Guide to living terrace roofs and green roofs

BCN

Ajuntament de Barcelona

1. INTRODUCTION

One of Barcelona's hallmarks is its terrace roofs. As a bird's-eye view will show you, they extend from Ciutat Vella to the Collserola mountain range. They are spaces that were once used a great deal. Oral and written memories attest to that. Their most common everyday use was probably for hanging out washing, work usually carried out with children around, who would meet up and play with their neighbours. So they were spaces for socialising, where people felt safe. Apart from that, neighbours would also spend time on them and hold parties there, especially on the eve of a festival. Thanks to the oral traditions that have come down to us, we also know that older boys and girls would jump from one roof top to another to do their courting. Our city used to have a "high life" in its most literal sense. A life that gradually disappeared during the second half of the 20th century when, basically, terrace roofs came to be used as spaces for installing equipment or storing rubbish.

The new millennium has seen Barcelona become a compact and extremely lively city. That makes it particularly attractive but means there are fewer uncrowded, traffic-calmed spaces, healthy spaces for socialising. Given that situation, Barcelona City Council presented a government measure to promote living terrace roofs and green roofs on new and existing buildings. A commitment that has led to the publication of this *Guide to living terrace roofs and green roofs*. The guide is intended to be a tool for encouraging a reappraisal of the roofs that top the city's buildings and their use by residents. For a city where there are no longer enough tranquil, green spaces at street level, having terrace roofs that are in good condition, "greened" and have facilities just waiting to be used for a pleasant break can mean a big improvement to the quality of life of its residents.

These are safe, outdoor spaces, where people can enjoy views of the city, enjoy more peace and quiet, sunbathe, read, do a physical activity, tend to their allotment or meet up with their neighbours. They are also spaces that can boost the quality of their environment, with green roofs that regulate the climate of the city and the building, help to reduce atmospheric pollution, provide a site for some very useful flora and fauna, and retain water. Barcelona has been rediscovering these opportunities, which are accessible to everyone: children, young people and older people are all returning to the city's terrace roofs and taking advantage of them. The guide aims to encourage and accompany this rediscovery process. We could immediately think of lots of questions on the transformation and possible uses of these spaces, which opens up a good many alternatives. The guide offers answers to the questions we ask ourselves, an explanation of the social and environmental benefits we can reap, technical advice for choosing the type of terrace roof we want and how to ensure we get to enjoy it.

Left page: *Nostra Senyora de Lurdes School.*

2.
LIVING TERRACE ROOFS AND GREEN ROOFS: DEFINITION AND BENEFITS

A **roof** is the exterior part of a building's ceiling and serves to protect it. **Terrace roofs** are the flat, slightly inclined, tileless roofs of a building, or part of a building, which can be comfortably walked on and used for carrying out various activities, such as hanging out washing, sunbathing, enjoying some fresh air, reading, and so on. They account for 67% of the surface area of roofs in Barcelona (1,764.4 hectares). Some have a specific use (school playgrounds, hotel gardens, community spaces, etc.) while others are simply places that accumulate junk and electrical equipment, such as antennas and air-conditioning units.

Terrats en Cultura. © Isaias Fanlo.

Servei Estació Roof. C/ Aragó, nº 270-272.

For the purposes of this guide, a **living terrace** roof shall be understood to mean one that residents make the most of and use for different activities, and a **green roof** as a building system with a plant finish on a bed of soil or substrate that is specially designed for obtaining environmental benefits. The plant cover may be total or partial and it does not refer to terrace roofs with potted plants but to building technologies for improving the habitat or saving energy consumption, i.e. technologies that fulfil an ecological function. Green roofs are a good example of multi-functional urban design.

Private roof on Via Laietana.

Left page: *22@ building roof*. © Jordi Surroca.

Benefits of using terrace roofs and installing green roofs

Living terrace roofs and green roofs are an important asset for reclaiming unused spaces in the city, as well as an opportunity for developing a more sustainable a Barcelona.

Thanks to the ecological advantages, economic advantages and free space they offer us, they are beneficial to people and the environment, in the same way that they help to improve the life expectancy of buildings and their energy balance.

Benefits for building owners and users

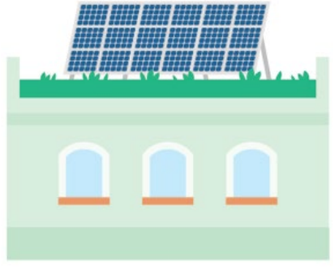
Increase in the building's price
Living terrace roofs and green roofs add value to the property as they create more sustainable and attractive buildings. Reclaiming these roofs and introducing new uses improve people's perception of these buildings and raise their property value.

If terrace roofs are properly managed and used, they can act as versatile recreational spaces, such as city allotments or commercial establishments (bars, restaurants, gyms, etc.) and provide more space for schools, social premises, hospitals, residences and the building's own residents.

Longer life for waterproofing
A green roof provides an extra layer of insulation.

Annual and 24-hourly differences in temperature of over 100 ºC and 60 ºC respectively on traditional or gravel roofs, as well as direct exposure to UV radiation, speed up the ageing of the waterproofing membrane, leading to cracks and eventually leaks.

Both the vegetation and the substrate protect the waterproofing membrane by alleviating the effects of temperature fluctuations.



Acoustic insulation
City noise is a cause of stress and sleep deprivation for part of the population. A green roof reduces the reflection of sound by up to 3 dB and improves acoustic insulation by up to 8 dB. That can improve the quality of life of people who live near noisy places.

Heat insulation
One of the most important benefits of green roofs is their reduction of heating and cooling costs, depending on the type of roof that is built and the thickness of the soil it uses. Flats located immediately under an unprotected terrace roof with flawed insulation will become overheated. The additional insulation that green roofs provide reduce temperature transfers between the inside and outside of buildings. They reduce excessive heat during the summer and minimise heat losses in the building during the winter.

Producing solar energy and HSW
Terrace roofs are ideal places for putting up solar panels and HSW (hot sanitary water) units. Solar panels put up on a green roof can produce up to 16% more energy, as the plants there act as a natural cooling system for the panels.

Another unique feature in this alliance is that green roofs help to remove pollutants from the air, because they prevent suspended particles from latching on to solar cells. They also help with maintenance by enabling solar panels to absorb more solar light and generate more energy. The same applies to HSW screens.

Environmental benefits

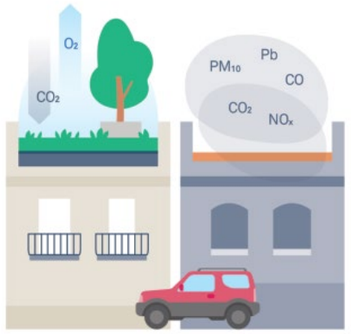
Reduction in the urban heat island effect
Global warming, the increase in waterproof surfaces, excess heat from residential buildings, industry and traffic are causing a rise in temperature in cities.

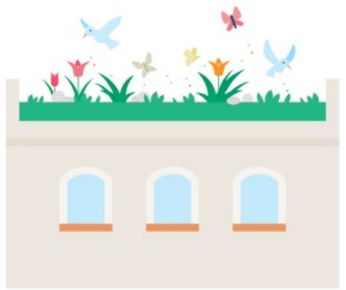
The difference in temperature between cities and the countryside or the peri-urban space surrounding it is known as the “urban heat island effect”. This heat difference can reach nearly 10 ºC in the summer and so reduce the quality of life and health of the city’s inhabitants.

In densely populated areas, where green spaces are few and far between, roof gardens may be a good solution as they reduce the urban heat island effect through the process of transpiration and humidification of dry air, which improves the climate and increases people’s sense of well-being.

Collecting and storing water
Green roofs act as a storage tank for rain water. Rain water can be reused, through cistern technology, for irrigating the roof itself or put to other uses (toilet, cleaning, cooling appliances etc.) Green roofs are very important tools for preventing local floods, as the rain water - depending on the green-roof system and depth of the culture medium - that goes directly to the sewerage system can be reduced by between 50% and 90%. This effect can reduce stress on the sewerage system over the year and during periods of high rainfall.

Moreover, rain brings nutrients, sediments, hydrocarbons, organic chlorine and heavy-metal compounds from the surfaces of buildings and roads. When rain passes over a roof garden, its vegetation filters and absorbs some of these pollutants.





Reduction in pollution levels
Vegetation can improve air quality. It has been demonstrated that it is effective in reducing atmospheric pollution thanks to its capacity for filtering particles and absorbing pollutant gases.

A square metre of green roof can filter 0.2 kg of dust in the air and smog particles in a year. In addition, nitrates and other dangerous materials in the air and rain are deposited in the culture medium.

Creation of new habitats for fauna
Green roofs can compensate for part of the green spaces lost in the construction of buildings and create the right spaces for fauna in the middle of our cities. Many insects, birds and plants can find refuge in these reclaimed nature spaces.

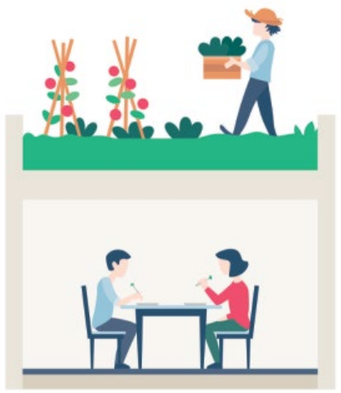
The new habitats integrated into buildings are used for creating fauna links between the city and the nearest woods and help with the movement and dispersal of wildlife.

Improvements in the urban landscape and quality of life
Roof gardens are a good solution for the fight against the high building density in most of our cities.

The urban landscape could change substantially if part of today’s roofs with a gravel finish were turned into green roofs. There is a link between including green areas in the urban fabric and reducing stress and recovery times for patients, just as there is with improving work productivity.

Boosting urban agriculture
Living terrace roofs and green roofs can be used as spaces for producing food for local distribution and supplementing a restaurant's cuisine, or even for selling on a commercial scale.

Urban agriculture makes it possible to maximise the production of fresh fruit and vegetables in spaces that have been under-used in cities until now. This can help to cut down our ecological footprint, reduce poverty (by creating resources and jobs), increase food and nutritional safety and recycle rubbish. It can also help to bridge the gap between producers and consumers, thereby reducing prices and solving supply problems.



Allotment roof. Nostra Senyora de Lurdes School

3.
FAQS

3.1
On general aspects

Do living terrace roofs and green roofs work in new and old buildings alike?

Yes. Living terrace roofs and green roofs can be installed on a wide range of roofs. When a new building is under construction, the plans are now drawn up taking into account the loads that the structure has to bear.
Existing buildings require the roof design to be studied so it meets the requisite load conditions.
Some existing buildings have sufficient capacity, but in any case, a structural engineer must check in advance the weight that the structure can hold, to ensure the building's safety.

Can I do any kind of activity on terrace roofs?

Each terrace roof is a unique case and a preliminary examination has to be made of the activities that may or may not be carried out there. The study will have to take account of the technical aspects (structural, above all) to know if the weight the roof is able to bear limits the activities we may wish to carry out on it. For example, if we want to install an allotment or a swimming pool, the structure must be capable of bearing a greater load than if we want to build a sunbathing area or a sports court.
Either way, a study will have to be done regarding the needs of the residents, the building's architectural potential and its existing facilities.
On that basis, the following uses could be established:
Functional use (hanging out washing, having an allotment, a green roof, a storage place, etc.)
Recreational use (areas for walking, sunbathing, reading, gatherings, kids' games, holding occasional parties, sport, etc.)
Ecological use (harnessing and producing energy, collecting and storing water).

Will everyone be able to go up on the terrace roof? Will it be safe?

In theory everyone with authorised access would be able to go on the roof: owners and tenants, in the case of private buildings; customers and users, in the case of establishments with facilities on their roofs (such as hotels and sports centres) and students and patients in schools and hospitals respectively.
Roof-access doors would have to be treated similarly to building-access points, to ensure people without authorisation are denied entry.
As for protection against falling off, checks would have to be made to see if the perimeters of such terrace roofs complied with safety regulations. Where their edges are insufficient for the new function of the terrace roof (for example, as a space for ball games), they would have to suitably adapted for the intended new use.

Will it be accessible? Are there solutions to architectural barriers?

Access is one of the most important aspects of ensuring the success of living terrace roofs. Properties must have stairs to connect each flat or storey to their roof terrace. Wherever possible, it is important for such properties to have lifts that reach the same level as the terrace roof. That way people with reduced mobility can get access, ensuring maximum inclusion and use of the roof.
Access to the terrace roof is comparable to access to the building from the street, so it must have the same dimensions and services as the access points provided for in the law currently in force. In any event, if the building does not have optimal access conditions to the terrace roof, an expert will have to visit and study it, and make a redevelopment proposal.

Will I lose my privacy?

