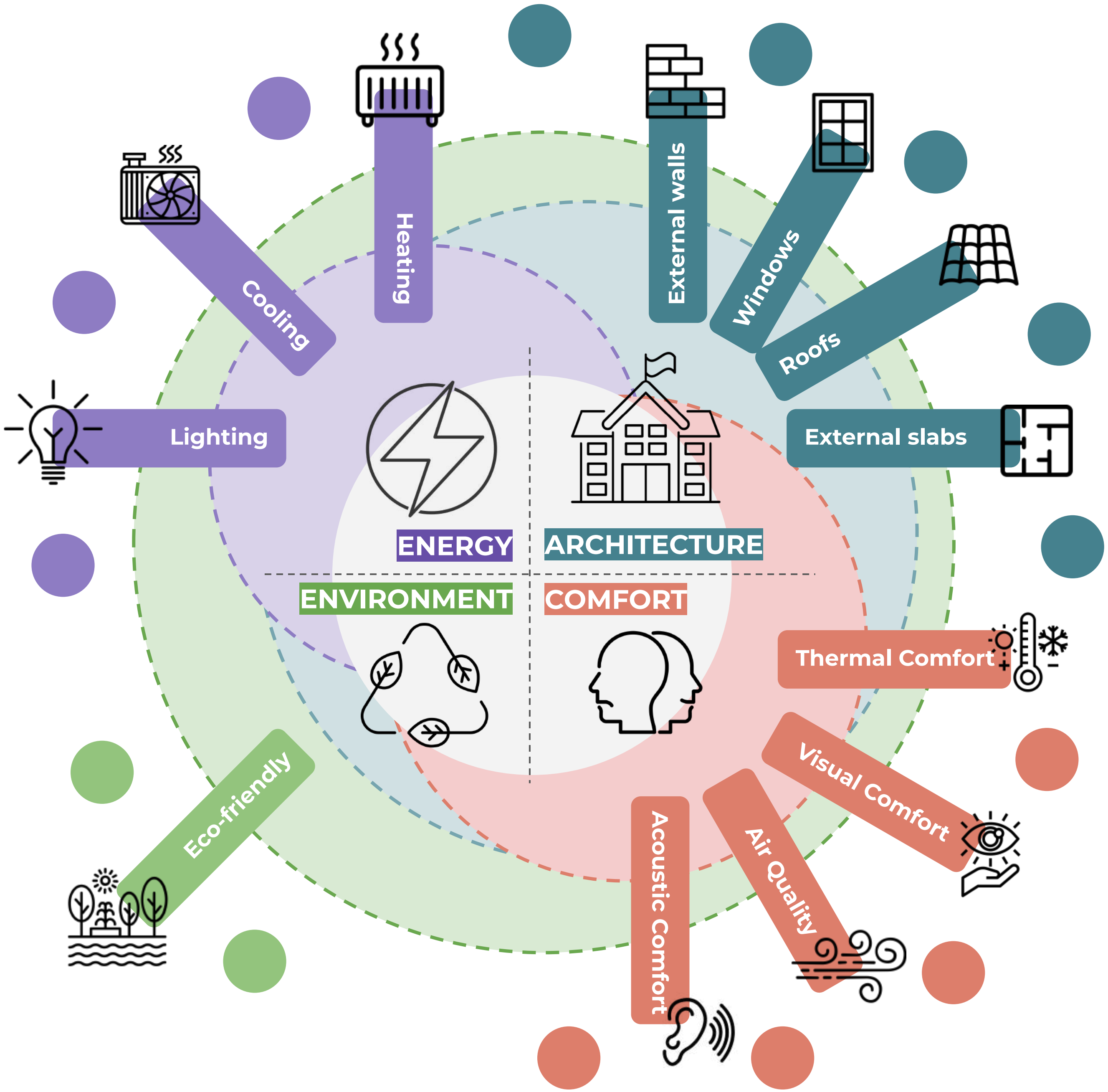
Rooted in **vernacular building traditions exploiting natural and renewables resources** in the **unique socio-climatic and cultural context of the Mediterranean area**, but also looking to **technological advancements** in the green building sector, innovative and eco-sustainable retrofit strategies can **reduce at the same time the energy demand** of the existing building (by augmenting building performance) and **minimise the negative environmental impact** (lower carbon emissions), at the same time **improving indoor comfort and wellbeing and architectural quality.**

The **10 retrofit strategies in the Abacus** have been selected on the basis of the **environmental imperative** (all of them comply with the environmental objective), to address energy and IEQ criticalities by intervening on the existing building.

Discovering, debating and selecting the best retrofit strategies to solve the criticalities of the existing university/public building is the precondition to set pervasive renovation processes, going further energy efficiency to envision more ambitious scenarios of quality and sustainability.

Retrofit strategies from 1 to 7 can be considered as **'passive',** since their contribution to the building's performance does not require energy consumptions after the intervention. Strategies from 8 to 10 can be instead considered **'active'**, regarding the integration of technologies using/producing energy across the building's lifecycle.

explore **strategies**



The best path to explore the 10 retrofit strategies, and then the related technologies and linked materials, is to initiate from the criticalities analysed in the existing building.

Considering the four overarching renovation objectives, it is possible to move across the most critical aspects to find the best strategy to begin the retrofit co-design process.

Starting from the identified criticalities, the matrix consents to individualize and move to the most appropriate strategies

RETROFIT STRATEGIES		ENERGY			ARCHITECTURE				COMFORT				ENVIRONMENT
		COOLING	LIGHTING	HEATING	WALLS	ROOFS	WINDOWS	SLABS	THERMAL	AIR	VISUAL	ACOUSTIC	ECO-FRIENDLY
1	VALORISE DAYLIGHT		●		●	●	●				●		●
2	ALLOW NATURAL VENTILATION	●					●		●	●			●
3	INTEGRATE SHADING DEVICES	●					●		●		●		●
4	UPGRADE THE OPAQUE ENVELOPE	●		●	●	●		●	●			●	●
5	REPLACE FIXTURES	●		●			●		●	●	●	●	●
6	INSERT GREEN ELEMENTS	●			●	●	●						●
7	REGULATE OUTDOOR MICROCLIMATE	●							●	●	●	●	●
8	INTEGRATE RENEWABLE ENERGIES				●	●	●						●
9	CONSIDER EFFICIENT PLANT SYSTEMS	●	●	●					●	●	●		●
10	DIGITALIZE MANAGEMENT	●	●	●			●		●	●	●		●

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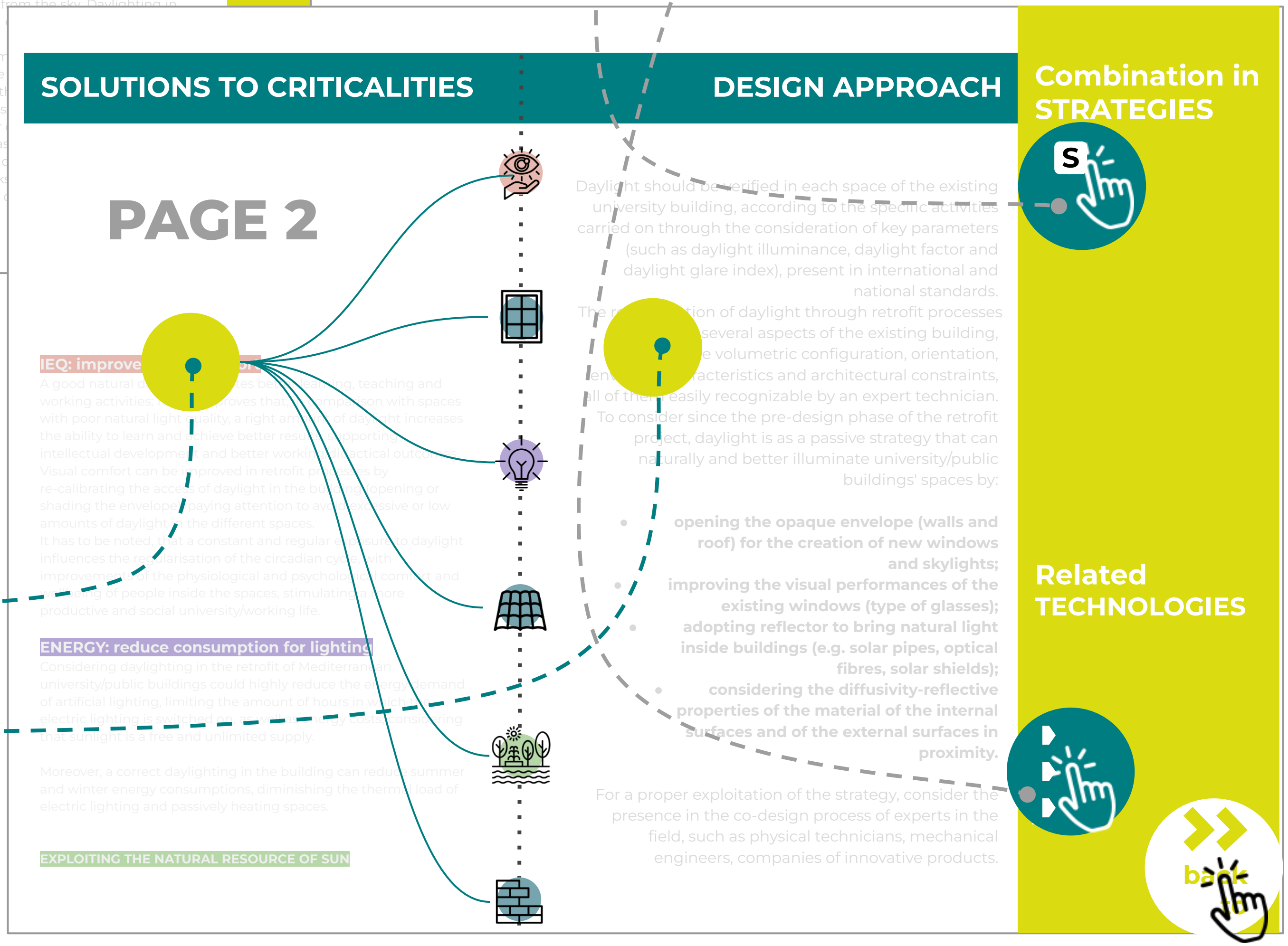
Navigating on the borders of the page, it is possible to explore:

➔ **Combination in strategies**

How the strategy can be matched with other strategies for an integrated retrofitting design process (link to other strategies)
;

➔ **Related technologies**

Retrofitting technologies to comply with the strategy (links to the level Technologies).



For each strategy, the Abacus provides information organised in 3 main sections:

1. Description
Explanation of the strategy with reference to the overcoming retrofitting objectives;

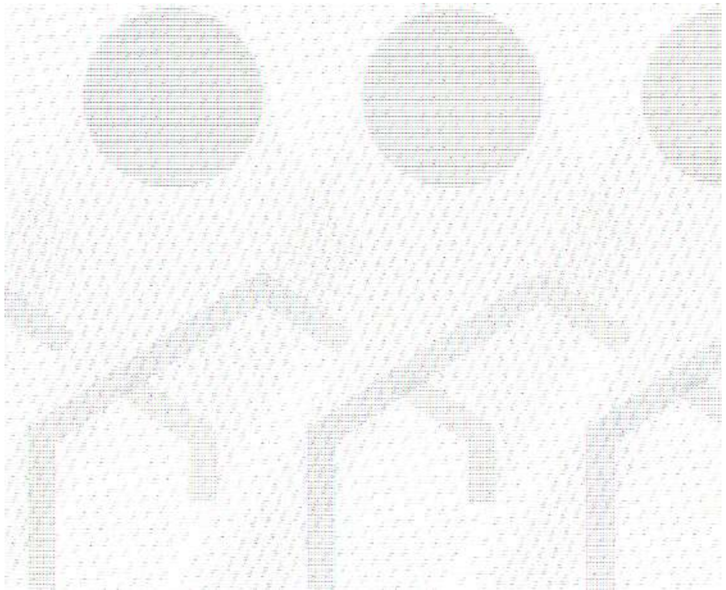
2. Solutions to criticalities
How the strategy can help to solve the criticalities of the university/public building;

3. Design approach
How the strategy can be approached in the retrofitting pre-design.

1

STRATEGY

Valorize daylight



Considering daylight in the retrofit of university/public buildings is particularly advantageous in Mediterranean countries, where a **high radiation is available** and balanced during most of the year and a **clear blue sky** is frequent. For this reason, free solar energy can be exploited as a **passive strategy for illuminating, warming and valorizing** the existing building.
It has to be considered that daylight is the combination of **direct sunlight and diffused light** from the sky, but also the one reflected by the **surrounding natural or built environment**.
Daylighting in design is the **correct opening of the building envelope** to control and optimise the penetration of solar radiation in indoor spaces.
In educational and working spaces the quality of daylight is fundamental to ensure the ideal condition for studying, reading and being focused, with the **natural dynamism of light positively influencing motivation, creativity and sociality.**
Dark spaces or areas with an excessive amount of light should be avoided to not experience unpleasant effects such as eye fatigue, due to poor quality of light or overlit (glare effect).
A correct daylight is designed to create an **uniform and well distributed illuminance** inside spaces, paying attention to the specific destination of use (usually in standards) and to activities requiring difficult visual tasks, looking at illuminating high quality spaces with the dynamism of daylight accompanying the university/public building daylife.

SOLUTIONS TO CRITICALITIES

DESIGN APPROACH

IEQ: improve visual comfort

A good natural daylight promotes better learning, teaching and working activities: research proves that, in comparison with spaces with poor natural light quality, a right amount of daylight increases the ability to learn and achieve better results, supporting intellectual development and better working/didactical outcomes.
More efficient and productive academic/working performances can be entrusted by valorising the quality of daylight in all the university/public building spaces.
Visual comfort can be improved in retrofit processes by re-calibrating the access of daylight in the building (opening or shading the envelope), paying attention to avoid excessive or low amounts of daylight in the different spaces.
It has to be noted, that a constant and regular exposure to daylight influences the regularisation of the circadian cycle, with improvements of the physiological and psychological comfort and wellbeing of people inside the spaces, stimulating a more productive and social university/working life.

ENERGY: reduce consumption for lighting

Considering daylighting in the retrofit of Mediterranean university/public buildings could highly reduce the energy demand of artificial lighting, limiting the amount of hours in which the electric lighting is switched on, as well as energy costs, considering that sunlight is a free and unlimited supply.

Moreover, a correct daylighting in the building can reduce summer and winter energy consumptions, diminishing the thermal load of electric lighting and passively heating spaces.

EXPLOITING THE NATURAL RESOURCE OF SUN

Daylight should be verified in each space of the existing university building, according to the specific activities carried on through the consideration of key parameters (such as daylight illuminance, daylight factor and daylight glare index), present in international and national standards.
The re-integration of daylight through retrofit processes depends on several aspects of the existing building, such as the volumetric configuration, orientation, envelope characteristics and architectural constraints, all of them easily recognizable by an expert technician.
To consider since the pre-design phase of the retrofit project, daylight is as a passive strategy that can naturally and better illuminate university/public buildings' spaces by:

- opening the opaque envelope (walls and roof) for the creation of new windows and skylights;
- improving the visual performances of the existing windows (type of glasses);
- adopting reflector to bring natural light inside buildings (e.g. solar pipes, optical fibres, solar shields);
- considering the diffusivity-reflective properties of the material of the internal surfaces and of the external surfaces in proximity.

For a proper exploitation of the strategy, consider the presence in the co-design process of experts in the field, such as physical technicians, mechanical engineers, companies of innovative products.

Combination in STRATEGIES

S2 **Allow natural ventilation**
the entering of daylight can also be the occasion to allow natural ventilation

S3 **Integrate shading devices**
to avoid sunlight to create overlighting and overheating

S5 **Replace fixtures**
consider glasses with more/less visibility

S10 **Digitalize management**
consider BMS or Smart management systems able to control artificial illumination in relation to natural daylight, such as to regulate shading systems

Related TECHNOLOGIES

- **High quality and smart fixtures**
- **External shadings**
- **Reflectors**

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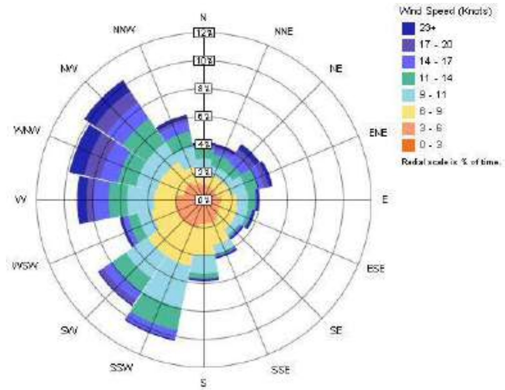
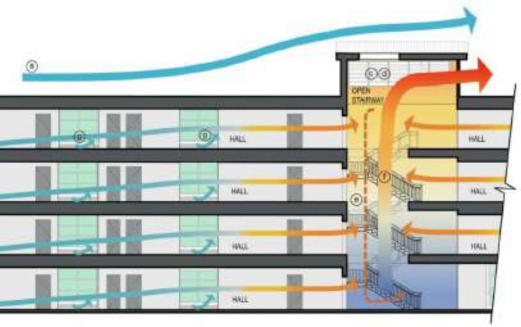
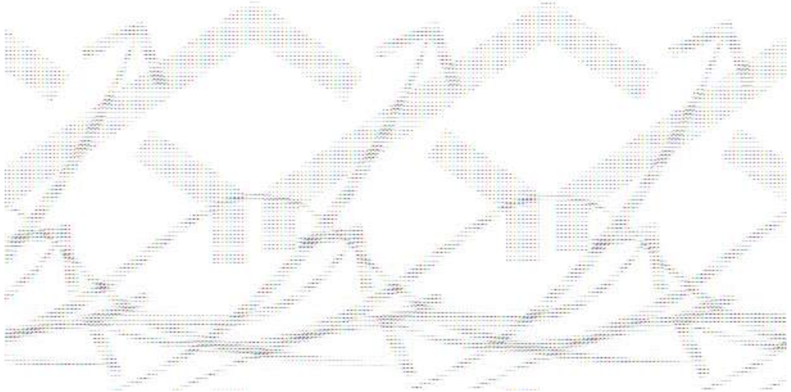
2

STRATEGY

Allow natural ventilation







A efficient natural ventilation inside university/public buildings is fundamental to ensure **air quality, comfort and health** for all the university/citizen community.

Natural ventilation is the air movement from outside to inside the building and vice versa, occurring without the use of mechanical systems, thanks to the exploitation of

- Wind forces around the building, creating differences in pressure (wind-based ventilation)
- Temperature differences between the inside and the outside of the building (stack ventilation)
- Combination of the two.

Designing for natural ventilation requires the management of such **driving passive and natural forces** (wind and temperature gradient), by **wisely sizing and positioning building's openings** (windows, doors, skylights, but also air inlets and outlets).

The ventilation of the existing university/public building can be re-evaluated in the retrofit design process, considering the potential of natural ventilation to guarantee a good ventilation rate and efficient air exchange without, or supporting, mechanical systems.

SOLUTIONS TO CRITICALITIES

IEQ: improve air quality

Natural ventilation consents to passively evacuate exhausted air and bring fresh air inside spaces, permitting the dissipation of indoor pollutant concentration (carbon dioxide, carbon monoxide, formaldehyde, odour, ozone, particulates, VOCs, and others). Research shows that increased ventilation rate is associated with improvements in academic/working performances. Additionally, natural ventilation systems have been shown to consistently outperform mechanical systems with respect to complaints of Sick Building Syndrome (SBS).
It has to be noted that a correct natural ventilation or combination with mechanical systems can reduce the spread of airborne viruses.

IEQ: improve thermo-hygrometric comfort

In the Mediterranean climate, natural ventilation can act as a heat dissipator in the spring/summer/autumn period, consenting to freely cooling spaces and controlling internal humidity (condensation reduction). Thermo-hygrometric comfort depends on the rate of occupancy and the presence of electrical/electronic equipment, whose sensible and latent heat can be passively dissipated by allowing a natural ventilation consistent with the occupational/process requirements.
Natural ventilation is exploited to favour convective and evaporative cooling: a higher but controlled air speed can increase the sweat evaporation from skin, improving the thermal sensation of comfort for occupants.
Moreover, it has shown that the acceptable thermal comfort range for natural ventilated buildings is significantly larger than for buildings with standard mechanical HVAC systems.

ENERGY: reduce consumption for cooling

Contributing to the dissipation of heat, natural ventilation can significantly reduce the energy demand for cooling in the summer period, considering that the technologies to improve natural ventilation can be cheaper to install and operate than a full mechanical plant.

