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Envolvente biosolar en el mercado municipal de Vallehermoso
Bio-solar envelopment in the municipal market of Vallehermoso

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Resumen-- **Se analiza la posible colocación de un ajardinamiento y de paneles fotovoltaicos en la cubierta y en la fachada del Mercado Municipal de Vallehermoso, debido a las ventajas que pueden presentar cuando se incorporan dichas tecnologías conjuntamente. Se lleva a cabo un estudio de soleamiento. Se elabora un inventario de soluciones de elementos ajardinados y de paneles fotovoltaicos en cubiertas y fachadas existentes. Se realiza un análisis de la estructura portante de la cubierta y la fachada. Por último, se estudia la viabilidad de un sistema conjunto de ajardinamiento y de paneles fotovoltaicos. Una vez estudiadas las posibilidades que ofrece el mercado de elementos vegetales y sistemas fotovoltaicos, la solución que se considera más adecuada consiste en combinar paneles fotovoltaicos clásicos con una cubierta vegetal de pequeño porte y de la mayor biodiversidad posible.**

Palabras clave— Mercados municipales; eficiencia energética; sostenibilidad; envolvente biosolar; entorno construido.

Abstract— **The possible placement of landscaping and photovoltaic panels on the roof and façade of the Vallehermoso Municipal Market is analysed, due to the advantages that can arise when these technologies are incorporated together. A sunlight study is carried out. An inventory of solutions for landscaped elements and photovoltaic panels on existing roofs and façades was drawn up. An analysis of the load-bearing structure of the roof and façade is carried out. Finally, the feasibility of a joint system of landscaping and photovoltaic panels is studied. Once the possibilities offered by the market for plant elements and photovoltaic systems have been studied, the most appropriate solution is considered to be a combination of classic photovoltaic panels with a small green roof with the greatest possible biodiversity.**

Index Terms— Municipal markets; energy efficiency; sustainability; bio-solar envelope; built environment.

I. Introduction

To contribute to moving Madrid's markets towards more sustainable management, as modestly indicated in the Strategic Plan for Municipal Markets (PEMM 2017 - 2021) (Ay. Madrid, Plan estratégico de los Mercados Municipales de Madrid 2017-2021., n.d.) and decidedly in the Guía de Sostenibilidad de los Mercados Municipales 2022 (Parada Rodríguez, Fernández Nieto, Jaenike Fonato, Acosta Pérez, & Rodríguez Calvo, 2022), an intervention on an essential element within the circular economy such as energy efficiency and the optimisation of infrastructures is proposed.

To contribute to this objective, the possible placement of landscaping and photovoltaic panels on the roof and façade of the Vallehermoso Municipal Market is analysed.

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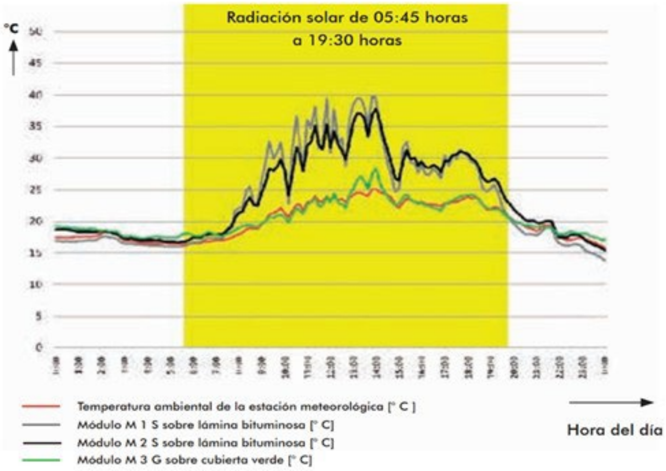

Fig.1. Temperatures of photovoltaic panels on a July day relative to their surroundings (ZinCo, 2021)

Fig.2. Agrivoltaic project in Babberich (Rodriguez, 2021)

The aim of this research is to analyse the feasibility of integrating both technologies, photovoltaic and landscaping, into the building envelope, due to the advantages they can present when incorporated together.

In addition to the added benefits that these strategies generate separately, combining them produces additional advantages that result from the synergy that arises between photovoltaic use and the naturalisation of roofs and façades. Vegetation improves the performance of photovoltaic elements and vice versa.

