Guide to decarbonising building renovations

Solutions for renovating residential buildings following decarbonisation and urban resilience criteria

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INTRODUCTION

DECARBONISATION OF THE BUILDING STOCK

Across all sectors, society shares the common goal of decarbonisation to meet the climate neutrality targets set out in international, national, and local agendas.

The building sector accounts for around 40% of CO_2 emissions and therefore holds enormous potential for reducing the emissions we have committed to cut as a society (a 55% reduction by 2030 in the European Union). According to the Long-Term Strategy for Energy Renovation in the Building Sector in Spain (ERESEE 2020, p.199), by 2030, residential fossil fuel consumption must be reduced by 35% and completely phased out by 2050.

Decarbonising the building sector is a major challenge but also a valuable opportunity to shape new ways of building and living. Recognising the complexity of decision-making in the built environment, with its trade-offs and co-benefits, it is essential to take a broad and integrated approach. This means considering the full carbon life cycle (both embodied and operational) alongside the wider social impacts, including well-being, toxicity, working conditions, and comfort. Equally, economic assessments must go beyond short-term direct costs to include both quantitative and qualitative impacts on employment, maintenance costs and types, productivity, and health and safety outcomes.

To achieve decarbonisation, emissions must be reduced as broadly and effectively as possible, addressing all vectors that contribute to lowering CO_2 impact. While policy and legislation are increasingly evolving towards a systemic view of the elements influencing emissions reduction in the sector, not all regulations reflect this holistic approach yet. In this guide, we propose solutions that target all decarbonisation vectors, both direct and indirect.

In that regard, it is important to highlight that, in Spain today, embodied carbon accounts for roughly one third of total emissions from buildings. Technologies and strategies to reduce operational emissions are already well developed, making it increasingly feasible to virtually eliminate emissions during this phase by lowering energy demand and shifting towards clean, renewable energy sources. However, given the projected levels of new construction, renovation, and system upgrades, overall emissions from Spain's residential sector are expected to rise in the coming years due to embodied carbon (the emissions associated with material production, construction, renovation, and demolition), which is projected to account for more than 50% of the sector's cumulative emissions over the next 30 years.[1]

[1] Ref. Green Building Council.

The decarbonisation strategies employed in the building sector have evolved as follows over time:

- **Reducing energy demand**

  Initially, efforts to cut emissions focused on lowering energy use during a building's operational phase, and this is where the regulations have the most impact.
  Many renovation projects, especially those receiving public funding, already address this vector. However, a significant proportion of renovations still focus purely on maintenance, failing to deliver real reductions in energy demand.

- **Reducing energy consumption in construction**

  More recently, attention has turned to emissions generated during the construction or renovation phase (embodied energy in materials and construction systems). The potential of this decarbonisation vector is still not being fully harnessed. The market does offer solutions but these tend to be, on average, slightly more expensive in the short term than high-emission alternatives. As a result, low-embodied-energy solutions are not systematically chosen, especially as current subsidies rarely consider embodied energy and instead focus mainly on demand reduction.

- **Renewable energy generation**

  There is also growing recognition of the need to incorporate renewable energy sources to at least partially offset energy use. In practice, however, renovation projects tend to make limited use of this potential (e.g. photovoltaic canopies).

- **Urban model**

  Finally, there is a whole set of indirect decarbonisation strategies that aim to create the conditions for a sustainable urban model. These strategies are linked to urban resilience, public health, and citizen well-being, and are essential for maintaining the continuity of the urban model, which is the lowest CO_2-emitting model available.[2]

CLIMATE CHANGE AND URBAN VULNERABILITY

Cities are the lowest CO_2-emitting urban model, and therefore, to decarbonise, we cannot do without this type of urban grouping but must actively promote it.

To ensure the success and continuity of dense urban areas, especially as we face increasingly frequent extreme weather events, it is crucial to improve factors such as urban resilience (heat island effect, drainage, and rainwater harvesting, etc.), public health, and urban biodiversity. We must ensure that cities are healthy, comfortable, and sustainable.

This must also be achieved by incorporating these factors into all existing building renovations. Only through a systemic vision that includes all decarbonisation strategies (both direct and indirect) can we generate an overall impact in decarbonisation of the residential sector. Any investment in a building renovation that does not align with CO_2 emissions reduction, understood as a systemic process, will be a missed opportunity, as it will prevent similar renovations in this direction for many years to come.

Barcelona has a Climate Plan, its roadmap for making the city climate-neutral and well adapted to climate change by 2030.

This guide explores in greater depth the proposals and construction solutions available to achieve the maximum possible decarbonisation of the building stock.

[2] "Compact cities have lower carbon emissions, but poorer air quality, less green space and higher mortality rates", Isglobal.org, 04/07/2024.

OBJECTIVES OF THIS GUIDE

This guide provides practical advice, aside from the current regulations, on carrying out building renovations that are aligned with decarbonisation processes and climate change adaptation, offering a practical and operational perspective for decision-making. It mainly focuses on actions within a Mediterranean climate context, such as Barcelona's, although much of the analysis and proposals can be extrapolated to other regions.

To ensure this transition (due to the scale, urgency, and need for resources and capacity), the participation of all stakeholders is essential, and resources are needed to support the diverse actions of those involved. The guide is aimed at industrial sectors, professionals, local authorities, and citizens, so that everyone, within their level of responsibility, can incorporate as many practices as possible that align with the strategy of decarbonisation and urban resilience. The premise is that any renovation that does not have a clear impact on these vectors will be a missed opportunity. This guide should be useful to both public authorities preparing a set of tender specifications and to any communities of property owners who may be preparing to carry out works on their building, as well as professional guilds and specialised technicians.

It has been drafted by the BIT Habitat Foundation, in collaboration with the Municipal Institute of Housing and Renovation (IMHAB), within the framework of the European URBANEW project, a multi-stakeholder initiative focused on innovative solutions for urban regeneration. URBANEW is part of the EU Mission's pilot programme "100 Climate-Neutral and Smart Cities by 2030", of which Barcelona is a member. The project promotes a systemic transformation to ensure that the residential, commercial, and public and private building sectors reduce their carbon footprint and improve energy efficiency.

Most of the solutions included here are the result of a call for participation in the "Marketplace of Innovative Low-Carbon Renovation Solutions" from companies in the sector, within the framework of the "URBANEW Innovating in Building Renovation for Decarbonisation" event held in April 2024. During this event, different organisations presented concrete solutions aligned with the objectives established in the project.

In that regard, for the transformation to take place, there must be industries that innovate and find solutions to the challenges presented, and it is also essential that developers, whether public or private, are aware of and apply these solutions. The lack of demand is a limiting factor for innovation, and the lack of appropriate solutions hampers potential demand. One of the main objectives of this guide is to overcome this situation, providing, through outreach and training, the incentives for industry to innovate and for renovation promoters to apply the innovation.

The guide is structured around five interrelated objectives that maximise decarbonisation and sustainable urban regeneration in every sense.

- **Objective 1:Energy savings and efficiency**
- **Objective 2: Circular economy and embodied energy**
- **Objective 3:Resilience and climate change adaptation**
- **Objective 4: Improvement in health**
- **Objective 5: Diversity and biophilia**

Those objectives are successively broken down into strategies, and these in turn into systems, which refer to the specific construction systems applicable in each case.

Each system is accompanied by a set of icons, which visually indicate its characteristics and potential.

- **Energy savings and efficiency**
- **Circular economy and embodied energy**
- **Resilience and climate change adaptation**
- **Improvement in health and comfort**
- **Biodiversity and biophilia**
- **Community activation**
- **Adaptable to the context**
- **Innovation**

Investment:
low medium high

Decarbonisation:
low medium high

This guide is designed as a living document to be updated and enriched in future editions by all stakeholders in the sector, with the aim of making it as useful and practical as possible, and contributing to the decarbonisation we are committed to.

OBJECTIVE 1: ENERGY SAVINGS AND EFFICIENCY

Energy renovations are supported by a reasonably sound tool, the Technical Building Code (CTI), which in recent years has been progressively tightening requirements regarding the energy efficiency of buildings during their operational phase. Its section on energy saving (HE) sets out the conditions for reducing energy consumption.

However, this national regulation has not yet been updated to align with the new Directive (EU) 2024/1275 of the European Parliament and of the Council of 24 April 2024 on the energy performance of buildings, which is already in force. Among other provisions, this directive requires that all existing buildings must become zero-emission buildings by 2050. This means that a large-scale renovation of most of the building stock must take place before that date. As such, any renovation carried out from now on that does not follow this path will be a missed opportunity and a poor investment in the medium term.

In a renovation, the orientation of the building cannot usually be changed, and often the position of the façade openings neither. However, there are still many measures that can be taken to meet the Directive's targets. It is also important to remember that any renovation has a direct impact on improving health, comfort, and the quality of life of residents. Below, are some examples of strategies and solutions that can be implemented.

O1 STRATEGY 1

Improving façade insulation

Façades are key elements in reducing energy consumption during a building's operational phase, and improving them in existing buildings often presents certain challenges that must be taken into account.