EXPLOITING THE NATURAL RESOURCE OF WIND

DESIGN APPROACH

Re-introduce natural ventilation in existing buildings requires an initial analysis of the effectiveness of ventilation systems (natural and mechanical) in the existing university buildings, to carry out on the basis of international and national standards (i.e. ventilation rate, airflow).
Several factors can influence a good natural ventilation in the indoor spaces of the university/public building, to consider in the design phase:

- Building orientation and width;
- Dominant wind (speed and direction);
- Elements in the surround (natural or built environment which can obstacle or favouring wind);
- Size, location and operability of openings;
- Internal distribution and doors;
- Air inlets and outlets (if present);
- Mechanical ventilation systems (if present).

In this phase, simplistic assumptions can be made about the wind pressure distribution to determine the airflow through the building's openings and internal spaces.
On this basis, considerations can be made to improve natural ventilation by:

- Opening the opaque vertical envelope for the creation of new windows, positioned to allow cross ventilation;
- Considering that airflow should cross all the interior spaces, opening of doors or changing the doors' fixtures to allow air flows;
- Opening the roof for the creation of skylight can be particularly efficient in atria or staircase, whose typical height consent to exploit stack ventilation;
- Considering the integration of air inlets and outlets (grids or small vents) to provide background ventilation by opening the opaque envelope or by integrating in the existing fixtures;
- Ventilation ducts, solar chimney and wind tower can be considered, but they require more invasive interventions.

Combination in STRATEGIES

S1 **Valorise daylight**
envelope openings for natural ventilation can also optimise daylight

S3 **Integrate shading devices**
combining shadow with air passage

S5 **Replace fixtures**
consider high-quality fixtures with integrated inlet and outlet systems

S10 **Digitalize management**
consider BMS or smart management systems able to monitor air quality parameters (e.g. CO_2) and control opening systems

Related TECHNOLOGIES

High quality and smart fixtures

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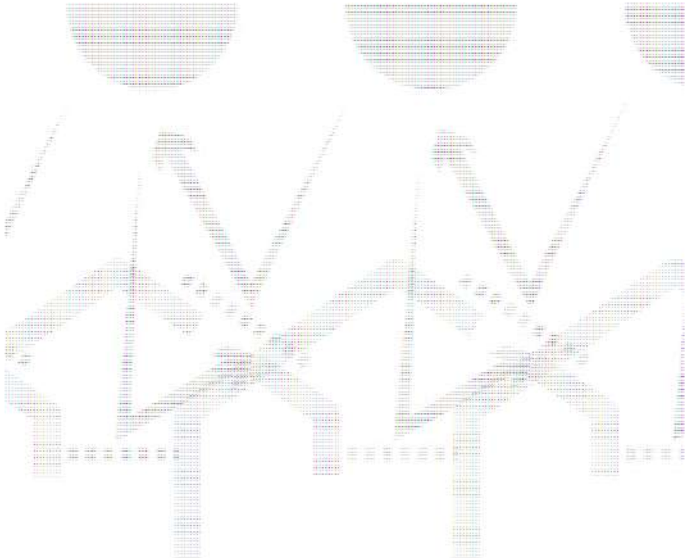
Integrate shading devices







In the Mediterranean climate, sun rays can be profitably exploited to **increase the thermal and visual comfort of indoor spaces in a natural and passive way**. At the same time, it requires to be carefully controlled to prevent unwanted overheating and overlight effects, highly impacting the indoor environmental quality and the academic/working activities performed in university/public buildings.

Sun shading systems or devices can **filter and regulate** the incident solar radiation, impeding/allowing it to pass through the transparent envelope and reach indoor spaces (for this reason, the most efficient position of shading systems is on the external side of the glass surfaces).

The design of sun shading devices has to consider that if a correct daylight is required the whole year, its thermal contribution has to be favoured in the winter period for passive heating, but avoided in the summer one. External shading devices can be **fixed or moveable**, positioned in the envelope or in an advanced position, also to create liveable external spaces with a mitigated outdoor microclimate.

Retrofitting with shading devices requires an attentive evaluation of the existing university/public building, the different **destination of uses**, the **dimension and orientation of the transparent envelope and its typology**, in order to evaluate the integrability.

It has to be noted that the integration of shading devices is an occasion to **improve architectural quality**, due to the high variety of shapes and materials consenting to create a new image of the university/public building.

SOLUTIONS TO CRITICALITIES

IEQ: improve thermo-hygrometric comfort

Shading devices can improve the indoor thermo-hygrometric comfort during the warmer seasons, by inhibiting solar radiation to heat indoor spaces. It is important to consider that solar radiation allows the free and passive heating during the cold periods of the year, requiring flexible shading solutions

IEQ: improve visual comfort

According to the exposition of the transparent elements of the envelope, the absence of solar shading devices can be responsible for overlight and glare effects in university spaces, negatively impacting the visual comfort of occupants. A correct integration of shading devices can ensure a high quality visual environment, supporting more productive studying and working activities

IEQ: improve air quality

shading devices consent to open the fixtures in the summer period avoiding the entrance of solar rays, so allowing natural ventilation while protecting against heat transfer

ENERGY: reduce consumptions for cooling

In a passive way, the integration of solar shading systems can drastically decrease the energy demand for cooling the indoor spaces, contributing to energy efficiency.

CONTROLLING THE NATURAL RESOURCE OF SUN AND WIND

DESIGN APPROACH

The introduction or improvement of shading devices in the existing university/public building starts from the consideration of the mostly exposed and not protected transparent surfaces, in relation to the destination uses and the main visual and thermal criticalities. The design of solar shadings is based on the assessment of the incidence of solar radiation on the building through the study of the solar path in the specific location, also considering the masses of the natural or antropic elements (such as trees or buildings) in the surrounding context.
To maximise the efficiency of solar protection/exploitation, the design of the shading devices should consider:

- The orientation of the shading elements (horizontal for south exposition and vertical for east and west);
- The depth or frequency of shading elements, in relation to the solar angle across hours and seasons (considering at least summer and winter solstices - maximum and minimum sun elevation);
- The shape of the shading elements, consenting to maximise the control of solar radiation;
- The different materials, in relation to the reflective/absorptive proprietes;
- The movement of shading elements, to create flexible and adaptable configurations;
- The possibility to experiment adaptive materials for innovative shading elements, those that for chemical composition or shape can adapt in relation to external environmental factors (phase and shape changing materials).

A cost-effective integration of new shading systems in the existing building requires an attentive assessment of the framing system supporting the transparent envelope (dimensions, typologies, shape and bearing capacity); in case of more consistent addictions, consider the consistency of opaque envelope, or the structural system; an alternative should be the definition of self-standing solutions. Vegetal elements can be adopted for shielding, in particular deciduous plants that lose their leaves in winter, passively protecting the transparent envelope in summer and allowing free passive thermal loads for heating.

Combination in STRATEGIES

S2 **Allow natural ventilation**
natural air flows in indoor spaces while protecting against solar radiation

S4 **Upgrade the opaque envelope**
match with the new finishings

S5 **Replace fixtures**
integrated in the new fixtures

S6 **Insert green elements**
use green elements to shade

S7 **Regulate outdoor microclimate**
detached from the building can act as thermoregulator of outdoor spaces

S8 **Integrate renewable energies**
ideal place to integrate PV systems-

S10 **Digitalize management**
managed automatically in a digital way, exploiting BMS or smart management systems

Related TECHNOLOGIES

- **External shadings**
- **BIPV**
- **Green façade**
- **High quality and smart fixtures**
- **Double skin façade**

back to strategies

Upgrade the opaque envelope

Opaque walls, roofs and ground floor slabs are usually the largest part of the building envelope in direct contact with external environmental conditions, highly influencing indoor environmental quality in particular for the thermal aspects, and so the overall energy performances of the building.

In the Mediterranean climate, the building's opaque envelope **protects the indoor environment both against heat losses in winter and against heat gains in summer.**

The retrofit strategy of improving the thermal performance of the opaque envelope is mainly related to the concept of mass, insulation and ventilation.

Thermal mass refers to the capacity of materials composing the building envelope of absorbing, storing and releasing heat across the time; for this reason, the advantages of thermal capacity (or inertia) can be evaluated considering the time of occupancy of the building. The addition of thermal mass in building retrofit interventions consents not only to dampen the amplitude of the thermal wave, but also to delay the time between the impact of the thermal wave on the external surface and its arrival, with a lower intensity, on the internal side of the envelope.

To be efficient, thermal mass has to be combined with **insulation**, related to the capacity of certain materials to reduce the heat transfer between the envelope layers in contact, consenting to mitigate thermal losses/gains across the envelope and so towards the indoor spaces.

The **ventilation** of the opaque envelope, through the creation of an air channel in between the external insulation layer and the cladding system, passively allows to evacuate indoor heat in summer (with solar radiation activating stack ventilation - open channel) and to insulate in winter (closing the channel, air act as insulation layer).

Beyond the aesthetic requalification of the building, the sole re-cladding can be an occasion to improve the thermal/energy performances of the opaque envelope by adopting materials with advanced properties (e.g. thermal plaster, bricks with thermal mass, green elements).

The upgrade of the opaque envelope can be an occasion to redefine the aesthetic quality of the university/public building, consenting to give a new life to exterior walls, roofs and slabs thanks to the substitution/addition of **new finishes, colours and materials,** which can contribute to create a **new image and meaning**, linked to sustainability.

SOLUTIONS TO CRITICALITIES

IEQ: improve thermo-hygrometric comfort

Better performances of the opaque envelope guarantee better indoor condition in relation to thermo-hygrometric comfort, consenting to maintain a more stable internal temperature toning down the oscillation of external ones, both in cold and warm seasons;

IEQ: improve acoustic comfort

The addiction of thermal mass, air chambers and insulation layers have the advantage to insulate internal spaces from outdoor noise, consenting to guarantee more silent and quiet spaces in the university/public building

ENERGY: reduce consumption for cooling and heating

Passively mitigating the indoor thermo-hygrometric conditions against the outdoor environment, the upgrade of the opaque envelope consents important energy savings, both for heating and cooling

ARCHITECTURE: improvement of architectural quality

The upgrade of the opaque envelope can be an occasion to redefine the aesthetic quality of the university/public building, consenting to give a new life to exterior walls, roofs and external slabs thanks to the substitution/addition of new finishes, colours and materials, which can contribute to create a new image and meaning, linked to sustainability.

EXPLOITING THE THERMO-HYGROMETRIC PROPERTIES OF MATERIALS TO REGULATE INDOOR CLIMATE

DESIGN APPROACH

The best way to start a proper upgrade of the existing opaque envelope is to acknowledge the dimension, composition and layering of all its parts , as basis to perform an analysis of its thermo-hygrometric performances, to be conducted in dynamic regime. The selection of the best technologies and materials for the up-grade can be guided by considering the requirements in international or local standards for thermal performances. It is important to consider the potential architectural constraint of the university building,mainly regarding the alteration of external fronts, in order to consider intervention in the internal or external side of the envelope.

The optimisation of the opaque envelope thermal performance can be obtained by:

- Adding thermal mass layers, considering the thickness and the weight in relation to the existing bearing structure;
- Adding thermal insulation layers, preferably in the external side of the envelope or according to the destination of use
- Creating a ventilation air channel in between the external insulation layers and the finishings.

A feasible integration of such technologies requires taking into account existing architectural constraints; in this case it is possible to evaluate the use of innovative materials, which can guarantee higher performances with lower quantities (e.g. thickness)

Combination in STRATEGIES

S3 **Integrate shading devices**
combine interventions on the envelope to optimise construction works

S5 **Replace fixtures**
combine interventions on the envelope to optimise construction works

S6 **Insert green elements**
under determined conditions, the addition of green elements can optimise the thermal performances of the opaque envelope

S8 **Integrate renewable energies**
combine interventions on the envelope to optimise construction works

Related TECHNOLOGIES

- **Ventilated envelope**
- **Thermal insulation**
- **BIPV**
- **Green façade**
- **Green roof**
- **Double skin façade**

back to strategies

5

STRATEGY

Replace fixtures

The transparent is usually the **weakest part of the building envelope**, responsible for unwanted thermal dispersions and/or gains (for conduction, convection and radiation) highly impacting energy efficiency. At the same time, **glass and openable elements** are fundamental to guarantee a **constant contact with the external environment,** consenting the natural illumination and ventilation of indoor spaces.
Transparent building elements are usually composed of two main parts, the glass and the frame, and can be combined with internal or external shading systems.
According to the degree of obsolescence in addressing thermal and visual requirements, the retrofit project can consider the **partial upgrading of the fixture** (glass substitution) or the **complete replacement** (frame/glass substitution). Revealed by the period of construction, the most common condition is the absence of thermal break in the windows' frames and the presence of single glasses.
Nowadays, the market offers solutions with high performance frames (with **thermal break systems** reducing thermal exchanges) and double or triple glazing, also equipped with **air gap** (usually filled with argon), acting as thermal resistance.
Most advanced solutions combine high performance frames (e.g. integration of micro-ventilation) and glasses, treated to control, filter and select the entry of solar radiation in relation to the thermal and visual components. For example, low-emission glasses have an addition of coating surfaces (with metal/oxide molecular materials) in internal or external glasses, drastically reducing the radiation exchange (up to 75%).

SOLUTIONS TO CRITICALITIES

IEQ: improve thermo-hygrometric comfort

High-quality fixtures can minimise thermal dispersions through the transparent building envelope, contributing to reducing heat losses in winter and gains in summer;

IEQ: improve acoustic comfort

High.quality fixtures can guarantee better levels of sound insulation, consenting to obtain a correct acoustic environment in university spaces;

IEQ: improve visual comfort

The adoption of glass with absorption or reflective properties (can select the spectrum of solar radiation entering in the university space, consenting to customise the visual environment according to the exposition and the destination use of different spaces;

IEQ: improve air comfort

The substitution of the obsolescent transparent elements of the envelope with a different typology of fixtures (e.g. different opening systems or with integrated micro ventilation) can improve the natural ventilation of university spaces and the resulting indoor air quality;

ENERGY: reduce consumption for cooling and heating

Around ⅔ of the energy lost from a standard window is related to radiation through the glazing. Since heat is conducted through the window frame, the global replacement of fixtures has great advantages in terms of energy consumption for heating and cooling.

EXPLOITING THE NATURAL RESOURCES OF SUN AND WIND

DESIGN APPROACH

The need to substitute fixtures in university buildings emerges from the analysis of criticalities, starting from the thermal energy dispersion through the transparent envelope, and the evaluation of the fixtures obsolescence.

The possibility of replacement requires to consider the presence of historical/architectural constraints: in this case, it is necessary to evaluate solutions that have the same image of the previous, while performances can be highly improved.

The design of fixtures' replacement can be guided by the the following considerations:

- exposition to weather factors: windows or transparent surfaces more exposed to solar radiation and prevailing winds;
- type of opening: possibility to optimise the opening of windows, to improve the use and ventilation options, always considering the safety of users;
- type of frames: insulated frames with thermal breaks;
- position: continuity with the insulation layer of the opaque envelope;
- type of glasses: according to the exposition and destination use consider the most advanced solutions (e.g. low emittance, selective, solar absorption, evacuated, athermal, photochromatic, electrochromic glasses);
- glass treatments: to improve the performances and architectural quality of the transparent envelope (e.g. holographic. screen-printed, liquid crystal, prismatic glasses).

Combination in STRATEGIES

S1 **Valorize daylight**
more efficient fixtures can improve the quality of the solar radiation entering in the indoor spaces, by selecting and filtering the different light wavelength

S2 **Allow natural ventilation**
different type of openings or micro ventilation systems in the new fixtures can support natural ventilation and improve indoor air quality

S3 **Integrate shading devices**
the substitution of fixtures can be the right occasion to integrate, if not present, shading systems

S6 **Insert green elements**
under determined conditions, the addition of green elements can optimise the thermal performances of the opaque envelope

Related TECHNOLOGIES

- **High quality and smart fixtures**
- **External shadings**

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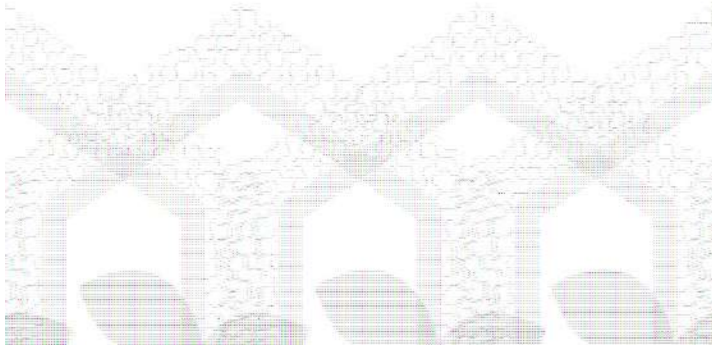

6

STRATEGY

Insert green elements

‘Greening’ building and urban spaces is a contemporary but ancient strategy to exploit the advantages of **vegetation inside, on and around the existing building**.

Considerable environmental benefits have been demonstrated in the integration of green elements in building, in terms of **mitigation of the outdoor microclimate, increasing of biodiversity and ecological value, and protection against environmental pollution**.

Equipping the existing university/public building with green features (with dedicated technological solutions for **indoor, outdoor and envelope integration**) is also an opportunity to allow considerable reduction of energy consumptions and greenhouse gas emissions, with related economic, environmental and social implications.

Another important aspect inspiring the **biophilic approach** of integrating nature in living spaces lies in the **human benefits** in terms of perceived comfort, social and psychological wellbeing for occupants and enhancement of air quality for city dwellers.

Inserting green elements is very feasible and, depending on the building criticalities, there are various solutions that can be embedded outdoors or indoors. Examples go from the planting of trees or hedges in the building's surrounding spaces to the application of green façades, green roofs, natural elements in the balconies or inside buildings.

Given the demonstrated multi-benefits, the low costs **(maintenance needs to be considered)**, and the high integrability, the greening of existing buildings can be considered one of the most promising renovation strategies.

IEQ: improve thermo-hygrometric comfort

In outdoor spaces, the presence of vegetation guarantees the absorption of sunlight (50 percent is absorbed and only 30 percent is reflected) decreasing temperatures for a fresher and more pleasant climate in the building's surroundings, and so in indoor spaces. Moreover, vegetation can be used as a shading device, consenting to optimise its natural performances;

IEQ: improve acoustic comfort

Another benefit of the green elements is the damping of the noise and reduction of noise pollution. Vegetation absorbs sound waves, such as those produced by air and vehicular traffic, and reduces their propagation.;

IEQ: improve air quality

Green elements, both internally and externally, reduce air pollution: through the process of photosynthesis, vegetation retains airborne pollutants (CO_2 and dust) and releases new oxygen. They also greatly reduce electrosmog from electronic devices (e.g. computers, screens, smartphones)

ENERGY: reduce consumption for cooling and heating

Green elements, both the leaves and the soil, can be used to control increase the heat exchange: leaves can be used as solar shading, minimising the energy demand for cooling, the soil (i.e. in green roofs) can be exploited as thermal mass to delaying the heat transfer, with during benefits both in summer and in winter.

EXPLOITING THE NATURAL RESOURCES OF SUN AND WIND

Considering the various kinds of greening technologies in the market, the definition of the optimal solution for the existing building involves a compromise within a number of constraints and limitations.

The best choice has to combine:

- building characteristics/conditions, such as orientation, wind protection, structural resistance;
- maintenance system requirements;
- financial benefit and costs;
- stakeholders'/tenants' perspectives.

Depending on the adopted technology, green elements can be plant inside or outside the university/public building's spaces, integrated in the building envelope (external walls or roofs), applied to balconies or terraces, or used as a shading system (e.g. climbing plants).
Each green solution can result in greater or lesser reduction of energy consumptions, but all of them have qualitative benefits on the Indoor Environmental Quality, the perceived comfort and wellbeing of the occupants.

