Journal of Housing and the Built Environment
https://doi.org/10.1007/s10901-022-09973-x

ARTICLE

Urban regeneration through retrofitting social housing: the AURA 3.1 prototype

Rafael Herrera-Limones[1] · Miguel Hernández-Valencia[2] · Jorge Roa-Fernández[3]

Received: 21 March 2021 / Accepted: 1 August 2022

Abstract

As a large proportion of housing stock does not meet the current demands for energy and comfort (leading to high levels of obsolescence and vulnerability), the annual rate of energy upgrades for the existing stock must be increased. The AURA Strategy is an intervention methodology which focuses on the regeneration of neighbourhoods or obsolete urban fabrics which suffer from high levels of architectural, urban and socio-economic vulnerability. Within this context, the AURA 3.1 prototype was developed for the Solar Decathlon Europe 2019 Competition. The project was based around a sustainable construction strategy for the urban regeneration of obsolete residential neighbourhoods, through the reuse of existing buildings considering Mediterranean climate and energy. The Poligono San Pablo neighbourhood was chosen as the case study. This article presents the main retrofit action: the juxtaposition on the existing building of a structural-architectural system which provides new technological and spatial features. Quantitative data regarding the validity and effectiveness of the AURA Strategy could be collected from the monitoring of the Pavilion prototype during the competition. Two first prizes were won in contests with on-site measurements: Comfort conditions and House Functioning. Third place was also obtained in the Sustainability contest, thus confirming the enormous possibilities the AURA Strategy has for sustainable urban regeneration in retrofitting social housing, within the limitations of the competition.

Keywords Urban regeneration · Retrofitting social housing · Solar decathlon · Sustainability · Comfort · Housing function · Modular extensions

✉ Miguel Hernández-Valencia
mhvalencia@us.es

[1] Instituto Universitario de Arquitectura y Ciencias de la Construcción, Escuela Técnica Superior de Arquitectura, Departamento de Construcciones Arquitectónicas 1, Research Group HUM-965, Universidad de Sevilla, Av. Reina Mercedes 2, 41012 Seville, Spain

[2] Instituto Universitario de Arquitectura y Ciencias de la Construcción, Escuela Técnica Superior de Arquitectura, Departamento de Estructuras de Edificación e Ingeniería del Terreno, Research Group HUM-965, Universidad de Sevilla, Av. Reina Mercedes 2, 41012 Seville, Spain

[3] Instituto Universitario de Arquitectura y Ciencias de la Construcción, Escuela Técnica Superior de Arquitectura, Departamento de Construcciones Arquitectónicas 1, Research Group TEP-206, Universidad de Sevilla, Av. de Reina Mercedes 2, 41012 Seville, Spain

Published online: 14 September 2022

1 Introduction

Approximately 35% of existing housing stock in the UE is over 50 years old (European Commission, 2016) with the number of residential buildings from the 1950s, 60 s and 70 s being particularly high. The lack of available resources for housing construction, alongside the speed at which economic, sociological, and technological changes are produced in the contemporary context, lead to serious obsolescence (García Vázquez, 2015), meaning inadequacy in terms of current requirements (García-Pérez et al., 2020).

As a consequence, it is not uncommon to find residential neighbourhoods where housing has a usable floor area below that of contemporary standards per inhabitant and needs to be transformed for use by families of a heterogeneous nature (couples without children, the elderly, single parent families, one person households, shared housing) or for new uses (teleworking, storage, space for HVAC systems); buildings with accessibility problems due to the architectural barriers for people with disabilities (no lift); buildings lacking thermal and acoustic insulation in carpentry, facades or roofing; buildings with low energy efficient (Hess et al., 2018) or, in some cases, inexistent air conditioning or heating systems; neighbourhoods with degraded public spaces, a lack of green space (Sendra, 2016), or public spaces occupied by private motor vehicles without the necessary facilities for low environmental impact transport methods (bicycle, public transport). This can be construed as architectural, building, sociological, energy and urban obsolescence (Vázquez et al., 2016).

By updating housing stock, the European Union aims to improve both energy efficiency by 27% before 2030 (2030 Climate & Energy Framework, 2022) and the decarbonisation agenda in line with the 2050 long-term strategy (2050 Long-Term Strategy, 2022). However, the replacement rate of existing buildings by new-builds hardly reaches an annual 3% (IEA ECBCS 2011). That is why the annual rate of energy upgrades in existing housing stock must be increased (Power, 2008), in order to meet the objectives of Horizon Europe 2030 satisfactorily.

A substantial part of the scientific community's efforts is currently focused on improving both the energy efficiency of existing buildings (Zhou et al., 2016) and interior comfort. To achieve this, research is undertaken into the building's current energy behaviour. This can be affected by various factors including, above all, the urban morphology (Vartholomaios, 2017), the characterisation of the thermal envelope, occupant impact (Guerra-Santin & Tweed, 2015) and building technologies (Yoshino et al., 2017). Nevertheless, studies addressing the issue from an urban strategy perspective (Hernández-Valencia et al., 2014) (Fernández-Galiano, 2021) in response to the demands of the 21st Century city are scarce (Pardo-Bosch et al., 2019) (Monteys, 2011).

Improvement strategies, both from a neighbourhood and urban level approach (Caputo et al., 2013), are usually assessed with simulation programs (Foucquier et al., 2013) (IEA ECBCS 2013) and optimisation criteria (Penna et al., 2015) (Chantrelle et al., 2011) (Asadi et al., 2012), which lead to the problem of performance gap (Asadi et al., 2012), between real and simulated values, thereby reducing the usefulness of energy performance simulation tools to predict the energy behaviour of a building Zero Carbon Hub (Carbon Hub, 2013) mainly due to users' patterns of use. Consequently, to evaluate the improvement of specific building solutions, test cells are used (León-Rodríguez et al., 2017) (Alonso et al., 2016), with prototypes or full size architectural models which aim to minimize the environmental impact with a coordinated approach, combining passive conditioning strategies with active systems.

The international Solar Decathlon competition is an opportunity to work on the development of projects that integrate urban regeneration in the context of energy-efficient housing and optimal indoor environmental conditions. This competition challenges participating universities from around the world, in collaboration with institutions and businesses, to design, build and set up a self-sufficient prototype dwelling powered by renewable energy. However, the ultimate aim of the competition is not only the final construction of the livable prototype (which will serve the double function of showcase house and technically monitored and measured unit), but also the whole teaching and research process which tests specific aspects of the scale model such as energy efficiency, engineering, sustainability of the proposal, its comfort conditions, etc.

The decathletes (recent graduates, post-graduate students and final year undergraduates), guided by professors and researchers from various backgrounds form a transversal team which undertakes the competitive process as a "project-based learning tool" (Herrera-Limones et al. 2020).