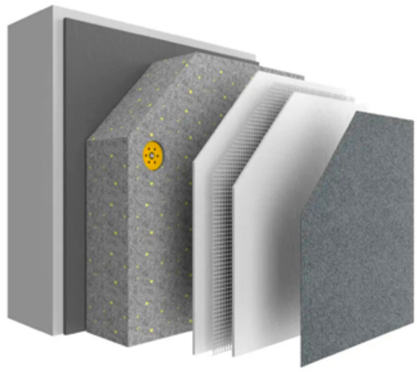
The most effective way to incorporate insulation into a façade is from the outside, using a continuous layer of cladding that protects the building both thermally and in terms of airtightness. This continuous layer should cover the entire surface, avoiding thermal bridges such as those at slab junctions. External insulation also allows buildings with ceramic brick walls to retain thermal mass on the inside, thereby improving indoor comfort. The drawback is that in many existing urban areas, façades may be protected or feature distinctive architectural elements that make the application of this kind of solution difficult or even unfeasible.

Wall insulation can be applied to either the interior or exterior face of the wall. Wherever possible, insulation should be applied externally, as it is the most effective way to reduce thermal bridging and avoids reducing the usable internal floor space. That said, in some cases external insulation is not an option, often due to the presence of features that must be preserved.

01 S1 SYSTEM 1

External insulation bonded to the wall

- Commonly known as ETICS (External Thermal Insulation Composite System).
- This system involves bonding insulation panels to the external wall surface, finished with a reinforcing mesh and a render coating.
- There are ETICS systems available using low environmental impact materials (cork, lime-based mortars) though these tend to be slightly more expensive.
- Rock wool insulation made from basalt, offers superior performance compared to petroleum-based insulants. It provides high water vapour permeability, fire resistance, and excellent acoustic properties.

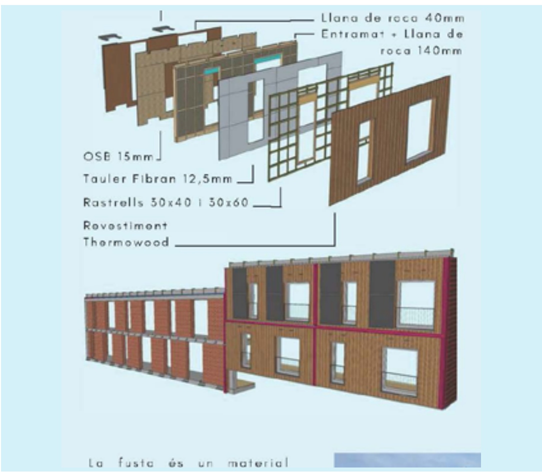


Arrevol.com

01 S1 SYSTEM 2

Ventilated façade

- A façade system with a ventilated cavity, industrialised and dry-mounted.
- The insulation is placed inside a ventilated air cavity.
- The exterior finish can be made from various materials (ceramic, stone, metal, wood, etc.).
- In façades exposed to solar radiation, this system performs better than an ETICS system, as the ventilated cavity reduces overheating of the façade.
- The current regulation (CTE-SI) requires that the materials used are fire-resistant to prevent the spread of fire through the cavity. There are construction solutions available that ensure fire-resistant performance.

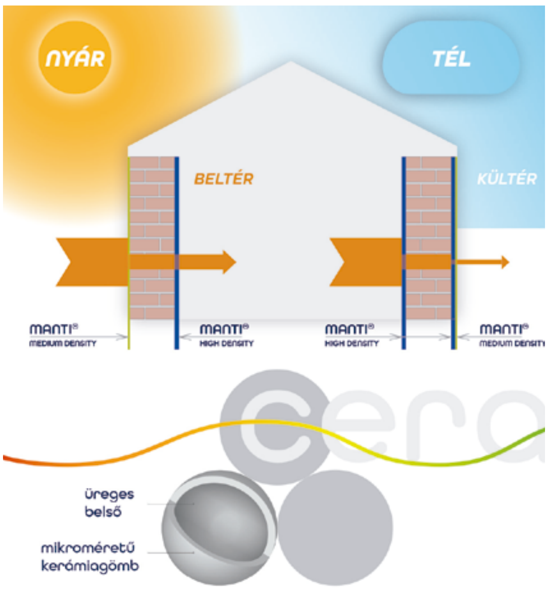


Energy renovation of an existing façade using a lightweight timber framework, Tallfusta

01 S1 SYSTEM 3

Thin-layer thermal paints

- Solar reflective paints that help prevent overheating of façade or roof surfaces by blocking solar radiation on opaque surfaces. There are special transparent paints available for historic buildings.
- They cannot replace thermal insulation in residential buildings, as they also block temperature capture through radiation during the winter.
- Useful for protecting heritage-listed buildings with protected façades from the heat.



Manti.hu[3]

[3] The Hungarian company Manti Ceramic claims that by applying their paints to the inner side of the façade, heat is prevented from escaping to the exterior in winter. For now, their certificates only validate the protection against heat entering from the exterior.

01 S1 SYSTEM 4

Interior dry lining insulation

- Dry lining applied to the interior side of the façade with panels (plasterboard, fibre cement boards, etc.) that create a non-ventilated cavity with thermal insulation.
- This solution reduces the usable interior space of buildings and does not address thermal bridges at the level of the concrete slabs, which will need to be resolved with additional insulation, either using the same dropped ceiling solution or thin-layer systems.
- There are insulation materials available with varying environmental impact, (cost-effective solutions like rock wool, or more sustainable and generally more expensive options like cellulose, cork, wool, or cotton).

Arrevol.com

01 S1 SYSTEM 5

Filling existing air cavities

- This system is suitable when the cavity is of sufficient size, at least 10 centimetres, and is continuous and clean.
- It is recommended to later verify with a thermal camera that proper insulation has been achieved in the cavity.
- Various injectable materials exist, such as graphite-expanded polystyrene beads, mineral wool fibres, cork, wool, cotton, or cellulose fibres. It is advisable to choose materials with the least environmental impact, and in the case of cellulose, ensure long-term durability.
- This system does not resolve thermal bridges in the concrete slab area (floor and ceiling), which must be addressed with conventional insulation, at least in the ceiling area, by adding an insulated dropped ceiling in a 1-metre strip towards the interior. To ensure total elimination of the thermal bridge, this 1-metre strip should also be insulated on the floor.

URSA

01 S1 SYSTEM 6

Thin-layer thermal sheets

- Multilayer sheets, approximately 1 centimetre thick, equivalent to conventional thermal insulation of greater thickness.
- It cannot be used as an exterior finish nor left exposed on the interior without finishing, unlike thermal paints.
- It is a good solution for interior insulation, as it does not significantly reduce the usable interior space and helps eliminate thermal bridges at the concrete slab face.
- Some manufacturers offer solutions that, in addition to providing thermal insulation, also block radon gas, as required by the current CTE in certain cases where the building is in contact with the ground.

Air-bur Termic

01 STRATEGY 2

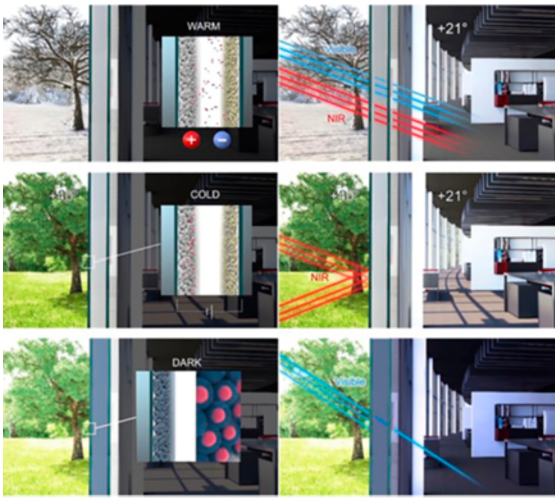
Improvement of exterior closures

Closures are another element that needs to be improved to reduce the energy consumption of the building envelope. The CTE-HE regulation already covers this, and complying with the current version of this regulation is sufficient to clearly improve this parameter.

The solar factor of the glass must be carefully adjusted to avoid the greenhouse effect but without losing too much thermal solar radiation in winter. This needs to be studied for each orientation.

Aside from what the regulations require for energy saving, it is advisable that the glass panes within the same closure, separated by an air gap, have different thicknesses in order to provide more efficient acoustic insulation inside. Each glass thickness better protects against a specific frequency, and it is important that the two panes differ to avoid creating an acoustic bridge at a particular frequency.

Systems are being developed that can activate or deactivate the passage of a large part of solar radiation according to needs at any given moment, although these systems have not yet reached the market at competitive prices.



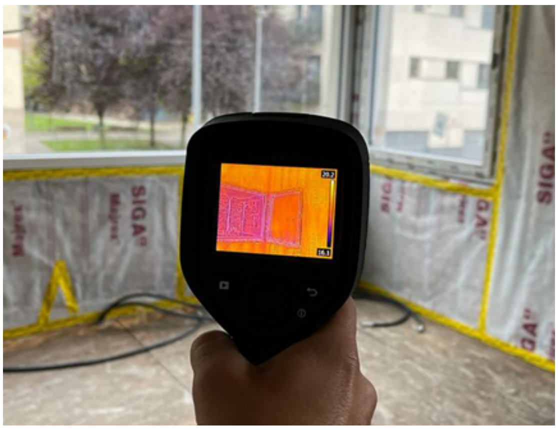
Project Smart Dynamic Glazing for ZEB envelopes, Leitat Technological Center

01 STRATEGY 3

Reducing leaks through the façade

It is essential to ensure that all surfaces in contact with the exterior are airtight to prevent thermal leaks that increase heating and cooling consumption. This must be accompanied by a good ventilation system to guarantee good indoor air quality.