We can use communal terrace roofs that are used exclusively by some owners or tenants (penthouses) as an example. Attempts to turn the terrace into a communal area and a place for holding activities could make some of them reluctant to accept any change of use, for fear of losing their privileged privacy.
Strategies would have to be found for ensuring their needs as users continue to be covered, despite the change, and for such needs to be included in the new plan. If these needs are incompatible, solutions could be sought for sharing the space. There are architectural elements that allow part of the terrace to remain private and the rest of the area to become a shared part. The elements may be flexible, that is, allow some interaction between public and private spaces (blinds, stained-glass windows, curtains, etc.) or completely blocked off, through closed perimeters, to enable complete separation between the common and private areas and thereby preserve intimacy.

Will there be any noise?

So long as the roof has proper acoustic insulation, there will be no sound-related problems.
The benefits section explains the acoustic insulation that green roofs provide. Terrace roof areas without green roofs ought to include acoustic insulation too, to minimise the impact their use may have on flats located immediately below them.
Likewise, where roof terraces are managed by residents, it is important to include a definition of the uses they will be put to, along with the times and types of users, to avoid any possible acoustic excesses.

3.2
On green roofs

Can I put a garden on any building?

Almost all roofs can be given a garden, including those with shaded areas, roofs with low load-bearing capacity, roofs on high-rise buildings, with limited access, etc. As in any project, these will require specialist engineering, a good design and preliminary studies by a specialist professional.

Can I have a sloping green roof?

Yes, you can have a green roof with a slope of up to 45 degrees (approximately).
If the roof has a slope of over 45 degrees, technical solutions specific to vertical gardens will have to be adapted to the design, to ensure the stability of the drainage systems, the substrate and the vegetation.

Are leaks likely?

Provided there is guaranteed, secure, root-repellent waterproofing, there should be no leaks.
Waterproofing must be done with synthetic waterproof sheets which, being protected by the green roof from direct solar radiation and abrupt temperature changes, will have a long useful life and be free of water leaks.

Will it bear the weight?

It depends on the activity intended. In the case of new buildings, the use that is going to be made of the terrace roof must be taken into account from the planning stage, and the corresponding calculations made, so the structure will support the weight.
Existing buildings will have to be visited by an engineer or architect to check the load that the building can bear and, where necessary, a structural reinforcement will have to be built to ensure its safety.
There are several technical solutions that enable reductions in the weight of the green-roof systems: very light substrates, systems requiring little soil, etc.

Can I combine vegetation with recreational spaces? And with allotment areas?

Yes, they are perfectly compatible.
Current systems make it possible to alternate spaces with vegetation and paved areas, resting areas, areas with furniture, pergolas, an allotment area, and so on. In any case, a study will have to be made on the most appropriate roof system for each element and the best location for each use.

Can I combine it with solar panels and HSW?

Yes, not only can these be combined but they may improve their performance.
It has been shown that solar panels work more efficiently on a green roof than on a conventional roof. Solar panels perform less well over 25 ºC. The vegetation reduces the roof's temperature and increases the efficiency of the solar panels.

Do they need to be maintained? Who is responsible for this?

It is important for the vegetation to be maintained and this will have to be taken into account in the design and management of any project.
If you wish to keep maintenance to a minimum, you are advised to choose an extensive or semi-intensive green roof, with low maintenance requirements.
Besides the vegetation, the maintenance of the roof's other elements needs to be taken into account, as with any terrace roof with no vegetation: the equipment that might be installed there, the surfacing and the drainage.
Maintenance can be carried out by specialist gardening companies or the tenants themselves.

Does a green roof have to be watered?

All plants need a minimum amount of water to live. Depending on the type of vegetation you choose, a roof can be built with few water requirements.
In any case, you are advised to install a watering system to ensure that the vegetation adapts and the plants have the necessary water during warmer periods.

How much water is required?

There is no single answer: the water required will be calculated according to the vegetation, substrate, climate and environmental influences as well as the design and type of system used. To minimise the use of drinking water for watering the plants, rain water can be used and a plan can be designed for reusing the building's grey water.

How much does a green roof cost?

Costs vary significantly depending on the location and the project.
Key factors influencing costs include the size of the roof, the slope, the design, the types of materials used on the roof (for example, where a structural reinforcement is needed, the volume of substrate required, the type of vegetation, the system's components, the hard surfaces, the furniture and trappings, etc.) access to the roof and the type of maintenance needed.

What is the life expectancy of a green roof?

The useful life of a green roof is directly related to the quality of the design, building and maintenance that it has and especially to the durability of the building system's components (retention covers, drainage sheets, filters and types of substrate). Several green roofs in Europe have lasted over 75 years and are still functioning.

22@ district. © Quico Domingo

4.
SOCIAL AND TECHNICAL ASPECTS OF LIVING TERRACE ROOFS AND GREEN ROOFS

Green roofs and, above all, living terrace roofs are new spaces in the city that boost and build social and neighbourly relations, improve the integration of diversity and strengthen social participation.

So, by reclaiming terrace roofs we are recovering the social roles they had in the past but adapting them to new urban needs, and assigning a large part of them to promoting the social, leisure and recreational activities of resident communities.

If we are to have terrace roofs that are inclusive and can be enjoyed by all the residents, we need to examine various social aspects, such as use requirements, potential users and space management. Participatory building tools will also need to be included, where residents, in collaboration with professionals, are involved in the design to create collective spaces that are adapted to their needs.

Social aspects aside, we must also take account of the technical considerations that will enable all the potential activities on terrace roofs to go ahead with total piece of mind. A physical examination of the existing roof must be carried out to establish the building potential and alterations required so the space can accommodate the social functions desired.

4.1
Social aspects

The use of living terrace roofs

Living terrace roofs for collective use are communal, multi-faceted, multi-purpose and multi-cultural spaces. The use made of terrace roofs can vary depending on the needs and interests of the users.

There is no need to apply all uses to the same spaces or even necessarily at the same time. A clear definition of the uses the roof is to have will help to achieve a good distribution of the space, enabling activities to be planned and managed in the best possible way.

Terrace roofs can be used in ways that are necessary for the residents but which the building cannot include for want of space. Some of these uses may not have been planned originally, when the building was designed, but have become crucial over time, bearing in mind the current social context, for improving the residents' quality of life . These terrace roof functions may be called functional uses.

Examples of functional uses include the following:

- Hanging out clothes
- Storage
- Generating sustainable energies
- Planting vegetables for self-consumption
- Collecting and storing water

There are other uses that contribute to the well-being to those who adopt them. These are recreational uses, which are usually leisure activities and voluntary. A large part of the success of these roof activities is down to the fact that the space intended for this use meets the expectations of its users. Examples of these uses include the following:

- Walking
- Doing sport
- Reading
- Resting
- Chatting
- Sunbathing
- Rehearsing
- Gardening
- Playing
- Holding social and cultural activities: concerts, exhibitions, association meetings, etc.

There are functional activities which, depending on how they are organised, can also be included among the recreational activities, such as having an allotment on the roof. A third type of use could be profitable or commercial. Such a use is associated with private forms of managing roof terraces where there is a sole owner or association that defines the activity and use that will be carried out on the roof. These uses would include all activities where terrace roofs help to enhance the service they offer for clients or users. Here are several examples:

- Café or hotel-bar terraces
- Renting urban allotments
- Older people's homes, hospitals and schools
- Sports facilities
- Other

Users

When it comes to defining uses and their incorporation into the roof's design, various aspects of the users must be taken into account:

- Age of the people: this point is decisive when it comes to designing security or deciding on building materials, bearing in mind the interests of this group and accessibility issues.

- It is also important to know whether they are the property's residents or users enjoying the access they have been given for carrying out an activity there: school students taking a break or office workers having a rest on the roof, for example.

- The maximum number of users who will be doing an activity, as well as how often the space will be used, is also relevant information that will help to establish a user map.

Private or collective use of the terrace roof

The definition of the terrace roof's uses will also be determined, to a large measure, by who owns the property.

It is obvious that the design or decision process for a private space, where the promoter is the owner and uses the terrace roof privately or for their business, will differ from that for a community of owners, where residents or tenants are the users of the space. In the former case, the preliminary work for redeveloping the terrace roof is simpler.

If a communal terrace roof is to be successfully redeveloped with residents making use of it, it is essential for all the users to have their say: terrace roofs must be suitable spaces for meeting the needs of all the users of the property.

With this aim in mind, the community of residents can embark on a participatory or consultation process during the first stages of design, to collect and listen to everyone's contributions and include them, along with the building's technical study, to promote a comprehensive redevelopment proposal.

When a community of owners decides to take an active part in the design of a space, the process is slower but more innovative and causes a large social transformation, while also strengthening a feeling of involvement and responsibility in the implementation of the project and a sense of belonging to the place.

An architect or landscape gardener can be commissioned to offer a design based on a technical examination and list of requirements that the community will later on approve, validate and legitimise.

A good participatory process has to have all those involved properly established before it can go ahead:

Residents: they need to play an active part, so they can contribute ideas, raise objections, make concessions, etc.

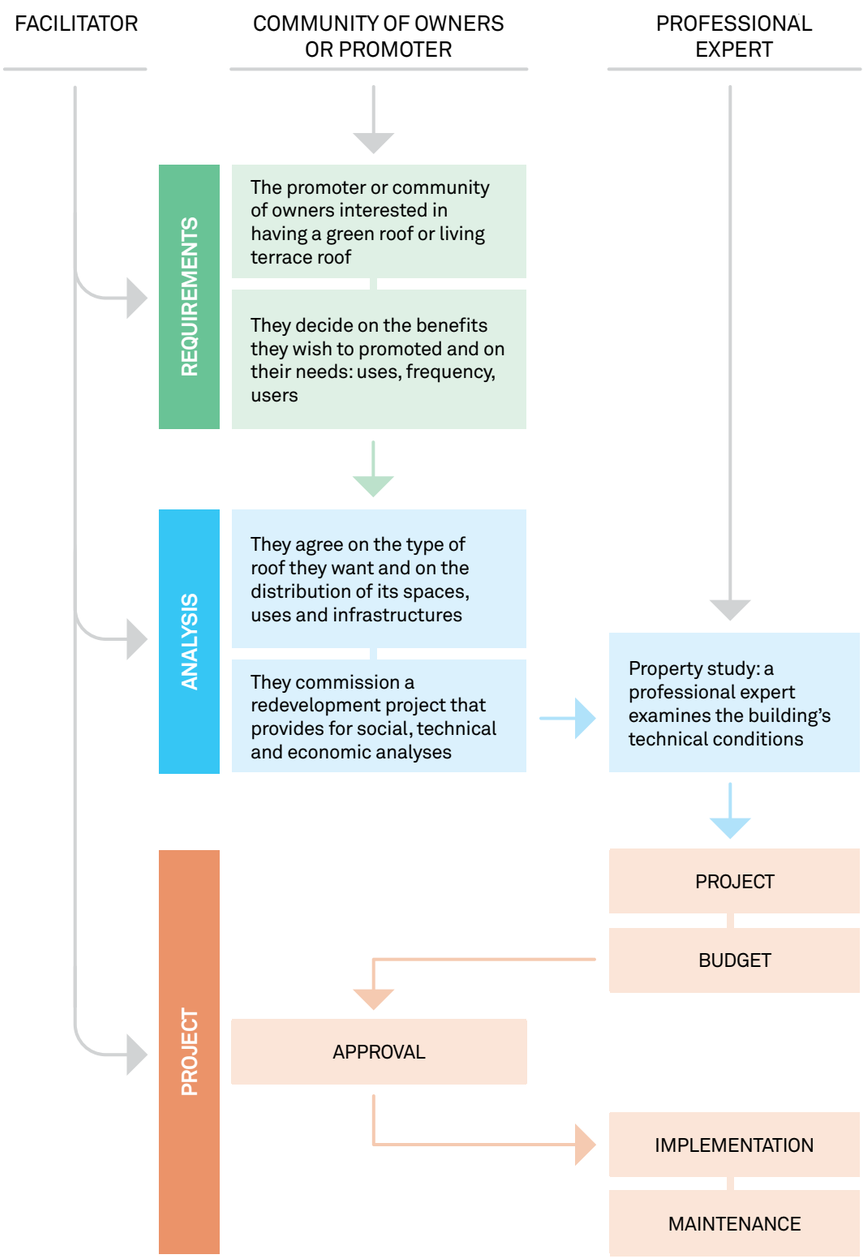
A lead group representing the residents: people from the community who can dedicate more hours to the participatory process and take responsibility for ensuring residents have all the information they need, for planning meetings, etc.

Participatory process facilitator: will be tasked with livening up residents' meetings and helping them to reach agreements and consensus. A key player who will ensure fairness among people and that the diversity of all the residents is reflected in the project.

Structural professionals, architects, landscape gardeners, etc.: these are the people who supply residents with technical information on buildings or aesthetics, so they can choose between the options proposed.

The participatory process finishes once a satisfactory, consensual, collective solution has been reached that the whole community can take on board.