The main objective comes to fruition in the final two-week phase of the competition when the various prototypes are evaluated on site at the organisation's designated location. However, what is more significant, is the learning process through which the urban and social project is developed, leading to this archetype of sustainable habitat, ready for testing under scientific and even humanistic parameters.

The latest edition of Solar Decathlon Europe, which took place in July 2019 in Hungary (hereinafter SDE19), emphasized the simulation of retrofitting existing buildings using modern technologies and a mix of modern and reclaimed materials while focusing on interior comfort. The entry from the University of Seville (Spain) team was the AURA 3.1 Project.

This article focuses on the design and development of the AURA 3.1 Project for the SDE19 competition. The proposal addresses one of the challenges faced by European public administrations: the need to introduce new models for sustainable development in our cities (Wassenberg, 2013). The project is based on the idea of urban regeneration rather than new construction, recycling the fabric of existing urban buildings. A sustainable construction strategy is proposed to regenerate obsolete residential neighbourhoods considering Mediterranean climate and energy.

The Polígono San Pablo Neighbourhood is chosen as the case study as it suffers from many of the obsolescence issues outlined above: the neighbourhood was built in the early 1960s and a high percentage of buildings have poor accessibility and no lift at all. The high average age of the local residents worsens the situation. The buildings also have thermal and acoustic insulation problems and degraded public spaces. In summary, it is an urban area with a high level of vulnerability suitable for developing the premises on which the AURA strategy is based.

2 Methods

The Aura Strategy is an intervention method focused on the regeneration of neighbourhoods or obsolete urban fabrics with a high level of architectural, urban or socio-economic vulnerability (Fig. 1).

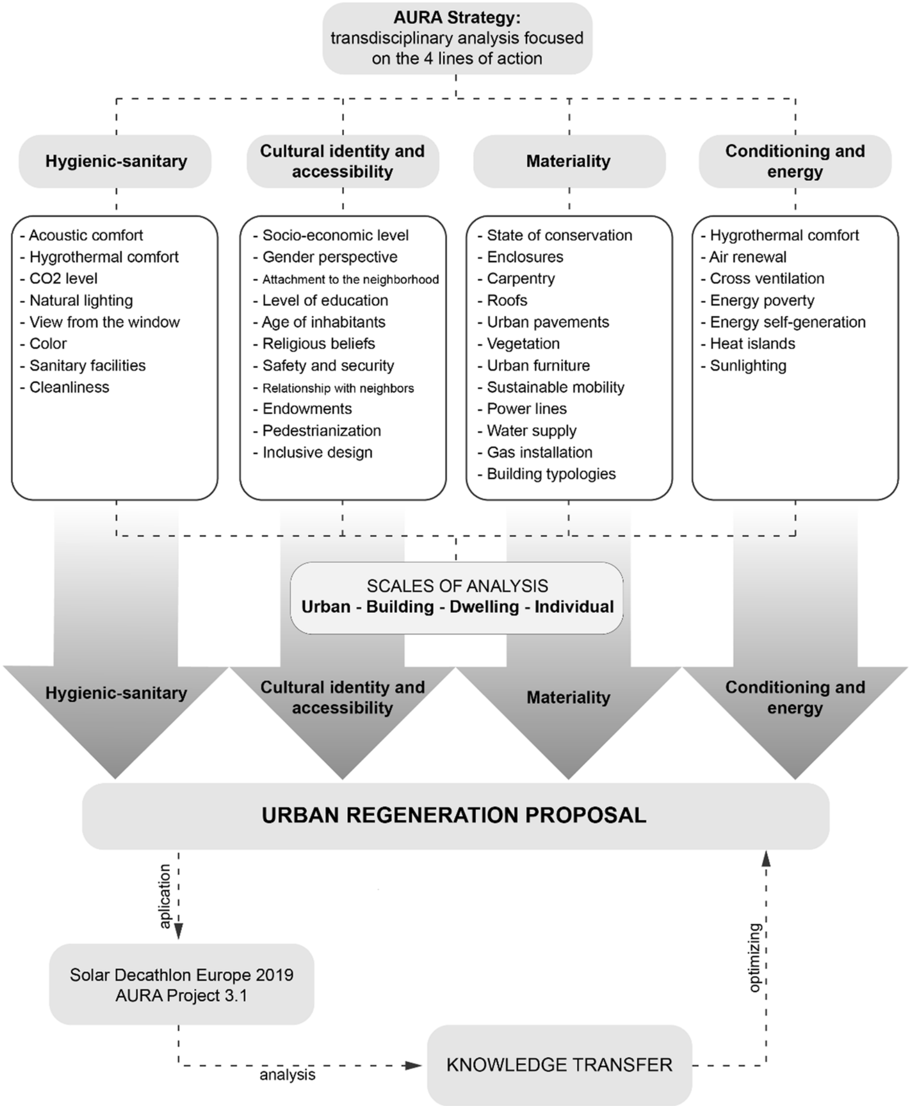

Fig. 1 AURA Strategy

Its method is based on four lines which allow a transdisciplinary analysis giving rise to a global intervention proposal for the urban area studied. The common aim of these four lines is to achieve both quantitative and measurable, as well as qualitative comfort for the individual. To do so, aspects such as the effect of habitat on health or cultural identity on the way of living are taken into account.

Based on the ideas put forward in the urban strategy, the design and prefabricated construction of a life-size housing-pavilion prototype were carried out. This is reflected in this article in the following phases or chapters (Fig. 2).