The systems to be used can include elastic sealants for walls or adhesive tapes for joints and connections with closures. It is important to ensure that the materials have a low environmental impact and emit few volatile organic compounds.


Dycon

01 STRATEGY 4

Exterior solar protections

The installation of shutters, eaves, fixed slats, Venetian blinds, or awnings allows buildings to be protected from solar radiation either statically or dynamically.

For fixed systems, on south-facing orientations, horizontal slats or eaves (with a 1:1 ratio) are the most suitable to allow solar radiation during winter and shield the building in summer when the sun is lower.

For east and west-facing orientations, a combination of horizontal and vertical protections is usually a good option.

Active systems rely on a good management system, whether automatic or manual. An automatic system enables an “absence mode” that manages solar radiation throughout the day, ensuring the user returns home under optimal conditions. This requires an automated control system with both an absence mode (automatic pilot) and a manual control mode.

01 STRATEGY 5

Roof insulation

Roofs are another key surface for thermally protecting buildings and therefore must be properly insulated to reduce the energy demand of the buildings. This guide focuses on flat roofs, which make up the vast majority of roofs in residential buildings in Barcelona.

It is important to consider that roofs are highly exposed to solar radiation, especially during the summer. The first stage of any renovation is to study the building in questions, and one of the most important analyses to carry out is on the structural elements. This study must determine, among other things, whether the structure can support an increase in load or not.

It should also indicate whether the dead loads can be reduced or not, since even if the structural elements cannot support additional load, removing a traditional Catalan roof may allow for the incorporation of new elements that significantly enhance the roof’s performance.

If new elements can be added, priority should be given to installing a green roof with a water retention system, which also provides thermal insulation, acoustic benefits, urban resilience, biodiversity, and more.

If it is not possible to use heavy elements, insulation must be ensured with lightweight solutions, making sure that, in addition to providing thermal insulation and waterproofing, the installed systems also offer good performance in terms of maintenance.

Traditional ceramic tile roofs are difficult to maintain because, without insulation, they undergo considerable expansion movement, contain numerous joints, and often develop leaks over time. Consequently, many of these roofs have been fitted with an additional waterproof membrane, which itself has limited lifespan, leading to accessible roofs being used primarily for maintenance access only.

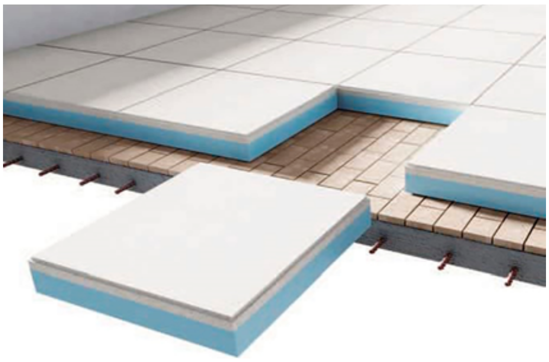
Whenever the structure can support the additional load, it is advisable to take advantage of the roof renovation not only to add insulation but also to enable rainwater harvesting and gardens. This may require removing the weight of existing layers, such as ventilation cavities typical of traditional Catalan-style roofs, which made sense for uninsulated roofs but are less relevant for insulated ones.

See the descriptions of these elements in the sections on Resilience and Biodiversity.

01 S5 SYSTEM 1

Permeable slab

- This consists of a walkable slab that incorporates thermal insulation within the same element, which is installed dry (without mortar) and directly protects the waterproof membrane. Since it is installed dry, the slab can be removed to access maintenance of the waterproof membrane without needing to break the roof. These slabs offer greater durability and require less maintenance than traditional solutions with a self-protected membrane exposed to the elements or protected by ceramic tiles. They also facilitate improved insulation without the need to add an additional layer of concrete.
- The slab consists of a layer of draining concrete bonded to the insulation, measuring approximately 50x50 cm, making it easy to handle for installation and removal when maintenance is required. It is a relatively lightweight solution since there is no need to add a new metal *deck* or compression layer. The system comprises a waterproof membrane protected by geotextiles, and the lightweight permeable slab that incorporates the insulation within the unit itself.
- Permeable slabs are suitable for communal use of the roof as they protect the membrane and, being laid over the existing roof, they are compatible with the original slopes. The porous finish, however, tends to get dirty quite easily.
- To ensure proper water drainage, it is important to create channels in the slabs located near the drainage outlets by cutting strips of insulation on the underside of these slabs. Otherwise, in the event of heavy rainfall, water may temporarily pool on the surface and the permeable slabs could begin to float.
- One of the advantages of this system is that the drainage points remain protected, reducing the risk of roof flooding. Care must be taken with the flatness of the base and the installation process to prevent cracking of the slabs.
- Among the various alternatives on the market, we recommend slabs with a porous concrete layer with a thickness of at least 35 mm. Available insulation layers typically range from 4 to 6 cm.

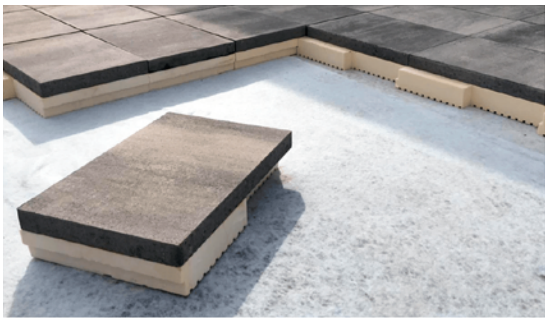


Llosa Danolosa, by Danosa

01 S5 SYSTEM 2

Non-permeable slab

- This alternative is similar to the previous one but instead of using porous and lightweight draining concrete slabs, it uses denser concrete slabs. Since the pieces are not porous, drainage must be directed towards collection points (either by drilling holes into the slabs or by incorporating perimeter collection channels with grilles and/or gravel).
- Compared to the permeable slab, it offers the advantage of a cleaner and more durable finish due to its lower porosity, and it does not crack with use. Additionally, the insulation features interlocking joints, which make the paving stones more monolithic. However, this comes at the cost of slightly more difficult maintenance, a higher price, and greater unit weight compared to the draining alternatives.



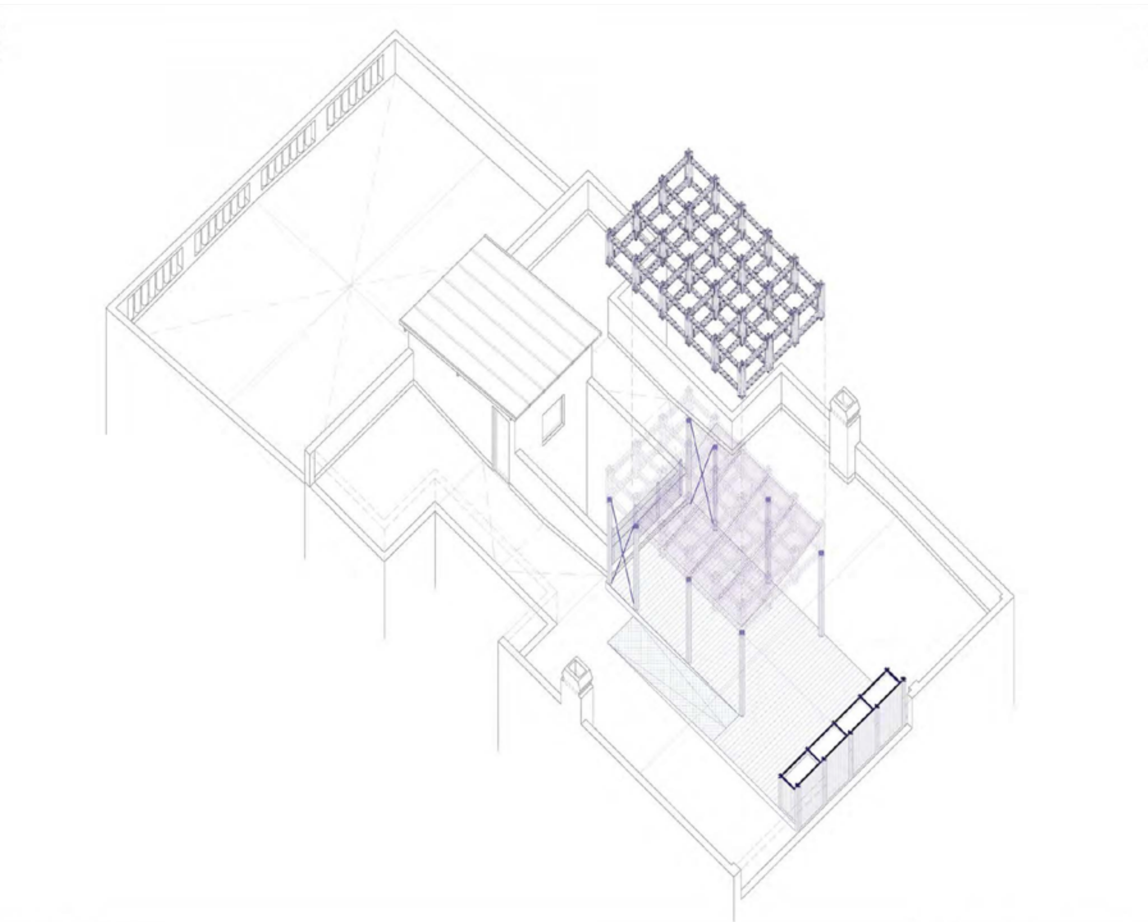
Llosa Infinity, by Breinco

01 STRATEGY 6

Shading for roofs

In addition to insulating roofs, their thermal performance can be significantly improved by incorporating shading elements. Ideally, this can be achieved using photovoltaic panels, which offer the following advantages:

- Protecting the roof from direct solar radiation.
- Providing a surface for renewable energy generation without occupying usable roof space.
- Encouraging the use of the roof as a communal space.
- Reducing the heat island effect.