One of the most important positive effects is the improvement in the performance of the solar panels due to the temperature reduction of the green roof. The efficiency of the panels reaches its maximum at 25º and worsens as this temperature increases. If there is a plant element surrounding the photovoltaic installation, the temperature of the panels decreases, as shown in Fig. 1, compared to that reached with other solutions, which results in a higher yield and economic benefit for the installation.

The vegetation can be placed under the photovoltaic panels, using them as protection if direct sunlight is not needed, or in the gaps created between the strips of solar panels, generated by the need to avoid the shade cast between elements. Placing vegetation in this way is not only an aesthetic enhancement of the whole, but also an enrichment of biodiversity.

Biosolar systems can achieve self-sufficiency thanks to the fact that the electrical energy produced can be used for irrigation pumps or other elements that may be needed for the care of the vegetation. In this way, the combination of photovoltaic and plant elements gives the ensemble freedom in terms of placement and independence from its surroundings.

The use of the energy produced in favour of the ecosystem it accompanies allows the development of productive initiatives also from the agri-food point of view, incorporating vegetable gardens and productive crops.

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The scaling up of this initiative to large farms, as shown in Fig. 2, has been called Agrivoltaica. Although the type of cultivation is conditioned by the machinery that can be used and the amount of light that reaches the plants, there are numerous benefits such as the reduction in the amount of water used or the blocking of direct light, which is often harmful to some products.

In addition, the emergence of photovoltaic energy provides a new source of income that can help the business sustainability of these initiatives in years when the harvest is not good. This combination of systems contributes to the ecological transition towards the use of renewable energies in the primary sector.

To develop a proposal that combines vegetation and photovoltaic solutions to take advantage of the above benefits, it is noted that the two most important issues that need to be considered are how the system is linked to the building and the size and growth of the vegetation.

In terms of the supporting structure, it is necessary to find a combined answer for the vegetation and the PV panels that meets the requirements of both systems.

For the vegetation, it is necessary to select vegetation that will thrive with less solar radiation when growing under the PV panels and whose growth will not shade the energy-producing cells.

On the roof, it will be necessary to have small vegetation or to use high supports that raise the photovoltaic panels above the plants. On the façade, on the other hand, the plants used should have a small and controlled growth or, at least, the maximum size they can reach should be considered to leave a separation space between the photovoltaic and plant solutions.

II. Methodology

Firstly, sunlight is studied from different perspectives. On the one hand, the Geoportal Viewer (Ay. Madrid, Geoportal del Ayuntamiento de Madrid, 2022) has been used to produce a series of simulations showing the shadow cast by the buildings on the market as a function of the month of the year and the time of day. Secondly, a 3D model of the market and the surrounding buildings has been made, with which the total

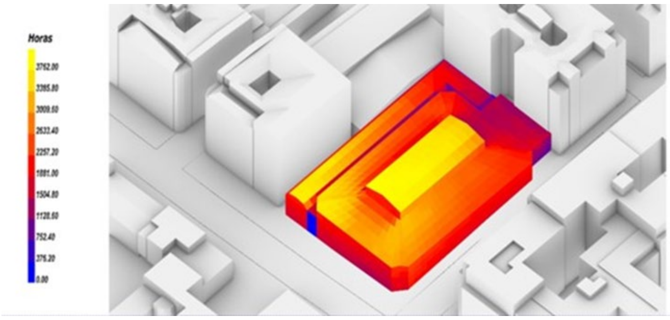

Fig. 3. Annual hours of sunshine on the Vallehermoso Market envelope (Source: Own elaboration)

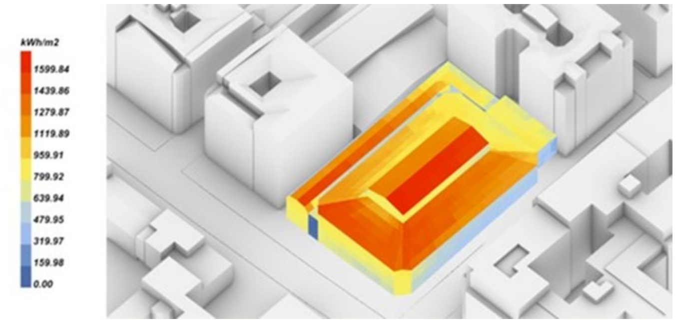

Fig. 4. Annual radiation on the envelope of the Vallehermoso Market (Source: Own elaboration)

hours of sunshine received per year and the total annual radiation have been obtained directly, thanks to the software used: Rhinoceros, Grasshopper and Ladybug.