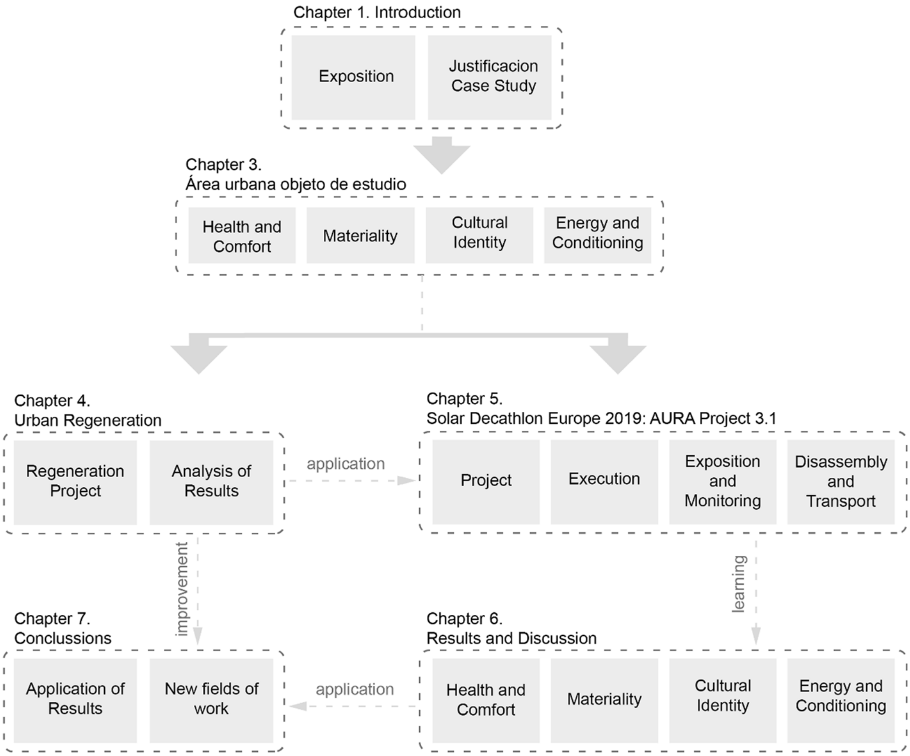

Fig. 2 Diagram of the publication table of contents

- Chapter 1: Choice of case study

The area of study, located in the city of Seville, was initially chosen based on criteria provided in the study of spatial vulnerability patterns in the city of Seville between 2001 and 2011(Hernández 2018). This study was based on indicators such as: level of studies, unemployment rates and housing.

- Chapter 2: Analysis and Diagnosis of the study área

Transdisciplinary study at four scales (Urban – Building – Dwelling – Individual) focused on four lines of action:

  - Hygiene-Health line,
  - Cultural Identity and Accessibility Line;
  - Materiality Line,
  - Retrofitting and Energy Line,

- Chapter 3: Urban proposal.

A sustainable strategy in an urban environment was proposed. Obsolete residential neighbourhoods would be regenerated in the context of European, Mediterranean climate and energy. Developing a sustainable building strategy for the urban regeneration of existing obsolete residential As outlined in the SDE19 competition rules, the Poligono San Pablo neighbourhood of Seville (Spain) was chosen for intervention.

- Chapter 4: Prototype design and Construction.

Development of design and construction documents for the pavilion/prototype to be built on University of Seville premises. The design of the final prototype was carried out across the AURA Strategy following the criteria and lines established in Stage 2 of the urban rehabilitation proposal.

Other objectives of this stage were the development of the model, audio-visual material, media, and website as well as continuing the search for financial support. Documentation for this phase was submitted successively following the timeline and specific content set out by the organisers of SDE19.

- Chapter 5: Prototype Construction.

The objective of this phase was to carry out the tasks required to ensure the actual construction of the prototype. These included the drafting of an on-site operations plan, the specifications for the final construction project and preliminary competition construction tests on University of Seville premises.

The different pieces forming the AURA 3.1 Prototype for SDE19 were prefabricated in modules (as a 1:1 scale model) and later transported and reassembled for exhibition on the Solar site in Hungary.

- Chapter 6: Exhibition, monitoring of the Pavilion/prototype and disassembly

The main actions in this phase were the defence, monitoring and setting up of the pavilion/prototype along with the continual dissemination of assessments during the final phase of the competition.

During the 21-day competition period the prototype fulfilled two functions. Firstly, it was an exhibition pavilion, open to the public. Secondly, it served as a monitoring laboratory to enable participation in the various contests. In this period, all the team's previously planned strategies were carried out with the aim of achieving maximum efficiency when presenting the project to the seven contest juries and the three contests with on-site measurements.

Once the contest period was finished, there was a long prototype exhibition period (Fig. 3). During this period all the results were analysed, and all the related documentation prepared. The pavilion/prototype was then dismantled. While the hired elements were returned to their point of origin, the majority of the prototype remained in the host country where it will be given a "second life" in another architectural configuration at another location. This will allow follow up studies and monitoring to be carried out.

- Chapter 7: Learning, Results and Discussion. Application of learning to the urban proposal

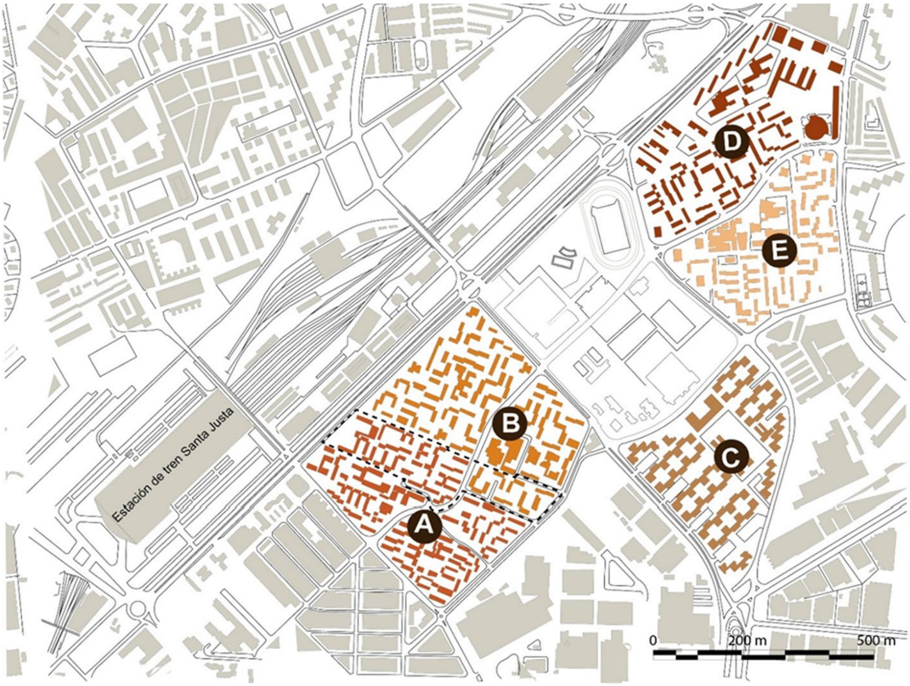

Fig. 3 Districts into which the San Pablo neighbourhood is divided APPROXIMATE INDICATIVE SCALE. Source: Final Degree Project by Ana Seco + Elena do Campo, ETSAS

After the SDE19 competition it is essential that there is critical reflection on the aspects and concepts that can be applied to the urban proposal. It would be interesting to analyse which questions that arose in the design, construction and assembly processes can be adapted at urban scale. To do so, the concepts are once again structured on the four basic lines of the AURA Strategy.

Table 1 Districts in the Poligono San Pablo neighbourhood

	Year	No of buildings	No of homes
District A	1964–1966	127	2006
District B	1964–1966	160	1920
District C	1974–1976	80	2600
District D	1963–1968	106	1400
District E	1964–1966	86	1498

3 Selection criteria for the urban area of study

3.1 Legal and historical context of the neighbourhood

The Sevillian neighbourhood known as the Polígono San Pablo was built by the government between 1963 and 1967. The project consisted of the construction of more than 8800 social houses in five time phases (Table 1). Each of these phases represented one of the five districts (labelled A,B,C,D and E) in the neighbourhood.