Process to be followed when implementing a living roof terrace or green roof project



Ownership of terrace roofs

Several natural or legal persons may have title to or own a terrace roof.

The complexity of the decision-making process for redeveloping a terrace roof will depend on the nature of its ownership.

Groups of terrace-roof owners

1. Private owners, whether natural or legal persons
Ownership implies authority to choose the redevelopment or design desired for the roof, within the framework of the current law in force.

2. Ownership by a community of property owners
This is the body that governs relations between a building's residents. It is made up by all the owners of the various elements the building consists of: flats, premises, parking places, etc. As for rented flats, it is their owners - and not their tenants - who belong to the community of owners. All owners have the same rights and obligations.

In this case the decision-making process for the roof terrace redevelopment must be participatory, and follow processes such as the ones explained above.

It is important to have all the residents taking part and informed, even if they are not owners, as the success of the terrace roof lies in their making proper use of it.

3. Ownership by more than one community of owners
This would involve bringing together several communities of property owners or communities and individual owners, for the purpose of turning "a terrace roof into a unique category that belongs to all the residents in the block or building complex".

The idea behind the redevelopment is to unite the various terrace roofs, to increase the free space available for leisure and recreation, of comparable size to an urban space but with its use restricted the new community. To unite them by cutting out the different levels and increasing the surface area.

In order to formally bring about union of owners, a completely new community of owners could be set up for the purposes of the Commonhold Property Act.

Or a private contract could be drawn up between the members of the community of property owners, under which they agreed to a shared use.

The latter formula is more flexible, less costly and may have time limits. The former is much more complex.

As in a simple community of owners, the decision-making process for the redevelopment of the terrace roof must be participatory.

Terrace roof management

One we have a fully functioning living terrace roof, with spaces assigned to the planned uses, it is necessary to specify how the roof, or space, will be managed.

Management is understood to mean the organisation, planning and funding (where appropriate) of the various facets of the terrace roof.

Activity management
To ensure good understanding and avoid disputes between the space users, it is important to establish a set of rules for positive interaction and use of the space, right from the start.

A proposal for regulations could include the following:

- User map of the space: which can be done in each place.
- Time limits for uses.
- Seasonal limits for uses.
- Indications of the type of user who can use a specific space.
- Timetable of specific activities reserved for spaces so they do not overlap.
- Appointing a person or group of people to be responsible for ensuring proper use is made of the terrace roofs (it could be a rotating duty among members of the community of residents).

Terrats en cultura. © Isaias Fanlo

Maintenance management
Terrace roof maintenance is crucial if we are to prevent the space from deteriorating. Someone has to be tasked with cleaning it and with looking after its fittings, facilities, surface, furniture, vegetation and game areas.

These tasks may be taken on by the community and shared between its members. Another option is to outsource all the work. An intermediate solution, whereby part of the work is done by residents and another by companies specialising in maintenance, is also an option.

Safety and security management
Another aspect that needs managing is safety and security, from two perspectives: first, protecting people or things from falling off the roof and second, preventing unauthorised people from entering communal or private spaces connected to the building. To ensure safety from falling, the roof's perimeters and access points must satisfy the current law in force. It is the community's responsibility to carry out thorough, periodic inspections of the perimeters and danger points. And to ensure good accessibility to and from the roof too.

The community is advised to have the periodic inspections and maintenance of danger points to be carried out by authorised companies.

As regards security from intruders, this can be resolved by providing terrace roofs with monitored access points (such as intercom entry systems) so no one without authority to enter the building can gain access to the roof.

Where the building has non-resident users taking part in an activity there (for example, office workers, gym users) access to the roof must be provided for.

Building a green roof. Laguna Lanao Gardens.

4.2
Technical aspects

To design a living terrace roof or green roof we need to understand the features of the location. This chapter explains how to assess a proposed location for a living terrace roof or green roof, bearing in its building and environmental features. It also outlines the various parameters and basic elements required for building a green roof safely and reliably.

Although this chapter has been written for situations involving already existing buildings, it could be very useful when considering a living roof for a building still at the planning stage.

The technical and environmental aspects and parameters that need to be considered are presented below.

Location and weather conditions

In the first place, the weather conditions and physical location of the roof must be taken into account, especially if the aim is to have a roof with vegetation, or create places for relaxing and sunbathing or requiring shade during the summer.

Climatological factors may vary according to a building's geographical location, its orientation and height, and even between one building and those surrounding it.

The following climatological factors need to be taken into account:

- Wind: the higher we go, the greater the wind speed, so it is important to be familiar with the usual air currents round the building to distribute the terrace roof's uses properly. For example, to put resting spaces in the most sheltered areas, and put up windscreens where necessary, using blinds or fences with vegetation.

- Rain or humidity: this is a key factor where the aim is to cover the roof with vegetation. By taking rainfall and humidity levels into account, we can choose the right vegetation and irrigation system. It is practically essential to have an irrigation system in Barcelona, as the summer months are very hot and often dry.

- Orientation and sunshine: we need to study the sunshine and how it varies throughout the year, to find out the roof's sunny and shaded areas.

This will influence not just our choice of vegetation for a roof garden or urban allotment but also any other activity intended for sunny weather. For example, if an outdoor picnic space is desired which will be functional during the summer, it is important to locate it in a shaded area or, failing that, to think up a design for providing shade.

- Temperatures: high summer temperatures in Mediterranean climates can make some uses of terrace roofs inadvisable for users at certain times of the day. Resistant vegetation should be chosen that creates shade (trees, where permitted by the roof, pergolas covered with plants, etc.) and which not only reduces the temperature of the place but also humidifies the environment. Auxiliary architectural structures (porches, etc.) should be incorporated too, or auxiliary elements used (awnings, etc.)

Structure of the building

Before we embark on designing a roof, we need to know its load-bearing capacity. A structural engineer will have to carry out a study of the materials and the state of the existing structure to calculate the weight it can support and add a structural reinforcement, if necessary. In some cases it may be that a pillar has to be added or the existing ones strengthened. In others, a structural roof may have to be built which transfers the weight to areas where there are pillars and beams that support heavier loads.

The engineer may also point out the biggest areas on the roof for locating the heavier elements at these points.

To calculate the weight that the roof with its new uses can bear, we will need to know:

- The roof's dead load: the final total weight of the built roof, including all its associated elements and components (weight of the roof system, the substrate saturated with water, the weight of the vegetation at its maximum growth, the architectural elements that might be there, paving, etc.)

- The live load: the weight of the people who will use the space and of any type of mobile equipment that may periodically be used there. For example, a lawn mower for maintaining the garden.

- Provisional load: one-off loads created by meteorological elements, basically the wind, and by snow which, while hardly a regular occurrence, cannot be ruled out.

Acoustic and heat insulation

The insulation layer serves to limit heat and noise exchanges between the roof's interior and exterior.

If we are to make the most of terrace roof alterations, it is important to improve the roof's heat insulation and thereby save on energy for heating and cooling the building's top-floor flats.

It is also important to consider proper acoustic insulation, to minimise the impact noise may have, once the terrace roof is adapted, on those who live in the flats below.

There are many types of heat and acoustic insulation on the market that can do both jobs perfectly well.

Waterproofing

Waterproofing is crucial for a living terrace roof's success. Good waterproofing will ensure there are no leaks.

When work is carried out on an old building, it is important that the roof's watertightness is inspected by a qualified professional. A good option where the waterproofing is more than ten years old is to put a new waterproofing membrane in place to ensure there are no leaks.

There are several options for waterproofing membranes on the market. The most important requirement they have to meet, besides mechanical resistance, is that they be resistant to root penetration. Hence the regular use of the term "root-repellant". To ensure they are root-repellant we recommend the use of synthetic membranes, as organic ones (asphalt or bituminous) are susceptible to piercing by roots and may be chemically unstable.

If the roof has bituminous waterproofing in good condition and the aim is to have vegetation on the roof, it is essential to separate the roof system from the waterproofing, by means of a root-repellant sheet.

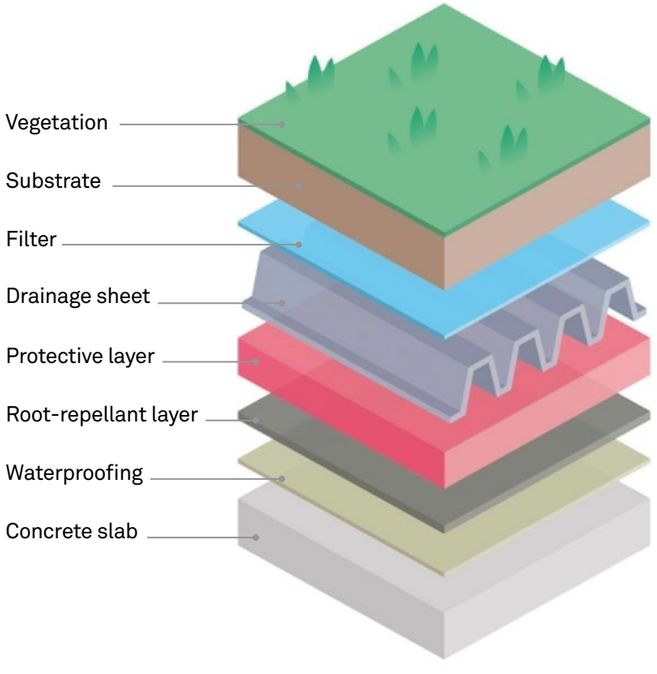
Installing a drainage board.

Green roof components

It is essential when designing and installing a green roof to provide the vegetation with a growth environment that is as similar as possible to the plant's natural environment.

So green roof systems have been developed using today's technology which aim to imitate nature through a **multi-layer building system**, where each layer included in the system meets a need shared by the plant and the entire system. In other words, it operates jointly and subsidiarily.

The following sections deal with the technical aspects of the layers that make up a green roof.



Waterproofing protection

It is important to put a protective layer in place, to prevent the waterproofing sheet from being damaged. You are advised to instal one of the following, depending on the finish (paving or green roof):

- Mortar surface over the waterproofing: in this case, the recommendation is to put a separating element between the sheet and the surface, to avoid possible damage, both mechanical and chemical, from the reaction of the cement over time as it hardens or dries. The protective layer can be a geotextile or a light plastic sheet.

- Floating surface over the waterproofing: a floating surface is understood to mean wooden or synthetic platforms that go over the cobbles or slabs placed over raised elements. In this case, the recommendation is to put a rubber sheet or a geotextile weighing over 300 g/m² between the waterproofing and the cobbles or slabs, to protect the sheet from the force of friction.

- Green roof or allotment over the waterproofing: in this situation, the layer can be used both to protect and to increase the water-storage capacity of the roof system. A synthetic cover weighing at least 44 g/m², is usually put between the green roof waterproofing sheet and drainage sheet. The protective covers have to be adapted to the green roof's future uses and the technical features varied according to use.

There is one exception: inverted roofs. Here it is advisable to use a separation layer that is permeable to water vapour, which rules out traditional geotextiles as these are not water-repellant. That way they allow the heat insulation to operate correctly.

In all cases you are advised not to use protective mortar layers owing to the possible release of carbonates and because they crack easily.

Green roof drainage sheet

This layer carries out the tasks of drainage, ventilation, water retention and protection of the waterproofing.

The layer will have different features according to the type of green roof or living terrace roof that is built. Depending on the slope of the roof, the type of vegetation chosen and the use that the terrace roof is put to (ornamental, for pedestrians, light vehicles, etc.), the type of drainage board will vary in height, drainage capacity, water-retention capacity and resistance to compression.

Drainage boards must always have openings for ventilation and water-evacuation channels, which ensure that excess water is never in permanent contact with the substrate, and thus maintain the ventilation capacity necessary for roots. Specific materials must be used for roofs, so materials designed for other uses, such as drainage boards for walls, are not suitable for these purposes.

Filters

The filtering layer is meant to prevent the substrate's fine particles from passing to the drainage layer.

It is essential to use geotextiles specifically designed for such work. You should rule out using geotextiles designed for carrying out separation on roofs without gardens, as these easily clog and the lower drainage boards collapse, so they stop working correctly.

Permeability and pore sizes are especially important features in the filtering layer.

Substrate for green roofs

Substrates are the key to good plant growth. Substrates for green roofs and terrace roofs are mixtures of specifically designed soil, which meet FLL 2008 and NTJ 11C quality criteria. You should rule out using natural soils or substrates prepared for gardening use.

The choice of substrate on a roof is extremely important. The right choice can mean the difference between the success and failure of the vegetation that is planted. It can even determine how long it might survive.

You will need to use a substrate that meets the following requirements if you are going to landscape the roof:

a) With regard to building factors it must:

- Allow drainage
- Respect the design of the building's loads
- Comply with the required protective function

b) As regards the needs of the vegetation, it must:

- Be suitable for the type of vegetation chosen
- Ensure the right functions for the vegetation's smooth development are permanently carried out
- Restrict maintenance costs during the planting stage and when the vegetation has taken root

The physical and chemical features that the technical substrates have to comply with for green roofs are clearly defined in the above-mentioned regulations and are a guarantee to the success and sustainability of green roofs and living terrace roofs.