Next, a classification of possible landscaping solutions and photovoltaic panels on the roof and façade is made. These solutions are obtained through a market study in which real models have been selected and their main characteristics have been ascertained.

The solutions studied have supports that must be anchored or supported to the structure of the building. The Vallehermoso Market is based on an existing construction that did not consider the appearance of these actions on its roofs or façades. For this reason, an analysis of its structure is considered necessary to evaluate whether it can incorporate this new element.

III. Results

A. *Sunlight*

Fig. 3 shows a perspective, in which a colour gradient representing the number of annual hours of sunshine received by the outer skin is superimposed on the building envelope.

Fig. 4 shows a perspective, in which superimposed on the building envelope is a colour gradient representing the total annual radiation received by the outer skin.

B. *Photovoltaic solutions*

Photovoltaic panels produce electricity from the sun, a renewable energy source. Their electricity production curve is directly related to the solar radiation curve, as their generation process is a direct process.

Photovoltaic panels produce electricity by means of the photoelectric effect, which consists of the photovoltaic cells emitting electrons when they receive electromagnetic radiation from the sun.

There are different types of cells, the most common being silicon. The most common forms of production (Fig. 5) are monocrystalline, polycrystalline and amorphous (or thin-film) silicon. Less common are composite cells (also thin-film) or organic cells. The price, efficiency or mechanical characteristics of the solutions will largely depend on the choice of cell type.

The most conventional system is the photovoltaic solar panel, used on all types of roofs, both flat and pitched. It consists of a group of cells placed in series and in parallel that make up the solar panel, accompanied by a structure that supports it.

Despite being an increasingly affordable and cost-effective solution, the search for greater efficiency and better architectural integration has led to the manufacture and marketing of other types of products (González Calle, 2022), which are described below.

Hybrid solar panels (Fig. 6a) combine the classic solar panel with the solar thermal panel system, being able to produce electricity and hot water at the same time using the same energy source, thus increasing the efficiency of the whole.

Another type of panel is the high concentration or CPV (Concentrated Photovoltaic) (Fig. 6b), which increases efficiency and makes the product cheaper by using lower-cost elements such as lenses or mirrors to concentrate the light on specific points where the cells are placed, thus reducing the number of cells and, therefore, the price of the panel.

Solar shingles (Fig. 6c) have emerged as a solution to replace the shingles of a conventional roof, their purpose being to replace the roof or to be integrated into it, depending on the amount of energy to be obtained, without being easily distinguishable. A system similar to that of a photovoltaic panel installation is used.

These tiles are an example of a type of product called

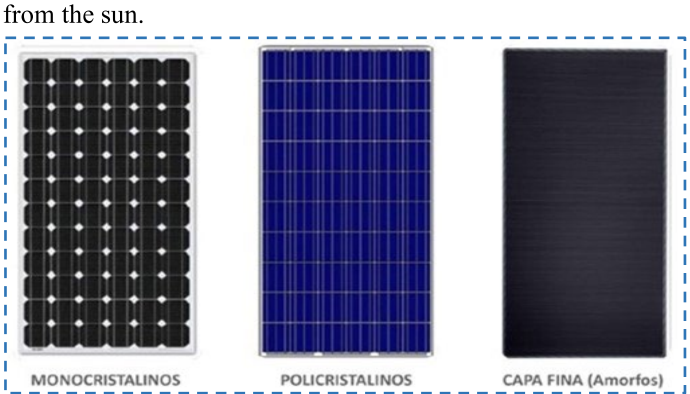

Fig. 5. Most common photovoltaic solar panels (Tritec Intervento, 2017)

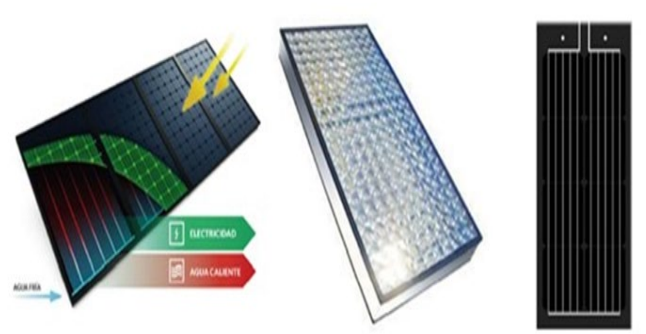

Fig. 6. Hybrid solar panel (Abora Energy, 2020), CPV panel (Soitec, 2022),

Fig. 7. BIPV for ventilated façade (Lledó, 2022), Amorphous silicon glass (Onyx Solar, 2022), Flexible photovoltaic film (Kalzip, 2022)

Fig. 8. Solar brick (Universidad EAFIT, 2022), Smartflower (Smartflower Ib 2022)

Building Integrated Photovoltaics (BIPV) (Fig. 7a), a technology that incorporates photovoltaic modules into building systems that are part of the building envelope (such as curtain walling or ventilated façades, for example), producing complete architectural integration and reducing the use of other building elements.