Combination in STRATEGIES

S2 **Allow natural ventilation**
different type of openings or micro ventilation systems in the new fixtures can support natural ventilation and improve indoor air quality

S3 **Integrate shading devices**
green elements can be used as shading devices, or can be integrated with them;

S4 **Upgrade the opaque envelope**
green facades and roofs can improve the envelope performance of the envelope

S7 **Regulate outdoor microclimate**
vegetation on the building envelope can be combined with vegetation in the surroundings

Related TECHNOLOGIES

- **Green roof**
- **Green façade**

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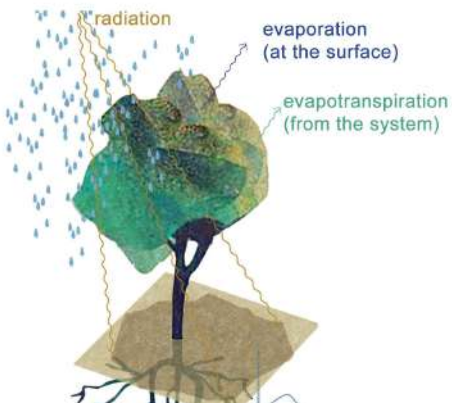
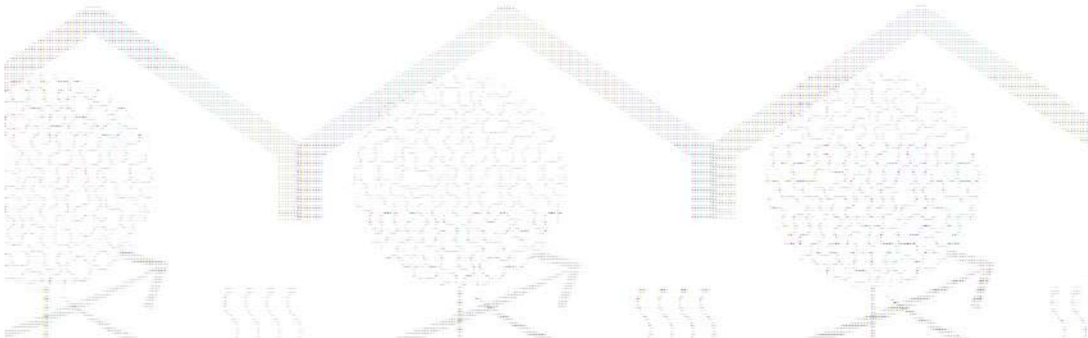
7

STRATEGY

Regulate outdoor microclimate





Differently to the others, this retrofit strategy does not regard any intervention on the university building. According to millennial strategies developed in the Mediterranean area in fact, it is possible to regulate the comfort of indoor spaces by **acting on the context surrounding the building.** Even if bioclimatic design strategies are usually exploited in the first design phases of new constructions, their efficiency can be found also in building retrofits, in particular in case of historical buildings characterised by important architectural constraints.

The regulation of outdoor microclimate mainly relies on taking advantage of **natural resources** (sun, water, wind and vegetation), which **can passively contribute** to all the dimensions of indoor comfort and reduce the energy demand of university spaces.

Considering the external spaces of university buildings, also as an **occasion of requalification**, it is possible to evaluate the integration of new architectural elements, amenities or surfaces to reduce extreme weather conditions. Such elements can act as buffer spaces capable of activating a microclimatic mitigation, with a positive influence on the indoor spaces. There is a **great variety of architectural solutions**, which need to be assessed in relation with the specific climatic conditions and building setting. For example, the insertion of **water basins** or fountains, combined with the **shadows created by vegetable masses or canopies**, can synergically favour the **evaporative cooling of external spaces**, mitigating the temperature of air entering in the building. Another example is the use of external surfaces characterised by roughness and light colours, which can **reflect the solar radiation** impeding the creation of the heat-island effect. It is important to consider that these outdoor expedients have the great potential to improve the quality of staying at the university, consenting the creation of spaces for studying and socialising in all the period of the year.

SOLUTIONS TO CRITICALITIES

IEQ: improve thermo-hygrometric comfort

The main objective of regulating outdoor microclimate is to improve the indoor thermo-hygrometric comfort by exploiting the passive properties of natural resources;

IEQ: improve acoustic comfort

The creation of buffer zones around the university building (e.g. by the means of trees or vegetable elements) can improve the sound environment of indoor spaces, acting as a noise barrier;

IEQ: improve visual comfort

Modifying the external spaces of university buildings it can be possible to optimise the entry of daylight, consenting to reach better visual performances in indoor spaces;

IEQ: improve air quality

Elements for the regulation of the microclimate can stimulate the wind speed in the warm period, supporting a better ventilation rate. Green elements can improve the oxygenation of the air surrounding the building. Water evaporation consents to entrap polluting particles and prevents their entry in the university spaces;

ENERGY: reduce consumption for cooling and heating

An efficient mitigation of outdoor microclimate can be useful both in the winter and summer seasons, consenting to reduce the demand of energy for heating and cooling university spaces.

ARCHITECTURE: improve architectural quality

The positioning of external elements and amenities can provide for a new image of the university building, contributing to the creation of more liveable study and socialising spaces.

EXPLOITING THE NATURAL RESOURCES OF SUN AND WIND

DESIGN APPROACH

The mitigation of the outdoor microclimate as a retrofit strategy requires the deep understanding and evaluation of the site where the building is placed, as well the analysis of its environmental conditions in the peculiar local context.
The design of architectural elements, amenities and surfaces for the microclimate regulation has to be guided by a deep and integrated analysis of the following environmental and architectural factors:

- Orientation: building envelope more exposed to the solar radiation;
- Prevailing winds: according to different seasons, invite or impede the entry of wind inside the building;
- Native or adapted vegetal essences: in order to avoid high water consumption for irrigation
- Annual rainfall: reuse of runoff water for the creation of water basins;
- Position of building openings: in order to impede or favouring the entry of air fluxes;
- Materials of outdoor spaces: limit the presence of high absorption materials, not draining surfaces and surfaces whose reflection can impact the visual quality of indoor spaces;.

Combination in STRATEGIES

S1 **Valorize daylight**
different type of openings or micro ventilation systems in the new fixtures can support natural ventilation and improve indoor air quality

S2 **Allow natural ventilation**
interventions on the external context can augment the wind speed in the warm seasons, improving the natural ventilation of indoor spaces

S3 **Integrate shading devices**
architectural elements positioned in the surrounding of the university building can act as shadow devices

S6 **Insert green elements**
the most profitable architectural elements to regulate the outdoor microclimate are green elements, such as trees or climbing plants integrated in canopies

S8 **Integrate renewable energies**
for the regulation of external microclimate, such as for the creation of shadows, it is possible to adopt technologies for the production of energy from renewable sources (e.g. PV)

Related TECHNOLOGIES

- **Green roof**
- **Green façade**

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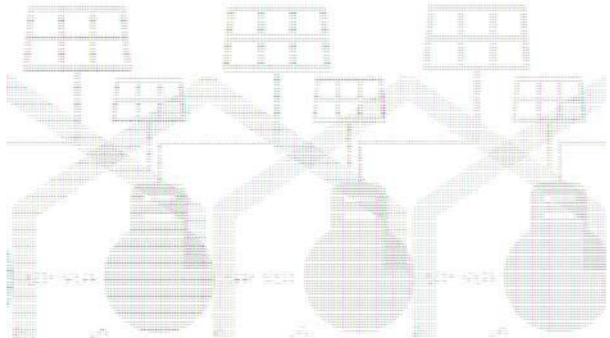

8

STRATEGY

Integrate renewable energies

Renewable Energy Sources must play a key role in the decrease of fossil fuels' request and, even if a complete substitution is still not fully suitable, **a deep integration could have an important positive effects**.
Many technologies exploiting RES are mature, such as photovoltaic systems, and could be implemented in buildings with a light impact from an architectonic point of view. A pending issue is related to the dynamic and almost unpredictable behaviour of RES and the availability of energy for different user profiles and purpose during seasons.
Those aspects assume such a relevance as the energy sharing and storage becomes the actual main task to improve. Positive energy districts, distributed production and, in general, **Smart City approaches represent the answer in order to manage the incoming and outcoming energy fluxes**, matching the instantaneous generation from integrated RES plants and the demand.
Actually, the birth of open associations among multiple actors (such as public administrations, companies and private citizens) is promoted, where renewable energy is locally produced and self-consumed, so that the environmental, economic and **social benefits would fall on the whole community**.

ENERGY: reduce consumption for heating, cooling and lighting

The knowledge of the actual energy consumption let analysing the criticalities of the existing and typology of user demand underling the different contributes (electrical vs. thermal loads). After the evaluation on the possibility of integrating renewable sources, their impact can be calculated in details.
Depending on the configurations and the available surface for new installations, energy consumption could be drastically reduced aiming at Near-Zero Energy Building or Positive Energy Building, with spillover on the overall community.

EXPLOITING THE NATURAL RESOURCES OF SUN AND WIND

Integrating RES in buildings request a good knowledge of the specific retrofitting context. In details, with the implementation of solar technologies, the designers have to collect the following information about the site:

- **geographical location**
- **available area for the plants**
- **position, orientation and shadowing of such areas**
- **energy user demand and profiles**

Starting from these boundary conditions, it is possible to set up dynamic models which could predict the production of the plants during the different seasons and evaluate the expected impact on the overall energy balance (also considering cost issues).
Since the models are parametric, multiple layouts can be compared optimising the best solution as a function of the different feasible technologies and their integration in buildings.
Energy storage can be taken into account in order to shift the energy availability and to match with the user profile.

Combination in strategies

S3 **Integrate shading devices**
optimising the displacement of the solar system could also be useful to reduce the contribution of solar gains in summer.

S9 **Consider efficient plant systems**
the electrification of heating demand could push towards the implementation of high performance heat pump

S10 **Digitalize Management**
An overall monitor/control system could let optimising energy fluxes matching production with user demand)

Related Technologies

- **Building Integrated Photovoltaic**
- **Heat pumps**
- **Building Management Systems**

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9

STRATEGY

Consider efficient plant systems

In existing buildings, service plants are often critical such as the envelope. Many installed facilities belong to the past decades and **works out of the optimal conditions**. In some cases only the heating loads are guaranteed and lighting devices do not still exploit LED technology.
For these reasons, effective and quite easy results in a retrofitting process could be achieved **updating a part or the complete services that supply the building**.
The knowledge of the existing configuration, the site's climate conditions and the typology of user demand and occupancy let configuring the best specific energy mix and the most suitable technologies.
Upgrading the plants' quality is **strictly necessary also in order to integrate renewable energy** in an efficient way. The impact of RES is relevant only if consumption is rationalised reducing waste due to obsolete services and applying a smart management of the involved components.

SOLUTIONS TO CRITICALITIES

ENERGY: reduce consumption for heating and cooling

After retrofitting the envelope (excluding cultural heritage), redesign plants with the state-of-art technologies is the most effective method to save energy substituting obsolete componentes and avoiding distributed loss. Also the fine regulation which is a common feature of new services allows minimizing the consumption in respect to real-time demand variation.

ENERGY: reduce consumption for lighting

Led technology represented a revolution in terms of energy need reduction for lighting. Despite of that, many existing old buildings keep services with neon lamps or similar. 70% of energy could be saved upgrading elements, also increasing their life.

IEQ: improve thermo-hygrometric comfort and air quality

New generation plants allow a more wide regulation of the operative conditions in order to set up specific environmental parameters in different sectors of the same building.

IEQ: improve visual comfort

Led technology permit to manage some specific parameters such as intensity and colour temperature that can be varied to obtain different scenarios depending on the working activity and external constraints.

DESIGN APPROACH

The replacement of services plant should be planned together with renovation of the envelope, inside the overall retrofitting process of building.

In some cases, such as for lighting, intervention could be implemented with a low impact on the existing and costs obtaining immediate benefits.

For the heating and cooling systems, different evaluations need to be considered not only about the central plant but also relating to the terminal equipments that work at different conditions (radiators, fan coil, radiant panels...).

The choice should be directed towards components with operative temperature close to ambient temperature, aiming at low piping thermal losses and high efficiency loops, also encouraging RES integration.

Building data are requested for finding an optimised solution such as:

- **detailed information of existing plant and distribution**
- **occupancy and user profiles**
- **net area and volume to be supplied**
- **energy fluxes history**

Combination in strategies

S8 **Integrate renewable energies**
modern systems are pre-configured to work with the integration of renewable energy

S10 **Digitalize Management**
recent plants are smart and interconnected through IoT protocols that allow a better overall conduction of the building

Related Technologies

- **LED lighting**
- **Heat pumps**
- **Building Management Systems**

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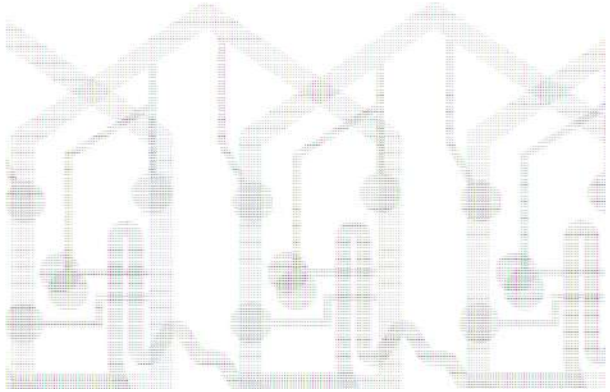
Digitalize management



The **information processing** is a fundamental aspect in the knowledge framework of a building for a rationalised and efficient management. The creation of a **well-organised database** is the only tool that permit analysing the existing situation from a general point of view and to improve optimised retrofitting scenarios. Data, if present, are often collected in several formats and stored under different "sectors" (for instance the various technical offices); they are usually characterised by fragmentation and difficult accessibility. **Digitalization opportunities** are indeed suitable for **standardizing, indexing and clarify all the useful information**. In this way, the knowledge can be also shared to the actors of the retrofitting process such as technicians of different disciplines, energy managers, decision makers and final users.

Furthermore, **IoT technologies** have a key role in improving the power of the building framework matrix data. Beyond the history of the context as it had been build, many systems can be installed in order to acquire many **objective and subjective parameters** that describe the conduction in progress as a function of external constraints, environmental changes and the needs and the behaviour of people living the building. Those information are sent by distributed spot sensors to a central system that collects data and publishes them into **common cloud servers and platforms**.

ENERGY: reduce consumption for heating, cooling and lighting

Digitalising information and especially the management strategies through IoT technologies, allows optimising all the sources integrating different services reducing time response and waste of energy.

IEQ: improve thermo-hygrometric comfort, visual comfort and air quality

The level of extensiveness that could be achieved in modern digitised information tools for buildings aims at a diversification of IEQ parameters depending on the needs of specific users in different areas

The digitalization towards smart management strategies starts from collecting the available information of the buildings. Such information are related to:

- the construction itself (history, wall stratigraphy, structural changes...)
- services (plants and distribution)
- user demand typology and profiles (energy and environmental needs, time schedules)

Only if they are universally codified, the existing situation could be clear and shared to the actors of renovation.
IoT technologies may help in designing a grid of elements (interconnected sensors acquisition softwares and actuators) for real time monitoring, suggesting new methodologies for a virtuous maintenance or a suitable scenarios of intervention.

Combination in strategies

S9 **Consider efficient plant system**
the digitalised management of new generation plants let improving fine regulation strategies in order to optimise the operating conditions

back to strategies

TECHNOLOGIES

PASSIVE

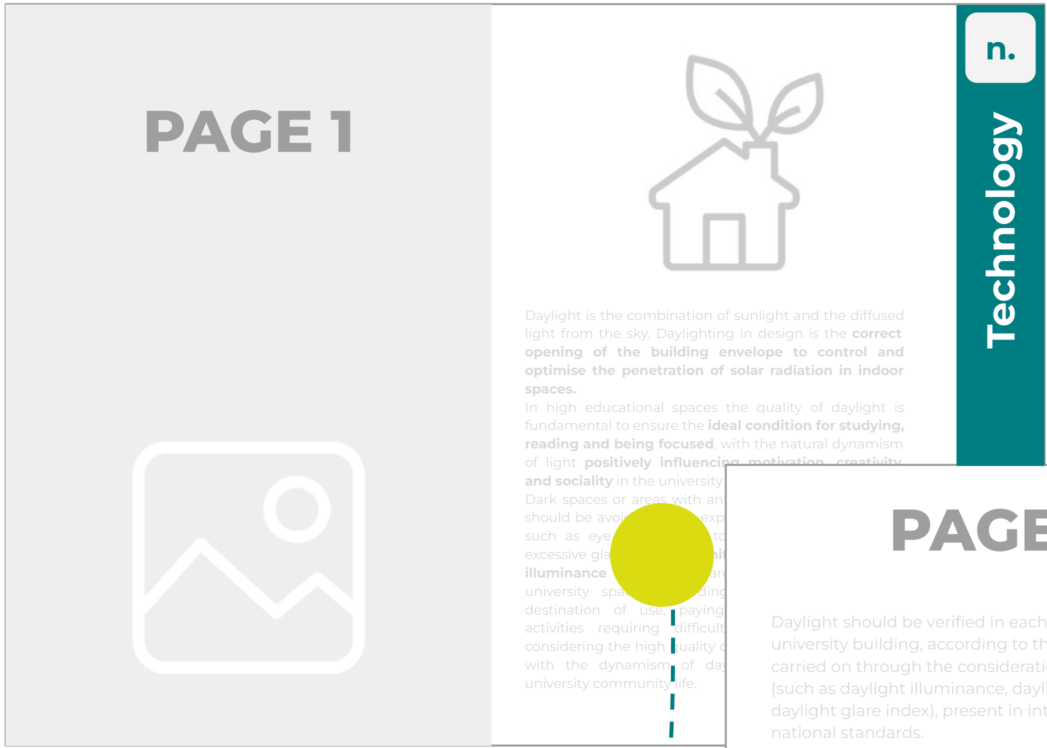
- >> Thermal insulation — 1
- >> Ventilated envelope — 2
- >> Double skin façade — 3
- >> Green roofs — 4
- >> Green façade — 5
- >> High quality and smart fixtures — 6
- >> External shadings — 7
- >> Reflectors — 8
- >> Nature Based Solutions — 9

ACTIVE

- >> Building Integrated Photovoltaics — 10
- >> LED-lighting — 11
- >> Heat pumps — 12
- >> Building management systems — 13

Discovering, debating and selecting the best retrofit strategies to solve the criticalities of the existing university/public building is the precondition to set pervasive renovation processes, going further energy efficiency to envision more ambitious scenarios of quality and sustainability.

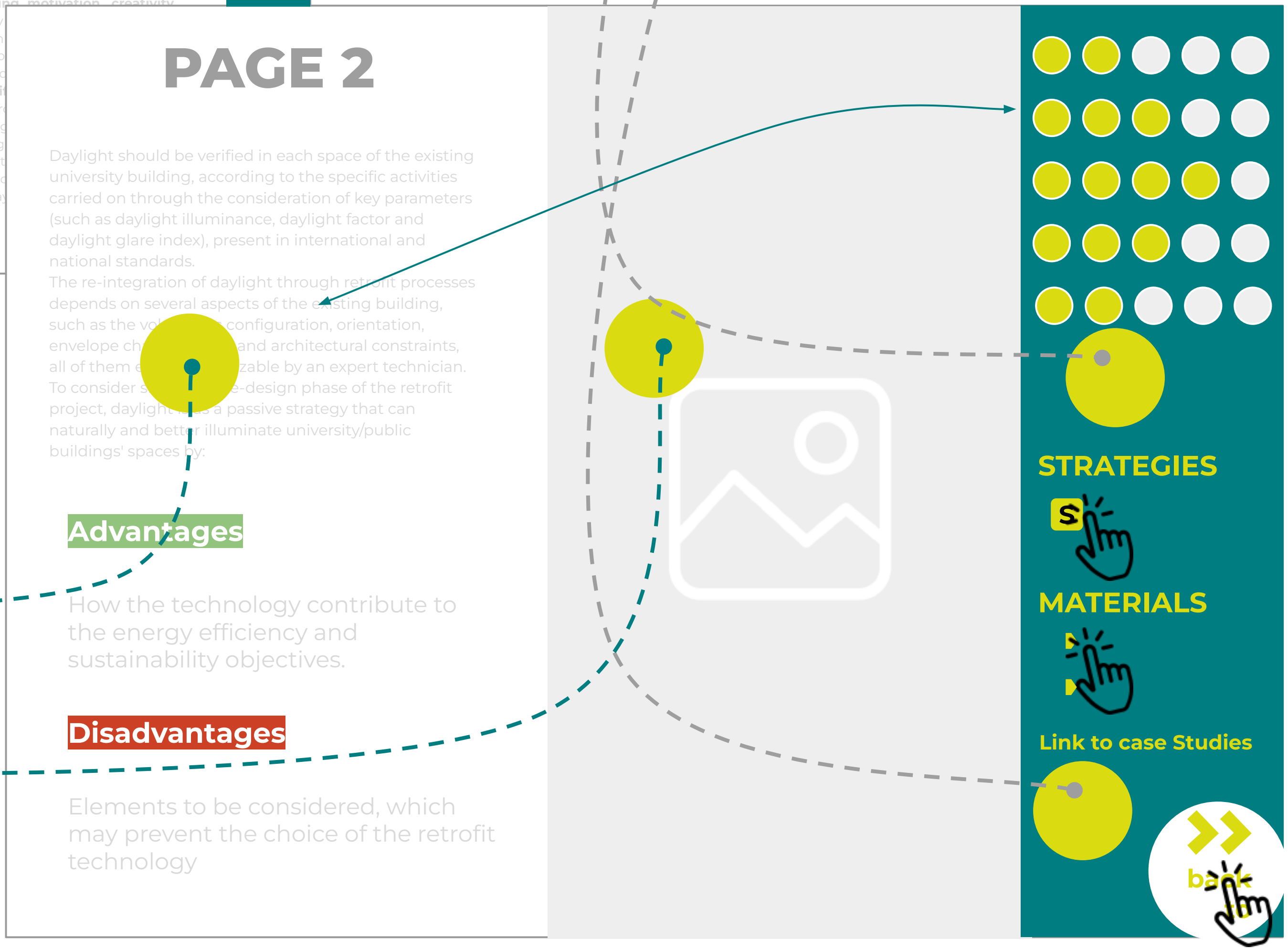
Retrofit strategies from 1 to 9 can be considered as **'passive'**, since their contribution to the building's performance **does not require energy consumptions** after the intervention. Strategies from 9 to 13 can be instead considered **'active'**, regarding the integration of technologies **using/producing energy across the building's lifecycle**.