"Reviure els terrats" (Bringing rooftops back to life) project.
REARQ-UPC research group, Oasiurbà association,
CRIT-UB research group, and GICITED-UPC research group

01 STRATEGY 7

Building electrification

Building electrification involves phasing out systems that produce direct emissions, such as those powered by natural gas, diesel, or butane. This is a necessary condition for effectively reducing CO_2 emissions, particularly as the electricity grid becomes decarbonised. The higher efficiency of electricity-based systems should enable a significant drop in primary energy consumption from current levels (286 TWh in Catalonia in 2023) to a much lower figure by 2050 (120 TWh), thanks to electrification.

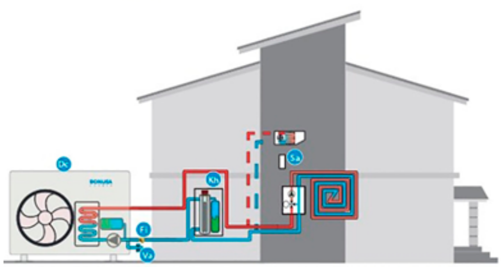
In this regard, the European Energy Efficiency Directive will ban the installation of fossil fuel-based systems from 2026. Existing boilers will need to be replaced by 2035. Naturally, it is advisable to anticipate this prohibition in all refurbishment projects carried out from now on, in order to work towards full decarbonisation.

Additional advantages of electrification include improved safety by removing combustible fuels from homes and a reduction in harmful gas emissions within urban environments.

01 S7 SYSTEM 1

Heat pumps

- Heat pumps offer an efficiency of around 300%, compared to conventional heating systems, which typically have an efficiency of about 90%.
- They generate energy both for climate control systems and for domestic hot water (DHW), making them a key element in the electrification and decarbonisation of the existing building stock. Heat pumps can be classified as aerothermal (air-based heat exchange) or geothermal (ground-based heat exchange).
- Geothermal heat pumps are more efficient but also more expensive than aerothermal systems, as they require underground circuits at significant depths to exchange heat with the ground. On the other hand, aerothermal heat pumps generally offer a better investment-to-savings ratio and are more commonly used. Each case must be studied individually to assess the suitability of the system, depending on factors such as ground type, available space for external exchange, etc.
- Systems in multi-family residential buildings operate through a recirculation circuit with thermal meters installed at the entrance of each dwelling. For permanently occupied homes, this system is more efficient than individual heat pumps. However, for occasional-use homes (such as second residences), they have a baseline consumption that can be significant.
- There are individual systems with indoor units equivalent to a large gas boiler and outdoor units of similarly compact size that can be installed in, for example, a gallery. This means that the space requirements are not significantly different from those of gas boilers, allowing them to be installed in existing homes without any issues.
- For systems in multi-family residential buildings, a centralised space will be needed to house the heat pump for climate control (either outdoors or in a well-ventilated area if it is an air-source heat pump), along with a small indoor unit equivalent in size to a large gas boiler.
- In either case, it is important to ensure that the system can maintain a specific temperature for the hot water to eliminate the risk of Legionella.
- It is recommended that the system uses a circuit based on water or another non-contaminating liquid to avoid issues from occasional leaks that could harm the environment or health.



Domus heating system

01 S7 SYSTEM 2

Electric cookers

- Another area where gas has traditionally been used is in cookers. These should also be replaced with electric versions.
- To reduce electricity consumption, induction cookers should be chosen. Although they are more expensive than ceramic hobs, the extra cost is offset over time through regular use.

01 S7 SYSTEM 3

Electric vehicles

- A combustion car consumes around 60 kWh per 100 kilometres, while an electric vehicle uses just 16 kWh. Installing medium-power chargers in buildings to charge electric vehicles helps reduce emissions, not only by encouraging the use of electric cars, but also because home chargers are more energy-efficient than high-power charging systems. To reduce emissions, it is advisable to leave home or work with a fully charged battery and only use ultra-fast chargers for long-distance journeys.
- The installation of electric chargers in car parks can become an additional opportunity for decarbonisation if vehicle batteries are integrated with an automated energy management system linked to the electricity grid. Parked car batteries can be used to reduce peak electricity demand in buildings, helping to stabilise the grid and lessen reliance on combined-cycle power stations, thereby cutting emissions. This approach can also generate cost savings for the connected residential community.
- Aside from electric cars, provision should also be made for the future installation of chargers for other electric vehicles such as bicycles, scooters, and motorbikes.

Endolla Barcelona

01 STRATEGY 8
Reducing energy consumption in buildings

In addition to electrifying a building's energy uses, it is also essential to reduce overall consumption through various strategies such as:

- Choosing low-energy appliances and lighting (energy class A, A+, etc.).
- Designing the electrical panel to easily switch the home into "absence mode," where only essential circuits (such as those for the fridge or security systems) remain active, ideally with a switch located outside the panel for ease of use.
- Separating the lighting circuit for darker areas from those near windows, allowing only necessary lights to be used.
- Installing motion sensors in shared areas and corridors of the home.
- Implementing automated control systems for various elements, or a home automation system that manages occupancy detection, climate control, solar radiation, and natural lighting.
- Energy recovery systems for ventilation air and domestic hot water.

01 S8 SYSTEM 1
Showers with energy recovery systems

- These enable the reuse of residual heat from the shower's hot water through a heat exchanger, which preheats the cold water, raising its temperature by approximately 12°C.

Zypho

01 STRATEGY 9
Renewable energy production

A key strategy for decarbonisation is the widespread implementation of renewable energy production systems. The density of cities makes achieving full energy self-sufficiency challenging, even with reduced demand and maximum installation of renewable energies. However, this does not prevent the need to install as much renewable capacity as possible to reduce energy dependence on other regions. To increase the efficiency of the grid, it is advisable that areas with higher demand also host at least part of energy production.

The system that adapts most easily to an urban environment is photovoltaic panels, due to their versatility and ease of maintenance. It is important to highlight that in recent years the cost of these solutions has dropped significantly, making their payback period increasingly manageable. There are companies specialising in financing and installing photovoltaic panels without the user needing to make any upfront investment.

01 S9 SYSTEM 1

Photovoltaic panels on the roof

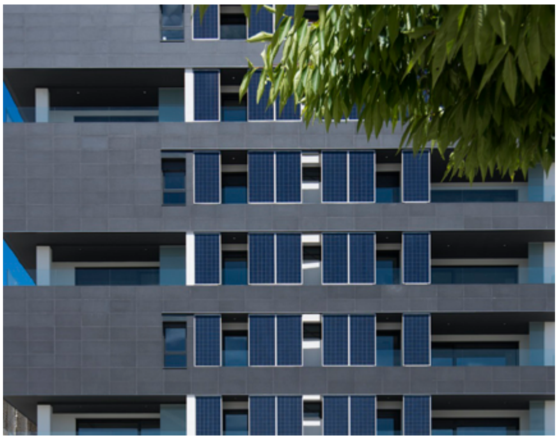
- Building roofs have enormous potential to host photovoltaic panels, whether directly installed on the roof surface or mounted on photovoltaic canopies. An additional advantage is that they reduce solar radiation on the building's roof, improving its performance during the summer months.
- Installing panels directly on the roof is the most cost-effective solution but it limits the potential for other uses (communal areas, green roofs, etc.).
- On pitched roofs, installing photovoltaic panels directly on the surface is an effective solution, especially when the roof has a favourable orientation. Even with limited direct sunlight, energy is still produced, although efficiency naturally decreases. It is advisable to make calculations to assess the financial return on investment, but generally, the orientation does not need to be perfect for the return to be satisfactory.
- For flat roofs, photovoltaic canopies should be the preferred option whenever possible, as they do not restrict the use of the building's roof space. It is important to check the requirements set by local planning regulations. Additionally, the building's structural capacity must be carefully evaluated to ensure the canopy can be installed safely and securely.
- Until recently, many urban planning regulations made their installation very difficult but increasingly they are being allowed, often with minor restrictions (such as not placing them within 3 metres of the façade).
- It is worth highlighting bifacial photovoltaic panels, which capture energy on both sides, making them even more efficient. In terms of innovation, mobile photovoltaic panels are also available on the market, allowing the sensors to be oriented towards maximum solar radiation at any given moment.

Solar Innova

01 S9 SYSTEM 2

Photovoltaic panels on the façade

- Façades generally capture much less solar energy than roofs, as they are usually less exposed to direct sunlight.
- In some cases, investing in photovoltaic panels on façades is justified, and they can be installed either vertically or as canopies.
- When it comes to renovations, due to their complexity, this approach makes the most sense when there is a comprehensive intervention on the façade or on a party wall.
- Maintenance tends to be more complicated than for installations on roofs.