Vegetation

The vegetation that needs to be planted on a terrace roof will depend largely on the roof's use and, therefore, the type.

Plants chosen for an ecological roof designed to suit the city's weather and natural conditions, with low maintenance and water consumption, will not be the same as for a roof garden designed for people to spend time on and enjoy, which will have more ornamental vegetation requiring more maintenance.

Chapter 5 in this guide describes the various types of green roof you can find and the types of vegetation that are associated with each of them.

Even so, there are a few general considerations that may serve as a guide for all green roofs.

When it comes to choosing vegetation, we need to take account of the following parameters so we can be sure the plants develop well:

- The roof's micro-climate: temperature, humidity, rain, sunshine levels, wind, salty winds, etc.

- The maximum thickness of the substrate the roof can bear: the load capacity, the weight that the terrace roof can support, may be a limiting factor.

- The vegetation's habitat and capacity for growth: vegetation is recommended which has shallow and horizontal root growth, as well as a slow rate of growth.

- The plants' water requirements.

In general terms, priority must be given to species that easily adapt to extreme conditions (resistant to abrupt changes in temperature, to wind, etc.) species that are resistant to disease with few nutrient requirements, that are not allergenic or toxic, that are resistant to urban pollution, have unaggressive root development (so they cannot damage the waterproofing or other building elements) and which are not invasive.

Zona Nord Library roof.

a) Succulents

b) Herbaceous perennials

c) Underground perennials and subshrubs

d) Shrubs

e) Trees and palms

Depending on the thickness of the substrate and its maintenance, and in accordance with NTJ 11C, the groups of vegetation that can be planted on a roof are as follows:

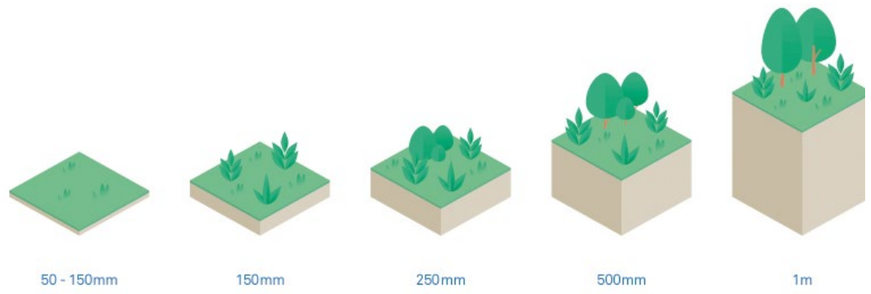
a) Succulents (plants that accumulate a large quantity of water in their leaves or stems, and which have a thick, fleshy, juicy appearance; almost all cacti and Crassulaceae).

b) Herbaceous perennials (herbaceous perennial plants that conserve their green leaves throughout the year) and true grasses.

c) Underground perennials (herbaceous plants whose parts living above ground are annual) and **subshrubs** (similar to shrubs or dwarf shrubs, generally short, which only present lignification at the base of their stems).

d) Shrubs (woody plants, generally between 1 m and 5 m high, which branch from their base and do not have a single, prevailing trunk).

e) Trees (woody plants, generally with a simple stem or trunk, often naked at the base and with a separate layer, which normally reach 5 m in their adult stage) and **palms**.



Water evacuation on the roof

A good water-evacuation system is extremely important on a terrace roof, to ensure there is an outlet for water during torrential rain, no increase in the roof load and no spills over the facade. The elements used for this purpose are as follows:

- Scuppers
- Gargoyles
- Surface channels
- Water-collecting conduits on lower-gradient levels (on sloping roofs)

The quantity of drainage elements must be calculated correctly. The parameters that need to be taken into account for producing a good design are as follows:

- Find out the maximum amount of rainfall in the shortest time possible (from historical data) and at the most unfavourable time.

- Find out the gradient of the roof, to determine what speed the water will reach, and the amount of water that can be collected in the evacuation elements.

- After analysing the above, establish the size, number and diameter of the drainage elements needed .

The drainage elements have to be recordable, in other words, they have to be easily accessible so a visual inspection can be carried out and they can be cleaned to prevent possible blockages.

It is recommended that the roof has a gradient of at least 2%, to allow the water to circulate correctly and flow to the drainage points, and that there should be no seasonal flooding points.

Drainage devices on green roofs are more complex, as they include their own evacuation elements and drainage systems.

This is a favourable point as green roofs absorb a large part of the rain water in all layers (cover, drainage sheet, substrate and vegetation) and allow the excess to flow out gradually. This makes fewer or smaller water-evacuation elements necessary and therefore reduces the costs of the collective water-evacuation system.

Surfaces and facings on the roof

The way round, living areas and access points are elements that make up a living terrace roof. These have to be included at the planning stage, to fit in with their role in the project. In the case of green roofs, paths also allow proper maintenance to be carried out without having to walk over the vegetation too much.

The same is true of other elements and accessories, such as spotlights, rubbish bins, sheds for keeping tools in and so on. Their installation on the roof has to be planned.

The following technical considerations need to be taken into account for their construction:

- Their foundations or roof attachments must not affect the water flow and must conduct water to the drainage points with the smallest gradient necessary. The best solution is to use drainage sheets, such as subbases or lost formwork (a type of formwork used for laying foundations that stays in the work instead of being removed). Drainage sheets can perform this role and allow the water to circulate throughout the roof, by protecting the waterproofing membrane and enabling water to flow correctly.

- The foundations or attachments must not damage the waterproofing, to prevent any possible water leaks. Special attention needs to be given to the buffers between the materials, to ensure their watertightness.

- The elements installed must not exceed the roof's weight limits.

Irrigation systems

It is highly recommendable for green roofs in Mediterranean areas to use an automated irrigation system, as there is usually insufficient rain during the hottest months to cover the plants' water needs.

As green roofs are highly exposed to sunlight and wind, the most advisable type of irrigation is subsurface drip irrigation. This system allows the water to be distributed in a controlled way and, being subsurface, cuts down losses through evaporation. The location of the pipes will have to be borne in mind during maintenance operations so they can be treated with care and protected from any damage.

Where it is considered necessary to use sprays or sprinklers, the wind effect must be taken into account. Wind action may cause an uneven water distribution, leading to irregular plant growth and corresponding water losses. There are irrigation system manufacturers in the market that have been developing sprays which use less pressure and emit larger and heavier water drops to minimise the wind effect.

The following factors need to be taken into account in designing a good irrigation system and calculating the water needed by the vegetation:

- Exposure to sunlight and the temperature.

- The usual forms of precipitation.

- The types of vegetation to be planted and their different water needs, so they can be compartmentalised if necessary.

- How water reaches the roof (volume flow, pressure, quality).

- The type of substrate, its thickness and its capacity for water retention and drainage.

- The total surface area to be irrigated.

With this information and professional advice, it is possible to say which type of irrigation system will be the most efficient and how often the plants will need to be watered.

It is important to use automatic programmers to ensure water is provided and the use of water or humidity sensors is highly recommended as well, to prevent the plants being watered when it rains and ensure they get just the right amount.

Whenever possible, rain water should be used for irrigating the vegetation and grey water purification systems installed so that can be reclaimed and used for irrigation too.

Inspections and monitoring of the irrigation system must be included in the planned maintenance work.

Despite the fact that ecological or biodiverse green roofs are meant to operate independently and in a sustainable way, it is important to ensure their vegetation is planted properly. That is why it is advisable to instal automatic irrigation. Irrigation doses will gradually reduce until the vegetation covers the entire roof. Back-up irrigation can always be used whenever there are dry spells.

Maintenance

We need to be aware of the roof maintenance costs, so they will have to be studied at the planning stage. That way a decision can be made on the feasibility of the given proposal.

The section on roof maintenance must set out the maintenance tasks and who will carry them out.

The following table provides a broad outline of the various elements that have to be maintained, the associated tasks and their recommended frequency.

Roof maintenance

Element groups	Maintenance tasks	Frequency
Building elements: terrace roof walls and perimeter limits, surfaces, architectural elements, waterproofing	Visual technical inspection Checking fixings Detecting possible hot spots and keeping all the roof elements in good condition. Waterproofing and arranging, where necessary	Two or three times a year
Installations: drains, irrigation system, lighting, intercom, various electrical fittings (antennas, air-conditioners, ventilation, etc.)	Visual technical inspection Checking and cleaning scuppers, gargoyles, channels, ventilation systems, skylights, etc. Inspecting, regulating and cleaning irrigation equipment Monitoring and checking lighting and other installations	Every three months
Furniture and auxiliary elements: furniture in the strict sense, lightweight pergolas, blinds, awnings, children's games, etc.	Conserving varnishes and paints Checking fixings and anchor points Visual technical inspection Cleaning	Once or twice a year
Vegetation: succulent plants, herbaceous plants, underground perennials, shrubs, trees and palms	Mowing and trimming Pruning Weeding Replacing and replanting Fertilising Disease control	Depends on the vegetation. A study must be carried out for each project
Roof	General cleaning tasks: emptying rubbish bins, cleaning surfaces	Weekly

Provision must be made for the tasks that have to be carried out by professionals and those that can be outsourced or carried out by the owners themselves.

Summary of the data required for the technical analysis of the roof

A summary of the parameters required for analysing the project's technical and environmental conditions is shown opposite. The building's residents can find some of this information on specialist websites (temperature data, precipitations, etc.) but other data will need to be studied by various professionals.

Data that have to be noted before the site can be analysed

Weather information	Maximum and minimum temperatures Annual rainfall Wind variations Effects of climatological factors which depend on the height of the building
Local environmental conditions	Possible fire risks Urban atmospheric pollution Analysis of the local vegetation Risks of plant disease and pests
Structural loads	Maximum load capacity of the roof Estimated one-off loads Estimated permanent loads
Drainage network	Drainage points Preventive measures to avoid blockages in the event of torrential rain
Roof surface area and shape	Total useful area Space available for cultivating vegetation Roof gradient Water collection and storage possibilities Quality of the existing work: state of the waterproofing, walls, safety, etc.
Access	Accessibility for people (older people, people in wheelchairs, etc.) Access for lifting and carrying up work materials, substrate, etc. Access for maintenance, safety anchor points, lifelines Installation access: water points, lights etc.

5.
WHAT TYPE OF LIVING TERRACE ROOF OR GREEN ROOF DO I WANT?

5.1
Where to start?

It is essential to know what you want to achieve, that is, the purpose of renovating the roof, as this will affect the design, construction and level of maintenance required. For example, a green roof designed for the purpose of increasing the building's aesthetic value could focus more on using species of ornamental value rather than on species with low water tolerance and low maintenance or on the value of the habitat. The same design may not be appropriate for a user aiming at low maintenance, minimising irrigation water and stimulating biodiversity.

The following points should be borne in mind: the use that will be made of the roof, the vegetation you want to use, maintenance, the irrigation and drainage available, the maximum budget, safety issues, managing the space, etc. Consideration of these issues is crucial for the success of a living terrace or green roof design.

The table on the next page is a simple guide to the various solutions, or key aspects, you need to take into account, depending on your aims. The solutions are explained in greater detail in **Chapter 5.2 Types of roofs.**

Left page: *C/ Tarragona, 173.*

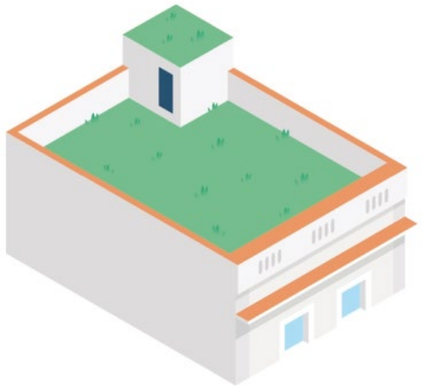
I want a roof...	Points to bear in mind	Types of roof
To improve biodiversity	Include groups of indigenous plants. Part of the substrate has to come from the habitat you want to boost. It is advisable to use elements such as rocks, trunks or bark to attract fauna.	**NATURALISED ROOF**
To save energy, for heat and acoustic insulation	Increase the depth of the substrate, instal irrigation, choose leafy plant species to provide shade in the summer.	**SEMI-INTENSIVE ROOF** **INTENSIVE ROOF**
To produce energy with solar panels or HSW panels	Choose vegetation that could cover the entire roof surface, instal irrigation, think about the panel fixing elements.	**ENERGY-GENERATING ROOF**
To store water and reduce surface runoff	Increase the depth and water-retention capacity of the substrate, use plants with high water absorption. Look for roof-building systems that can act as cisterns.	**SEMI-INTENSIVE ROOF** **INTENSIVE ROOF** **WATER-ACCUMULATING ROOF**
For recreational use (leisure, garden, activity space, rest areas, etc.)	Increase the load capacity, ensure roof access, use roof systems that can be used as if they were lost workforms and could be the base for architectural elements, furniture and other installations. Provide for the lighting, as well as the drinking and irrigation water system. Devise the perimeters and access to the roof.	**INTENSIVE ROOF** **MULTI-PURPOSE ROOF**
To create an allotment	Increase the load capacity, depth and organic content of the substrate, ensure accessibility to the roof is good and instal irrigation.	**ALLOTMENT ROOF**
To improve the city environment	Use the maximum possible roof area for vegetation.	**EXTENSIVE ROOF** **SEMI-INTENSIVE ROOF** **INTENSIVE ROOF**

Types of roofs

Pg: 46 Pg: 48 Pg: 50 Pg: 52 Pg: 54 Pg: 56 Pg: 58 Pg: 60

5.2
Types of roofs

EXTENSIVE ROOF



This is a light vegetation roof system, planted in a shallow substrate low in nutrient content. It includes vegetation with few development and maintenance requirements. It is practical, provided that paving is added to the vegetation, as the latter is not very tread-resistant.