The Case Study includes part of phases A and B, which were the first to be built. The neighbourhood was designed and constructed with an important number of infrastructures, open air green spaces and good communication. Near District C, the city's largest sports centre, known as Seville Sports Palace, was built (Fig. 3).

Given its wide range of facilities and the central location within the city, this was an urban project with huge potential. Unfortunately, today the neighbourhood is rundown, old, poor and, as a consequence, isolated from the rest of the city.

The historical context in which this neighbourhood was developed is significant due to recent legislation on social housing and a burst of new construction techniques. The legislation aimed to standardise the quality of building methods and improve comfort conditions within the home.

The confusing industrialisation process of social housing in Spain during the 50 and 60 s is marked by industry's lack of technological possibilities (Pizzorni, 2000).

In this environment of austerity, the starting point for the definition of social housing can be found in the 1954 "Low Income Housing Law", its subsequent "Application Legislation" and the "Technical and Building Regulations Legislation" (Sambricio, 2003) passed in 1955 for "low income" housing. This internal legislation "aspired to be the vade mecum for the drafting of projects" (BOE.Es—BOE-A-1955–10,118, 2022.) and provided not only budgeting advice but also a series of old-fashioned construction recommendations which aimed to economise on resources and minimised the health conditions in housing. These homes were built by the Obra Sindical del Hogar (OSH—Housing Trade Union) as part of the National Institute of Housing's Union Plan (PSV).

3.2 Morphology of the neighbourhood

The neighbourhood is composed of compact units served by a small commercial area. They are designed so that between blocks there is adequate space for community living.

Greater efforts are made in these spaces regarding paving and gardens. Principal pedestrian movement is designed in rings so that all the residential units, as well as their central provisions, are linked to the neighbourhood's commercial area. Secondary pedestrian routes give access to the blocks and other buildings.

Parking areas considered in the original design are less than adequate for the current needs of the neighbourhood, as the ratio of vehicles per inhabitant is greater now than when designed. More parking spaces were originally assigned to higher class blocks. Around the buildings, there are large areas of resistant varieties of plants.

The organisation of the residential blocks which make up Districts A and B responds to the general criteria for an independent neighbourhood, with the creation of a central commercial area and dwellings around common spaces.

During the analysis carried out in the neighbourhood, it was particularly important to recognise the construction types in order to methodologically systemise knowledge of habitability in the Polígono San Pablo Neighbourhood.

Three types of residential building, differentiated by their spatial-construction system have been recognised. However, before defining these architectural types, we should highlight the different joins between them which form the architecture in the Sector. The following types of joins can be recognised:

- *Single block*
- *Terraced Rows*, from longer to shorter in length and joined by the party walls between dwellings. The facades of adjoining buildings can either be aligned or slightly set back from one another to fragment the rows.
- *Angles*, characterised by their unique way of joining buildings along a common vertex or a shorter portion of one of the sides of the blocks, so that facades are set back deeply in the rows.

In terms of building types, the following can be observed:

- *Double Bay*, a building type in which the vertical communication core corridor serves two buildings. Both buildings face in opposite directions and all elements are exterior ventilated without the need for interior courtyards. This type of construction allows for cross ventilation and the orientation is adapted to achieve maximum sunlight. It is the basic hygiene type adapted by contemporary architecture.
- *H Type*, a building type in which four blocks are linked by a corridor. Two blocks share the same party wall as in the double bay type. The vertical communication core is located in the centre of the H form, creating inner courtyards between dwellings on each side of the facades. These inner courtyards are generally overlooked by secondary and service bedrooms and provide lighting and ventilation for the stairwells.
- *Tower blocks*, these isolated, independent structures have a higher number of floors.

The neighbourhood geometry alternates high and low blocks, creating a mesh of diverse public spaces between them. There is a subtle seriality between the most intimate spaces, found closer to the residential blocks and the more open, general spaces where points of special interest such as churches, larger commercial areas and civic centres are located.

3.3 Vulnerability rates in the neighbourhood

The Polígono San Pablo Neighbourhood is an opportunity to apply and develop the sustainable urban regeneration concepts identified by the Aura Strategy. Its conclusions are extrapolatable to other case studies with similar vulnerability indicators to this urban area (García Vázquez, 2015).

The San Pablo Neighbourhood was chosen for this research as it is considered one of the neighbourhoods in Seville which meets the established vulnerability rates (Aja et al., 2018) (Vázquez, 2016). The relevant Spanish Governmental institutions have graded the San Pablo Neighbourhood as being Level II vulnerability since 1991, with reviews in 2001 and 2011 (Aja et al., 2018). It is therefore considered an historic problem, systemic to the neighbourhood (Table 2).

Table 2 Vulnerability rates in the case study area

Year		IStu (%)	IUnem (%)	IHou	CL
1991	San Pablo (districts were not differentiated)	24	34	–	V
2001	San Pablo A and B	24.97	28.60	0.53%	V
2011	San Pablo A and B	17.71	31.60	15.67%	V

Key: "IStu"/"IUnem" / "IHou": indicator values for studies, unemployment and housing "CL": vulnerability classification ("VL": low vulnerability "V": medium vulnerability "VS": severe vulnerability; "VC": critical vulnerability)

A neighbourhood is classified vulnerable on the basis of three Basic Vulnerability Indicators: unemployment, level of studies and housing (Instituto Juan de Herrera DUyOT & Ministerio de Fomento, 2016).

4 Results of the analysis and proposal for urban actions

4.1 AURA strategy: case study analysis

If the four transdisciplinary lines of action determined by the AURA Strategy are considered, a series of weaknesses and deficiencies are determined (Fig. 4) in the Polígono San Pablo Neighbourhood. These are particularly acute in the selected area of study: Districts A and B, which highlights their urban, architectural and social obsolescence.

Fig. 4 Planimetry of the different analyses carried out in the Neighbourhood

As a result of this transdisciplinarity developed in the AURA Strategy, many of these weaknesses could belong to more than one line of action if they are analysed at different scales: urban, building, dwelling, and individual.

The most significant of these are detailed below:

4.1.1 Health and comfort weaknesses

One of the parameters to consider is that the Polígono San Pablo Neighbourhood has a high number of residents over the age of 64 (Seville Town Council). In districts A and B, this figure represents 13% of the total population.

This means that accessibility deficiencies should be considered even more relevant, and the doctor-patient ratio should be lower than in other neighbourhoods where the average age is lower. However, this is not the case.

The monofunctionality of the different areas of this neighbourhood mean that there are zones which are rarely frequented, leaving them unsafe, rundown and unmaintained.

4.1.2 Relative analysis of cultural identity and accessibility

One of the most important problems in the neighbourhood is accessibility. Even the lowest buildings (5 floors) were designed without lifts. This, alongside the previously discussed issue of the aging population, gives rise to situations where the elderly are unable to leave their own homes.