Navigating on the borders of the page, it is possible to explore:

→ **Pre-evaluation of the technology**
Degree of preferability of the technology

→ **Related strategies and materials and Case studies**
Upper level strategy and deriving materials (links to the other two levels of the Abacus).



For each technology, the Abacus provides information organised in 3 main sections:

1. Description
Explanation of the technology and its main functioning in relation to the strategies and the overcoming retrofitting objectives;

2. Main features
How the technology works and how it can improve the building performance (reference to the degree of preferability)

3. Technological details
Drawings explaining the functioning and composition of the technology

explore **Pre-evaluation**

Pre-evaluation of technologies to understand their **preferability** (from 1 = low, up to 5 = high)

1) Typological Integrability
The capacity of the retrofit technology to be adapted to the typology and constraints of the existing building (e.g. heritage);

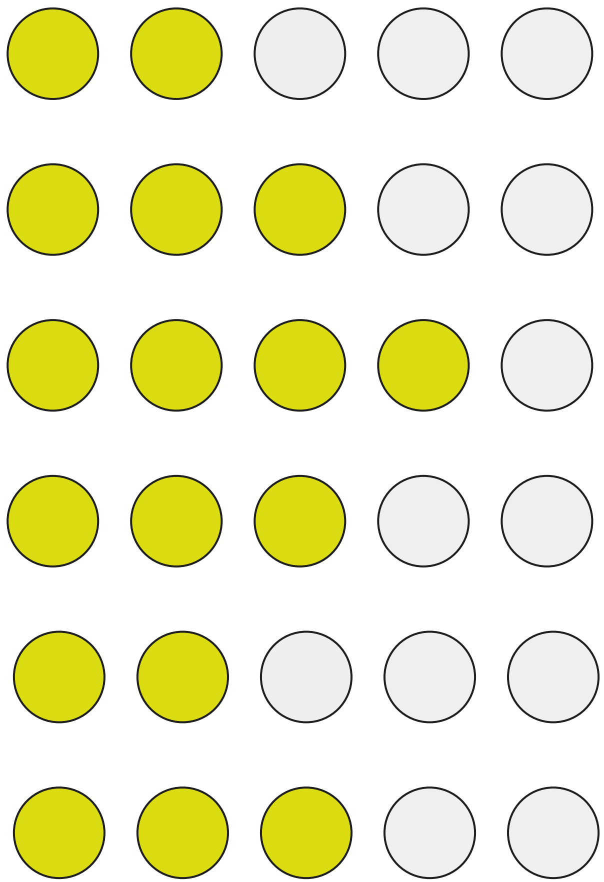
2) Technical Feasibility
The feasibility of the technical integration into the existing building technological system;

3) Design Effort
The level of detail of the architectural project and relative procedures;

4) Maintenance Effort
The level of maintenance required by the technology;

5) Budget Range
The average cost of the technology (to evaluate in the local context);

6) Integration in Technological Mix
The possibility of mixing with other retrofit technologies



Historic building renovation, Patù - Italy, Luca Zanaroli, 2013

Thermal insulation

Thermal Insulation consists in the addition of layers of thermal insulation material to the opaque envelope of the existing building, in order to create a barrier to the heat transfer between the inside and the outside of the building and through its technological layers.

The position of a new thermal insulation layer on the existing envelope mainly oriented to its physical configuration and the related normative restrictions, with the best option of the external position. The thickness of the new layer depends on the thermal-insulation material adopted, its composition and density.

The insulation layer consents to highly improve the thermal inertia of the building, keeping the indoor temperature and the sound environment at comfort levels, optimising the energy performance for heating and cooling across the whole year.

The material used for thermal insulation must be chosen also regarding aesthetical quality and the relation from indoor and outdoor.

To guarantee the typological integrability with the existing building envelope, it is important to ensure the continuity of the thermal insulation layer in order to avoid thermal bridges [1];

The degree of feasibility in existing buildings is related to the presence of not-standard architectural elements [2];

Provide a detailed design of the discontinuity points (angles or openings), such as an attentive pose in the construction phase, that usually not require specialised workers [3];

The durability of the technology requires periodic inspection and maintenance, considering that infiltration, humidity and condensation can compromise the correct functioning of the insulation material [4];

The cost of the intervention, depending on the material selected and complexity of the pose, can be rapidly amortised in time by the reduction of energy demand [5];

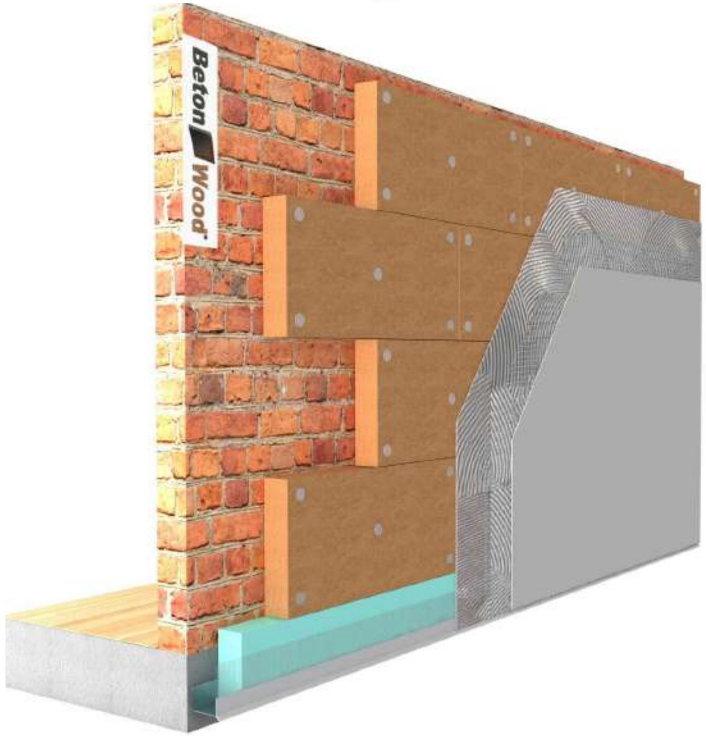
Prefabricated solutions can offer external or internal thermal insulation systems coupled with cladding systems, allowing a faster construction stage [6].

Advantages

- Reduce cooling and heating demand;
- Improve insulation, whether thermal and acoustic;
- Eliminate thermal bridges
- Improve aesthetic quality

Disadvantages

- Require external space around the building
- Require attention in the execution phase
- Difficult to integrate in historical buildings



1. Typological integrability

2. Technical Feasibility

3. Design Effort

4. Maintenance Effort

5. Budget Range*

6. Integration in technological mix

Strategies

S4 **Upgrade the opaque envelope**

Materials

Thermal Insulation materials

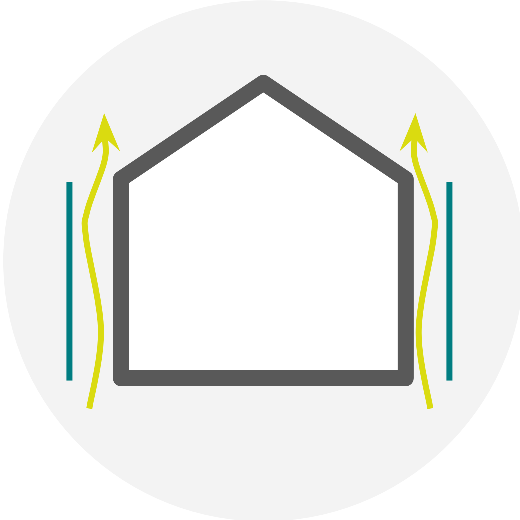
Link to best practices

2R, 4R, 5R, 7R, 8R, 9R, 2Nc, 3Nc, 4Nc, 8Nc, 9Nc

back to technologies

Showroom BP Studio, Firenze - Italy, Claudio Nardi, 2001

Ventilated envelope



The ventilated façade is a technological system recognised for the efficiency in the retrofit of the vertical opaque envelope. It consists in the positioning of an insulation layer in the external side of the existing wall and the creation of an air gap (5-10 cm) before the new cladding system. The air chamber consents the natural activation of convective air movements (stack effect), thanks to the temperature difference with the external side and the presence of openings on the bottom and at the top of the vertical surface.

It is particularly profitable for the Med climate due to its behaviour in the summer period, when the solar radiation impacting the external cladding activates the upward air movement in the air chamber, consenting the heat dissipation of the opaque envelope (for this reason, the best functioning is on the most exposed surfaces).

In the winter period instead, when solar radiation is less intense, the presence of the air chamber slows down the cooling of the envelope, also consenting the disposal of humidity.

Due to the dimension of the air cavity needed for the functioning of the convective air movements, the retrofit solution requires a minimum space and the comprehensive availability of surface, with a low technological integrability [1].

The arrangement of the ventilated façade requires the installation of a substructure to hold up the detached cladding system and separate it from the insulation layer. For this reason it requires to be attached to a consistent architectural layer, requiring an attentive pre-evaluation of the technical feasibility [2].

The ventilated façade requires an attentive design of all the technological parts, in particular the closing elements and the aspects related to fire prevention [3],

The provision of periodical inspection and substitution of damaged elements can maintain the correct functioning of the technological solution, and it is facilitated by the presence of dry solutions [4]

In comparison to other façade solutions, the cost of the ventilated façade has to consider the substructure (usually metallic or wooden), but highly depends on the chosen finishing dry system [5].

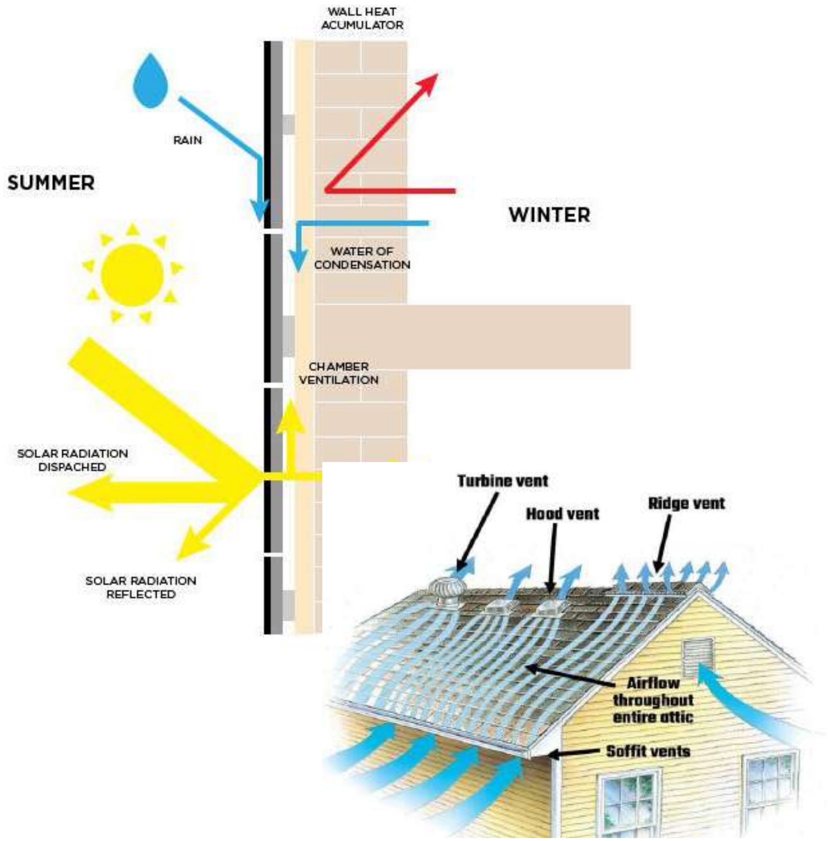
The solution involves a high integrability in technological mix, starting from the possibility to combine with insulation layers and with a wide range of cladding systems [6].

Advantages

- Evacuation of summer heat thanks to ventilation
- Insulation in winter period with state air
- Possibilities to use different finishings
- Dry solutions
- Elimination of condensation risks

Disadvantages

- Integrability highly depends on the specific configuration of the existing building and constraints
- For a proper functioning the air channel should be in between 5-10 cm to allow stack ventilation



1. Typological integrability

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2. Technical Feasibility

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3. Design Effort

● ● ○ ○ ○

4. Maintenance Effort

● ● ○ ○ ○

5. Budget Range*

● ● ○ ○ ○

6. Integration in technological mix

● ● ● ○ ○

Strategies

S4 **Upgrade the opaque envelope**

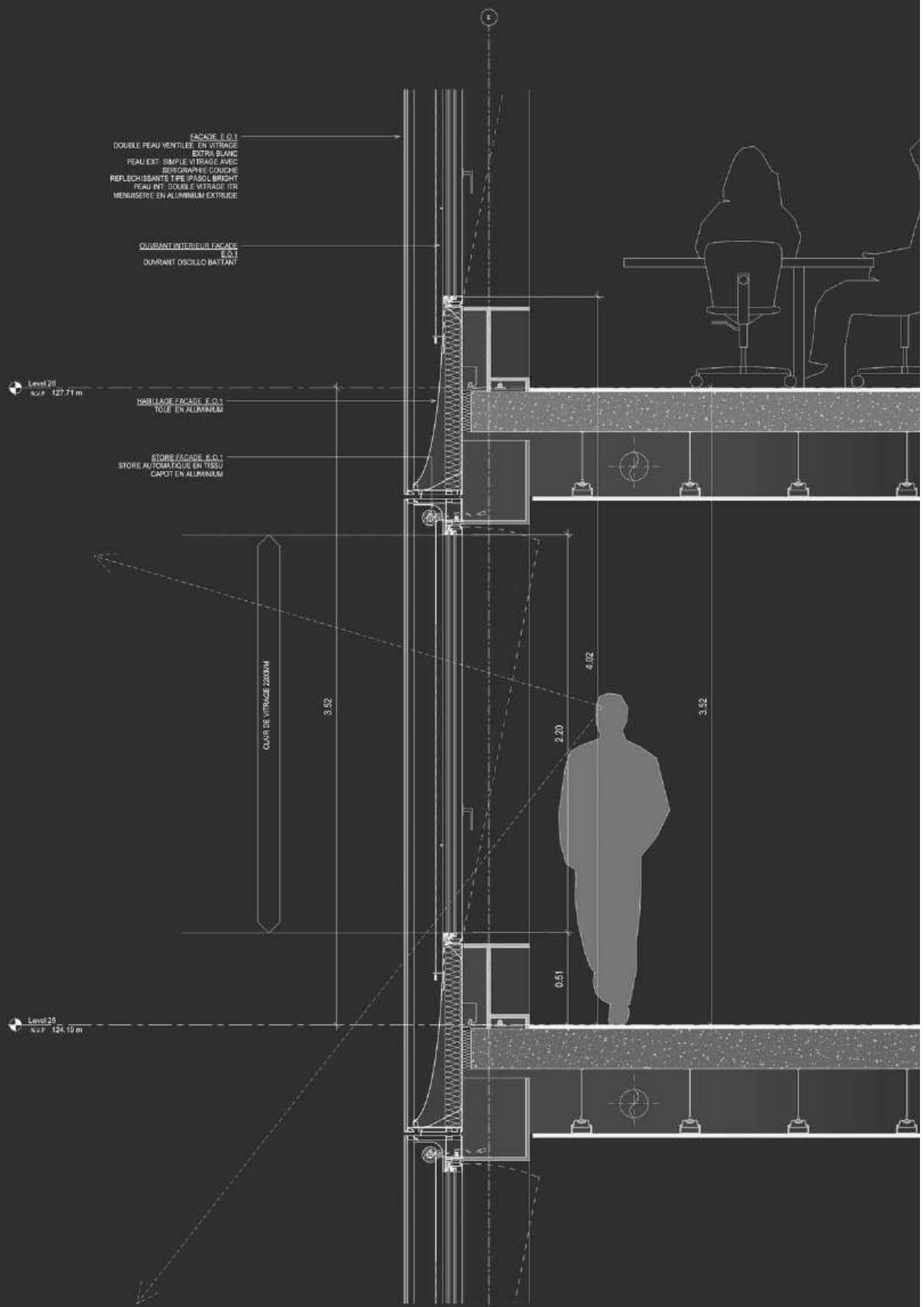
Materials

Thermal insulation materials

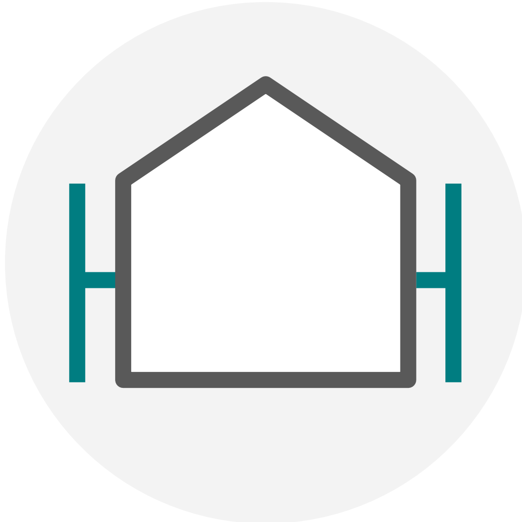
Link to case studies

2R, 6R, 9R, 6Nc, 7Nc

back to technologies



Palace of Justice, Paris - France, Renzo Piano, 2008



3

TECHNOLOGY

Double skin façade

The double skin façade is a retrofit technology consisting of the addition of a new continuous layer to the existing building, usually glass, wherein air flows through the intermediate cavity. This space (which can vary from 20 cm to a few metres) acts as an insulation layer against extreme temperatures, winds, and sound, improving the building's overall efficiency. The airflow through the intermediate cavity can occur naturally or can be mechanically driven.

Thanks to their versatility, double-skin façades are adaptable to cooler and warmer weather: through minor modifications, such as the opening or closing of inlet or outlet fins or activating air circulators, the behaviour of the façade can be adapted to different weather conditions.

During the winter season, the air buffer works as a barrier to heat loss consenting passive heating, with the sun-heated air contained in the cavity used to preheat indoor spaces, reducing the demand for mechanical heating systems.

In the summer period, the air in the cavity can be evacuated outside the building exploiting the natural chimney effect, consenting to mitigate solar gain and energy saving for cooling.

Not requiring to work in adherence, the double skin facade has a great potential of typological integrability with the existing building, but it is space consuming, requiring a minimum available space around the building [1].

The technical feasibility is linked to the configuration of the vertical surfaces and the possibility to consider attachment points [2].

The double skin façade requires a detailed design both at technological level and in relation to the context conditions of the site (e.g. sun path evaluation and physical obstruction) [3].

For the correct functioning of the double skin façade, it is important that all the components are working well, requiring a constant maintenance effort to avoid undesired conditions (e.g. condensation) [4].

For the high amount of material and the presence of active technological systems, for the functioning of the air cavity, the double skin façade requires an initial high cost [5].

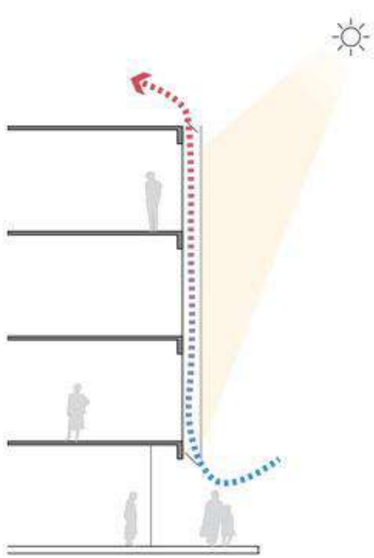
According to the façade orientation, double-skin façades can be coupled with shading and PV systems, revealing their high integrability in retrofit technological mix [6].