AIMS

- Improve the city's environment
- Save the building's energy
- Reduce the building's life-cycle costs
- Acoustic insulation
- Aesthetic improvements

INDICATIVE COST

Between 70 and 90 euros/m^2, roughly. That includes: waterproofing, drainage system, substrate, vegetation and irrigation.

VEGETATION

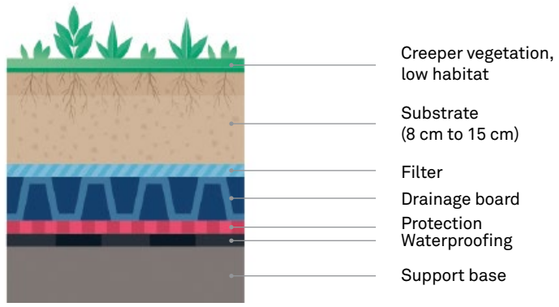
Succulent plants (most from the genus Sedum), perennial herbaceous plants, true grasses, ornamental bulbs and underground perennials.

SUBSTRATE

This is usually mineral and very porous. Its thickness varies between 8 cm and 15 cm.
It is recommended that you do not use less than 10 cm of substrate for a Mediterranean climate.

WEIGHT OF THE ROOF

Between 120 kg/m^2 and 225 kg/m^2.



MAINTENANCE

Low.
This is limited to ensuring the vegetation is properly planted: preventing unwanted plants from spreading, accurately monitoring the availability of water for the plants during the first stages of growth, monitoring and cleaning the scuppers or drainage systems to prevent blockages that lead to the accumulation of unwanted water on the roof.

IRRIGATION

Drip-irrigation systems are recommended.
Irrigation is required mainly during the planting period and it can be tapered off as the plants grow, to the point where additional irrigation is only required during periods of drought.

BUILDING SYSTEM

Owing to the thin layer of substrate and, therefore, the vegetation's exposure to extreme conditions, it is the roofs themselves that require most attention to ensure they are built correctly.
Two of the most important parameters that need to be considered are ensuring good aeration for the roots and good drainage throughout the roof. This can be achieved by designing a minimum gradient for the roof (starting from 2%) or, where that is not possible, by using draining boards of over 4 cm high and using a highly porous substrate that provides the necessary aeration and drainage.
It is important to retain the maximum quantity of water possible on such roofs, so it is advisable to use a water-retention cover and nutrients, plus a draining board that serves to store water as well as providing an air chamber and filter that separates the board from the substrate, to ensure the drainage system operates at its best.

POSSIBLE COMBINATIONS

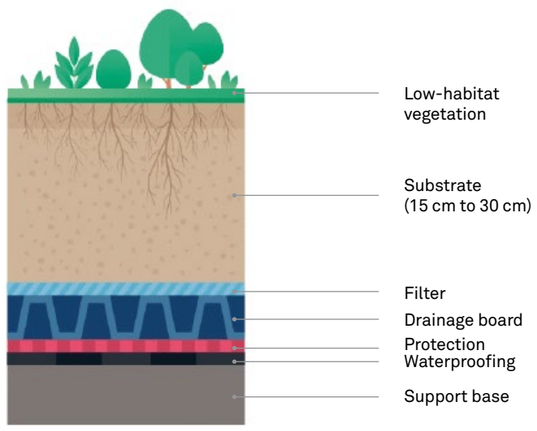
This type of roof can be combined with multi-purpose, energy-generating and allotment roofs.

SEMI-INTENSIVE ROOF

This is a green roof with features somewhere between those of an extensive roof and an intensive roof or garden. It usually has more substrate and the vegetation needs more maintenance than on extensive roofs. Despite that, the idea behind these roofs is the more independent they are the better, so Mediterranean-type vegetation well adapted to our area is usually planted on them. This type of roof allows a more elaborate design than the ones used for extensive roofs, with more aesthetic compositions, by playing with the colour bands, volume, shapes, etc., of the vegetation.
These are roofs where people can move around and, therefore, easier to combine with leisure areas.

AIMS

- Improve the city's environment
- Save the building's energy and collect water
- Reduce the building's life-cycle costs
- Acoustic insulation
- Aesthetic improvements
- Recreational use, people can walk around there and spaces can be included for leisure

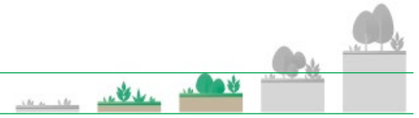


INDICATIVE COST

Between 90 and 130 euros/m^2, roughly. That includes: waterproofing, drainage system, substrate, vegetation and irrigation.

VEGETATION

Herbaceous, aromatic, bulbous, creeper and low-habitat shrub plants.



SUBSTRATE

This is usually mineral and porous.
Its thickness varies between 15 cm and 30 cm.
The percentage of organic material is higher than it is for the substrate on extensive roofs.

WEIGHT OF THE ROOF

Between 150 kg/m^2 and 450 kg/m^2.

MAINTENANCE

Moderate.
This will depend a lot on the type of vegetation.
Maintenance will include removing unwanted plants and checking the irrigation system.
Occasional use of fertilisers, trimming and pruning, phytosanitary control, etc.
As with all roofs, it is also important to check the drain pipes to prevent blockages in the water-evacuation system.

IRRIGATION

It is advisable to use a drip-irrigation system.
These roofs require very little water. Once the vegetation has taken root, it will only need to be irrigated twice a month during the spring and autumn and once or twice a week during the summer. This will depend on the location of the roof, the species planted and the weather conditions.

BUILDING SYSTEM

Water retention is just as important on semi-intensive roofs as it is on extensive roofs to keep the irrigation needed to a minimum and to ensure sufficient aeration for the plants. That is why it is advisable to use a water-retention cover, a drainage board that also stores water while providing an air chamber, and a filer that separates the drainage board from the substrate, to ensure the drainage system operates at its best. The drainage boards are nearly 4 cm higher than those on extensive roofs, owing to the different vegetational requirements. Semi-intensive roofs need more water storage and air space.

POSSIBLE COMBINATIONS

This type of roof can be combined with multi-purpose, energy-generating and allotment roofs.

INTENSIVE ROOF

Intensive green roofs or roof gardens offer users the kind of benefits expected from a garden. They are specially designed for recreational use and may have elements such as lighting, water sheets, cascades, paths for people, pergolas, children's games, various surfaces, furniture and high-habitat vegetation (trees, palms, etc.)

AIMS

- Improve the city's environment
- Save the building's energy and collect water
- Reduce the building's life-cycle costs
- Acoustic insulation
- Aesthetic improvements
- Recreational use, people can walk around and spaces can be included for leisure

INDICATIVE COST

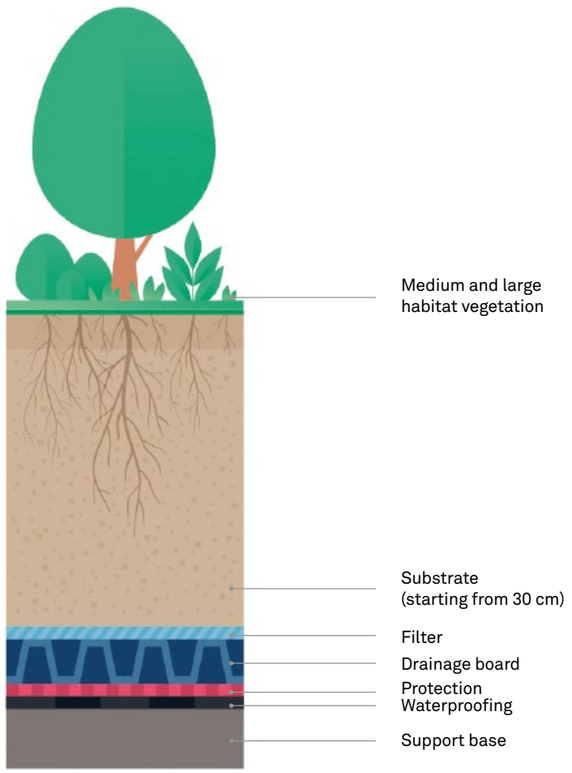
From 150 €/m^2.
It is difficult to give a fixed price, as it will depend on the roof's design and uses.

SUBSTRATE

This has a mineral and porous part and a considerable organic-matter part, as the vegetation has more nutrient requirements.
The substrate's thickness varies from 30 cm to 100 cm.

VEGETATION

Herbaceous, aromatic, bulbous, creeper and low-habitat shrub plants, trees and palms.



WEIGHT OF THE ROOF

From 650 kg/m^2.

MAINTENANCE

High.
This will depend a lot on the type of vegetation that is planted, though generally it will require the same maintenance as an intensive garden.
Maintenance will include removing unwanted plants and checking the irrigation system, using fertiliser, trimming and pruning, phytosanitary control and treatment, mowing, cleaning paved surfaces, the upkeep of furniture, paving, tiling, structures, water installations and lighting.
As with all roofs, it is also important to check the drain pipes to prevent blockages in the water-evacuation system.

IRRIGATION

It is advisable to use subsurface drip-irrigation systems, though spray or sprinkler irrigation is sometimes used for grass.
Watering will depend a lot on the vegetation, the roof's location and weather conditions.
It is a good idea to put hydrants on the roof so a hose can be used to make cleaning paved surfaces, furniture and other installations easier.

BUILDING SYSTEM

Protective and water-retention sheets are more resistant on intensive roofs than in the two previous cases, as they have to support more weight and the action of the vegetation's roots is more aggressive. The drainage sheet has to be higher to provide more air for the roots and avoid asphyxiation problems. Sheets ranging from 4 cm to 6 cm in height are usually laid. The combination of these two layers, along with the thickness of the substrate, results in better water storage on the roof.

POSSIBLE COMBINATIONS

This type of roof can be combined with multi-purpose, energy-generating, allotment and cistern roofs.

NATURALISED ROOF

A naturalised or biodiverse roof falls under the extensive or semi-intensive category, though they are specifically designed for fostering the habitat of certain flora and fauna. Their purpose is to create a habitat with indigenous flora and fauna. They could be used as fauna connectors between several green spaces.

AIMS

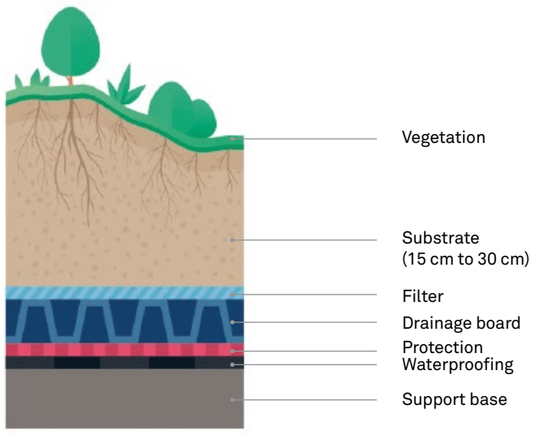
- Increase biodiversity
- Reclaim habitats damaged by construction
- Improve the city's environment
- Save the building's energy and collect water
- Reduce the building's life-cycle costs
- Acoustic insulation
- Aesthetic improvements

INDICATIVE COST

Similar to that for extensive or semi-intensive roofs. Between 70 € and 130 €/m^2.

VEGETATION

Indigenous species are usually used, communities that belong to the local plant communities.
Some indigenous species may be replaced by non-indigenous ones with similar features to achieve the same effect of increasing the city's faunal biodiversity.
Herbaceous, aromatic, bulbous, creeper and low-habitat shrub plants.



SUBSTRATE

The substrate usually used has features somewhere between those of extensive and semi-intensive roofs. Where possible, part of the area's natural soil is mixed with the technical substrate of extensive roofs. The thickness will vary from 15 cm to 30 cm.