Another group of BIPV is amorphous silicon glass (Fig. 7b). This is a glass integrated into the envelope's window and door frames, with amorphous silicon photovoltaic cells embedded in its mass, which are not visible. They allow natural light to enter the interior of the building and at the same time produce electricity. The less transparent the glass is, the higher the output.

Thin-film cells can also be used to create flexible PV foils (Fig. 7c), thin-film solar panels that can be curved and adapted to the profile of the envelope on which they are placed.

Photovoltaic solutions are still an element with much room for development and improvement. Proof of this is one of the most experimental proposals, still under development at EAFIT and yet to be marketed: the solar brick (Fig. 8a). It is a rectangular plastic prism with a small solar panel on its outer face. This piece replaces traditional bricks, making it possible to create "solar walls".

The last photovoltaic system (Fig. 8b) consists of a solution that rotates following the path of the sun. In addition, it has the ability to automatically retract in the absence of light or strong winds that could damage it. This operation also serves as a self-cleaning system for the product.

C. Landscaping solutions

The vegetation proposals are divided into roof and façade solutions due to the different characteristics and needs of both parts of the envelope, although some systems can be applied in both locations.

There are different types of green roofs, although they usually have a similar stratified system, with layers of protection, waterproofing and drainage under the substrate that supports the vegetation. A very important characteristic for the choice of the system is the slope of the roof, which is especially important if it exceeds the 5° limit.

The two most common roof solutions are extensive and intensive. The former (Fig. 9a) is a light vegetation system with a shallow, low-nutrient substrate, so that vegetation hardly develops or requires maintenance. The intensive system (Fig. 9b), on the other hand, has a deeper substrate, which facilitates the growth of any type of vegetation, making it possible to create attractive gardens or even use the roof as a production surface by converting it into an orchard. The disadvantages of this system are its heavy weight and its difficulty in being used on steeply sloping roofs.

To solve the problem of landslides on steeply sloping roofs, anti-slip systems (Fig. 9c) are available that place substructures or anchored point elements that serve to generate a greater number of supports and divide the green roof into sections.

Another subdivided roof solution is that of pre-cultivated modules (Fig. 10a), which are interlocked with each other. The vegetated trays already contain all the necessary layers and allow the desired result to be achieved quickly.

The last approach is known as blue cover or cistern cover (Fig. 10b). This does not focus so much on vegetation as on the storage and controlled drainage of rainwater, although green solutions are often related to this system to make use of the accumulated water for irrigation.

For façades, there are many solutions that can create a different image. They offer the same advantages as a green roof. They have an additional advantage: they improve the aesthetics of the city because they are more visible from the streets. Solutions can be grouped into three categories from a constructive point of view (Olivieri, Francesca, 2013): continuous, consisting of modular elements and consisting of point elements. These categories can be further subdivided into more concrete solutions, allowing for greater precision in the search for products.

Some of the solutions are not covered by any manufacturer due to the natural condition of green façades or the particularity of the solution. An example of this is the continuous, unsupported façade (Fig. 11a), where only an area of land is needed and a climbing plant that gradually invades the façade and integrates with it. Like the previous solution, vegetal concrete (Fig. 11b) is being developed, treated so that mosses or small vegetation can grow on it.

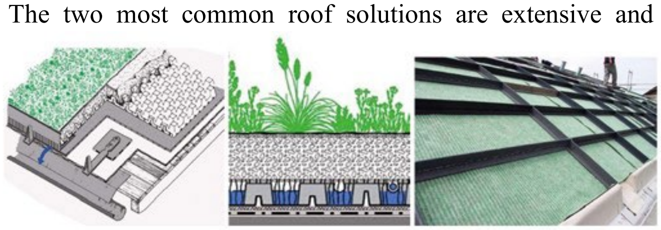

Fig. 9. Extensive (ZinCo, 2022), intensive (ZinCo, 2018) and anti-skid

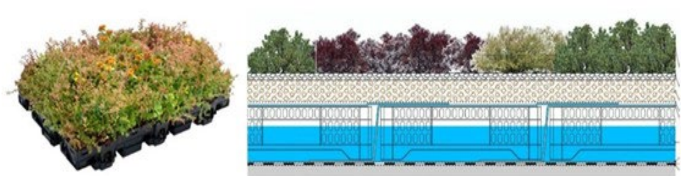

Fig. 10. Modular roof (Le Prieuré, 2022), Cistern roof (Singular Green, 2022)