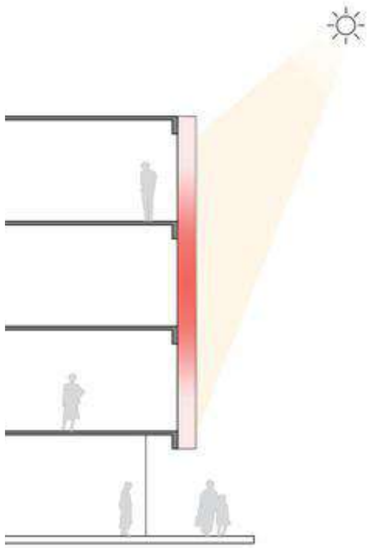
Advantages

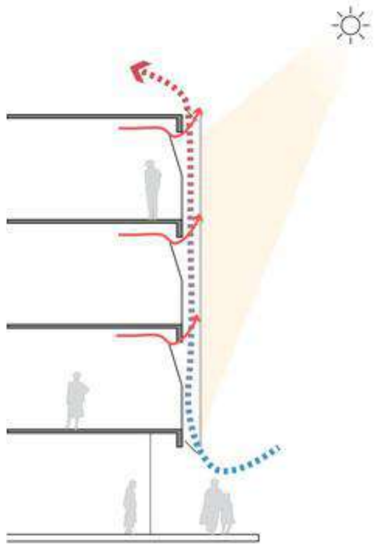
- Reduce cooling and heating demand;
- Allow clear views and natural light;
- Improve insulation, whether thermal and acoustic;
- Allow natural ventilation and air renewal, creating a healthier environment;
- Aesthetic value (unification of facades)

Disadvantages

- Much higher initial cost of construction;
- Space consumption;
- Detailed design;
- Maintenance demand (risk of condensation);
- It may fail to function properly if the context changes significantly (shadings).







1. Typological integrability

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2. Technical Feasibility

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3. Design Effort

●●●●○

4. Maintenance Effort

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5. Budget Range*

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6. Integration in technological mix

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Strategies

S3 **Integrate shading devices**

S5 **Upgrade the opaque envelope**

Materials

Glasses

Link to case studies

3R, 8NC, 9NC

back to technologies

Green roof

Primary school - Bruxelles - Belgium, Vice Verda, 2017

Retrofitting by green roofs is an unique occasion to merge the most impactive objectives of sustainability, from energy efficiency to a better use of resources, also considering social aspects.

There are several benefits in adopting green roofs as retrofit solutions, such as the passive control of thermal and acoustic comfort in the indoor spaces thanks to the solid soil layer as an efficient thermal mass, supporting energy efficiency, providing air quality with green elements and new spaces for wellbeing and social activities, also reducing the urban heat island effect and the possibility to collect rainfall water for reuse.

There are two main types of green roofs, extensive and intensive, related to different lightweight or heavier support structures, thickness and weight, functional layers and typologies of plants.

The possibility to integrate green roofs in existing roofs depends upon the following elements: position of the building; location; orientation of the roof; height above ground; pitch; weight limitations of the building; typology of planting; sustainability of components; and levels of maintenance.

Creating a green roof in an existing building may require a deep intervention on the existing roof, it is important to pay attention to any architectural constraints [1].

The technical feasibility of a green roof relies on an attentive evaluation of the existing roof made by structural engineers and experts in the field [2].

The well functioning of a green roof derives from the correct design and pose of the different functional layers, in particular the ones for the impermeabilization of the existing roof [3].

The maintenance degree of a green roof depends on the type (intensive or extensive), typologies of plants and technological systems installed (e.g. irrigation system), with extensive green roofs made of native or adapted plants as the best option to reduce maintenance efforts [4].

Installing a green roof for the retrofit of an existing building requires an important initial cost investment, but it pays back not only with the improvement of energy performances but considering the environmental and social benefits deriving from the green elements [5].

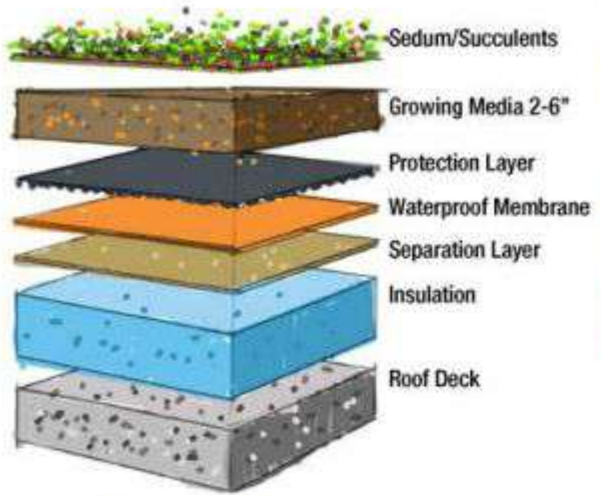
The green roof can be easily coupled with other retrofit technologies, such as thermal insulation and integration of renewable energy systems [6].

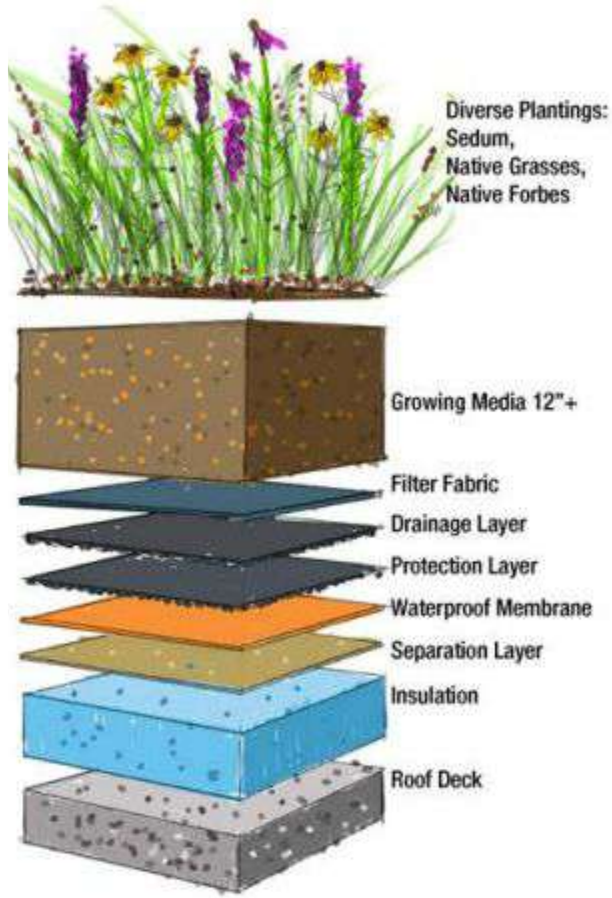
Advantages

- Protection of the building from high temperatures in summer and low in winter, resulting in the cost reduction of cooling and heating
- Increasing plant and animal biodiversity
- Integration with the context

Disadvantages

- High cost of construction
- Considerable weight and need for adequate structural calculation
- Consumption of space
- High attention during the project phase
- High initial installation cost





1. Typological integrability

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2. Technical Feasibility

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3. Design Effort

●●○○○

4. Maintenance Effort

●●●●○

5. Budget Range*

●●●○○

6. Integration in technological mix

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Strategies

S4 **Upgrade the opaque envelope**

Materials

Vegetation

Link to case studies

8Nc, 9Nc

back to technologies

Green façade

Caixa Forum, Madrid - Spain, Herzog & de Meuron, 2007

Greening the vertical envelope of existing buildings can bring several benefits aligned with the retrofit objectives of energy efficiency, environmental sustainability, architectural quality and social wellbeing; moreover, it addresses critical urban challenges, such as reducing the heat-island effect, capturing CO2 and increasing biodiversity.
The strategic use of vegetation as an architectural element in retrofit projects mainly regards solar control: green elements can be used as solar shadings for transparent elements, but can be extended to the whole façade to improve thermal performance also in the opaque part.

In the Mediterranean climate, and according to the orientation of the building, a good option is the adoption of deciduous plants, thanks to their variable configuration offering positive relapses both in summer (leaf growing: solar shading) and in winter (leaf fall: passive solar gain).

Different technological solutions consent to the vegetation to grow in a vertical shape, from the most traditional use of climbing plants, to the use of more complex technological systems concentrating all the elements for the plants growing, such as structural systems (grids), suspended soil systems and irrigation systems.

The adoption of green façades gives the possibility to reach greater levels of architectural quality, by composing the green element for the definition of a new image of sustainability for the university/public building.

Moreover, such solutions contribute to control the external micro-climate, reducing temperature and activating passive cooling, capturing smog and CO2 while creating new oxigen for a better air quality.

The integration of a green façade is based on an attentive assessment of the existing vertical envelope in order to evaluate the possibility to attach, hang or superimpose the green elements and the respective growing/supporting system [1];

The technical feasibility of a green façade is based on the correct choosing of the vertical green system matching the specific structural, technological and aesthetic characteristics of the existing envelope [2];

The design of the green vertical system not only focuses on the structures to suspend the soil or the green elements, but also on the deriving green masses and their impact on the existing building, mainly in terms of shading [3];

The efforts related to maintenance depend on the types of plants and the technological systems installed (e.g. irrigation system) [4];

The cost of the integration of a green façade strictly depend on the specific technological system adopted to suspend/grow green elements, but requires the consideration of the deriving environmental and social benefits [5];

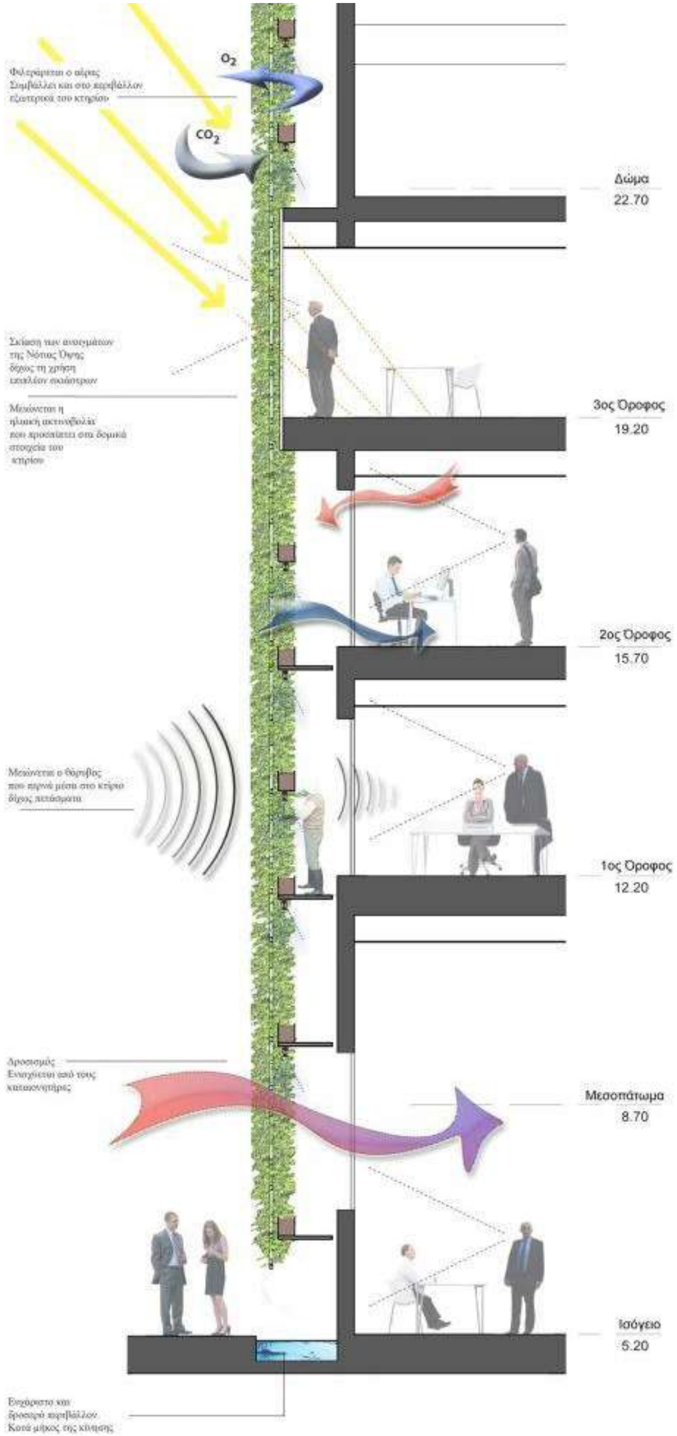
The green façade can be matched with other retrofit technologies, in particular external shading and nature based solutions [6].

Advantages

- Increasing plant and animal biodiversity
- Integration with the context
- Improve insulation, whether thermal and acoustic;
- Allow natural ventilation and air renewal, creating a healthier environment;
- Aesthetic value (unification of facades)

Disadvantages

- Much higher initial cost of construction;
- Space consumption;
- Detailed design;
- High cost of maintenance



1. Typological integrability

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2. Technical Feasibility

●●○○○

3. Design Effort

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4. Maintenance Effort

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5. Budget Range*

●●●○○

6. Integration in technological mix

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Strategies

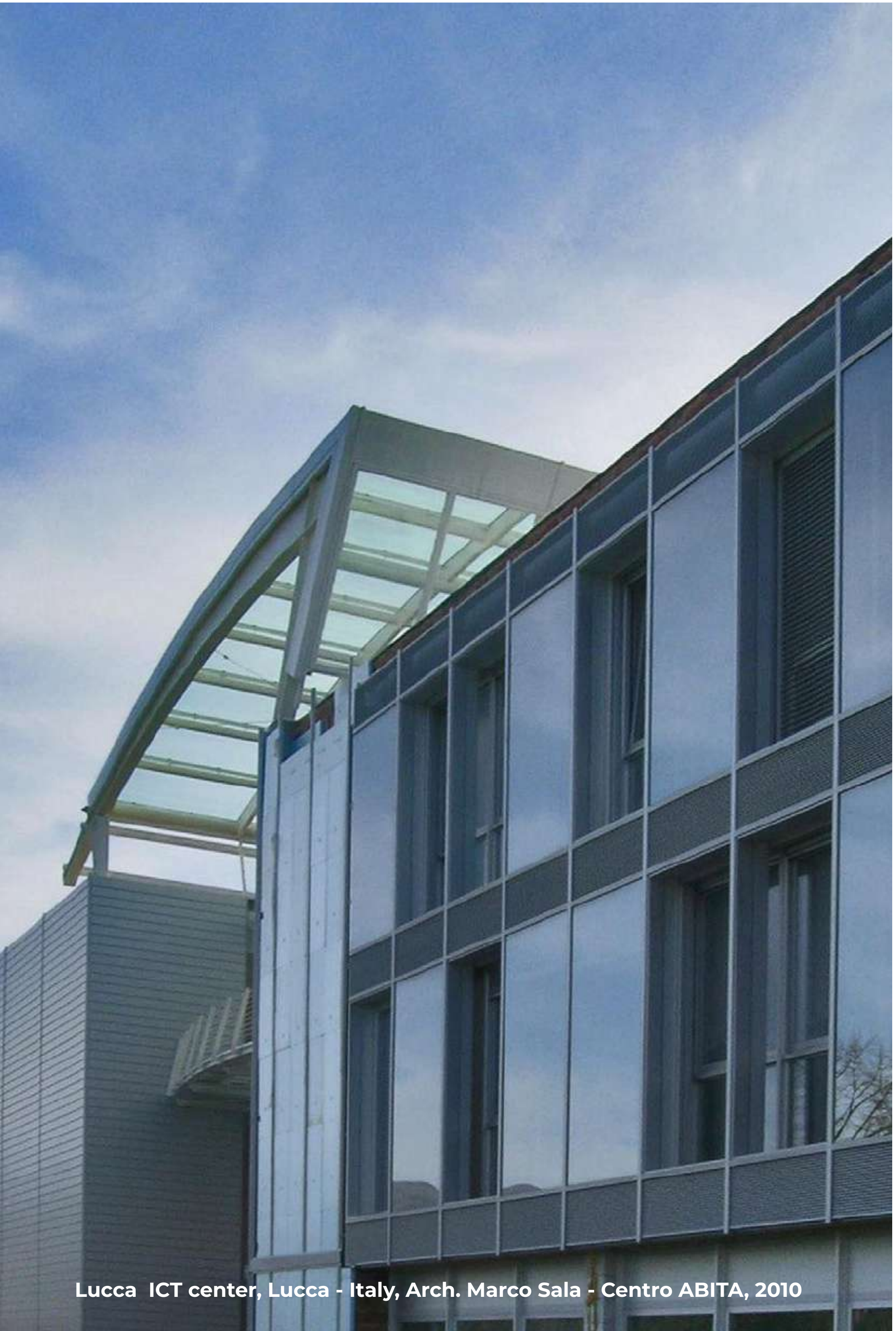
- **S3** **Upgrade the opaque envelope**
- **S4** **Upgrade the opaque envelope**
- **S6** **Insert green elements**
- **S7** **Regulate the outdoor microclimate**

Materials

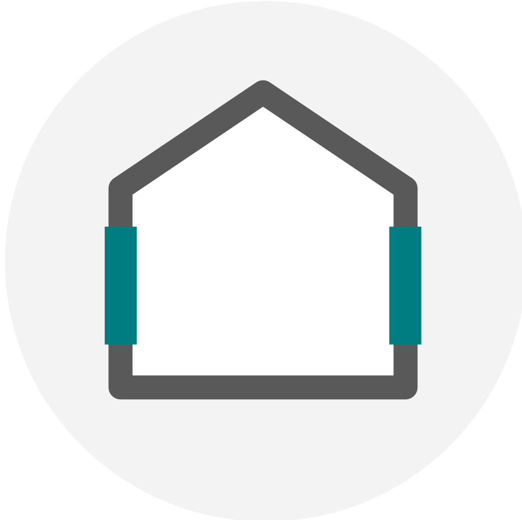
- **Vegetation**

back to technologies

High quality and smart fixtures



Lucca ICT center, Lucca - Italy, Arch. Marco Sala - Centro ABITA, 2010



The upgrading or replacement of existing windows can highly improve the building's visual, acoustic, thermal and energy performances, since the technological evolution in the last decades consents the presence in the market of a wide range of performing but cost-effective solutions.

Developments regard the two basic elements composing the window (frame and glass) and the augmented possibilities to integrate additional components and devices.

Regarding the framing systems and going beyond new materials for slimmer and lighter framing systems (e.g. composite fibers), recycled materials, efficient thermal break profiles, integration of intelligent ventilation and heat recovery systems, new finishings. For innovative Glasses, see the dedicated sheet in Materials.

Additional elements can be found integrated in windows systems, such as shading devices, PV energy panels, heat recovery systems and reflectors.

The automation of the opening/closing of windows systems is possible thanks to the advancements in battery technologies with smaller, quieter and faster motors at a good price. Moreover, the possibility to integrate IoTs devices opens towards smart windows, enabling a remote and more flexible control, automation and management.

The substitution of obsolescent transparent envelope with high quality and smart windows is favoured by the presence in the market of a great variety of materials and finishing, consenting to maintain or improve the aesthetical characters while upgrading the energy performances [1];

The integration of new windows and/or glasses depends on the specific structural characteristics of the existing openings, both at the level of frames and of walls [2];

The substitution or upgrading of the transparent envelope requires an attentive consideration in the design of the details, augmenting in the case of integration of additional components, such as shadows and heat recovery systems [3];

The integration additional components, such as smart systems for control and automation, may require a more advanced maintenance [4];

The cost for the windows' substitution and replacements can widely range according to the peculiarity of the building (e.g. presence of architectural constraints), the selected technologies, materials and accessories. Due to the high influence on building energy performance, the initial investment can be amortised in short times [5];

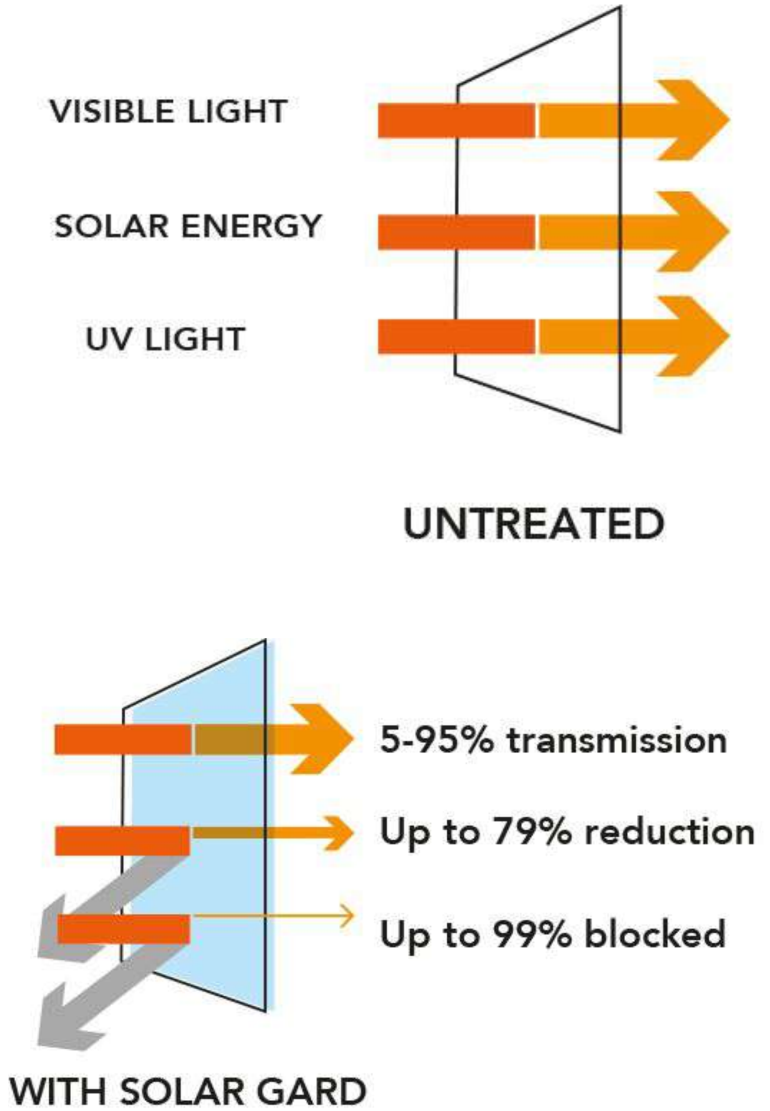
The substitution of windows can be combined with different other technologies, due to the possibility of integration of reflectors, shading devices, systems for the production of photovoltaic energy and heat heat recovery systems [6].