However, the problem of accessibility does not solely occur at building scale. It should also be considered at urban scale where pedestrian areas around buildings have been diminished as a result of the widening of roads for traffic or increased parking áreas in response to the growth in the number of cars per household. Despite the large areas of open space between buildings in the neighbourhood, the rise in the number of cars per household has had a negative effect on the use of these spaces as more parking spaces have been introduced.

4.1.3 Materiality deficiencies

The San Pablo Neighbourhood was originally built for low-income individuals which conditions the ability that residents have to upgrade their homes or community spaces. Frequently they are contingent upon government subsidies.

Among the buildings' deficiencies is the lack of thermal insulation in the envelope, leading to deficient thermal comfort inside the dwellings, as demonstrated by measurements taken in situ.

4.1.4 Deficiencies related to retrofitting and energy

From a retrofitting and energy perspective, the fact that there are buildings with the same facade design, but different orientation means that different, independent actions must be proposed at building scale.

The complete absence of self-generated energy systems means that residents are dependent on commercial energy, leading to numerous counts of energy poverty.

4.2 Urban regeneration proposal

The main aim of the AURA 3.1 project for the SDE19 in Hungary, was the urban and social regeneration of an obsolete, outdated neighbourhood built in the 1960s: the Polígono San Pablo, Seville.

The proposal understands the home as vital heritage for citizen wellbeing and the support that is needed to enjoy a healthy and decent quality of life whilst also forming part of the city's production dynamic, creating shared wealth and social stability without harming the environment, and inclusive, safe, resilient and sustainable living environments.

This means that intervention on the built urban fabric of today's cities should be addressed from the necessary characterisation and improvement of quality in terms of habitability, social cohesion and energy efficiency so that it is affordable and makes efficient use of natural resources.

This project addresses the need to work on residential obsolescence in neighbourhoods within the geographical context of Andalusia. These neighbourhoods, which were on the outskirts of cities in the 1950, 60 and 70 s, now form part of the urban complex.

The existing urban fabric, with its imperfectly transformed and often obsolete buildings and public spaces, links these places with the collective identity of the people who inhabit them, and forms a fundamental part of the recent memory of cities.

In an effort to slow down suburban expansion and, as an alternative to development plans for new land, the concepts of regeneration, reuse and recycling of the existing and underused space prevail in AURA 3.1.

A change in paradigm in the contemporary urban model is therefore encouraged. This should focus on compaction, densification and the promotion of construction and existing spaces as a factor for urban competition and as a model that guarantees a home as a right and not a commodity.

A system which adds to existing buildings is proposed, permitting their extension and transformation. An independent structure which adds flows, staircases, lifts and general installations is provided. This structure is given the name "connecting envelope" and will be able to link different buildings and in some cases extend into nearby public spaces, thus affording them new opportunities for use (Fig. 5).

The proposal consists of adding a habitable space to the facade of an existing building which will allow the building to house new facilities, create new connections and above all, improve accessibility. Furthermore, it will act within the urban space, generating shade and forming part of the urban landscape, etc. The dwelling modules, known as "gadgets", will be added to the skin and will function as dwellings or extensions of these, or extensions of the building's common areas.

The development of the urban project ranges from intervention in the dwelling, buildings and public space to infrastructures, all resolved with the same element: the connection envelope.

The envelope therefore solves the issues of connections at high level between buildings with galleries, accessibility problems, shade in public spaces, and the incorporation of infrastructures to house new facilities and urban furniture.

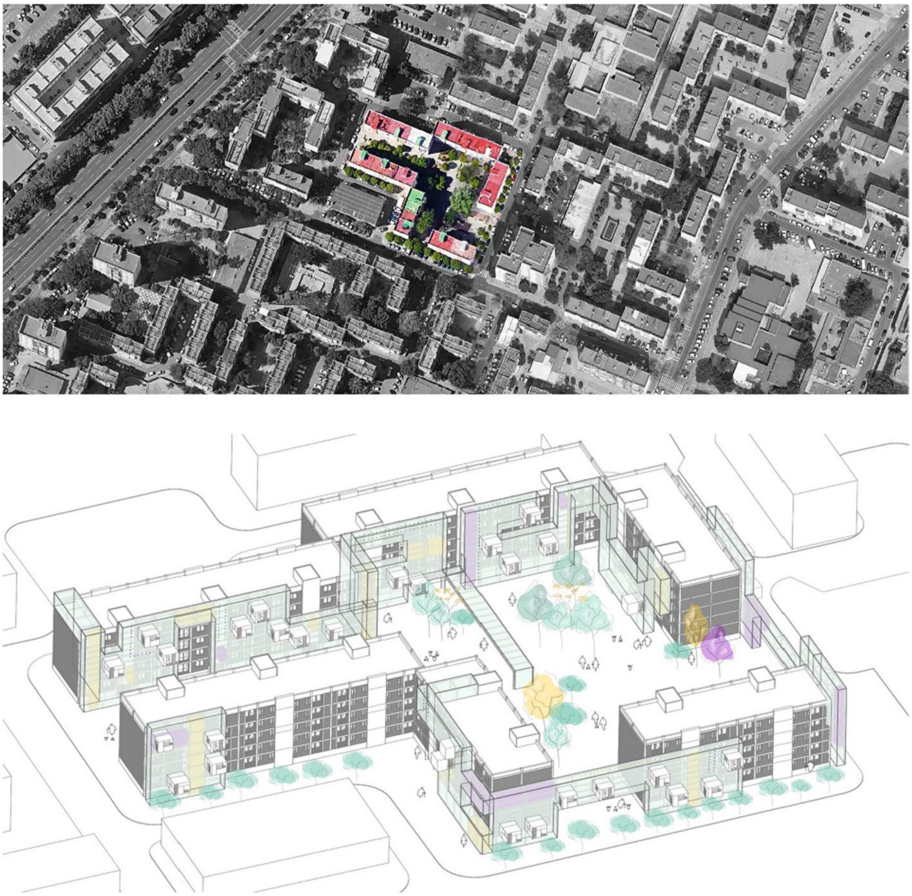

Fig. 5 Implementation of the AURA Strategy in the San Pablo neighbourhood of Seville, built in the 1960s and 70 s

4.2.1 Improvement in social opportunities and economic and environmental benefits

This system is adaptable to various urban situations and solves different problems at the same time, not only at building scale but also at urban space scale. The project has two main aims at urban level:

1. Improving the quality of life for local residents.
2. Creating a new urban image which protects its identity.

The consequences of this improvement can be classified as follows:
a. Improvement in social opportunities:

- Update and increase in the type of dwellings.