Abaigar.com

01 STRATEGY 10

Systems combining various solutions

Various solutions have been developed, at different stages of maturity, that combine systems to improve the energy efficiency of buildings.

These are industrialised systems that address multiple issues simultaneously and generally offer significant improvements with minimal impact on the interiors of residential buildings. This facilitates carrying out works without the need to relocate residents.

01 S10 SYSTEM 1

Façade system using photovoltaics

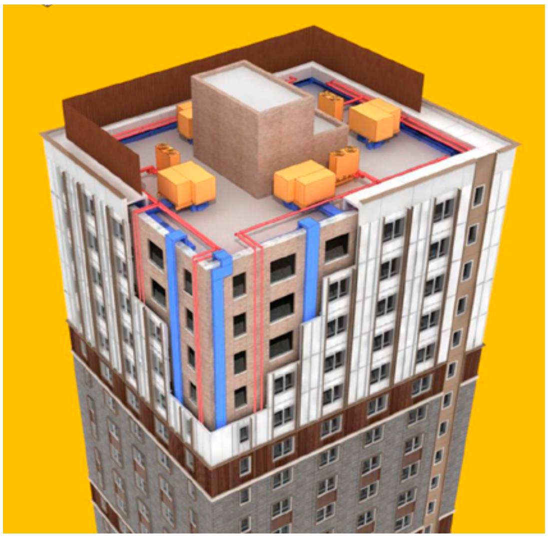
- There are systems that combine insulation and photovoltaic production in façades, such as the Plug-n-Harvest solution. This is an industrialised system adaptable to any building typology, featuring intelligent management and designed according to circular economy principles. It is the result of a European research project.

Source: H2020 Plug-N-Harvest European project. Kit of modular and industrialised façade solutions. Aiguasol, EIG, Picharchitects, Garcia-Faura, Housing Agency, among others

01 S10 SYSTEM 2

Integrated façade and climate system

- This modular system, developed in New York, combines a new insulating façade skin with a fully electrified ventilation and climate control system that supplies air through the windows.
- It is specifically designed for multi-family residential buildings.
- The climate control consists of heat pumps located on the roof (or basement if geothermal), a water-based heating and cooling circuit, and units integrated within the new façade thickness.
- The only interior work required is the removal of the old windows once the new façade is installed.
- The windows cannot be opened for ventilation, so ventilation relies entirely on continuous electrical supply.



Hydronic Shell Technologies

OBJECTIVE 2: CIRCULAR ECONOMY AND EMBODIED ENERGY

Effective management of material resources should help reduce CO_2 emissions and extend the lifespan of materials to prevent their depletion.

This can be achieved by promoting the circular economy and minimising the embodied energy of the materials used.

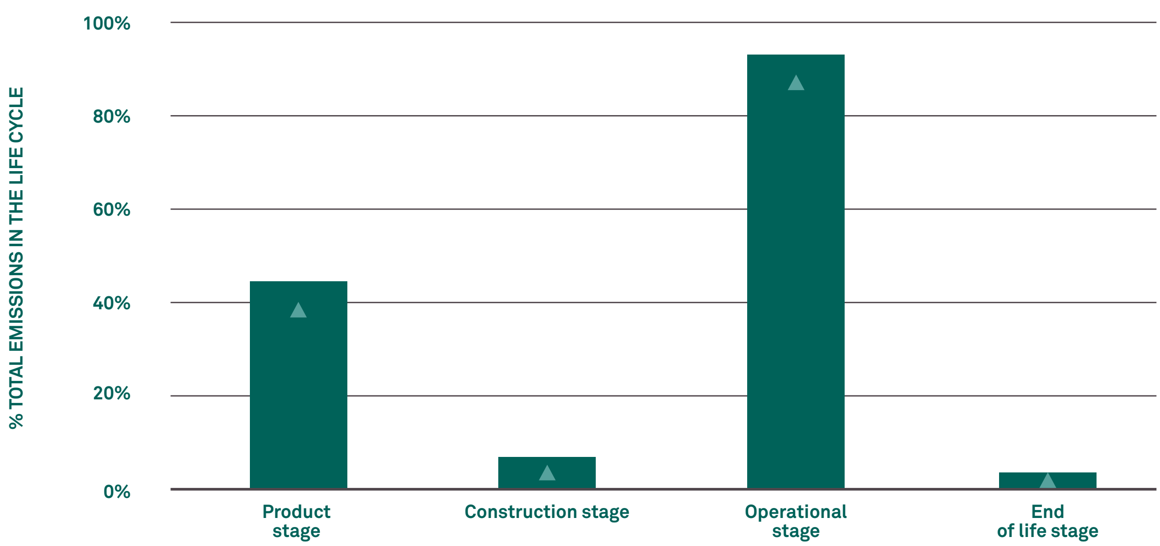
The first consideration with regard to the circular economy is whether the desired objectives (comfort, health, functionality, etc.) can be met with fewer materials. Often, solutions are used out of tradition rather than added value. Redirecting resources (economic, material, time) towards what genuinely adds value will be more efficient.

Is it really necessary for a home to have a dropped ceiling throughout, for instance? Should an old lift cabin be replaced, or could it be refurbished? Even if a building's entrance door isn't listed, why not prioritise its maintenance instead of swapping it for a new one? Can the soil from an excavation be reused within the same site? Or could steel profiles from a dismantled shed be repurposed to strengthen some beams?

Then it is important to choose low-impact materials, preferably certified, that possess sufficient quality to be reused, recycled, or eventually recovered. It is also advisable to select durable solutions that do not quickly become outdated.

Construction materials release CO_2 during their production and installation, so careful selection of both the types and quantities of materials used is crucial to minimise the CO_2 footprint of renovations.

Generally, this means favouring dry construction techniques that provide maximum performance with minimal material usage, and prioritising materials with low CO_2 impact, such as timber or highly recyclable materials.



Siebert S. et al. (2019)

O2 STRATEGY 1

Recovery of pre-existing materials

Every renovation results in CO_2 emission savings, since demolishing a building and constructing a new one generates CO_2 emissions derived from transportation, material production, and construction activities. In contrast, during a refurbishment, all materials that are not discarded and used for the new building do not incur additional CO_2 emissions.

That said, emissions can be further reduced in a refurbishment by preserving all existing materials and systems that still offer adequate value.

Landfill tipping fees should not be set too low, to encourage the greatest reasonable reuse of materials.

Wooden joinery in good enough condition can be repaired and upgraded with thermally efficient glass, rather than being replaced by aluminium frames. It is important not to discard elements by default without first determining whether keeping them is economically or functionally impractical.

Maximising the reuse of existing materials should help to achieve the best outcomes while minimising the need for new resources.

O2 STRATEGY 2

Designing flexible and adaptable spaces

In addition to short-term strategies for reducing CO_2 emissions, it is important to also consider the long term in every intervention, as CO_2emissions need to be controlled for the future as well.

Consequently, the need for further renovations (and the associated emissions) should be minimised over the medium term. This involves anticipating possible new uses and requirements as much as possible to prevent premature obsolescence of the work carried out.

To achieve this, renovations should prioritise maximum flexibility in spatial layout, allowing changes of use with minimal additional work.

High-quality components and materials should be used that allow for proper maintenance and durability.

02 STRATEGY 3

Low embodied carbon materials and systems

The less carbon needed to manufacture a component and its materials, the more emissions will be reduced during the construction phase.

When choosing low-emission materials, it is important to consider Eco-labels (ISO 14024) and Environmental Product Declarations (EPDs) (ISO 14025).

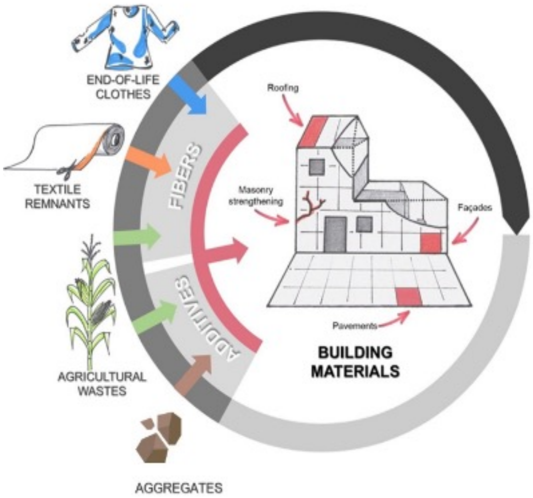
EPDs can be found on the websites of certification agencies (such as AENOR), sustainability organisations (like the BGCE materials platform), or directly from manufacturers.

The use of life cycle assessment tools to measure the project's emissions impact throughout its entire life cycle (tools such as TCQi GMA, OneclickLCA, and others) is also recommended.

Materials derived from recycling are a good option to reduce emissions.

Some materials have high emissions due to their manufacturing processes. For example, in the case of concrete, the industry is making efforts to produce lower-CO_2-impact concretes by using cements that currently reduce emissions by around 25%.

When using low-impact material solutions, choosing the version of each material that has the lowest possible emissions is key.