Advantages

- Reduce cooling and heating demand;
- Allow clear views and natural light;
- Easy to install

Disadvantages

- Need for air exchange systems
- High cost for materials



1. Typological integrability

2. Technical Feasibility

3. Design Effort

4. Maintenance Effort

5. Budget Range*

6. Integration in technological mix

Strategies

S5 **Up-grade the opaque envelope**

Materials

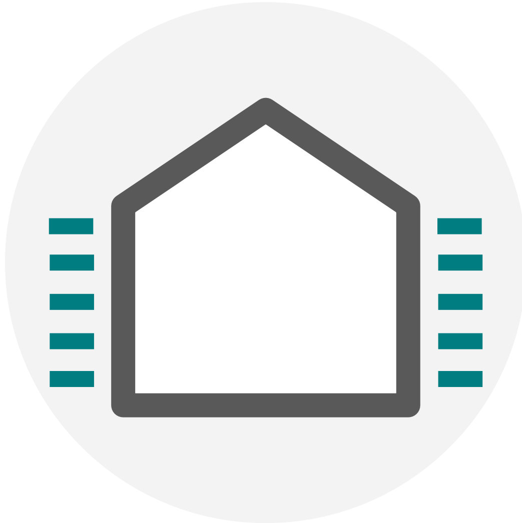
Glasses

Link to case studies

2R, 4R, 5R, 6R, 7R, 8R, 1Nc, 2Nc, 3Nc, 4Nc, 5Nc, 6Nc

back to technologies

La Marseillaise, Marseille - France, Jean Nouvel, 2018



External shadings

External shadings are architectural elements intended to protect the transparent envelope from direct solar radiation. Their position in the outside of the building makes them the most profitable type of shading system, impeding the sun from reaching the transparent envelope and overheating it during the summer period. .

External shadings can be fixed or mobile. If fixed, they have a minor installation and maintenance cost, while mobile ones can create more possibilities to adapt to external conditions, considering that the movement can be activated manually or by BMS.

The shape of shading elements strictly depends on the orientation of the transparent envelope to protect, and requires a very attentive design: to protect the south exposition, they have to be horizontal, while for façades exposed to east and west, external solar shadings assume the shape of vertical elements. In all cases, the dimension, depth and distance between elements needs to be calculated according to the climatic zone and latitude.

External shadings can be realised in a wide range of construction materials, according to the cost, the local context/market and the aesthetic value. Moreover, shadings can be concentrated on the single transparent element or run across the whole façade, requiring structural solutions but giving a new image to the existing building.

The realisation of new external shadings can be combined with other technologies, in particular the substitution of fixtures, the creation of reflectors, the integration of PV systems and the use of nature based solutions.

The integrability of solar shadings in existing buildings depends on the possibility to intervene on the existing envelope: if no architectural constraint is in place, the possibility of integration is very wide [1];

The technical feasibility of the addition of new external systems is related to the possibility to hook them up to the existing envelope: nevertheless, innovative shading systems can be very light, integrated in windows or be totally detached from the existing envelope [2];

The design of new external solar shadings requires an attentive conceptualization, related to the definition of the better shape according to orientation and exposition [3];

Shading devices can be really easy to maintain. This condition must be supported by material used. Moreover some elements can be replaced or repaired [4];

The cost for the installation of shading has a range according to the difficulties of the project, the materials and the technologies installed [5];

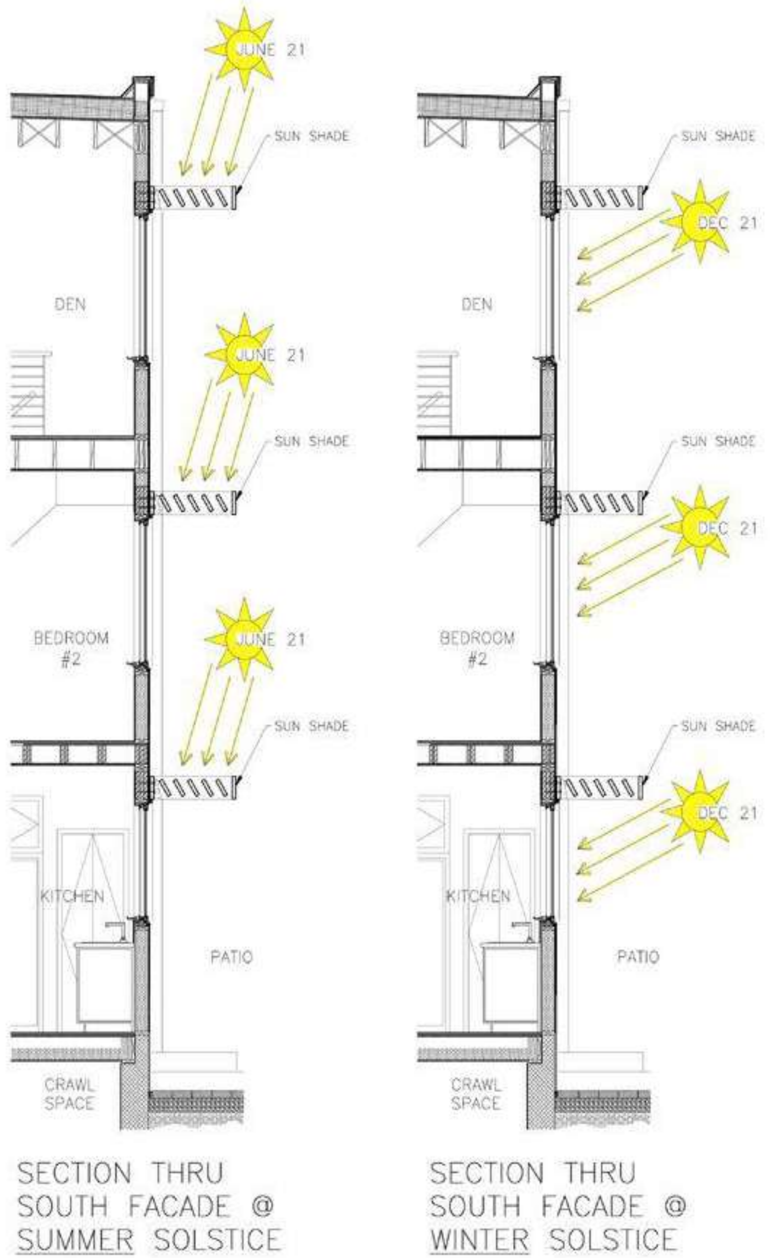
This technology can be mixed with a lot of other technologie. For example, you can install photovoltaic panels on it or shading can be mixed with green vertical facade or thermal insulation. Shading devices admit a lot of possible range of mix of technologies [6].

Advantages

- Reduce cooling and, in some cases, heating demand
- Allow natural light management optimising visual comfort
- Improve acoustic insulation
- Aesthetic value (unification of facades) with a large choice of materials

Disadvantages

- Space reduction
- Detailed design and study of solar radiation



1. Typological integrability

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2. Technical Feasibility

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3. Design Effort

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4. Maintenance Effort

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5. Budget Range*

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6. Integration in technological mix

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Strategies

S5 **Up-grade the opaque envelope**

Materials

External shadings

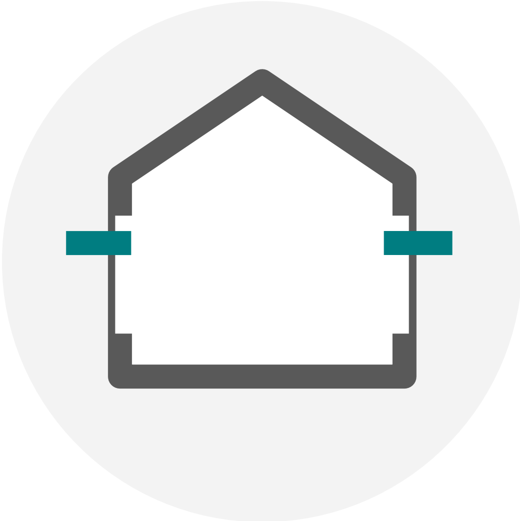
Link to case studies

1Nc, 3Nc, 4Nc, 5Nc, 6Nc, 7Nc, 8Nc

back to technologies

Light shelves application

Reflectors



Reflectors are architectural elements used to increase the amount of natural light inside the building. There are several types:

- Reflective shelves
- Fibre optics (https://www.solarreviews.com/blog/guide-to-fiber-optic-solar-lighting)
- Solar tunnel

The solar shelves consist of horizontal elements placed at a certain height from the ceiling, such that the solar radiation with their inclination does not directly affect the internal surface of the building, causing an unpleasant feeling of glare, but hit the shelves that thanks to their reflective upper surface deflect the light spreading it into the environment.

In recent years, some lighting systems have also been developed using fibre optics. These systems consist of three elements: a collector, a fiber optic cable and a lighting body. The collector through a lens system channels the light in the optical cable that being connected to a lamp or a strip brings light indoors. However, this system is linked to the amount of light present in the external environment. In addition, over a cable length of about 10 meters, the light intensity transported begins to decrease.

The last element is the solar tunnel, that is a real metal tube whose internal surface is highly reflective that thanks to a transparent semisphere at the upper outer end captures sunlight and radiate inside the building.

From a technical point of view, the installation of these systems must take place in an area sufficiently close to the external solar radiation in order to operate [1]

The correct operation of the light shelves, fibre optics or solar tunnel is always determined by the meteorological variable of the external environment. [2]

The initial cost of intervention is quite limited and the use of these systems does not require subsequent maintenance [3]

The reflectors may be complementary or even replace any photovoltaic panels if they are installed only to obtain energy suitable for lighting [4]

Reflectors are easy to install on both newly designed and retrofitting buildings [5]

These technologies can be easily integrated with some others, thanks to their transversal use. [6]

Advantages

- Improve clear views and natural light;
- Reduction in electricity consumption and expenses

Disadvantages

- Variability of efficiency according to weather

1. Typological integrability

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2. Technical Feasibility

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3. Design Effort

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4. Maintenance Effort

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5. Budget Range*

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6. Integration in technological mix

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Strategies

S5 **Up-grade the opaque envelope**

Materials

Thermal mass materials

back to technologies

NBS - Nature based solutions

Residential Parks, Boulogne Billancourt (Paris) - France, Agence Ter, 2015

Emerging as key-concept in the most innovative urban policies, Nature-Based Solutions (NBS) refers to systems where "nature" is mobilised to render urban areas more resilient to climate change.

Deriving from Green and Blue Infrastructure and Ecosystem Services, NBS are considered able to reach a wide range of benefits for the urban area, such as biodiversity, mitigation of the heat island effect, air quality, sustainable water cycle, and for people living there, as improving health and wellbeing of individuals and representing occasions for social cohesion for the community.

NBS cover a broad spectrum of applications and related technologies; for the purpose of building renovation, a simplified model can be referred to indoor plants, green roofs and walls (single technologies in the Abacus) and green/blue landscaping. Since students, researchers and officers spend a lot of their time indoors in university buildings, indoor plants can be introduced as a multi-functional, low-cost, low-maintenance and air-cleansing solution. Indoor plants are generally soil-based, but also non-soil solutions can be explored (i.e. hydroponic), such as more unconventional indoor vertical greenery.

The immediate surrounding of the university/public building can be considered in building retrofit projects to exploit the multiple benefits of green/blue infrastructures, organised networks of green spaces and elements, water and other natural features (es. trees, vegetation, fountains, drainage surfaces, etc). For example, it is possible to obtain the combined effect of vegetation and water to induce evaporative cooling in the summer period, reducing the building energy demand for cooling.

Nature-based solutions (NbS) can be effectively integrated into built environments to improve sustainability, resilience, and energy efficiency. In existing buildings depends on the possibility to intervene on the existing envelope [1];

Aslo the choice of eco-friendly building materials and construction techniques minimizes environmental impacts. This includes using recycled materials, sustainable timber, and virtuous manufacturing processes [2];

NBS requires an attentive design of all the elements to implement and optimize it. For example, water usage is a central topic of NbS and it must manage in a carefully way. [3].

The maintenance degree of a nature based solution should be relevant in the all life of technologies caused from the presence of vegetation [4];

NBS can has an high cost due to the study of the project [5];

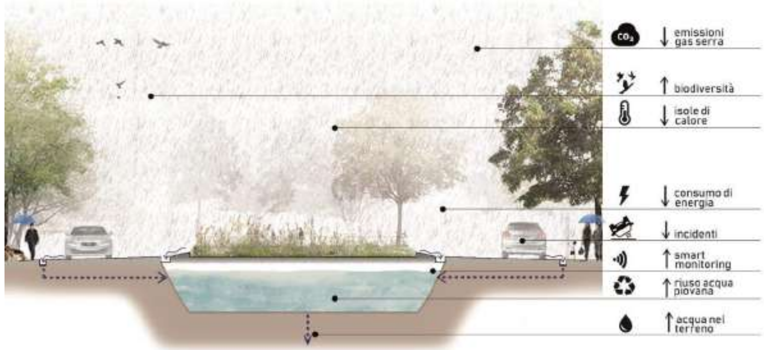
NBS can be mixed with some other technologies as this technology provides the use of external space of the building. In addition to green roof and façades systems implementation, biophilic principles can be applied to promote the inclusion of natural elements such as natural light, ventilation, and greenery within building interiors. These elements improve occupants well-being, productivity, and overall satisfaction [6].

Advantages

- Biodiversity conservation
- Local climate mitigation (reduction of heat islands phenomena)
- Passive solutions avoiding energy request
- Purification of the surrounding environment and improvement of quality of life (physical and mental)

Disadvantages

- Complexity and long term time planning, requiring interdisciplinary collaboration
- Conflicts on the land use with agricultural and other urban
- High initial cost of realization and maintenance
- Uncertainty on the outcomes that makes benefits difficult to measure in the mid-term (such as climate change mitigation)



1. Typological integrability

2. Technical Feasibility

3. Design Effort

4. Maintenance Effort

5. Budget Range*

6. Integration in technological mix

Strategies

S5 **Up-grade the opaque envelope**

Materials

Thermal mass materials

Link to case studies

5Nc

back to technologies


Children Hospital Meyer, Florence - Italy, CSPE + ABITA

BIPV - Building integrated photovoltaic

The Photovoltaic Systems represent the most mature technology to produce energy (electricity) from renewable sources (Sun irradiation). In the last 20 years, the improvement in performance and durability, the national incentives and the ease in installation, have increased its diffusion in many contexts.
Integration in buildings is one of the main issue: since PV plants can be easily applied to every kind of roof area (flat or tilted), other non-standard solutions could be set up, for instance covering vertical facades such as shading devices.
During the design phase, the evaluation of the plant's peak power and the yearly energy production must be addressed in order to evaluate the impact of the intervention on the overall energy consumption and its payback time (technical and economical assessment). User-friendly tools such as PVGIS could be used for that scope at least for a preliminary investigation. The following parameters need to be fixed:

- location of the plant (site's latitude and longitude);
- size and orientation of the available surface (azimuth and tilt of the plant);
- kind of PV technology (mono-crystalline, poly-crystalline, amorphous Silicon);
- possible large shading phenomena due to other buildings and obstacles.

PV systems can be used also to provide thermal energy (heating and cooling) if the plant integrates Heat Pumps. In such way, at least a part of the conditioning of environments, will be guaranteed by renewable energies. This configuration is particularly suitable in summer seasons when the high energy production meets the peak of cooling demand.

Installing PV panels should not require a deep intervention on the existing roof, architectural constraints and limits could arise only in cultural heritage contexts [1].

The technical feasibility of a PV plant is a standard procedure made by the designer and installers of a common professional companies [2].

PV system are such a widespread technology that application is foreseen in many different contexts. Plants are modular and scalable to different sizes [3].

The maintenance degree of a PV plants should not be relevant in the 10-15 years. Components should lose their performance slowly during time, just unpredicted damage has to be checked [4].

Installing a PV systems does not require an important initial cost investment (depending on the size), but the payback time would be around few years thanks to national incentives and cost avoidance [5].

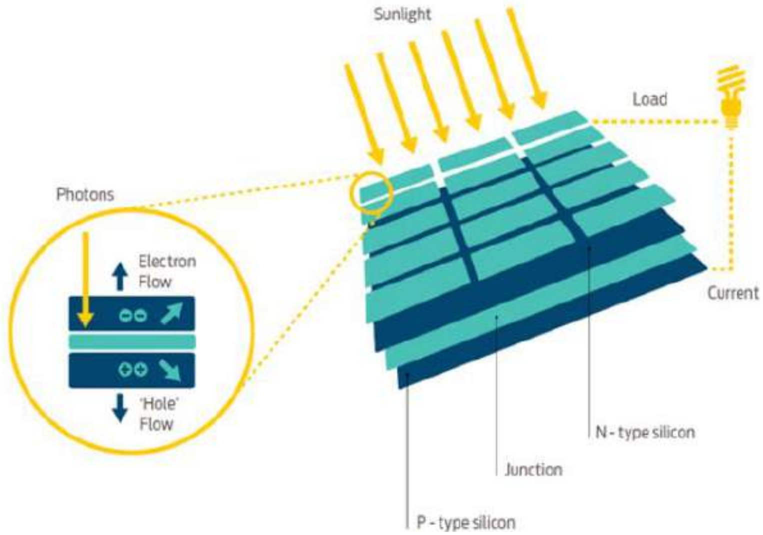
The PV plants could produce "clean" energy for supplying other systems with high performance such as heat pumps, coverings a part of the heating/cooling demand [6].

Advantages

- Plants are easy to install
- No need of structural intervention in the existing
- Investment costs paid back in few years
- National incentives promote this kind of technology
- Surplus energy can be sold to the grid (depending on contrats)
- Electricity can be converted in thermal energy for the air conditioning of environments through heat pumps

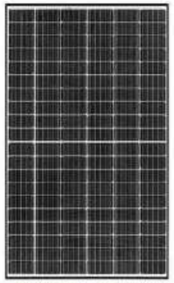
Disadvantages

- The energy production is usually not matched with the demand profile
- Energy storage systems (batteries) are still not enough efficient and competitive
- In cultural heritage buildings, restrictions could be applied on the installation of standard PV panels that could have a high architectural impact

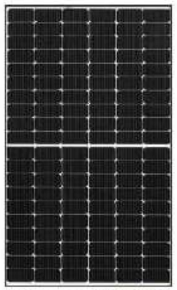



Poly PERC


Mono PERC


Half-cut mono PERC


Shingled mono cells


Half-cut mono PERC MBB


Half-cut N-Type TOPcon


Half-cut N-Type HJT


N-Type IBC

1. Typological integrability

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2. Technical Feasibility

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3. Design Effort

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4. Maintenance Effort

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5. Budget Range*

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6. Integration in technological mix

●●●●●

Strategies

S3 **Integrate shading devices**

S8 **Integrate renewable energies**

S9 **Consider efficient plant systems**

Materials

PV - Photovoltaic panels

Link to case studies

1R, 2R, 4R, 7R, 9R, 1Nc, 2Nc, 3Nc, 4Nc, 5Nc, 6Nc, 7Nc, 8Nc, 9Nc

back to technologies

LED - lighting

Led lighting application

The conversion of lighting plants from the incandescent/fluorescent lamps to LED technology represents one of the most effective tools to achieve the energy saving in the building sector and it has revolutionized the lighting industry itself due to the overall efficiency, exceptional lifespan, and design flexibility.

LED technology allows for a significant reduction in energy demand while also minimizing the environmental impact.
Furthermore, LEDs offer a wide range of lighting control possibilities, enabling designers to tailor the lighting environment to the specific needs of each space. Lighting can be adjusted based on natural light, time of day, or user preferences, enhancing visual comfort and contributing to occupant well-being.

In addition to energy and comfort issues, LEDs come in a variety of color temperatures and design options, allowing the creation of atmospheres in every setting. Creative use of LEDs can transform spaces, highlight architectural elements, and enhance the overall aesthetics of buildings.