- Improvement in the accessibility of the collective dwellings. The system solves one of the main problems of these buildings through the inclusion of lifts in the double surface.
- Improvement of public space and image with a visually recognisable system.
- Incorporation on new street furniture to generate shaded and leisure areas.

b. Economic benefits:

- Actions on existing buildings reduces costs, avoiding those brought about by demolition works and the construction of new buildings.
- The incorporation of new technologies to transform the neighbourhood into a Smart City means greater efficiency and management of the neighbourhood.

c. Environmental benefits:

- The system has been designed to be able to use materials which are reusable (such as the structural system added to the surface) and recycled (the design of the envelope with the framework system).
- The incorporation of both thermal and photovoltaic sustainable solar energy, which will provide the buildings and/or the neighbourhood with energy.
- Improvement in building energy efficiency with the incorporation of a double skin.
- Implantation of passive systems in the buildings.
- Creation of acoustic barriers for homes and public spaces.
- The system makes it easier to reuse water as supply systems are separated.

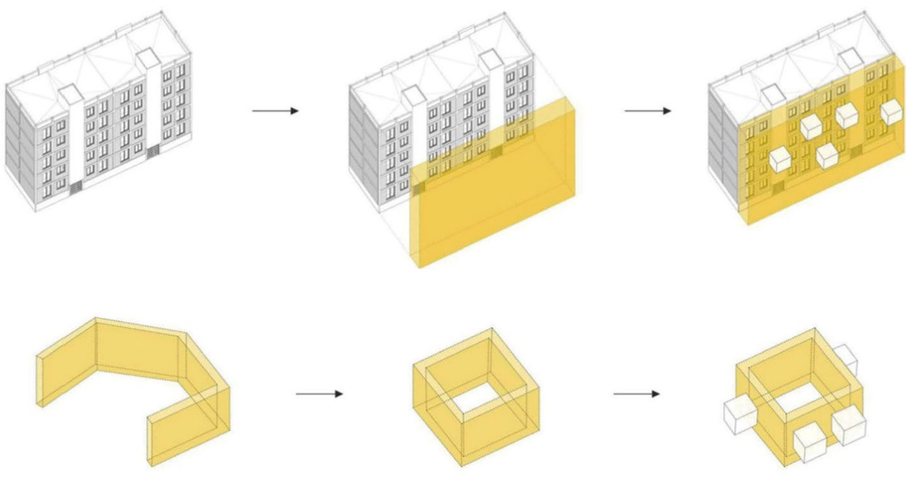

Fig. 6 Above from left to right: existing building, connection envelope (in yellow) and gadgets. Below from left to right: folded connection envelope (in yellow) and gadgets in the configuration of the prototype for the competition

5 AURA 3.1 prototype

5.1 Connection envelope

This first component is a new, independent load bearing structure which is connected to the existing building (Fig. 6). It consists of a double layered framework of rails and vertical restraints which form two parallel porticoed slab-less structures. The first layer connects to the facade of the existing building while the second is placed in parallel to the first with a 1.5 m separation distance. This connection envelope does not necessarily need to cover the whole façade of the existing building but can be organised depending on the specific requirements of each project. Furthermore, as this is an independent construction it is compatible with the uses of the existing building which means tenants do not need to be rehoused during the building works.

The connection envelope, as the link between the existing building and extension modules, serves the following purposes:

- Structural support for the home extension modules (these are described more fully later) which literally hang from this new structure.
- To update the energy efficiency of the existing building through the introduction of a new layer of thermal insulation on the envelope which incorporates more efficient technology.
- To introduce transition spaces between existing buildings and their extensions. These will be described in more detail later.
- To incorporate new common circulation spaces in the building (staircases, lifts, galleries) thus meeting accessibility requirements and eliminating architectural barriers while also introducing new accesses to homes and transforming typology through the emergence of new residential units with independent access.
- To connect to adjoining buildings to share basic elements (staircases, lifts), optimising usage and maintenance costs.
- To house the distribution networks for the building's new technological installations (heating and cooling, water, telecommunications, electricity, etc.) and related equipment (machines, electrical switch boxes, etc.)

Fig. 7 Prototype in the Solar Village during the assembly phase (Stenzendre, Hungary)

5.2 5.2. Modular extensions: "gadgets"

The "gadgets" create additional spaces for existing homes. They hang from the building envelope and can be configured at different heights along the length of the building. From a construction perspective, installation is immediate, in the style of "Plug and Play", as the modules literally hang from the building envelope and new utilities can be connected directly, in the same way as a conventional electrical plug would be connected to a socket (Figs. 7).

The freedom to vary the position of these extension modules allows the resulting space to be used according to the needs of the modified dwelling: a bedroom, a kitchen, a workspace, a bathroom, storage space, space for new systems, a kitchen garden…

The logic of this system gives rise to an evolving transformation of the multi-dwelling unit. Firstly, the connection envelope is built. The modular extensions can then be added progressively without affecting the other homes.

5.3 Design and construction. Construction concept

The central body of the structure was a lightweight, semi-permeable, textile double envelope. There is a 100 cm chamber between the two layers which houses installations, staircases and the access galleries for the extension modules and storage areas (Fig. 8). The envelope for the housing fragments (gadgets) was designed to limit the total weight of the unit. A sandwich panel was used which could later be terminated with different exterior finishes.

On the outside, cellulose fibre cement boards were placed over a lightweight galvanized omega steel stud "balloon frame" and then sealed to guarantee air and water tightness. On the inside, thermal laminate plasterboard was placed over a lightweight sub-structure. Between the outer and inner skin, layers of semi-rigid stone wool in varying density and thickness provided thermal and acoustic insulation. A non-ventilated chamber was also created to house the different installations.

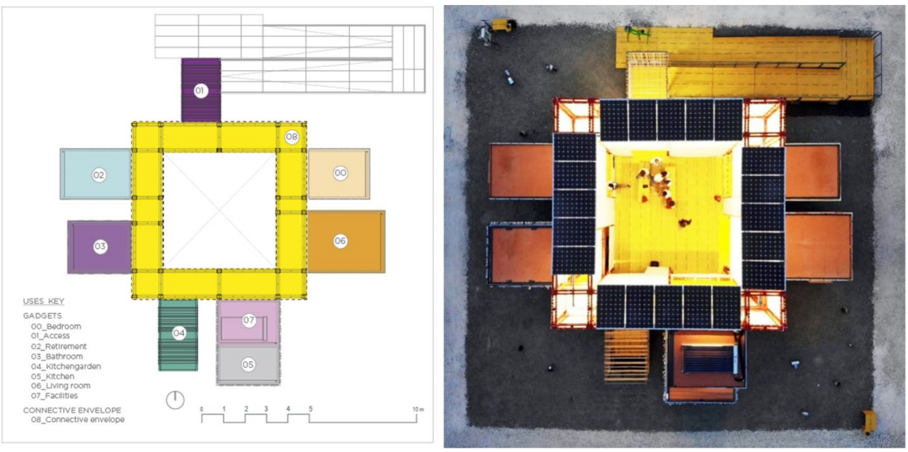

Fig. 8 Prototype AURA 3.1: schematic floorplan for the prototype and aerial view

Fig. 9 Prototype AURA 3.1: elevation view

5.4 Environmental conditioning and installations concept

The environmental conditioning and installations were designed in line with the general concept of the prototype: flexible, transformable systems which could be adapted to different architectural configurations (Fig. 9). They also had to meet various requirements:

1. Be highly energy efficient.
2. Guarantee demanding operating conditions of the building and environmental comfort.
3. Use renewable energies.
4. Have exceptionally low energy consumption.