Cementex, a construction material incorporating textile and agricultural waste, Polytechnic University of Catalonia

02 S3 SYSTEM 1

Renewable and recycled materials

There are various systems that incorporate renewable materials of natural origin or materials recycled from previous uses. Examples of best practices include:

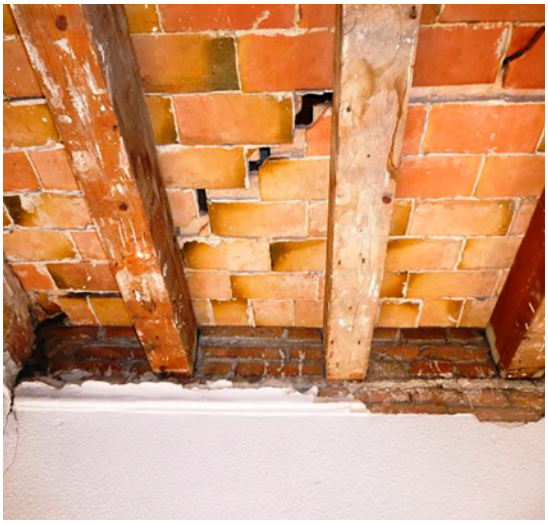
- Using 100% recycled steel.
- Using certified materials such as wood or bamboo to ensure they are sourced from sustainable productions with replanting.
- Using renewable insulation materials like cork, cellulose, mixed hemp and lime fibres, sheep's wool, etc.
- Prioritising systems that include a high percentage of recycled materials or components (in flooring, textiles, furniture, etc.).
- Examples in this guide: 01 S1 S1, 01 S1 S4, 02 S3 S2, etc.

AislaEcoTres

02 S3 SYSTEM 2

Wood construction

- Wood has a positive carbon footprint, generally capturing more carbon than is emitted during its production and transportation.
- It is advisable that the wood is locally sourced to avoid transport emissions negatively affecting this balance, and certified with sustainable replanting schemes (such as PEFC or FSC).
- Although wood will eventually release the captured CO_2 back into the environment (through burning or decay), it currently acts as a carbon "sink", buying time to address the climate emergency before that CO_2 is released, by which time hopefully the situation will have been reversed.
- There are wood construction systems that cover nearly all building elements: structure, façades, insulation, finishes, etc. except foundations and retaining structures.
- Its lightweight nature is particularly notable, as it adds very little extra load to the existing structure.
- In renovations, finishing materials are typically required more often than structural components (see 01 S1 System 2).
- When repairing existing wooden beam floors, prefabricated wooden panels reinforced with a cross-laminated timber (CLT) compression layer should be used instead of the traditional concrete compression layer. This system provides better bonding with the existing timber, allows for dry installation, and offers greater reversibility and ease of repair.



BCNstructures

02 S3 SYSTEM 3

Low-carbon concrete

- The concrete industry is currently developing mixes that reduce embodied carbon by around 20% compared to conventional concrete.
- These formulations use recycled aggregates, supplementary cementitious materials, and partially renewable energy in production.
- This development is essential, as concrete is an irreplaceable material in many construction elements (foundations, retaining walls, etc.).
- The most challenging component to decarbonise in concrete is its base, cement. The European Cement Association, Cembureau, has committed to reducing CO_2 emissions from 667 kg per tonne of cement in 2017 to 550 kg by 2050.
- Other cements, still in development, aim for even lower carbon emissions.

Molins

02 STRATEGY 4

Use of industrialised construction systems

The adoption of industrialised construction systems offers numerous advantages, some of which have a direct impact on the circular economy. One key benefit is the reduction of waste generated on-site. Producing components off-site in a workshop allows for better optimisation of resources (materials, energy, water, etc.) and significantly cuts down on waste at the construction site.

The less construction that takes place in situ, the fewer the associated drawbacks (fumes, waste, noise, longer execution times, health and safety risks, etc.). Moreover, in cases where residents continue to occupy their homes during renovation work, the disruptions typically caused by conventional construction are greatly reduced.

Aside from these benefits, industrialised construction creates higher value-added jobs, boosts the local industrial economy, and facilitates the use of systems and products that are exportable, replicable, and potentially carbon-reducing.

See examples of industrialised systems in this guide: 01S1S2, 01S5S1, 01S5S2, 01S10S1, 01S10S2, 03S1S2, 03S2S1, 03S2S2, etc.

In recent years, Barcelona's Municipal Institute of Housing and Renovation has implemented industrialised construction systems to accelerate the development of public housing in the city.You can learn more about this in *Qüestions d'Habitatge* [Housing Issues], Issue no. 24.

OBJECTIVE 3: **RESILIENCE AND CLIMATE CHANGE ADAPTATION**

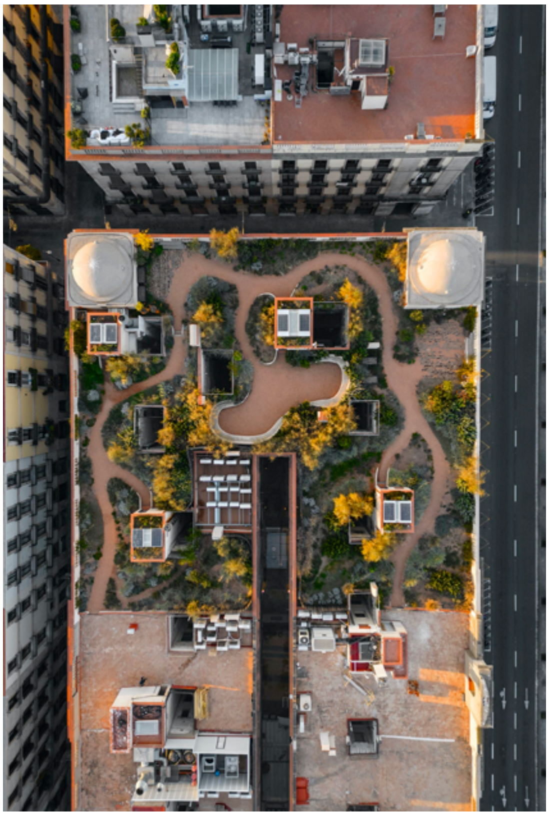
As mentioned in the introduction, decarbonising our society requires that the dense and compact urban model, which produces the lowest emissions, be embraced as a model for the future and adapted to withstand the effects of climate change.

This primarily involves making cities resilient to rising temperatures, heavy rainfall, and drought. Current building regulations rarely address these challenges, although some new local byelaws are beginning to do so. For instance, we still see new buildings in our cities being constructed with dark or even black façades, which contribute to the urban heat island effect by increasing local temperatures.

It is also the case that almost none of the residential building renovations include systems for rainwater collection and reuse. This would minimise the consumption of water for irrigation or toilet flushing and avoid adding pressure to the sewer system during heavy rains, which would also reduce the risk of flooding and prevent wastewater treatment plants from becoming overwhelmed during intense rainfall events.

Efforts have been, and are still being, made to develop infrastructure to tackle drought and build large containment reservoirs. However, buildings themselves have not yet been fully harnessed as a key part of managing these challenges at source.

There are technically feasible and economically effective solutions available to address these issues at the scale of individual buildings. Adopting such measures will help ensure cities can respond effectively to a future marked by climate instability, thereby safeguarding the urban model and maintaining its emissions efficiency.



O3 STRATEGY 1

Reducing the heat island effect

This is a key factor in maintaining comfort in cities. Rising temperatures are one of the main contributors to increased mortality in urban areas, and this rise in temperature is significantly higher than in the surrounding regions.

The consequences of rising temperatures are well documented in numerous scientific studies.[4]

[4] Examples of studies published by ISGlobal: "Heat Caused Over 47,000 Deaths in Europe in 2023, the Second Highest Burden of the Last Decade" 12/08/2024; "High Temperatures May Have Caused Over 70,000 Excess Deaths in Europe in 2022" 21/11/2023; "Record-breaking Heat in the Summer of 2022 Caused more than 61,000 Deaths in Europe" 10/7/2023; "Over 4% of Summer Mortality in European Cities is Attributable to Urban Heat Islands" 01/02/2023; "Without Strong Mitigation Measures, Climate Change Will Increase Temperature-Attributable Mortality in Europe" 08/07/2021; "Heat Now More Lethal Than Cold for People with Respiratory Diseases in Spain" 20/05/2020.

03 S1 SYSTEM 1

Reflective materials for façades and roofs

- This is a solution that is generally low-cost in renovation projects, or sometimes even cost-neutral, making it a measure that should be included in any refurbishment.
- It involves selecting colours and/or materials with a high Solar Reflectance Index (SRI) for all surfaces exposed to solar radiation. This typically means opting for lighter colours: the higher the reflectance, the lower the heat absorption.
- When using paints, they do not need to be special products, but they must have a certified SRI rating, information which is usually available on the websites of manufacturers who provide certification.
- An extreme example can be found in the thermal paints described in section 01 S2 System 3.
- Regarding construction systems, there is a wide variety of finishing elements available, such as concrete slabs, ceramics, etc.
- A minimum SRI of 70 is recommended for roofs with a slope below 15%, an SRI of 50 for roofs with a steeper slope, and an SRI of 30 for walkable paving and exposed façades.