WEIGHT OF THE ROOF

The roof's weight is between 200 kg/m^2 and 450 kg/m^2.

MAINTENANCE

Low.
This is limited to ensuring the vegetation is properly planted: accurate monitoring of the availability of water for plants in their first stages of development.
Monitoring and cleaning scuppers and drainage systems to prevent blockages that can

IRRIGATION

Drip-irrigation systems are recommended.
Irrigation is needed above all during the planting period and it can be tapered off as the plants grow, with back-up irrigation required only during periods of drought.

BUILDING SYSTEM

The same technical considerations need to be taken into account as those for extensive and semi-intensive roofs.
It is a good idea to include different elements such as trunks, mulch, stones and decomposing branches, to entice the fauna.

POSSIBLE COMBINATIONS

This type of roof can be combined with energy-generating roofs.

ALLOTMENT ROOF

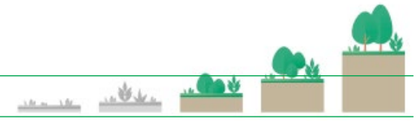
This is a type of roof that specialises in producing food. It is defined as intensive, as it requires a large amount of water and nutrients as well as high maintenance.
An allotment on a terrace roof can be designed in several ways, depending on the role of the area that it occupies on the roof. One could be to dedicate the entire surface area to the allotment (with the exception of access points, paths, resting areas, a place for leaving tools, etc.), using intensive roof building systems. And another could be to assign one part of the roof to this role, using planter boxes or containers, and the rest to other functions.
In both cases, the recommendations in the point on technical aspects must be followed and, where plant pots or boxes are installed, it is important to stress the need for root-repellant waterproofing, even if this only affects a few areas of the roof. Roots could break through the pot, the paved surface and reach the waterproofing layer.

AIMS

- Improve the city's environment
- Save the building's energy and collect water
- Reduce the building's life-cycle costs
- Acoustic insulation
- Create resources and self-employment
- Contribute towards food and nutrition security
- Recycle compost
- Environmental education, to revive farming expertise
- Encourage participation, working together and inter-generational relations

INDICATIVE COST

From €120/m^2, but this will depend a lot on the substrate.



VEGETATION

Garden, aromatic and medicinal plants, fruit trees.

WEIGHT OF THE ROOF

From 450 kg/m^2.

SUBSTRATE

Partly mineral and porous (to provide aeration and good drainage) and partly organic matter (to provide the vegetation with the necessary nutrients for their proper growth). It is important to include a technical roof substrate.
Fertiliser will need to added to the substrate periodically to keep it fertile over the years.
The substrate's thickness will range from 30 cm to 40 cm, and may reach 60 cm where fruit trees are planted.

MAINTENANCE

High.
The tasks that have to be carried out are the ones you would expect with any horticultural activity.
They include planting, removing unwanted plants, adapting and monitoring the irrigation system, adding fertiliser, organic fertiliser, phytosanitary control and treatment, digging and shallow digging, pruning and trimming, collecting, and cleaning the paths.
As with all roofs, it is also important to check the drain pipes to prevent blockages in the water-evacuation system.

IRRIGATION

It is advisable to use subsurface drip-irrigation systems, to avoid damaging them during the various jobs carried out in the allotment, and to instal hydrants.
It is also important to design a system that allows the drip mechanisms to adapt to several distances, as there are rotation systems in an allotment that can change the distance between the necessary drips.
Watering will depend a lot what is planted on the roof, the roof's location and the weather conditions.

BUILDING SYSTEM

The same scheme as for intensive roofs. The design for the allotment perimeter has to take account of the paths, to bridge the gap between the vegetation area, which will be at least 30 cm high, and the path area, which may be 8 cm high in total. It is advisable to consider spaces in the design where a shed for tools and materials can be located, as well as areas with benches, water points that can be connected to hoses, and an area for producing compost.

POSSIBLE COMBINATIONS

This type of roof can be combined with multi-purpose, energy-generating, semi-intensive and cistern roofs.

WATER-ACCUMULATING ROOF

Water-accumulating roofs are designed for collecting and storing rain water for a variety of uses: irrigating allotments and landscaped areas, cleaning and flushing toilets. That implies cutting the demand for drinking water and improving self-sufficiency in cities.

There are several options for storing rain water:

a) Tank: water is collected by scuppers and drainage channels, filtered and conveyed to a tank on the roof or in another place (underground), and redirected from there depending on its intended use.

b) Cistern: this exploits the roof's entire surface as a tank for storing water, which is passed through a filter and redirected according to its intended use.
Excess water in these two options ends up in the sewerage system.

c) Cistern roof garden: this consists of a roof garden (extensive, semi-intensive or intensive) built with a drainage system that makes it possible to have a water tank covering the entire roof which provides water for the plants, through capillary action or the irrigation system pump.

That way water can be collected by means of the green roof itself (absorbed by the vegetation, substrate and other layers) and stored in the cistern. The green roof operates as a filter.

d) Cistern roof garden + tank: this is a combination of the first and third options that allows any excess water to end up in the water-collecting tank.

This is a very good option, given our climate conditions, with torrential rains and occasional large amounts of rain, as it enables the maximum amount of water possible to be collected.

INDICATIVE COST

Costs vary according to the various options, the roof's surface area, the quantity of water intended for collection and the system for reusing this water you want to install.

POSSIBLE COMBINATIONS

This type of roof can be combined with multi-purpose, energy-generating and allotment roofs.

Green roof with cistern. Fàbrica del Sol, Pg. Salvat Papasseit, nº 1.

Detail of the cistern.

ENERGY-GENERATING ROOF

Energy-generating roofs are designed for installing equipment that generates solar thermal or solar photovoltaic energy.

Terrace roofs, owing to their location and exposure to many hours of sunshine, are one of the best places for installing such equipment.

There are three options for installing solar or HSW (hot sanitary water) panels on the roof.

a) Instal them directly on the roof surface, on the existing surface, with the inevitable perforation of the waterproofing (increasing the risk of possible leaks).

b) Instal them on an element such as a porch or pergola, to double the roof's useful area (adding a shaded area to hold activities).

c) Instal them on an extensive green roof. In this case there will be no need to perforate the waterproofing, as there are bases for solar and HSW panels on the market that are balanced with the weight of the green-roof system.

Solar panels installed on a green roof can produce up to 16% more energy, as the plants there act as a natural cooling system for the panels. Evaporation from the roof's vegetation reduces the surrounding air temperature, which benefits the solar panels and prevents their performance falling when the ambient temperature rises above 25 ºC.

Another unique feature in this alliance is that green roofs help to remove pollutants from the air, because they prevent suspended particles from latching on to solar panels.

They also help with maintenance by enabling the panels to absorb more solar light and generate more energy. The same applies to HSW panels.

Mediatic Building. © Quico Domingo

Multi-purpose roofs are the most usual type for terrace roofs belonging to communities of residents because, as explained in section 5.1 on social aspects, a living terrace roof will be successful when the activities that take place there reflect all the needs of the building's residents.

AIMS

- Improve the city's environment
- Save the building's energy and collect water
- Reduce the building's life-cycle costs
- Acoustic insulation
- Aesthetic improvements
- Recreational use, people can walk round and spaces can be incorporated for leisure, children's games and relaxing in.
- Environmental education
- Encourage participation, working together and inter-generational relations
- Produce food

DESIGN

A good plan and design are required from the very beginning.

The following aspects need to be defined:

a) The uses, linked to the users' aims and needs.

b) The aesthetic or formal design, to give the whole roof a consistent and meaningful aesthetic which makes spending time there a pleasant experience. That means establishing the relationship between the various parts of the roof: routes or paths, access, as well as the visual relationships between the various activities that will take place there (if you want a visual relationship, rather than separating them). Basically, the landscape design.

c) The building elements intended for the roof, the surfaces, sheds, etc.

d) The design of the water, electrical, water-collection and other systems. It is necessary to establish where each group will go and do the necessary inspections.

e) The roof building system. Choose the best way to build the roof to so that it includes the results of the technical aspects analysed, ensures watertight waterproofing and proper water drainage, respects the maximum load that the roof can bear, etc. Consideration should be given to whether it is best to opt for a single building system or combine two or more systems.

f) The choice of vegetation and grouping it according to its water needs, exposure to the sun, aesthetic composition and functional needs.

g) The location and choice of auxiliary elements: type of furniture, pergolas, awnings, rubbish bins, etc.

MAINTENANCE

Maintenance will be high, moderate or low according to the roof's uses and design. In any event, planning must be made for each of the points described in the section on maintenance.

Pau Claris street.

6.
WHO DO YOU NEED TO CONTACT FOR BUILDING A ROOF?

Various people are involved in making the transformation of an inert roof into a living terrace roof or green roof possible.

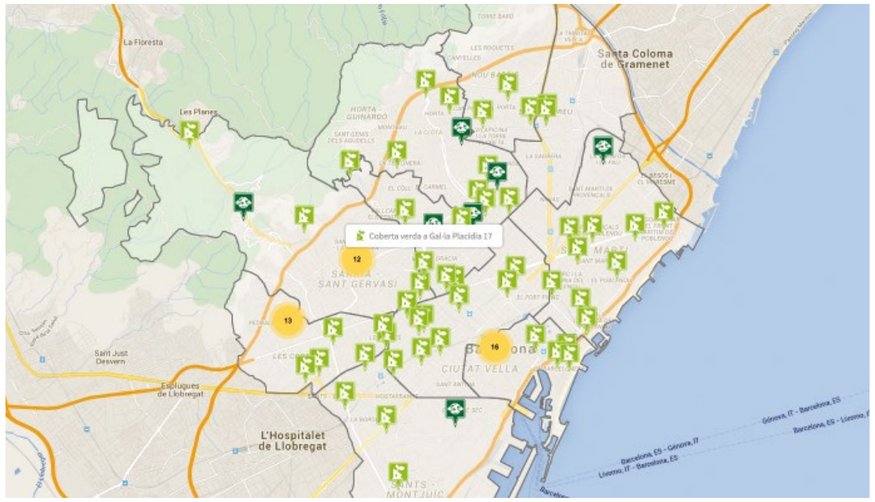
This chapter tells you who the main players involved in designing and building a redeveloped roof are, how to contact the various professional bodies and associations, and gives you links relating to this subject.

Barcelona City Council offers advice on creating living terrace roofs and green roofs, and on the procedure for obtaining grants and subsidies, through the Municipal Institute for Urban Landscape and Quality of Life (IMPUQV), which has an office that specialises in offering support to professionals, and through a housing office network (there is an office in each district) that deals with the public and provides information on the various grant and subsidy campaigns for redevelopments in progress.

For further information: **www.ajuntament.barcelona.cat/ecologiaurbana**

Barcelona also has the **More Sustainable Barcelona Map**, a tool that provides practical information on places of environmental, cultural and social heritage interest, from a sustainability perspective, as well as the current experiences, initiatives and resources in the city that help to improve the urban environment, build a fairer and more inclusive social structure and enrich the community and neighbourhood fabric.

Compiled jointly by the public, companies, associations and the authorities, the map enables users to locate, for example, the city's green roofs and add new ones.