Based on these prerequisites, "Plug and Play" installations were designed. These were fully integrated into the architectural proposal and complemented all the passive solutions for hygrothermal conditioning and air quality.

Most of the installation equipment (heat pump, electric switchboard, hot water tank, flat-plate solar collector, solar inverter, etc.) were housed in a systems room. From here, the distribution networks could be run via the central, pivotal space (the connection envelope) while the extension modules (gadgets) connected to the general network in the same way as the structure did.\

6 Results and discussion

6.1 Health and comfort

The Solar Decathlon competition assesses comfort in a home exclusively from a quantitative perspective, determining optimal ranges for thermal parameters, humidity, lighting and CO2. However, the AURA Strategy working method understands that the evaluation of comfort should also have a qualitative element.

It is therefore understood that the competition method is not a good example for the measurement of people's health: be they visitors to the prototypes, the theoretical users of the homes they represent, or the decathletes and researchers themselves. Only measuring parameters associated with quantitative comfort (and not in their whole, nor concerning non-physical questions at all) makes it impossible to know or address specifically the reality of the situation that these prototypes produce in people.

For this reason, although the AURA 3.1 prototype won the "Comfort Conditions" contest at SDE19, the team of researchers from the University of Seville carried out surveys among the participating students and professors, as well as visitors to the prototype in order to obtain a relation between the comfort in the dwelling and its effect on the health of its users (Herrera-Limones et al., 2020).

The aim is to develop a valid method which allows the evaluation of qualitative aspects of comfort from objective parameters (Millán-Jiménez et al., 2021).

6.2 Cultural identity and accessibility

The AURA 3.1 urban regeneration proposal is based on evolutionary and progressive planning. The planned actions are always compatible with residents remaining in the neighbourhood throughout the whole process, avoiding temporary evictions which would likely lead to the substitution of the most vulnerable social fabric by another with higher economic capacity. Residents' cultural links to the urban context are thereby protected.

The aim is to introduce devices which add to the existing fabric, leading to a sustainable urban regeneration with the ability to adapt to current and future needs. One main objective is to solve the accessibility of urban spaces and residential buildings which mostly lack lifts. The urban typology characteristic of the Polígono San Pablo: non-aligned, repetitions of blocks forming heterogenous open spaces often filled with cars, offers huge opportunities for adaptation with actions such as those proposed here.

The prototype built for SDE19 was based on this idea of urban regeneration. It did not represent a residential building or house, but a landscape formed by functional fragments which compose the residential buildings (living room, kitchen, bedrooms, bathrooms, kitchen garden, facilities). All these fragments hung from a support structure, around a courtyard, which was in this case the space for the visiting public and were related to the cultural and climate context of cities in the South of Europe.

6.3 Materiality

In the area of materiality, knowledge related to construction systems and the industrialization model can be gained. However, the materials used cannot be extrapolated as this was a prototype of limited durability for an exhibition.

Other aspects such as the energy rehabilitation of the buildings to be treated could not be tested. Aspects related to accessibility and treatment of urban spaces were not present either.

For these two reasons, from an economic perspective, it is incredibly difficult to extrapolate the prototype budget to an action at urban level on the neighbourhood. At competition level, the sustainable intention, from a budgetary perspective, was to propose the most profitable prototype possible in economic terms, in spending on material resources and in energy consumption. CO_2 emissions were also kept at a mínimum both for material resources where recycled products or hired systems were used, and logistics (Transport and auxiliary means).

Lightweight construction, quick assembly and low-cost methods were applied so that existing buildings were compatible with retrofitting works. The idea was to use the existing urban fabric and buildings, maintaining them throughout the process, and thus safeguard the identity of the inhabitants with their habitat.

This option maximizes the urban regeneration effect through a wider and better distribution of investment in vulnerable urban areas, increasing the profitability of the intervention and, consequently, optimising the use of available resources. It basically means the improvement of conditions in a greater number of homes and neighbourhoods through distribution, as opposed to more intensive and invasive transformation options which would only be economically viable if applied to a small number of buildings.

The prototype-pavilion was a specific configuration of the previously defined system, made up of a connection envelope and a series of additional modules, adapted to the competition requirements. The absence of an existing building in the actual competition was solved with the following action: the connection envelope structure was separated from the existing building and folded in on itself to form a square. On the exterior, the square shaped connection envelope served as the structural support for a series of extension modules. These modules housed the basic elements that the competition stipulated (bedroom, living area, bathroom, workspace) and further modules with additional uses (kitchen garden and space for systems). The modules were accessed via a series of staircases located at various heights in the interstitial space found in the connection envelope, as if it were a multi-dwelling unit over various floors (Fig. 9).

Looking inwards, the resulting square was an empty space which represented the existing building on which the intervention was to be carried out. In the show pavilion, this uncovered empty interior space is in fact a courtyard, a fundamental identifying element of Mediterranean architecture (Fig. 9). The empty space-courtyard, which was accessed via an exterior ramp, is the space from which the system was visited and exhibited, from where the extension modules were contemplated from inside a virtual, inexistent building.

6.4 Retrofitting and energy

The absence of thermal insulation in social housing in the Southern Spanish region of Andalusia is due to the fact that these houses were built in a time when there was no existing legislation to regulate thermal requirements. This makes it difficult to obtain optimum interior comfort conditions in line with current legislation.

The low incomes of the current residents suppose in many cases, great difficulty in affording the energy necessary to provide these homes with adequate interior thermal conditions, leading to situations of energy poverty. This has driven the development of low cost solutions and energy rehabilitation interventions which prioritise habitability conditions for users.

The prototype was built as a configuration adapted to the requirements of the SDE19 competition. The effectiveness of the proposal in terms of sustainability was shown by the two first prizes obtained in quantitative tests, based on the objective measurements collected with scientific equipment: Comfort Conditions and House Functioning. Furthermore, third prize was obtained in the Sustainability contest which demonstrates the huge possibilities that the AURA Strategy has in the field of sustainable urban regeneration in retrofitting social housing.