This technology not only saves energy and bills but also offers extraordinary potential to improve the occupants' experience and create more pleasant and environmentally friendly spaces.

LED lighting offers numerous advantages over traditional lighting technologies in terms of integrability and feasibility, especially for retrofitting processes [1].

LEDs can be easily integrated into a wide range of architectural design projects due to their compact size and flexible form factors. They can be embedded in ceilings, walls, floors, and even furniture, maximising together the overall visual comfort and the needs of specific areas [2].

LED lighting systems offer extensive customization options, allowing the improvement of tailored lighting solutions. They can control color temperature, brightness, and even dynamic lighting effects, enhancing the overall aesthetics of a space with minimal design effort [3].

Actually they have a longer lifespan compared to traditional lighting sources. With a typical operational life of 25,000 to 50,000 hours or more, they require less frequent replacement. This reduces the maintenance effort and costs associated with changing bulbs [4].

While the initial upfront cost of LEDs may be higher than traditional lighting options, their long-term cost-effectiveness is undeniable. Lower energy consumption, reduced maintenance, and fewer replacements lead to substantial savings over time, making them a budget-friendly choice in the long run [5].

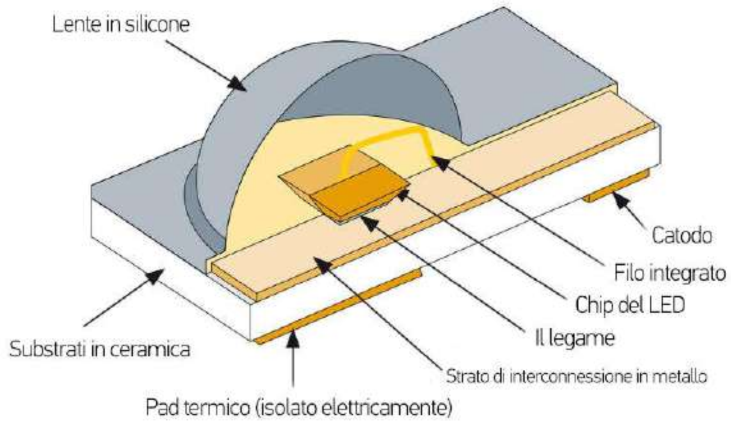
This technologies can be easily integrated with some others, cause they do not impact the structure of buildings [6].

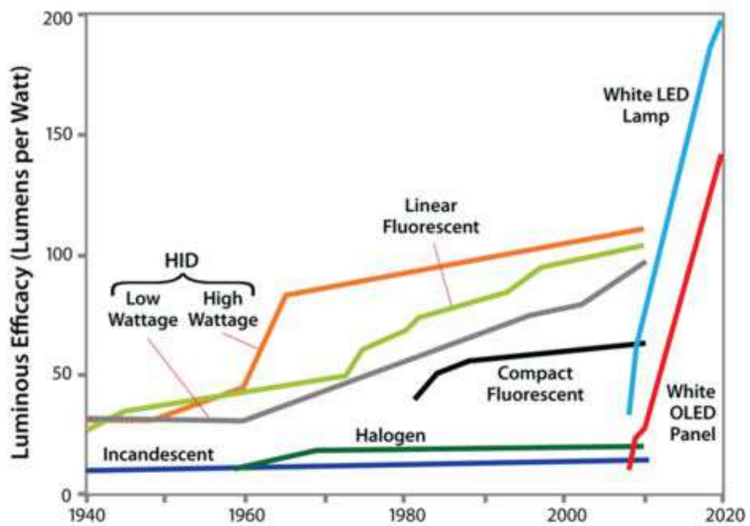
Advantages

- Energy savings up to 65%
- Easy implementation also in retrofitting context
- Versatility and customization for optimizing the global and local visual comfort
- Long service life of installed

Disadvantages

- Space is needed to position the inverters





1. Typological integrability

2. Technical Feasibility

3. Design Effort

4. Maintenance Effort

5. Budget Range*

6. Integration in technological mix

Strategies

S9 **Consider efficient plant systems**

Link to case studies

1R, 2R, 3R, 4R, 5R, 6R, 7R, 8R, 9R, 1Nc, 2Nc, 3Nc, 4Nc, 5Nc, 6Nc, 7Nc, 8Nc, 9Nc

back to technologies

Heat pumps

Heat pumps application

Heat pump technology has seen a relevant growth in the last 20 years. Thanks to new working fluids and optimised components the overall performance increased (COP above 3-4) and costs reduced.

With the spread of systems exploiting renewable energy source (solar irradiation, wind...) they took place in producing “green” thermal energy in building sector, instead of standard gas boilers or similar.

Nowadays, a single machine can produce heating in winter and cooling in summer season depending on the needs and boundary conditions. Split units such as fan coils should to be installed as terminal devices in the internal environments to supply them properly.

If the external ambient temperature is too low (around 0°C) or too high (>40°C) the heat pump is still able to operate but with very poor performances. It is to say that the convenience of installing this kind of systems needs to be evaluated depending on the specific location and available sources.
For instance, in case of a site with cold winter seasons, hybrid solutions are also available, matching heat pumps with back-up burners supplied by biomass fuel. On the opposite side, in hot climates, a consistent part of the electricity for cooling energy could be directly supplied by a proper PV plant.

A particular attention should be paid to the architectural integration of such systems: heat pumps are composed by an external unit that cold have a relevant impact on the context, especially in cultural heritage buildings. Centralised plants would be installed on flat roofs while the small size distributed ones are generally applied on the facade.

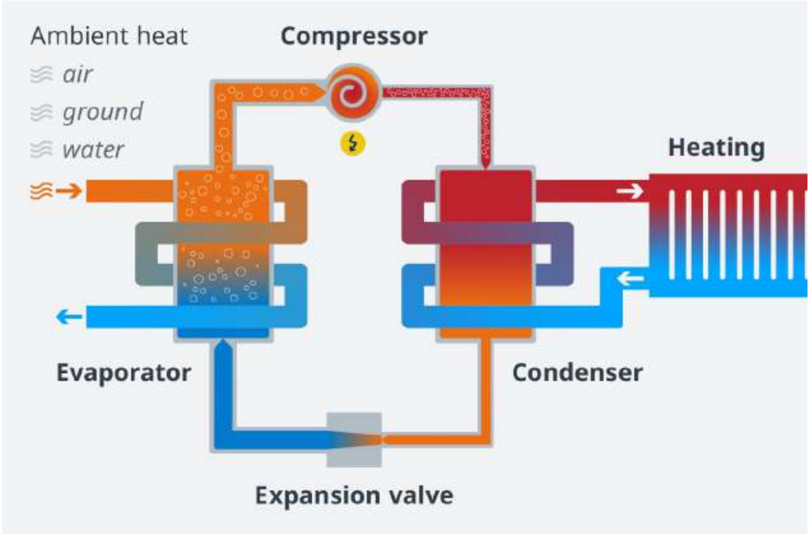
Installing heat pumps could require a relevant intervention on the existing, especially in old buildings. Architectural constraints and limits could arise in cultural heritage contexts [1].
The technical feasibility of heat pumps is a standard procedure made by the designer and installers of a common professional companies [2].
Heat pumps are a quite widespread technology and their application is foreseen in many different contexts. Plants are modular and scalable to different sizes [3].
The maintenance degree of heat pump should not be relevant if the installation is correct. some components like filters, sealing and working fluid have to be checked [4].
The cost of a heat pump depends on the size and the distribution plant, but the payback time would be reduced thanks to national incentives and cost avoidance if electricity is supplied by renewable sources [5].
The heat pump could be suitable with the integration of PV systems [6].

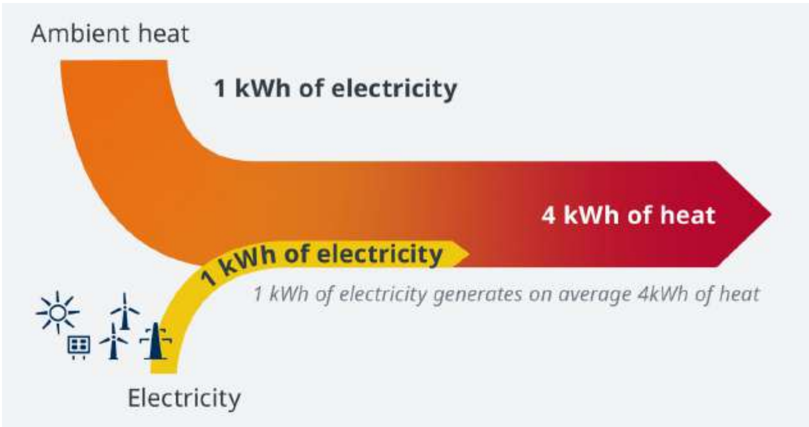
Advantages

- heat pumps convert electricity into thermal energy;
- winter and summer air conditioning is achieved with high efficiency;
- depending on the context, installation could be easy;
- some national incentives would push their application integrating PV systems;
- in summer seasons PV plants can supply the major part of the electricity needed for air cooling;
- the maintenance requirements are low.

Disadvantages

- in winter seasons, the energy production of PV plants would be generally low in respect to the supply request of a heat pump for heating, energy should be bought from the grid;
- in the existing context, terminal devices should be changed if standard gas boiler are present (fan coil instead of radiators).
- some particular external limit conditions avoid the operability of the heat pump and, in any case, the efficiency parameter (COP) could decrease a lot in off-design.





1. Typological integrability

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2. Technical Feasibility

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3. Design Effort

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4. Maintenance Effort

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5. Budget Range*

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6. Integration in technological mix

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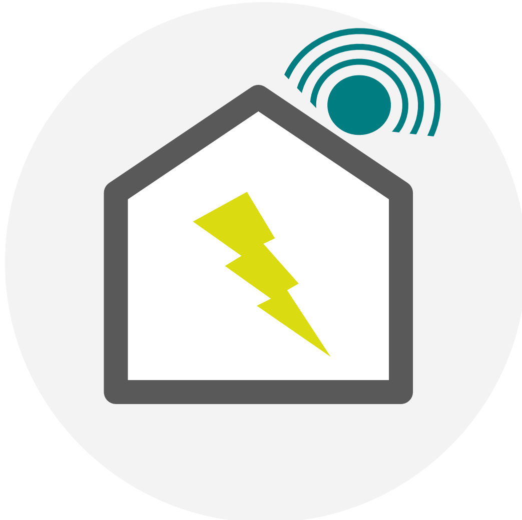
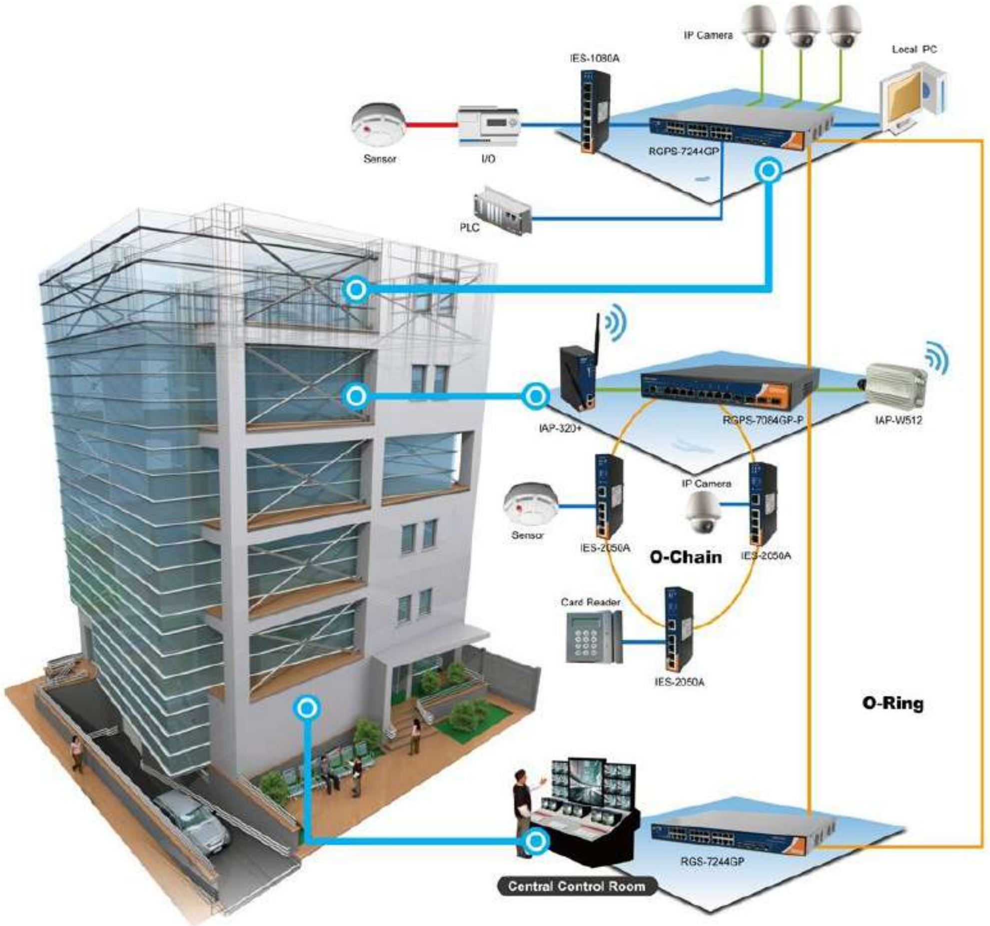
Strategies

S8 **Integrate renewable energies**

S9 **Consider efficient plant systems**

back to technologies





Building management system application

The Building Management System (BMS) is a set of monitoring/control methodologies and strategies for buildings, or parts of them, aiming at optimising its working conditions toward energy efficiency and IEQ improvement.

The mechanical and electrical equipments are managed by a central apparatus, on site or remotely, through a single interface that collects all the useful information. The components to keep under control are the following:

- air conditioning (heating and cooling);
- natural and mechanical ventilation;
- lighting;
- sprinkler system;
- security devices.

The BMS is composed by a complex grid of sensors spread all around the building, a software with a proper algorithm for data collection and analysis and many actuators for the intervention in respect to expected internal or boundary conditions' changes. That kind of automation must operate in real time avoiding peaks and waste of energy and a non efficient conduction (switching off plants and lighting with no occupancy for instance).

The use of a BMS allows an overall supervision by the technical staff through a single tool, reducing the possibility of error and the response time, both on site and remotely (desktop, tablet, mobile).

Emergency cases can be managed rapidly intervening before damages hit sensitive areas (such as server rooms...) and people.

Finally BMS let historicizing every single event related to the function of the different services:: the availability of long term data permit to evaluate the building along its whole life process for better planning of suitable future scenarios and risk management.

Installing BMS could require a relevant intervention on the existing, especially in huge buildings. Architectural constraints and limits could also arise in cultural heritage contexts [1].
The technical feasibility of BMS heat pumps is a standard procedure made by the designer and installers of a common IOT companies [2].
BMS require a dedicated design phase that is specific for each intervention depending on the complexity and the potential of the building and [3].
The maintenance degree of BMS is related to the number of auxiliary devices such as sensors and actuators but in general the monitoring should be in real time for guaranteeing he correct conduction of the building [4].
The cost of a BMS depends on the size of the system and the number of the available devices. The intervention in old buildings could be not applicable and convenient [5].
The BMS is intrinsically suitable for the integration of all the active and passive strategies for the management of a building [6].

Advantages

- the building could be completely mapped for what concerning all the services and operative conditions;
- setting up a BMS for a new building is suitable at the design phase.
- the monitoring/control system acts in real time;
- energy optimization is improved strongly on the basis of long time data collection;
- emergency situations are suddenly identified;
- IEQ could be managed with automated strategies;
- building information are available in shareable; formats (single smart buildings can connected in smart district and smart cities).

Disadvantage

- BMS for existing building could be difficult to implement (high impact on intervention and costs);
- maintenance of hardware, sensors and devices should be provided constantly during years;
- a trial period is necessary to optimise the management algorithm in the real application taking into account several variable parameters;
- the operating methods would be updated during the years if boundary conditions change;
- specialized staff have to be involved to work the BMS.

1. Typological integrability

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2. Technical Feasibility

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3. Design Effort

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4. Maintenance Effort

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5. Budget Range*

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6. Integration in technological mix

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Strategies

S1 **Valorise daylight**

S2 **Allow natural ventilation**

S8 **Integrate renewable energies**

S9 **Consider efficient plant systems**

Link to case studies

2R, 3R, 4R, 9R, 1Nc, 2Nc, 4Nc, 6Nc, 9Nc

back to technologies

MATERIALS

A catalogue of traditional and innovative materials for the technological solutions is organised in the Abacus to orient towards the use of the most eco-sustainable ones.

Objectives

Criticalities

Strategies

Technologies

Materials

>> Thermal insulation materials 1

>> Thermal mass materials 2

>> Glasses 3

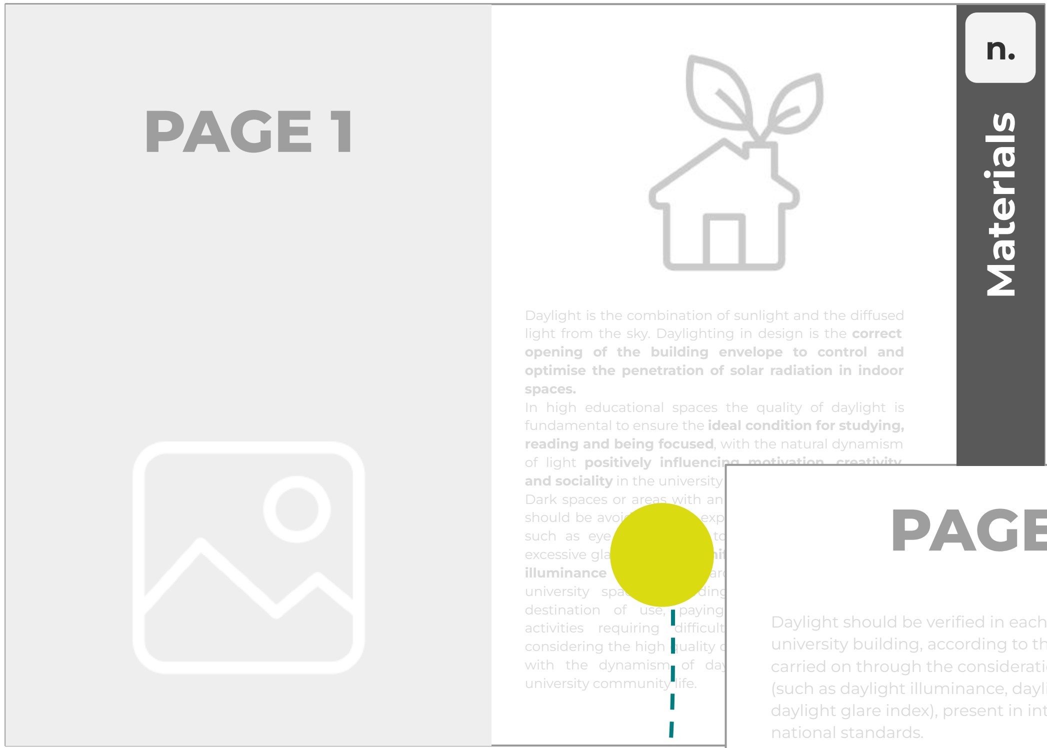
>> External shadings 4

>> Vegetation 5

>> PV - Photovoltaics panels 6

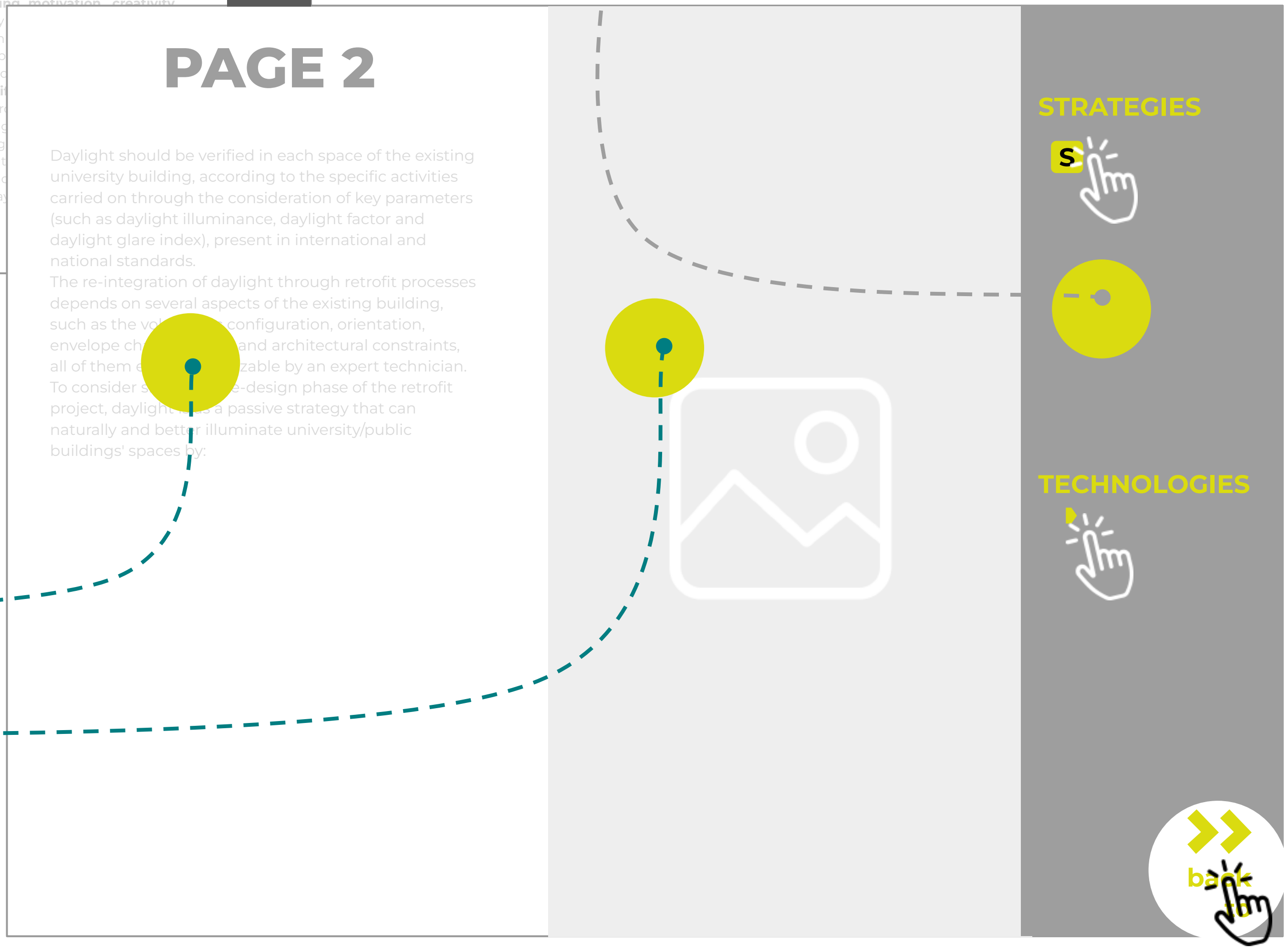
Discovering, debating and selecting the best retrofit materials to solve the criticalities of the existing university/public building is the **precondition to set pervasive renovation processes**, going further energy efficiency to envision more **ambitious scenarios of quality and sustainability**.