París Camps Arquitectura

03 S1 SYSTEM 2

Traditional green roofs

- Green roofs help reduce the urban heat island effect by preventing heat absorption and humidifying the environment, similar to how vegetation in the surrounding areas of cities lowers temperatures compared to urban centres.
- Although they increase the cost of roof renovations, they provide significant benefits in terms of resilience, health, and biodiversity.
- There are two types of green roofs: with or without water retention systems. This section focuses on traditional green roofs without water tanks, while the next section (03 S2) will describe green roofs with water retention tanks, which offer additional advantages.
- Traditional green roofs consist of a soil substrate layered over a drainage element, often capable of partially retaining water with a trough-shaped membrane. Some membranes have a double tray design, allowing for greater water accumulation.
- A common maintenance issue with traditional green roofs is the frequent need to clear drainage gutters, as vegetation debris can block them, leading to roof flooding. This problem is addressed with green roofs that include water retention systems.

ZinCo

03 STRATEGY 2

Rainwater harvesting and reuse

Climate change tends to exacerbate drought episodes and increase torrential rainfall. In climates like the Mediterranean, where these effects already occur naturally, such episodes are becoming increasingly severe and frequent, forcing cities to manage these scenarios as effectively as possible. Harvesting and reusing rainwater within buildings is key to minimising the devastating effects of torrential rains and reducing buildings' consumption of tap water for irrigation and/or toilet flushing.

The practice of collecting and using rainwater is a traditional strategy, still used in some old farmhouses through a tank that collects rainwater for later use.

It is difficult to add new tanks in the lower floors of existing residential buildings, as these spaces are often occupied by shops or parking areas. However, there is a place where tanks can be installed: the roof and exterior terraces.

If the water is used for drip irrigation, no special treatment is needed, but it should be purified in a specific tank before it is sent to toilet cisterns.

03 S2 SYSTEM 1

Water-retaining roofs

- Water-retaining roofs consist of a conventional floating floor with a waterproof membrane that extends above the floor level, creating a reservoir capable of holding between 10 and 40 cm of water, depending on the load-bearing capacity of the existing (or reinforced) structure.
- Ideally, the roof should hold 40 cm of water, which equals 400 litres/m^2. Considering that Barcelona receives an average annual rainfall of about 600 litres/m^2, with a 400-litre storage capacity and regular consumption for irrigation and/or toilet flushing, it is possible to utilise virtually all the rainwater that falls on the building.
- Of course, not all buildings are structurally prepared for this additional load, so each case must be studied to achieve the maximum possible water retention. One strategy is to also utilise external terraces, which, even if they do not receive rainfall directly, can collect water by sedimentation to maximise total water storage without overloading the slabs.
- If the floating floor fully covers the surface without gaps, the water does not stagnate or cause insect problems, unlike traditional water tanks.
- Inside the tank, one or more overflow outlets regulate the maximum water level. Since the floating floor (if properly constructed) is impermeable to leaves and plastic bags, these roofs are far less prone to flooding compared to roofs with exposed drainage channels.
- The water, always shaded, remains at more stable temperatures than the surface of a traditional roof, helping to keep the waterproof membrane in better condition. This effect can be enhanced by using permeable slabs, such as those described in section 01 S5.
- It is a dry construction system, which makes maintenance straightforward by allowing the roof to be emptied and individual floating floor slabs to be removed without the need for construction work or demolition of any elements.
- In terms of CO_2 emissions, there is little direct saving, although tap water requires energy (especially if it is obtained through a desalination process).

Hydronic Shell Technologies

O3 S2 SYSTEM 2

Water-retaining green roofs

- Water-retaining green roofs represent an evolution of the previous system (O3 S2 S1), adding a layer of soil (starting from 10 cm) on top of the floating pavement slabs.
- This solution offers a very comprehensive set of environmental benefits: it enables the roof to capture and reuse water, reduce the urban heat island effect, and promote biodiversity, all while being easy to maintain and durable. It also prevents mosquitoes from breeding and eliminates the risk of roof flooding.
- Geotextile membranes are placed over the slabs and extend down between the joints into the water storage tank. These membranes prevent soil from falling into the water while allowing water to rise by capillarity to moisten the soil. Irrigation can be supplemented with additional drip systems drawing water from the tank, especially useful for thicker soil layers.
- The system should include a valve or solenoid valve that adds water to the tank if the water level falls below a minimum threshold (e.g., 5 cm). This prevents the tank from emptying and the plants from drying out. This water inlet should have a meter (preferably connected to the management system) to track emergency water consumption.
- The position of the downpipes and valve beneath the slabs should be clearly identified to facilitate maintenance. If these components are located under the soil, plants with expansive roots should not be planted within at least 1 metre of distance.
- A separating element should be placed between the soil and the slabs (such as a metal plate).
- There are water-retaining roof solutions based on stacked plastic trays, with the upper tray containing the soil and plants and the lower one providing space for water collection. However, their water storage capacity is much lower than that of tanks with floating pavements, and given the rainfall patterns of the Mediterranean climate, they can empty quickly.
- Although this system is not very widespread, there are already buildings in Barcelona with water-retaining green roofs that have successfully collected 100% of the rainwater on the roof for years, using it to irrigate the gardens and supply the building’s toilets.

París Camps Arquitectura

03 STRATEGY 3

Reducing water consumption

In addition to managing rainwater capture at the source for use, it is important to reduce consumption across all water-consuming end points.

03 S3 SYSTEM 1

Water-saving taps

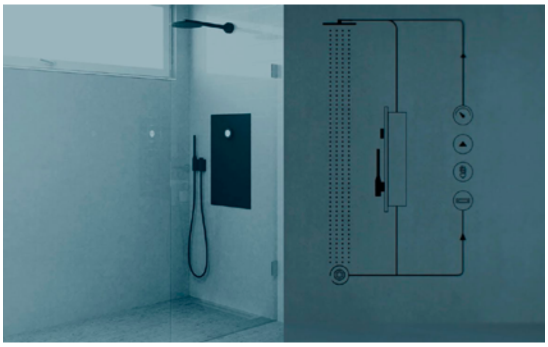
- Taps fitted with aerators: these can reduce water usage by between 30% and 90%. While most taps already include them, it is important to ensure they are efficient. Regular descaling maintenance should be planned.
- Flow restrictors: these help limit the flow rate, achieving savings of up to 70% in some cases. For instance, in showers, they can restrict the flow to 6–8 litres per minute. These may also be integrated into the showerhead.
- Automatic taps: these prevent water from flowing when not required, resulting in savings of up to 50%. They can be either mechanical or operated by a photoelectric sensor.

Ara newspaper

03 S3 SYSTEM 2

Circular showers

- These are equipped with a mechanism for immediate water recirculation and filtration, which can save up to 90% of water. Some models reuse the same water up to seven times. They may also include an application to monitor energy consumption.
- The filters should be regularly cleaned.



Orbital

03 S3 SYSTEM 3

Water-saving toilets

- Dual-flush toilets can save between 30% and 60% of water use.
- Rimless toilet models use 50–70% less water and are easier to clean, although they tend to be more expensive.
- Pressure-assisted cisterns use pressurised water to flush more effectively, saving up to 60% of water consumption.
- Urinals also reduce water use, especially high-efficiency models, although they are not commonly used in residential settings.

Flushmate

OBJECTIVE 4: IMPROVEMENT IN HEALTH

When planning a renovation, it is also important to consider improving the health and comfort of both the people who will inhabit the building and those in the surrounding environment.

Reducing indoor and outdoor pollution in buildings is key to improving and maintaining the densified urban model, which is the model that emits the least CO_2. Improving health conditions in cities supports the decarbonisation of society.

Numerous studies link pollution and health, and it is worth highlighting that buildings have the potential, largely untapped up to now, to reduce urban pollution.

Pollution causes scientifically proven mortality rates that cities and their buildings can and should work to minimise.[5]

O4 STRATEGY 1

Reducing urban pollution

Buildings can reduce urban pollution, although to date they have done so to a much lesser extent than they potentially could. It is essential to maximise the incorporation of air-cleaning capabilities in buildings undergoing renovations.

Buildings can purify city air by activating their exchange surfaces: façades and roofs. This can be achieved through two strategies:

- Covering buildings with photocatalytic surfaces that break down pollution into smaller, harmless particles.
- Incorporating vegetation into buildings, either on roofs or façades.

In this chapter, we will focus on the first approach, while the next chapter (Biodiversity and Biophilia) will explore the incorporation of vegetation into buildings.

Photocatalysis is a chemical reaction through which common construction elements such as flooring, tunnels, car parks, interior and exterior walls, and building envelopes, treated with titanium dioxide (a catalyst) gain self-cleaning and pollution-reducing properties when exposed to natural or artificial light. Under these conditions, the photocatalytic surface transforms harmful gases like nitrogen oxides (NOx), sulphur oxides (SOx), and volatile organic compounds (VOCs) into harmless nitrites and nitrates, which can be easily washed away by rainwater.