Take part: **www.bcnsostenible.cat**

Left page: *Green roof at the Joan Maragall Library.*

6.1
Professionals

Involved in planning and management

Architect or landscape gardener
- Designs the project, works with the client or user, establishes the distribution of spaces, vegetation, materials, etc. Defines the work consignments and their planning, with management and future maintenance included
- Coordinates and plans the work and building permits
- Reviews the process and inspects the building

Building or structural engineer
- Examines the current building or proposed design for a new building, to determine whether its structural elements are the most appropriate
- Works in coordination with the architect or landscape gardener

Participatory process facilitator or mediator
- Provides tools for establishing a smooth dialogue between the between the various parties, to take decisions and encourage agreements, for the purpose of reaching a consensus in the living terrace roof's design resulting from the residents' participation

Property manager
- Supports the owners or community of residents in processes relating to actions in the buildings (work, maintenance, taxes, grants and subsidies, etc.)
- Is very often the mediator between owners and tenants
- Advises community of property owner committees on all the processes

Involved in the roof's construction

Construction companies
- Construct the building or instal the structural reinforcement necessary for supporting the new uses of the living terrace roof or green roof
- Instal work elements included in the project: surfaces, walls, furniture fixings

Waterproofing and insulation companies
- Waterproof the roof and advise the architect on the finishes and on how to coordinate work elements and waterproofing
- Offer guaranteed watertightness
- Instal acoustic and heat insulation

Gardening companies specialising in green roofs
- Develop the landscape project
- Design and instal the irrigation system
- Provide advice on the appropriate substrate
- Recommend the most suitable vegetation for the roof
- Provide the architect with advice on green roof systems
- Supply and instal all the green roof elements: protection and retention cover, drainage sheet, filters, substrate and vegetation
- Advise on long-term maintenance and management

Lighting installation companies
- Advise the architect on the lighting design
- Instal the electrical system and lighting

Renewable energy installers
- Design and calculate the renewable energy, solar, thermal and wind-turbine facilities
- Instal the various elements

Suppliers and manufacturers of special green roof materials
- Advise the architect or landscape gardener and the gardeners
- Examine efficient green-roof systems for our climate
- Supply the necessary material for the roof

Suppliers and manufacturers of specific waterproofing materials
- Advise the architect or landscape gardener and the waterproofers
- Supply the necessary material for the roof

Plant nurseries that produce plants for green roofs
- Study vegetation adapted to our weather conditions that adapts well to green roofs
- Produce vegetation in optimal condition for planting on green roofs
- Inform and advise the gardeners

Involved in roof maintenance

Gardening and cleaning companies
- Clean the terrace roof and carry out maintenance tasks relating to the vegetation, irrigation system and water-evacuation system

Renewable energy companies
- Maintain the solar or HSW panels in accordance with the current law and needs of the building

Facility companies
- Maintain the facilities in accordance with the current law and needs of the building

Property managers
- Supervise the contractors' maintenance
- Negotiate and manage contract agreements

Communities of property owners
- Negotiate and manage contract agreements
- Allocate the budget and resources for maintenance activities

Useful links

Spanish Green Roofs Association (ASESCUVE). www.asescuve.org
Spanish Landscape Gardeners' Association (AEP). www.aepaisajistas.org
Barcelona-Lleida Property Managers' Association (CAFBL). www.cafbl.cat
Catalan Environmentalists' Association (COAMB). www.coamb.cat
Barcelona Association of Quantity Surveyors and Building Engineers (CAATEEB). www.apabcn.cat
Catalan Architects' Association (COAC). www.arquitectes.cat
Catalan Biologists' Association. www.cbiolegs.cat
Official Catalan Agronomic Engineers' Association. www.agronoms.org
Catalan Association of Agricultural Engineers and Agriculturalists. www.agricoles.org
Gardening and Landscape Foundation (FJIP). www.fjip-ntj.org

Right page: *Municipal Institute of Urban Landscape and Quality of Life* © MarcoPinarelli.

7.
ANNEXES

7.1
Vegetation

Recommended species for extensive green roofs, taken from the Technological Gardening Regulations (NTJ) 11C.
Special landscapes. Green roofs. Gardening and Landscape Foundation.

KEYS
(1) Scientific name: nomenclature according to the Index of Garden Plants (The New Royal Horticultural Society Dictionary).
(2) Group: hc = herbaceous cespitosa; hp = herbaceous perennial; ps = succulent plant; pv = underground perennial; sa = subshrub or dwarf shrub.
(3) Climatic region: AT = Atlantic; MC = Continental Mediterranean; ML = Coastal Mediterranean; SA = Subalpine.
(4) Exposure to sunlight: ○ = Full sun; ⦿ = Half shade; ● = Full shade.

Scientific name (1)	Synonyms	Family	Group (2)	Height (cm)	Climatic region (3)	Exposure to sunlight (4)
Aeonium canariense		Crassulaceae	ps	20-35	ML	○
Aeonium sedifolium		Crassulaceae	ps	15-40	ML	○
Aethionema grandiflorum		Brassicaceae	sa	15-30	AT, MC, ML	○
Ajania pacifica	*Chrysanthemum pacificum, Dendranthema pacificum*	Asteraceae	sa	30-40	AT, MC, ML	○
Allium sphaerocephalon		Liliaceae	pv	30-80	AT, MC, ML, SA	○
Aloe saponaria		Aloaceae	ps	40-70	ML	○
Aphyllanthes monspeliensis		Liliaceae	hc	10-40	AT, MC, ML	○
Aptenia cordifolia		Aizoaceae	ps	5	ML	○⦿
Arenaria balearica		Caryophyllaceae	hp	1-10	AT, ML	⦿
Argyrolobium zanonii		Fabaceae	sa	10-30	AT, MC, ML	○
Asparagus densiflorus	*A. sprengeri*	Liliaceae	hp	40-60	AT, ML	○⦿
Aster sedifolius		Asteraceae	pv	20-50	AT, MC, ML, SA	⦿
Asteriscus maritimus		Asteraceae	sa	10-40	ML	○
Astragalus massiliensis	*A. tragacantha*	Fabaceae	sa	10-30	ML	○
Ballota pseudodictamnus		Lamiaceae	sa	30-50	AT, MC, ML	○
Brachypodium phoenicoides		Poaceae	hc	30-80	MC, ML	○
Brachypodium retusum		Poaceae	hc	20-60	MC, ML	○
Brachyscome multifida		Asteraceae	hp	15-30	ML	○
Camphorosma monspeliaca		Chenopodiaceae	sa	10-60	MC, ML	○
Capparis spinosa		Capparaceae	sa	30-50	ML	○
Carpobrotus acinaciformis		Aizoaceae	ps	10-20	ML	○
Carpobrotus edulis		Aizoaceae	ps	10-20	ML	○
Centaurea cineraria	*C. candidissima*	Asteraceae	hp	30-80	AT, MC, ML	○
Centranthus ruber		Valerianaceae	hp/pv	-60	AT, MC, ML	○⦿
Cephalophyllum alstonii		Aizoaceae	ps	7-12	ML	○
Cineraria saxifraga	*Senecio saxifraga*	Asteraceae	hp	20-30	ML	○⦿
Cistus salviifolius		Cistaceae	sa	20-70	AT, MC, ML	○⦿
Convolvulus cneorum		Convolvulaceae	sa	10-60	AT, MC, ML	○
Convolvulus sabatius	*C. mauritanicus*	Convolvulaceae	hp	10-15	AT, MC, ML	○
Coris monspeliensis		Primulaceae	sa	10-35	MC, ML	○

Scientific name (1)	Synonyms	Family	Group (2)	Height (cm)	Climatic region (3)	Exposure to sunlight (4)
Coronilla minima		Fabaceae	sa	10-50	AT, MC, ML	○
Cotyledon tomentosa		Crassulaceae	ps	30-50	ML	○
Crassula lactea		Crassulaceae	ps	15-30	ML	○
Crassula marnieriana		Crassulaceae	ps	-50	ML	○
Crassula multicava		Crassulaceae	ps	15-40	ML	○◉
Crassula muscosa	*C. lycopodioides*	Crassulaceae	ps	10-50	ML	○◉
Crassula radicans		Crassulaceae	ps	5-15	ML	○
Cyanotis somaliensis		Commelinaceae	hp	15-20	ML	○
Delosperma cooperi		Aizoaceae	ps	5-10	AT, MC, ML	○
Delosperma lineare		Aizoaceae	ps	5-18	ML	○
Dicliptera suberecta	*Jacobinia suberecta*	Acanthaceae	hp	40-60	AT, ML	○◉
Disphyma crassifolium		Aizoaceae	ps	5-10	ML	○
Dorycnium hirsutum	*Lotus hirsutus*	Fabaceae	sa	20-60	MC, ML	○
Drosanthemum floribundum		Aizoaceae	ps	10-15	ML	○
Drosanthemum hispidum		Aizoaceae	ps	15-20	ML	○
Echeveria elegans		Crassulaceae	ps	3-5	ML	○◉
Einadia nutans	*Rhagodia nutans*	Chenopodiaceae	hp	5-25	ML	○◉
Erigeron karvinskianus		Asteraceae	hp	15-30	AT, MC, ML	○◉
Euphorbia resinifera		Euphorbiaceae	ps	40-60	ML	○◉
Faucaria trigrina		Aizoaceae	ps	10-15	ML	○◉
Felicia amelloides		Asteraceae	sa	30-60	AT, ML	○◉
Fenestraria rhopalophylla		Aizoaceae	ps	5	ML	○
Festuca glauca		Poaceae	hc	15-45	AT, MC, ML, SA	○
Frankenia laevis		Frankeniaceae	sa	5-15	AT, MC, ML	○
Frankenia thymifolia		Frankeniaceae	sa	5-30	MC, ML	○
Gasteria acinacifolia		Aloaceae	ps	-35	ML	○◉
Gazania rigens		Asteraceae	hp	-30	AT, ML	○
Glottiphyllum linguiforme		Aizoaceae	ps	5-10	ML	○
Graptopetalum paraguayense		Crassulaceae	ps	20-30	ML	○◉
Halimione portulacoides	*Atriplex portulacoides*	Chenopodiaceae	sa	20-80	AT, ML	○
Haworthia fasciata		Aloaceae	ps	5-15	ML	◉
Helianthemum apenninum		Cistaceae	sa	10-50	AT, MC, ML, SA	○
Helichrysum petiolare	*H. petiolatum*	Asteraceae	sa	40-60	AT, ML	○
Helichrysum rupestre		Asteraceae	sa	10-60	ML	○
Helichrysum stoechas		Asteraceae	sa	10-50	AT, MC, ML	○
Heliotropium amplexicaule	*H. anchusifolium*	Boraginaceae	pv	10-30	ML	○
Hippocrepis balearica		Fabaceae	sa	20-50	ML	○
Hippocrepis comosa		Fabaceae	sa	10-40	AT, MC, ML, SA	○◉
Hypericum ericoides		Clusiaceae	sa	5-40	ML	○
Hypericum olympicum	*H. polyphyllum*	Clusiaceae	sa	10-25	AT, MC, ML, SA	○
Iberis semperflorens		Brassicaceae	sa	30-50	AT, MC, ML	○
Isotoma axillaris	*Solenopsis axillaris*	Campanulaceae	hp	30-35	ML	○
Jovibarba hirta	*Sempervivum hirtum*	Crassulaceae	ps	2-5	AT, MC, ML	○
Kalanchoe delagonensis	*K. tubiflora*	Crassulaceae	ps	30-80	ML	○
Kalanchoe fedtschenkoi		Crassulaceae	ps	20-50	ML	○
Kalanchoe tomentosa		Crassulaceae	ps	-50	ML	○
Lampranthus aurantiacus		Aizoaceae	ps	-50	ML	○
Lampranthus blandus		Aizoaceae	ps	25	ML	○

Scientific name (1)	Synonyms	Family	Group (2)	Height (cm)	Climatic region (3)	Exposure to sunlight (4)
Lampranthus deltoides	*Oscularia deltoides*	Aizoaceae	ps	5-35	ML	○
Lampranthus spectabilis		Aizoaceae	ps	25-30	ML	○
Limonium caesium		Plumbaginaceae	hp	20-60	MC, ML	○
Limonium pectinatum		Plumbaginaceae	sa	30-50	ML	○
Linum suffruticosum	*L. tenuifolium ssp. suffruticosum*	Linaceae	sa	5-50	MC, ML	○
Lobularia maritima	*Alyssum maritimum*	Brassicaceae	pv	5-40	AT, MC, ML	○
Lotus berthelotii	*L. peliorhynchus*	Fabaceae	sa	10-30	ML	○
Lotus creticus		Fabaceae	sa	30-60	ML	○
Lotus cytisoides	*L. creticus ssp. cytisoides*	Fabaceae	sa	10-50	ML	○
Lotus sessilifolius		Fabaceae	sa	5-10	ML	○
Lygeum spartum		Poaceae	hc	40-70	MC, ML	○
Medicago marina		Fabaceae	hp	20-50	AT, ML	○
Micromeria juliana		Lamiaceae	sa	10-40	AT, MC, ML	○◉
Oenothera macrocarpa	*O. missouriensis*	Onagraceae	hp/pv	15-20	AT, MC, ML, SA	○◉
Ononis natrix		Fabaceae	sa	15-50	AT, MC, ML	○
Opuntia compressa	*O. humifusa*	Cactaceae	ps	10-30	MC, ML	○
Osteospermum barberiae		Asteraceae	hp	10-50	AT, ML	○
Osteospermum fruticosum		Asteraceae	sa	30-60	AT, ML	○
Otanthus maritimus	*Diotis maritima*	Asteraceae	hp	-50	AT, ML	○
Othonna cheirifolia	*Othonnopsis cheirifolia*	Asteraceae	sa	25-40	AT, ML	○
Pachyphytum oviferum		Crassulaceae	ps	10-12	ML	○
Paronychia argentea		Caryophyllaceae	hp	10-30	AT, MC, ML	○
Pelargonium x fragrans		Geraniaceae	sa	20-45	ML	○
Pelargonium peltatum		Geraniaceae	sa	15-40	AT, ML	○
Petrorhagia saxifraga		Caryophyllaceae	hp	10-20	AT, ML, SA	○
Phagnalon saxatile		Asteraceae	sa	10-40	AT, MC, ML	○
Phlomis italica		Lamiaceae	sa	20-60	ML	○
Phlomis lychnitis		Lamiaceae	sa	20-50	AT, MC, ML	○
Phyla nodiflora	*Lippia nodiflora*	Verbenaceae	hp	3-15	ML	○◉
Plantago albicans		Plantaginaceae	hp	10-40	MC, ML	○
Polygonum capitatum	*Persicaria capitata*	Polygonaceae	hp/pv	7-10	AT, MC, ML, SA	○◉
Putoria calabrica		Rubiaceae	sa	8-20	ML	○
Rhodanthemum hosmariense	*Leucanthemum hosmariense*	Asteraceae	sa	10-30	ML	○
Rhombophyllum rhomboideum		Aizoaceae	ps	5	ML	○
Rosularia aizoon	*R. pallida*	Crassulaceae	ps	10-15	AT, MC, ML	○
Ruschia prostrata		Aizoaceae	ps	5-7	ML	○
Ruschia tumidula		Aizoaceae	ps	-60	ML	○
Salvia lavandulifolia	*S. officinalis ssp. lavandulifolia*	Lamiaceae	sa	20-50	AT, MC, ML	○◉
Santolina chamaecyparissus		Asteraceae	sa	10-50	AT, MC, ML	○
Satureja montana		Lamiaceae	sa	10-40	AT, MC, ML, SA	○◉
Scabiosa farinosa		Dipsacaceae	sa	30-50	ML	○◉
Scutellaria orientalis		Lamiaceae	sa	7-25	AT, MC, ML	○
Sedum album		Crassulaceae	ps	5-10	AT, MC, ML, SA	○
Sedum dasyphyllum		Crassulaceae	ps	2-5	AT, MC, ML, SA	○◉
Sedum floriferum		Crassulaceae	ps	10-15	AT, MC, ML	○
Sedum forsterianum		Crassulaceae	ps	10-30	AT, MC, ML	○