Fig. 11 Unsupported vegetal façade (Lund University, 2022), Hormigón vegetal (Univ. Polit. de Cataluña, 2017)

Fig. 12. Mesh support (Boegger, 2022), frame support (GreenScreen, 2022) with planter (Gsky, 2022)

Fig. 13Bonded support (Singular Green, 2022), pre-cultivated box (Vivers Ter, 2022) and modular block (Scotscape, 2022)

Fig. 14. Stackable planter (Mobilane, 2022)

The adherence of climbing plants to the façade can be facilitated using a vertical support on which the plant is supported. This can be either cables or mesh (Fig. 12a) or a light metal structure (Fig. 12b). Another option is to place a raised planter (Fig. 12c) from which the vegetation is suspended.

There are systems that combine both solutions to produce a product in which a small mesh or light structure is added to a planter, avoiding the need for the vegetation to climb a great height, and allowing a variation of plants between planters.

In other solutions, the supporting structure is attached to the wall and covered with a series of layers in which the plants can take root (Fig. 13a). This system is accompanied by a hydroponic irrigation system.

Modular plant façades consist of systems that achieve a finish like that of continuous façades by means of independent pieces. This discontinuous procedure facilitates adaptability to the façade openings or the configuration of shapes or designs along the façade. Although there are many solutions, they can be divided into two main groups: pre-vegetated boxes that are placed on the façade (Fig. 13b) or modular blocks with containers that allow the vegetation to be inserted (Fig. 13c).

Fig. 15. Unsupported vegetal façade (Lund University, 2022), Hormigón vegetal (Univ. Polit. de Cataluña, 2017)

Fig. 16. Bonded support (Singular Green, 2022), pre-cultivated box (Vivers Ter, 2022) and modular block (Scotscape, 2022).

The last category would be that of point plant façades (Fig. 14), i.e. those configured by means of individual, isolated pots, or containers. Normally, a support or terrace is needed where the pieces can be placed, and the container can even be integrated into the façade if it has been previously designed in this way. There are also systems that allow the pots to be stacked, offering a more compact solution and an automatic watering system.

D. Mixed solutions

Some manufacturers have started to create products that combine both types of solutions. These proposals come from the world of green solutions, something that is evident in the lack of information on photovoltaic elements. They mainly focus on the combination of solar panels with green roofs: a layer is incorporated into the roof to anchor supports for the panels and is held in place by the weight of the soil itself (Fig. 15).

For isolated elements where a large irrigation system would be an excessive expense, use is made of a solar panel to power a water pump (Fig. 16a) or the MUAC system related to the vegetation fraction of the system such as the purification of polluted air produced by vehicles in cities (Fig. 16b).

Finally, (Fig. 17) shows another solution that combines the MUAC system with CPV panels, aiming at higher electricity production and not only self-sufficiency.

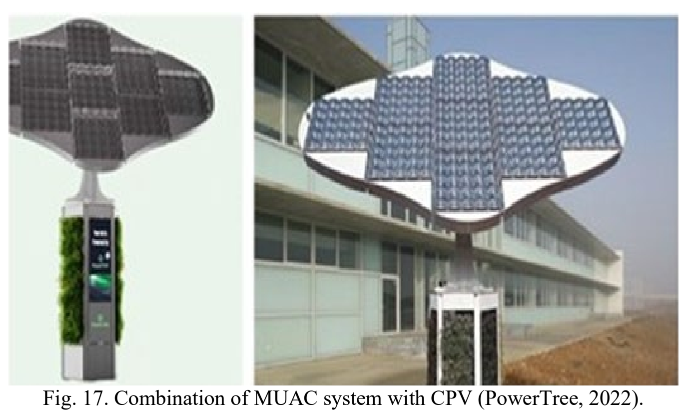

Fig. 17. Combination of MUAC system with CPV (PowerTree, 2022).