[5] Studies published by ISGlobal on pollution and health in cities include: "Prenatal Exposure to Environmental Chemicals Linked to Childhood Growth Changes" 18/10/2023; Exposure to Plasticizers in Pregnancy Associated with Smaller Volumetric Measures in the Brain and Lower IQ in Children" 28/09/2023; "A Natural Experiment Provides Evidence of Link between Air Pollution and Childhood Obesity" 03/08/2023; "Long-Term Exposure to Air Pollution and Severe COVID-19" 24/05/2023; "New Study Provides a Unique Resource for Understanding How Environmental Exposures in Early Life Affect our Health" 21/11/2022; "Even Before Birth, Children Are More Vulnerable and Have More Health Problems Caused by Environmental Factors Than Adults" 10/11/2022; "Study Findings Suggest Association between Exposure to Air Pollution – Particularly in the First 5 Years of Life – and Alterations in Brain Structure" 23/09/2022; "Young Adults with Higher Exposure to Household Air Pollution Show Worse Lung Function" 23/06/2022; "Preadolescents Exposed to High Levels of Air Pollution in their First Years of Life Display Changes in Brain Connectivity" 15/06/2022; "Greater Exposure to Nitrogen Dioxide Linked to Higher Levels of Biomarkers of Alzheimer's Disease in the Brain" 16/12/2021; "European Cities Could Avoid an Extra 114,000 Premature Deaths Every Year by Meeting the New WHO Air Quality Guidelines" 11/11/2021; "Cognitive Performance and Stress Worsen on High-Pollution Days in Barcelona" 14/09/2021; "Study Links Child Behaviour Problems to Prenatal Tobacco Smoke Exposure and Traffic Density" 26/04/2021; "Study Identifies European Cities with Highest Mortality Due to Air Pollution" 20/01/2021.

Photocatalysis, which was invented in Japan over 40 years ago, emerged as a response to environmental pollution mainly caused by road traffic in large cities, which also adversely affects indoor air quality. Not only does it have a proven decontaminating effect, but it can also significantly reduce maintenance and cleaning costs, as photocatalytic substances prevent the accumulation of dirt on surfaces more effectively than untreated ones and reduce unpleasant odours due to their biocidal and organoleptic properties.

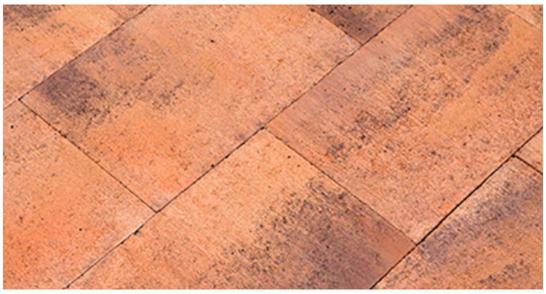
The Iberian Photocatalysis Association has produced a white paper detailing photocatalytic systems, tests, and applications. It also promotes "Product with photocatalytic activity" certification.

All kinds of materials with a photocatalytic finish are available. Below, we outline the most suitable ones for residential building renovations.

04 S1 SYSTEM 1

Photocatalytic slabs

- There are concrete slabs and paving stones with a photocatalytic finish available on the market, complete with certification.
- These slabs can be installed as flooring or as a façade finish (whether ventilated or not).
- They appear identical to their non-photocatalytic counterparts and are installed in exactly the same way.
- Some have certified reductions of NO_2 and NO by around 30% in specific streets. In addition to the pollution reduction in these streets, the effect of air movement helps carry cleaner air to other parts of the city. In the absence of wind, air quality improvement could reach up to 70%.



Breinco

04 S1 SYSTEM 2

Photocatalytic panels

- Porcelain ceramic panels, vitrified metal panels, as well as cement-based panels and mortars can also have a photocatalytic finish. These can be used as façade finishes or ventilated façades, as well as for interior finishes.

Tectónica

04 S1 SYSTEM 3

Photocatalytic exterior paints

- Photocatalytic paints can be used on exterior surfaces just like conventional paint. They come in a wide range of colours and various types are available, such as silicate-based and lime-based paints. These paints help to break down pollutants like nitrogen oxides, sulphur dioxide (SO_2), ammonia (NH_3), carbon monoxide (CO), solvents, formaldehydes, etc.
- They keep surfaces cleaner for longer than traditional paints.
- Of course, it is important to repaint using the same type of paint to maintain the photocatalytic effect.

ZinCo

04 STRATEGY 2

Reducing indoor pollution in buildings

Reducing indoor pollution in buildings is essential for improving the health of their occupants. Although it does not have as significant a direct or indirect impact on decarbonisation, it should be carefully considered when undertaking a comprehensive building renovation.

Below are some measures to improve indoor air quality:

- The photocatalytic materials described earlier can also be installed inside buildings to reduce indoor pollution. They help decrease:
  - pollution from vehicles that enters when ventilating the building,
  - organic pollution emitted by materials: volatile organic compounds (VOCs),
  - human viruses and bacteria (colds, flu, COVID-19, etc.).
- Improving ventilation and air filtration systems also enhances air quality. Some filters are photocatalytic as well.
- Choosing furniture materials, paints, and adhesives during refurbishment or afterwards helps minimise emissions of harmful chemical compounds, such as volatile organic compounds (VOCs) and formaldehydes. Regarding total VOCs (TVOCs), emissions should ideally be below 1 g/m^3, and formaldehyde levels less than 50 micrograms/m^3.

OBJECTIVE 5: **BIODIVERSITY AND BIOPHILIA**

To promote biodiversity, health, and urban resilience, streets and parks need to be increasingly filled with vegetation.

However, for this transformation and its effects to be truly significant, a large area of urban built surfaces that has so far been largely overlooked must be activated: the surfaces of residential buildings.

By greening roofs and façades during every renovation, not only will urban biodiversity be encouraged at a time when biodiversity is declining worldwide, there will also be a very positive impact on urban resilience and people's health, objectives discussed earlier.

All of this will make cities more liveable and, as a result, help preserve their decarbonisation potential.[6]

O5 STRATEGY 1

Incorporation of vegetation into buildings

It is feasible to structurally incorporate vegetation into buildings, both on roofs and façades, but until now this has not been considered necessary and therefore has not been regulated by legislation.

Until recently, the few regulations that existed (some voluntary, such as environmental certifications) placed greater emphasis on the extent of vegetated surfaces rather than their quality and potential. Fortunately, qualitative criteria are increasingly being integrated alongside quantitative ones.

There are now urban byelaws that regulate the incorporation of green roofs and façades with sufficient conditions to ensure they are truly effective environmentally, such as the Environmental Ordinance of the MPGM 22@ district in Barcelona. This byelaw specifically activates vegetation to meet parameters related to the water cycle, vegetation quality, and the promotion of biodiversity, among others.

[6] Studies published by ISGlobal on the benefits of incorporating naturalised spaces into cities include: "Children Living in Greener Neighbourhoods Show Better Lung Function", 17/07/2024; "Residential Green Space Is Associated with Higher Birth Weight", 24/01/2023; "Gardening Can Help Reduce Cancer Risk and Improve Mental Health, Study Finds", 12/01/2023; "Living in Greener Areas Is Associated With Better Mental Health and Less Medication Use", 05/12/2022; "Urban Environments With More Vegetation Are Associated With Better Health Behaviours in Children", 13/07/2022; "Living Near Green Areas Reduces the Risk of Suffering a Stroke by 16%", 15/03/2022; "Study Finds Lower Oxidative Stress in Children Who Live and Study Near Green Spaces", 01/03/2022; "Children with Higher Exposure to Air Pollution and Lower Exposure to Green Space have 62% increased risk of ADHD", 24/02/2022; "Living Near Green Space May Be Beneficial Against Symptoms of Premenstrual Syndrome", 02/12/2021; "Increasing Green Spaces in Cities Could Prevent Many Premature Deaths Every Year", 28/04/2020.

05 S1 SYSTEM 1

Vegetation on roofs and façades

- The incorporation of vegetation on roofs should enable the building to be activated to the greatest extent possible in terms of biodiversity, as well as water retention and reduction of the heat island effect. The system that best achieves this is the green roof with a water retention system (03 S2 System 2).
- Low water consumption plants should be planted, preferably native or well-adapted species, to reduce water use.
- Although ideally, in our climate, there would be around 40 cm of water retention and 30 cm of soil on average, the condition of many buildings often means this cannot be achieved without significant reinvestment.
- From 20 cm of water and 10 cm of soil upwards, significant benefits begin to emerge in terms of urban resilience, health, water savings, and biodiversity.
- Regarding vegetation on façades, the market offers various green wall systems, which are often expensive and require costly maintenance. In contrast, climbing plants supported by trellises are a simple and cost-effective solution that can be easily installed, whether planted directly in the ground or in planters of a reasonable depth (around 50 cm).

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05 STRATEGY 2

Biophilic design

Biophilia involves incorporating natural elements into spaces to promote a healthy experience and enhance well-being.

This guide does not go into detail on this topic, as it has a lesser impact on the decarbonisation of the building stock, but it is mentioned here because biophilic dynamics can add value to renovations in terms of environmental sustainability and social improvement.

Biophilia can be achieved in various ways. The most direct is by incorporating natural elements into buildings, which was covered in the previous section, but it can also be achieved through other design strategies:

- A design that promotes the presence of natural light and views to the outside
- Biodynamic or circadian lighting to adapt the colour of interior light throughout the day
- Interior surfaces with exposed thermal mass (such as slabs and floors) to activate thermal inertia and store heat comfortably and efficiently
- Prioritising natural materials over synthetic ones (finishes, furniture, etc.)
- Spaces with a good balance between order and complexity (layouts, textures, pathways), avoiding both dull spaces and unnecessarily complex ones

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