Scientific name (1)	Synonyms	Family	Group (2)	Height (cm)	Climatic region (3)	Exposure to sunlight (4)
Sedum hybridum		Crassulaceae	ps	5-10	AT, MC, ML	○
Sedum lydium		Crassulaceae	ps	3-10	AT, MC, ML	○
Sedum nussbaumerianum		Crassulaceae	ps	-15	ML	○
Sedum oreganum		Crassulaceae	ps	-15	AT, MC, ML, SA	○
Sedum pachyphyllum		Crassulaceae	ps	20-30	AT, ML	○
Sedum palmeri		Crassulaceae	ps	10-20	AT, MC, ML	○◉
Sedum praealtum		Crassulaceae	ps	30-60	AT, MC, ML	○
Sedum rubrotinctum		Crassulaceae	ps	15-25	ML	○
Sedum rupestre	*S. reflexum*	Crassulaceae	ps	10-30	AT, MC, ML, SA	○◉
Sedum sediforme		Crassulaceae	ps	15-60	AT, MC, ML	○
Sedum sexangulare		Crassulaceae	ps	5-10	AT, MC, ML	○
Sedum spathulifolium		Crassulaceae	ps	5-10	AT, MC, ML	○
Sedum spectabile	*Hylotelephium spectabile*	Crassulaceae	ps/pv	30-40	AT, MC, SA	○
Sedum spurium		Crassulaceae	ps/pv	5-15	AT, MC, ML	○
Sempervivum tectorum		Crassulaceae	ps	10-15	AT, MC, ML, SA	○
Senecio mandraliscae	*Kleinia mandraliscae*	Asteraceae	ps	15-30	ML	○
Senecio mauritianus		Asteraceae	sa	25-40	AT, ML	◉
Senecio rowleyanus		Asteraceae	ps	5-20	ML	○
Senecio viravira	*S. leucostachys*	Asteraceae	sa	30-60	AT, ML	○
Sideritis hirsuta		Lamiaceae	sa	10-50	AT, MC, ML	○◉
Staehelina dubia		Asteraceae	sa	10-40	MC, ML	○
Tanacetum ptarmiciflorum		Asteraceae	sa	40-60	AT, ML	○
Teucrium chamaedrys		Lamiaceae	sa	10-20	AT, MC, ML, SA	○◉
Teucrium polium		Lamiaceae	sa	10-45	AT, MC, ML	○
Thymus x citriodorus		Lamiaceae	sa	25-35	AT, MC, ML	○
Thymus pseudolanuginosus		Lamiaceae	sa	3-5	AT, MC, ML, SA	○◉
Thymus vulgaris		Lamiaceae	sa	15-30	AT, MC, ML	○
Thymus zygis		Lamiaceae	sa	10-30	MC, ML	○
Verbena peruviana		Verbenaceae	hp	7-15	AT, ML	○
Verbena tenera		Verbenaceae	hp	8-20	AT, ML	○◉
Zephyranthes grandiflora		Amaryllidaceae	pv	5-30	AT, ML	○◉

8.
BIBLIOGRAPHY

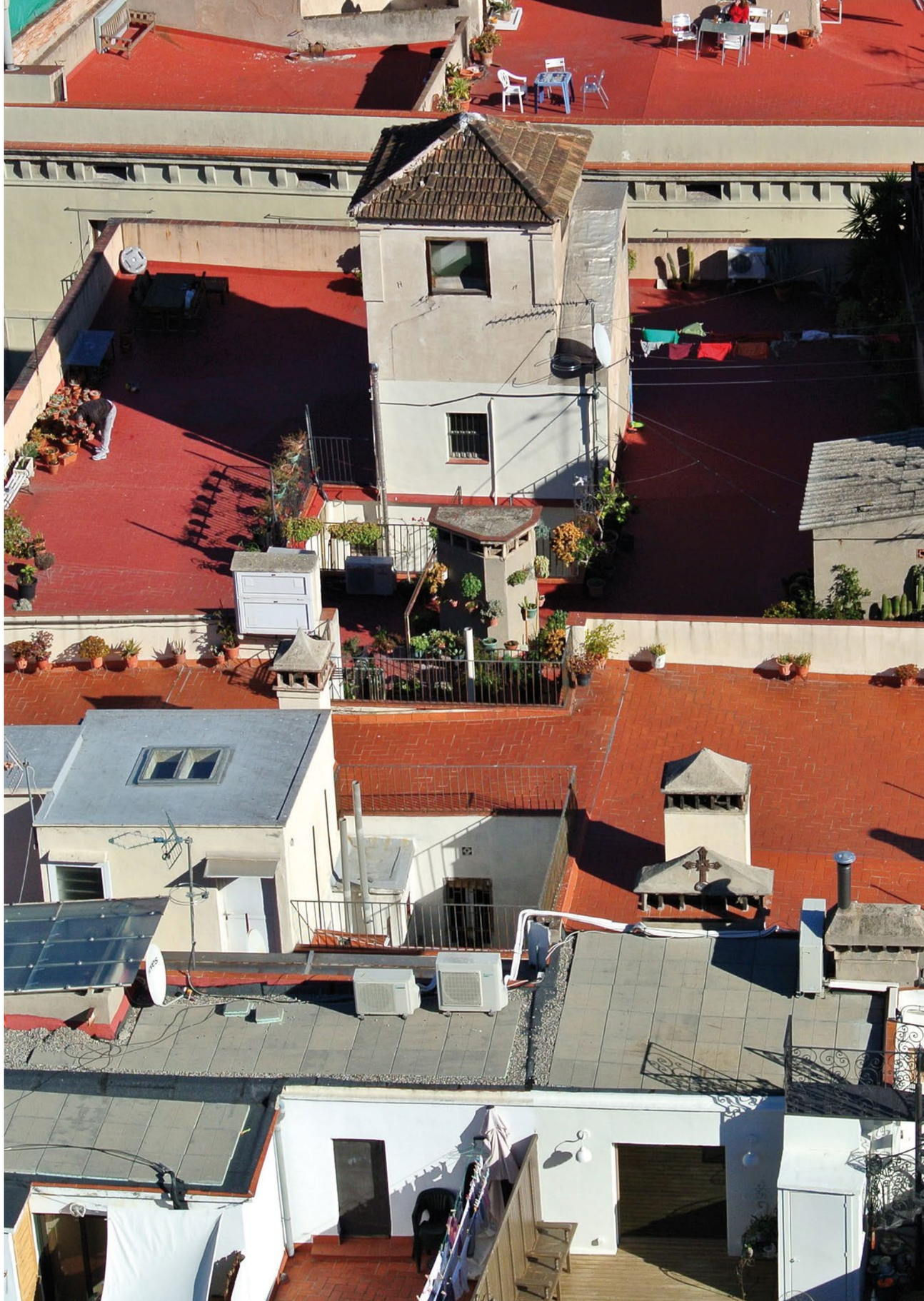
Books
BORJA, Jordi, MUXÍ, Zaida, **L'espai públic: ciutat i ciutadania**, Barcelona: Barcelona Provincial Council, Area of Cooperation, Technical Cooperation Office, 2001.
DELGADO, Manuel, JUAN, Anna, PIRANELLI, Marco, **Terrats de Barcelona**. **Entre el cel i la terra**, Barcelona: Municipal Institute for Urban Landscape and Quality of Life, 2012.
GEHL, Jan, **La humanización del espacio urbano**, Barcelona: Reverté, 2006.
MARTÍNEZ, Andrés, **Habitar la cubierta**, Barcelona: Gustavo Gili, 2005.

Articles
DREY, Sabine, **"Nuevos mundos sobre cubiertas existentes: ejemplos de compactación urbana"**, published in Detail nº. 8 Cubiertas, Year 2011, p. 808-814.
ENCAJES URBANOS, **"Azoteas colectivas: reactivando espacios en desuso"**, published in Paisea nº 25, La Cubierta Vegetal, p. 100-105.
SOLÀ-MORALES, Manuel, **"Espacios públicos / Espacios colectivos"**, published in La Vanguardia, 12-5-1992.

Theses and works
BCN ECOLOGIA, **Cobertes i murs verds a Barcelona. Estudi sobre les existents, el potencial i les estratègies d'implantació**, 2010.
ESPINET, UBACH arquitectes. **Habitar el terrat. Programa d'ús col·lectiu dels terrats de Barcelona i aplicació a l'illa CLIP**, 2012.
MILÀ, Marta. **De dalt estant. Recuperació de terrats com espai col·lectiu habitat.** Master's dissertation Laboratori de l'Habitatge al Segle XXI, 2014.
FOLCH, Ramón. **Rehabilitació arquitectònica i rescat socio-ambiental dels terrats i celoberts de Barcelona.** Urban Habitat Advisory Council Meeting of 22 July 2014.

Green roof guides
Germany. **Guidelines for the Planning, Execution and Upkeep of Green-roof sites.**
London. **Living Roofs and Walls.**
Melbourne. **Growing Green Guide.**
New York. **DDC Cool & Green Roof manual.**
Singapore. **A Concise Guide to Safe Practices for Rooftop Greenery.**
Sydney. **Green roof resource manual.**
Tokio. **Heat Island Measures Guideline, Green Wall Guideline.**
Toronto. **Guidelines for Biodiverse Green Roofs**

Regulations
FLL, **"Guidelines for the Planning, Construction and Maintenance of Green Roofing-Green Roofing Giodelines"**, Bonn: Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (FLL), 2008.
NTJ 11C, **Enjardinaments especials. Cobertes verdes**, January 2012. Gardening and Landscape Foundation.



Publishers
Area of Urban Ecology. Barcelona City Council. December 2015

Editors
Elisabeth Contreras and Isabel Castillo
(ASESCUVE, Spanish Green Roofs Association)

Technical coordination
Margarita Parés and Coloma Rull

Editorial coordination
Lis Francés

Graphic design and layout
Knock Brand Design

English version translation
Linguaserve I.S. SA

Layout of the english version
Endoradisseny

Illustrations
Mercè Iglesias

Acknowledgements
The content of the Guide for promoting living terrace roofs and green roofs was the result of a project in which the following people took part: Octavi Borruel, Gabino Carballo, Cristina Castells, Ariadna de Miquel, Sonia Frias, Nuria García, Tomás Gea, Xavier Hernández, Rosa López, Xavier Olivella, Montse Rivero, Jordi Ribas, Héctor Rodal and Sara Udina.

We would also like to express our gratitude to the following for their collaboration: Gardening and Landscape Foundation (FJIP); Terrats en Cultura; the Barcelona Urban Ecology Agency; the Nostra Senyora de Lurdes de Barcelona School; Pich i Aguilera, and Batlle i Roig Architects.

ASESCUVE · APE · Col·legi d'Administradors de Finques de Barcelona-Lleida · COAMB Col·legi d'Ambientòlegs de Catalunya · Col·legi d'Aparelladors, Arquitectes Tècnics i Enginyers d'Edificació de Barcelona · Col·legi d'Arquitectes de Catalunya Demarcació de Barcelona · Col·legi de Biòlegs de Catalunya · Agrònoms Enginyers Agrònoms de Catalunya · Col·legi Oficial d'Enginyers Tècnics Agrícoles i Perits Agrícoles de Catalunya

BCN
Guide to living terrace roofs and green roofs