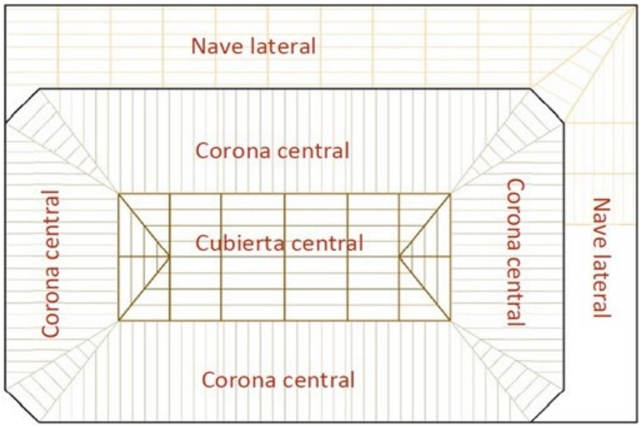

Fig. 18. Roof structure consisting of trusses (thick lines) and purlins (thin lines) supported by walls (black lines). Source: Own elaboration

Resistencia de cálculo	17,6	kN/cm2	Carga lineal máxima	6,20	kN/m
Módulo resistente IPE120	60,73	cm3	Carga superficial máxima	8,69	kN/m2
Momento resistente IPE120	10,69	kNm	Capacidad de carga disponible	580	kg/m2

Fig. 19. Central Structure with the skylight and its available load-bearing capacity. Source: Own elaboration.

E. *Bearing capacity of the roof structure.*

The roof structure (Fig. 18) consists of three parts: the central roof with the skylight is supported by longitudinal purlins supported by cross trusses resting on pillars; the roof of the central crown of the main market hall is supported by cross purlins resting on the perimeter wall and an inner truss resting on pillars; the side hall running on the north and east sides of the main hall has a roof which is supported by longitudinal purlins resting on cross trusses resting on perimeter walls.

The structure of the central part of the roof with the skylight can be seen in the following image (Fig. 19). The purlins, consisting of an IPE 120 rolled steel section, are supported on triangular trusses that are raised through a wall with windows that allow light to pass through, on a parallel chord truss resting on metal columns.

The maximum linear load and the maximum surface load that the purlins can support are calculated, to then obtain the load capacity available for the incorporation of new systems in the roof. The results obtained are shown in the following image (Fig. 19).

The roof structure of the central crown of the main market hall can be seen in the following image (Fig. 20). The purlins, consisting of an IPE 180 rolled steel profile, are supported by the perimeter wall and an internal parallel chord truss resting on metal columns.

The maximum linear load and the maximum surface load that the purlins can support are calculated, to then obtain the load capacity available for the incorporation of new systems in the roof. The results obtained are shown in the following image (Fig. 20).

The structure of the aisle running on the north and east sides of the main hall can be seen in the following picture (Fig. 21). The purlins, made of IPE 180 rolled steel sections, are supported by triangular trusses which are supported by perimeter walls. A small elevation in the centre allows natural light to enter.

The maximum linear load and the maximum surface load that the purlins can support are calculated, to obtain the available load capacity for the incorporation of new systems in the roof. The results obtained are shown in the following image (Fig. 21).

F. *Bearing capacity of the façade*

Para el análisis estructural se considera un muro de ladrillo de 40 cm de espesor. Sobre dicha fachada reposan la mitad de las cargas de las correas y vigas de la corona perimetral de la nave principal, tal y como se recoge en la Fig. 22. La otra mitad es recogida por los pilares metálicos interiores.

La capacidad de carga disponible del muro es de 180 – 64,2 =115,8 kN/m, que repartidos en los 7,5 m que tiene de alto, supondría una capacidad de carga dis-ponible de 15,44 kN/m^2, lo que equivale a 1574 kg/m^2.

Resistencia de cálculo	17,6 kN/cm2		Carga lineal máxima	3,03	kN/m
Módulo resistente IPE180	166,4 cm3		Carga superficial máxima	3,03	kN/m2
Momento resistente IPE180	29,29 kNm		Capacidad de carga disponible	3	kg/m2

Fig. 20. Structure of the central crown of the roof and its available load-bearing capacity. Source: Own elaboration

Resistencia de cálculo	17,6 kN/cm2		Carga lineal máxima	5,63	kN/m
Módulo resistente IPE180	166,4 cm3		Carga superficial máxima	5,63	kN/m2
Momento resistente IPE180	29,29 kNm		Capacidad de carga disponible	268	kg/m2

Fig. 21. Structure of the side deck aisle and its available load-bearing capacity. Source: Own elaboration