Retrofit materials from 1 to 4 and number 6 can be considered as **'passive'**, since their contribution to the building's performance does not require energy consumptions after the intervention. Retrofit material 5 can be considered as **'active'**,regarding the use of energy for the high difficult maintenance of the material.



Navigating on the borders of the page, it is possible to explore:

→ **Related Strategies and Technologies**
Upper level strategy and Technologies
(links to the other two levels of the Abacus).



For each material, the Abacus provides information organised in 3 main sections:

1. Description
Explanation of the material with reference to strategies and technologies and overcoming retrofitting objectives;

2. Main features
How the material works and how it can improve the building performance.

3. Technological details
Drawings explaining the functioning and composition of the material

Thermal insulation materials

The selection of the most appropriate thermal insulation material to upgrade the opaque envelope depends on different factors:

- **Performances:** consider the U-value of transmittance (W/mqK) of the material in relation to the thermal insulation performances to achieve, to calculate together with the other envelope layers;
- **Thickness:** consider the architectural constraints to insert the new envelope insulation layer;
- **Position:** according to the position internal or external to the existing wall, consider the different degrees of protection of the insulation layer;
- **Prefabrication:**
  some solutions in the market consent to add thermal insulation layers by providing multi-layer packs containing insulation with thermal mass layers and complete with finishing;
- **Environmental impact:**
  choosing natural, renewable or recycled materials for thermal insulation is always the best choice.
  The necessity to reach the thermal performances and respect the architectural constraints requires the choice of different materials. In this case it is important to consider the products’ green certificate or, if available, the calculation of LCA (Life Cycle Assessment).

PETROCHEMICAL

In the field of insulation petrochemical materials are widely used. They are characterized by high reversibility, durability, and strength. Their nature allows to be light, rigid or foamy (and therefore allow to occupy any pore). The high thermal performance is due to the presence of closed cells containing air inside the material.
However, this class of insulation has a high environmental impact, despite the research carried out in recent years in the field of recycling these materials.

- Expanded Polystyrene (EPS)
- Extruded Polystyrene (XPS)
- Phenol Formaldehyde (PF)
- Polyurethane (PUR)
- Polyisocyanurate (PIR)
- Urea-formaldehyde (UF)
- Expanded polylactic acid (PLA)

NATURAL

Natural insulation materials are made from natural fibres or aggregates of both animal origin (wool) and plant origin (cellulose or cork). The thickness of these insulators is on average higher than that of the others and have both a life span and a lower performance than petrochemical and inorganic insulators.

- Cellulose
- Coconut
- Flax Wool
- Hemp
- Sheep Wool
- Wood Wool
- Expanded cork

INORGANIC

Inorganic materials can be fibrous, porous or cellular. They have excellent fire resistance behavior. This type of material allows to optimize the thickness of the insulation obtaining excellent performance with the minimum thickness.

- Glass Wool
- Rock Wool
- Calcium Silicate
- Foam Glass
- Perlite
- Vermiculite
- Vacuum Insulation Panels-VIPs
- Thermosheet
- Aerogel

RECYCLED

This class of insulation is obtained through the recycling of insulating materials of other types (Petrochemicals) or other recycling materials such as PET bottles (through separate collection). For example, PET is also recyclable again.

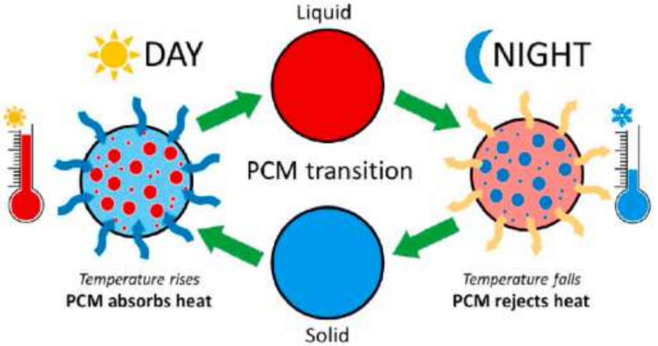
- Textile Fibers (es. cotton, wool, ...)
- Recycled from petrochemicals
- Recycled Glass Foam
- PET

ADVANCED

In recent years, increasingly innovative technologies and insulation systems have been developed such as Vacuum Insulation Panels or Phase Change Materials.

The former consist of prefabricated panels consisting of a rigid, highly porous core. The outer coating is highly waterproof and does not allow moisture or gas to come into contact with the inside
The latter, on the other hand, are based on the ability to store thermal energy of materials. Their use occurs both in roofing and in the facade. The right application of PCM reduces the cooling load, thus being able to design smaller technical systems.
Their operation is based on the transformation of the state of materials. During the day, PCMs absorb heat by transforming the state of the core material from solid to liquid/gaseous. During the night, on the contrary, the nucleus changes from gaseous to solid, completing the cycle.
With high summer temperatures, however, during the night the material is not transformed into solid and this compromises the effectiveness during the day.

- VIPs (Vacuum Insulation Panels)
- PCM (Phase Change Materials)



Combination in STRATEGIES

S4 **Upgrade the opaque envelope**

Related TECHNOLOGIES

Thermal insulation

back to materials

Thermal mass materials

Thermal mass is defined as the ability of a material to absorb, store and release heat. Some materials have also capacity not only to absorb but also to store heat (embodied energy); for examples concrete, bricks or tiles. Thermal mass, or the ability to store heat, is also known as volumetric heat capacity (VHC). VHC is calculated by multiplying the specific heat capacity by the density of a material.

- Specific heat capacity is the amount of energy required to raise the temperature of 1kg of a material by 1°C.
- Density is the weight per unit volume of a material (how much a cubic metre the material weighs).

In the material the higher the VHC, the higher the thermal mass. Water has the highest VHC of any common material.

Thermal mass materials should be able to absorb and re-radiate all the energy in a single day - night (diurnal) cycle. In considering thermal mass is very important consider also how fast heat is absorbed and release. Those capacities are influenced by heat capacity of the material, conductivity of the material, difference in temperature (known as the temperature differential or ΔT) between each face of the material, thickness of the material, surface area of the material, texture, colour and surface coatings (for example, dark, matte or textured surfaces absorb and re-radiate more energy than light, smooth, reflective surfaces), exposure of the material to air movement and air speed.

Materials as brick and concrete have a long thermal lag, so they absorb and release heat in a long time. Instead steel or metallic materials have a short lag times.

Factors that determine thermal mass

Specific Heat Capacity

The quantity of heat (J) absorbed per unit mass (kg) of the material when its temperature increases 1 K (or 1 °C), and its units are J/(kg K) or J/(kg °C)

Density

The mass (or 'weight') per unit volume of a material and is measured in kg/m3

Thermal conductivity

Measures the ease with which heat can travel through a materials

Material	Specific heat capacity	Thermal conductivity	Density	Effectiveness
Water	4200	0,60	1000	high
Stone	1000	1,8	2300	high
Brick	800	0,73	1700	high
Concrete	1000	1,13	2000	high
Unfired clay bricks	1000	0,21	700	high
Dense concrete block	1000	1,63	2300	high
Gypsum plaster	1000	0,5	1300	high
Aircrete block	1000	0,15	600	medium
Steel	480	45	7800	low
Timber	1200	0,14	650	low
mineral fibre insulation	1000	0,035	25	low

Combination in STRATEGIES

S1 **Valorise daylight**

Related TECHNOLOGIES

Thermal insulation

back to materials

Windows are composed from two main elements: frame & glass. The second one is very important for Architectural process and it can be consider one of the highest influencing material in the building in regard of letting solar energy comes inside.

Solar energy comes in three spectrums, ultraviolet rays, visible light, and near-infrared rays. Each spectrum has its different effect in the building. Ultraviolet spectrum is the main cause of fading the colours of materials. Also infra-red has bad effects of being the main source of heat in solar energy. While the visible light is the main source of light and a little heat, in addition to causing the light glare inside the building.

Glass is produced by founding sand , soda ash, dolomite, limestone and salt cake. It is manufactured in a factory, undergoing an intense process where temperatures reach up to 1500 degrees Celsius. Then the glass is fed into a bath of molten tin. where floats onto the surface, transforming into a sheet. The temperature is reduced, and the sheet is lifted onto rollers. The differences in flow speed and roller speed create glass sheets of different thicknesses and widths. The glass now undergoes some processing to take on and improve various characteristics. For example is cooled and reheated slowly to increase strength and prevent shattering. Or it is tempered, meaning it is reheated and chilled with sudden blasts of cold air. The glass may be glazed and coated with insulated window glazes, heat absorbing tints, or other coatings.

Glass is a good conductor of heat so we need to combine this element with air layer, gasses, film and so on to control heat in both summer and winter.

Float glass

Made from sodium silicate and calcium silicate, float glass is also known as soda-lime glass. Denomination come from the product process. It is used in both facade and internal wall.

Laminated glass

This type of glass consists of layers of ordinary glass bonded by a transparent, flexible material. The combination of two or more layer of glass as a sandwich allows a better strength characteristics.

Shatterproof glass

It doesn't break into sharp pieces in the event of destruction. It can be possible by the addition of a plastic polyvinyl butyral resin in the product fases.

Extra clear glass

It allows up to 92% of sunlight to be transmitted, which provides a very clear view. Color neutrality is due to a less presence of iron oxide. The application are some, like as facade, show-window and internal partition.

Tinted glass

It is simply coloured glass. A certain type of ion is added to the normal glass mix to produce coloured glass, where the colour doesn't affect other properties of the glass.

Tempered glass

It is a type of glass that is processed by treating the float glass, by applying controlled thermal and chemical treatments, so as to increase the strength.

Glass blocks

They are made from two halves pressed and annealed during the melting process of glass. The applications for glass blocks include walls and skylights, providing a pleasant aesthetic appearance when light passes through.

Wired glass

It has a wire mesh in the middle of its glass structure, for the fire security, indeed this internal structure aim to implement time for evacuating in case of fire. It is often used for schools, public buildings and so on.

Screen-printed

It is a simple glass with draw or writing. The technique use glaze, it can be of each colour.

Ultra Light glass with organic printed PV

This glass combines two technologies, light glass type and photovoltaics. PV are indeed print in the glass so aim to produce energy.

Evacuated glass

It is simply two layer of glass combined with a gap without pressure (7 atm). The glass need an internal structural reinforcement.

Electro-chemical

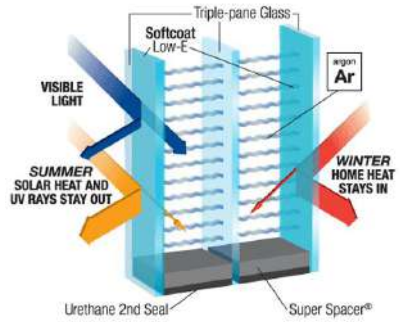
This technology characterised by 5 metal layers (nichel or Oxide tungsten) applied on the glass and link to two electrical conductors. So with electric tension metallic ions move around the layers and create an obscuration. (similar to photocromatic process).

Athermal

It is composed from highest presence of phosphate. This element absorb some Infrared rays without block visible rays. With an external metallic surface we can reflex also heat but not light.

Low-E glass (Selective)

It is created to minimize the amount of infrared and ultraviolet light that comes through your glass. Those rays are the most harmful for materials and human life.



Concrete glass

It is composed from concrete-glass bricks. So it have a similar characteristic of bricks wall. One single block have two shell of glass and inside air without umidity.

Photochromic

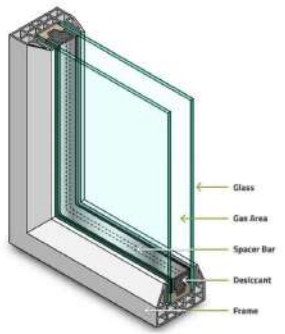
It is a glass that change the coefficient of transmission according to intensity of lights (for example sunglasses technology).

Holographic

This glass is composed from a sheet of glass where is applied a holographic film that aim a better distribution of lights.

Insulated glazed unit

It consists of two or three layers separated by air or vacuum. This air or vacuum or films acts as a good thermal insulator, so this glass doesn't allow heat to pass through it.



Double Glazing Glass

Combination in STRATEGIES

S1 **Valorise daylight**

Related TECHNOLOGIES

- **Ventilated envelope**
- **Double skin facade**
- **High quality and smart fixtures**

back to materials

External shadings

An important aspect of energy-efficient building design is represented from shading devices. This passive technology depend on well designed sun control. Technology prevent unwanted solar heat gain from entering to the building
Shading can be provided by natural landscaping or by building elements such as awnings, overhangs, trellises and frame. Shading devices can have an high impact on building appearance, so is the task of the designer to mix ease of production with aesthetics.

To properly design shading devices it is necessary to understand the position of the sun in the sky during the cooling season. The position of the sun is expressed in terms of altitude and azimuth angles.

- The altitude angle is the angle of the sun above the horizon, achieving its maximum on a given day at solar noon.
- The azimuth angle, also known as the bearing angle, is the angle of the sun's projection onto the ground plane relative to south.

External shading could be construct in very different materials, like wood, steel or fabric.

Combination in STRATEGIES

- **S2** Allow natural ventilation
- **S3** Integrate shading devices
- **S7** Regulate outdoor microclimate

Related TECHNOLOGIES

- Double skin facade
- External shadings
- Reflectors

back to materials

Vegetation

Vegetation is a dynamic material, it can grow and modify. It can assume a lot of color and change from one season to another. Its application on buildings can take place through three method:

- Vertical greening
- Vertical Garden
- Combined Vertical Gardens.

Each of three different typologies mentioned has different levels of efficiency and maintenance, as well as varying costs for production and management, But most importantly, each holds different potential benefits, which may be evaluated four classes of values:

- Ecological/environmental
- Didactic/cultural
- Aesthetic/symbolic
- Social/participatory

When designing green walls concept of planning benefits must reserve a special attention. Essentially, one must approach each case individually, carefully considering the different restrictions found in nature and in the urban environment, as well as the technological limits, evolutionary dynamics and maintenance needs of each different system. The three classes of vertical green considered are very adaptive on existing structures or part of projects for new creation.

Vertical Greening

Vertical greening contains all those traditional forms of cultivation. The relation between soil and plants remain and assume a particular importance. This techniques use climber species or runner plants, but also espalier tree. Vegetal material need always a supportive structure.

Vertical Garden

Vertical Garden contains a multi-material device aimed at creating a vertical layer where cultivate. It is based on controlled growth. Also hydroponic technique can be consider Vertical garden. Those cultivation, developed in the greenhouse horticulture and floriculture sector try to substitute the soil with solution of water and essential minerals.

Combined Vertical gardens

Combined vertical gardens are system the combine traditional cultivation with use of vertical plane. It is a mix of Vertical greening and vertical garden. They are often provided with automatic irrigation systems, and contain structure for catching rainwater. This system need structure independent or adjacent to existing building.

Combination in STRATEGIES

- **S2** **Allow natural ventilation**
- **S4** **Upgrade the opaque envelope**
- **S6** **Insert green elements**
- **S7** **Regulate outdoor microclimate**

Related TECHNOLOGIES

- **Green roof**
- **Green facade**

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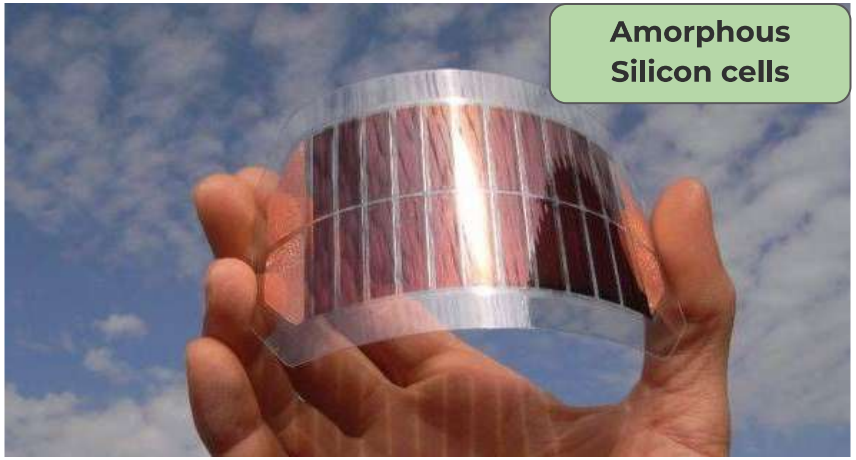
Photovoltaic systems are very widespread technologies for the exploitation of renewable energy sources.
Different materials have been tested to produce electricity from solar irradiation but the Silicon-based components are the most suitable, matching an optimization between performance and costs.
The state of art of commercial systems report that the solar energy can be converted with a peak efficiency of about 22%.
Attention should be addressed to shading phenomena, in the design phase, because it could affect the overall energy production even if partial. On the other side the conversion of solar irradiation is guaranteed in a wide range of inclination between the solar rays and the panel itself.
The sizing of a photovoltaic field depends, from a technical point of view, on the availability of area for panel installation. However, other economic considerations are necessary to strike a balance between the investment and maintenance costs and the energy produced over the years, the demand, and the surplus sold to the grid. In recent years, the contemporaneity factor between production and consumption has been gaining importance, given that energy storage devices are not equally mature in terms of technology and market penetration (high battery costs), and the price of energy sold to the grid is relatively low compared to the purchasing price.



Mono-crystalline Silicon cells

They are obtained through processes that aggregate the Silicon in a well-defined reticular structure and they are characterised by high peak efficiency (up to 22%). Actually they can produce energy for 20-25 years, losing less than 1% of efficiency each year. They appear such as compact uniform dark surface.

Poly-crystalline Silicon cells

They are similar to the previous one but with slightly less costs and performance (up to 17%) since the manufacturing process is less controlled. They keep better operative conditions in case incident radiation is not normal to the panel. They appear such as a spotted irregular surface, in blue tones.

Amorphous Silicon cells

The are characterised by lower efficiency (max 8%) but very high versatility. Silicon is deposed in a thin film layer on a stable support (glass is mainly used but also flexible materials are improved for that scope). Panels are indeed suitable for different layouts maximising the possibility of building integration (e.g. vertical semi-transparent shading solutions).

Combination in STRATEGIES

S8 Integrate renewable energies

Related TECHNOLOGIES

- External shadings
- Building integrated Photovoltaic

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