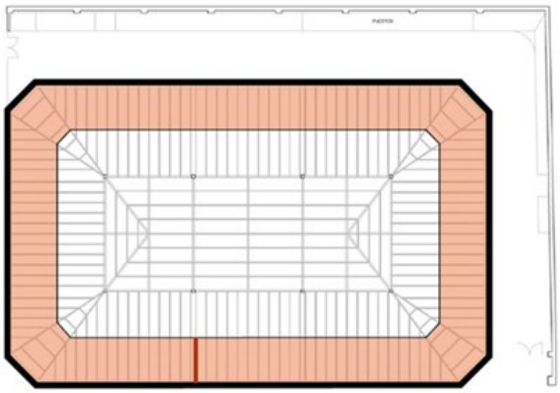

Fig. 22. Diagram of the tributary area of the façade wall. Source: Own elaboration

IV. CONCLUSIONS

A. Sunlight

The following conclusions can be drawn from a study of the market's sunlight:

- The roof has considerably illuminated areas, with values above 3500 hours of light per year.
- The facades have few hours of light per year due to the surrounding buildings and vegetation.
- The installation of photovoltaic panels would be most effective on the roof and is ruled out on the façade.
- In the case of façade landscaping, a selection of plant species that do not require a large amount of direct light should be used.

It is considered that the placement of landscaping and photovoltaic panels on the roof and façade should not follow a homogeneous treatment throughout the market envelope. On the façade there would be hardly any photovoltaic use.

B. Bearing capacity of the roof structure

It is found that the rafters and purlins of the roof structure support most of the green roof and photovoltaic panel solutions.

Only the purlins of the central crown are close to their maximum load capacity due to their large span, so a green roof would not be possible in this area. Only photovoltaic panels could be placed in this area due to their light weight.

Any vegetated and photovoltaic system solution with a load of less than 1574 kg/m^2 (almost all of them) could be supported on the façade without compromising its structural stability.

C. General conclusions

The sunlight study has identified three areas that receive a particularly high amount of radiation throughout the year: the central roof, the southern and western part of the central crown and the southern part of the aisle.

Because the façade is shaded most of the year, either by the trees in summer or spring, when the leaves fill their canopies, or by the shade cast by nearby buildings in winter, the possibility of installing photovoltaic panels has been discouraged.

Due to the existing slope of 10º, the intensive green roof and blue roof or cistern roof solutions have been ruled out as they are suitable for roofs with a slope of less than 5º.

As for the solutions that harness the sun's energy, some of them, such as solar tiles or photovoltaic glass, would not take advantage of their main characteristics and would therefore represent an additional cost that would not be used. Also, due to the combination of solutions, products such as the solar film, which is attached to the roof, would be blocked by the vegetation growing around it.

It is feasible to use photovoltaic panels, which can be classic, hybrid or high concentration, profitable according to data from some manufacturers from annual irradiation rates of approximately 1500 Kwh/m^2/year (González Calle, 2022).

The solution of hybrid panels is discarded because it would be an interesting solution if there is a greater use of domestic hot water in the market that would make the high cost of the panel profitable.

High concentration panels are also discarded due to their high initial investment.

The solution that is considered most appropriate is to combine classic photovoltaic panels with a small green roof with as much biodiversity as possible. Such a solution is commercially available, so its feasibility and manufacturability are guaranteed.

Extensive vegetation cover and pre-cultivated modules offer similar results. The choice should be determined by the complexity or variety of the proposed planting to be laid and the speed required for the complete installation of the system. The anti-slip type of vegetation cover could lead to savings if the profiles used to prevent the substrate from slipping and falling can be used as a supporting structure to which the feet that raise the solar panels above the vegetation are anchored.

The structural study shows the possibility of integrating solutions that combine extensive green roofs and photovoltaic panels on the central roof and the perimeter building, while only photovoltaic panels can be installed on the central crown, while on the façade it is possible to combine both systems without any problem.

Table 1 shows a summary of the main conditions studied for a biosolar system in the Vallehermoso market.

D. Proposed biosolar system for Vallehermoso Market

The proposal for an ecological roof in combination with solar energy from the ZinCo brand (ZinCo, 2022) was chosen as a solution. This system, in addition to proposing the union of solutions with a single product, allows the mounting of the solar panel supports without the need to perforate the roof or the waterproofing layer. This is achieved thanks to the retaining layer that makes up the roofing solution called solar base SB 200 (Fig. 23).

This ABS plastic product has a system of profiles on its lower face that serve to stiffen the piece and anchor, on the upper face, the SGR solar base supports (ZinCo, 2022) on which the photovoltaic panels are supported. These supports have different inclinations that allow the photovoltaic panels to be arranged at the optimum angle for the greatest energy production. The supports are anchored by screwing them to the profiles, as shown in the following picture (Fig. 24).

TABLE I
CONDITIONS FOR A BIOSOLAR SYSTEM IN THE VALLEHERMOSO MARKET

	Central Roof	Crown	Perimeter	Façade
Sunlight	Óptimo sur Bueno norte	Bueno sur y oeste Malo norte Pésimo este	Bueno ala norte, faldón sur Regular ala norte, faldón norte Pésimo ala este	Pésimo sur y oeste
Slope	Extensive vegetation roof	Extensive vegetation roof	Extensive vegetation roof	Green Façade
Structure	Extensive vegetation roof and photovoltaic panels	Photovoltaic panels	Extensive vegetation roof and photovoltaic panels	Landscaping and photovoltaic panels

Once these support pieces are anchored in the retaining layer, which is placed on top of the drainage and waterproofing layers, the substrate layer is spread, the weight of which provides the necessary ballast to prevent the movement that wind suction would cause in the panels. On the underside, a system of multidirectional channels allows for proper drainage of the roof.

The result (Fig. 25) is a solution that combines roof naturation and photovoltaic panels. A direct linkage is created not only positionally on the roof, but also in terms of constructive and structural integration between the natural and photovoltaic parts of the system.

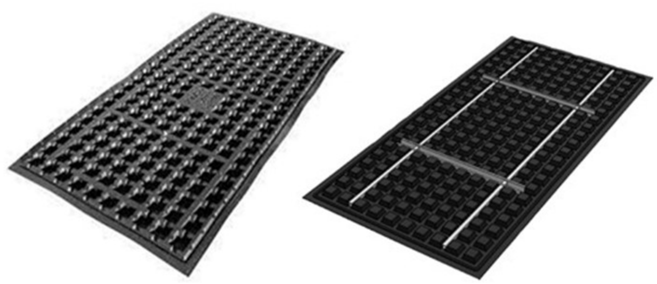

Fig. 23. SB 200 solar base top and bottom (ZinCo, 2022)

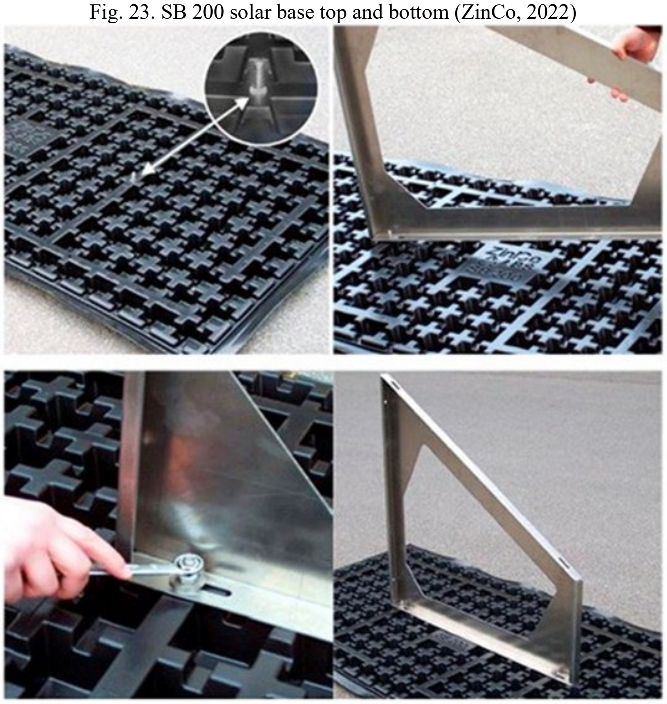

Fig. 24. Ensambling procedure for SGR brackets on the SB 200 Solar Base (ZinCo, 2022).

Although at first glance the implementation of the biosolar system may be considered costly, the significant amount of benefits - separately and as a whole - of the solution at an ecosystemic (flora and fauna) and energy level, makes this operation an investment that will significantly improve the conditions offered by the Vallehermoso Market as an architectural element, both for its workers and for the residents of the Chamberí district.

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Fig. 25. Proposed solution and result after incorporation of the topsoil (ZinCo, 2022)

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