Nevertheless, it is important to mention that the competition assesses the comfort of the prototypes through continual monitoring of the parameters over the ten-day competition period. The prototype is therefore only tested under the specific atmospheric conditions on the days that monitoring takes place. The prototype's environmental behaviour is not assessed the rest of the year. In climates such as Budapest's, where the winters differ greatly from the summers, the assessment of the prototypes, under competition methodology, can be considered incomplete, as the dwelling must meets the user's needs throughout the whole year.

7 Conclusions

The AURA 3.1 prototype is an experience of AURA strategy: a sustainable construction strategy for the urban regeneration of neighbourhoods with obsolete social housing, in the Mediterranean energy context. The proposal facilitates the adaptation of existing cities to sustainable cities to meet twenty-first century demands.

The results of the Solar Decathlon Europe 2019 experience should be verified in real neighborhoods, with consideration for the different lines of work outlined in this article: Health and Comfort, Cultural Identity and Accessibility, Materiality, and Retrofitting and Energy. The simplifications set out in the rules of the SD competition do not take into account the complex variables relevant to the success of future interventions in obsolete residential neighbourhoods.

In relation to the Health and Comfort line, gathering the opinion of the local residents via tools based on surveys and interviews is deemed important. An assessment method should be established which can be extrapolated to these types of neighbourhoods. This is an opportunity to make advances in the links between medicine and architecture and make the evaluation of health and comfort conditions in the design for future generations possible.

In terms of Cultural Identity, the AURA Strategy foments interventions which allow residents to continue living in their homes during the regeneration process, through progressive and evolutionary actions. These should be combined with participatory processes which provide local residents with a sense of participation in the intervention and thus connecting them to the urban and socio-cultural context.

Nevertheless, with regards to Materiality, it should be pointed out that while the construction materials and products used in the prototype are not directly extrapolatable to real cases because of the competition's specific constraints based on temporality, transport and economic limitations, there do exist aspects of the AURA Strategy which are fully applicable:

The main retrofit proposal consists of the juxtaposition onto a social housing block of a technological-structural system which provides new technological and spatial features. This prefabricated system is composed of a connection envelope and extension modules with the following characteristics: fragmented system enabling a more widespread application over a greater number of multi-dwelling units and with the capacity to adapt to the specific requirements of each building/home; progressive system which does not require a complete construction to be operational; a system compatible with the use of the building during the construction process; a system open to the incorporation of future needs.

The AURA Strategy energy proposal is based on a strategy of controlled passive interior-exterior transfer to improve comfort conditions in social housing. Rather than employing the habitual solutions focused on the reduction of energy consumption, the priority was on improving comfort. These passive strategies are complemented with systems based on renewable energies. The effectiveness of the thermal behaviour in the prototype was verified in the monitoring period of the competition. Of particular relevance were the results obtained on the passive days when the best relation between scores for comfort conditions (temperature, relative humidity, C02 contests) and energy consumption were achieved.

This urban regeneration method continues to be developed through the "Direct Application of the AURA Strategy by the University of Seville solar Decathlon TEAM in the rehabilitation of obsolete Andalusian neighbourhoods" research project.

The current context of climate emergency and decreasing demographics justifies the upgrade of existing buildings over an increase in the number of new builds. At a time when the very concept of sustainability is threatened by the term's overuse and government policies have been ineffective, strategies which focus on the living conditions of the working classes are credible and economically viable as part of the process to meet the still utopian theoretical assumptions set out by the UN in its Sustainable Development Goals.

Acknowledgements The authors would like to thank SD-US Team (Universidad de Sevilla, Spain) who participated in the 2019 edition of the Solar Decathlon Europe, held in Budapest (Hungary). Likewise, the authors thank to Ana Camila Vargas Palomo and Álvaro López-Escamilla, for the contribution in figures and final revision, and the professors Ángel Luis León-Rodríguez and Rafael Suárez, for their contribution to the energy topics of the article.

Author Contributions All authors have conceived, designed and performed the experiments; analyzed the data; have written, reviewed and approved the final manuscript. All authors have read and agreed to the published version of the manuscript.

Funding Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature. Research Project: "Direct application of the Aura Strategy by the SD-US Team for the regeneration of outdated Andalusian housing estates", as well as a methodological approach for Polígono San Pablo, Seville (as a case study for the extrapolation of results to similar environments, through the implementation of sustainable regeneration in the working-class residential area). The project was granted in the resolution of July 28th, 2021 by the Ministry of Development, Infrastructure and Territorial Planning (Local Andalusian Government), within the 2020 call for grants for carrying out research projects in the areas of housing, rehabilitation and architecture.

Data availability The authors declare the availability of data and material. The article has not associate data. https://institucional.us.es/proyectoaura/

Code availability Not applicable.

Declarations

Conflicts of Interest The authors declare no conflict of interest.

Consent for publication The authors consent for publication.

Ethical approval. The authors declare ethics approval.

Consent to participate The authors consent to participate.

References

2030 climate & energy framework. Retrieved March 21, 2022, from https://ec.europa.eu/clima/eu-action/climate-strategies-targets/2030-climate-energy-framework_en#ecl-inpage-911

2050 long-term strategy. Retrieved March 21, 2022, from https://ec.europa.eu/clima/eu-action/climate-strategies-targets/2050-long-term-strategy_en

Aja, A., Alonso, R., Suárez, I., Gómez Giménez, J., González, I., Córdoba Hernández, R., Gómez, J., Gutierrez, J., Mateos, F., & Cáceres, S. (2018a). *Barrios Vulnerables de las grandes ciudades españolas. 1991/2001/2011*. Instituto Juan de Herrera.

Aja, A., Surez, I., Córdoba Hernández, R., Gómez Giménez, J., González, I., Mateos, F., Heredia, M., & Pérez, M. (2018b). *Vulnerabilidad residencial y social en las grandes ciudades españolas. 2001/2011*. Instituto Juan de Herrera.

Alonso, C., Oteiza, I., García-Navarro, J., & Martín-Consuegra, F. (2016). Energy consumption to cool and heat experimental modules for the energy refurbishment of façades. Three case studies in Madrid. *Energy and Buildings, 126*, 252–262. https://doi.org/10.1016/j.enbuild.2016.04.034

Asadi, E., da Silva, M. G., Antunes, C. H., & Dias, L. (2012). A multi-objective optimization model for building retrofit strategies using TRNSYS simulations, GenOpt and MATLAB. *Building and Environment, 56*, 370–378. https://doi.org/10.1016/j.buildenv.2012.04.005

AyuntamientoDeSevilla. Informes de Salud 2017 — Servicio de Salud. Retrieved March 23, 2022, from https://www.sevilla.org/servicios/servicio-de-salud/plan-de-salud/informes-de-salud-2017

BOE.es - BOE-A-1955–10118. Retrieved March 21, 2022, from https://www.boe.es/buscar/doc.php?id=BOE-A-1955-10118

Caputo, P., Costa, G., & Ferrari, S. (2013). A supporting method for defining energy strategies in the building sector at urban scale. *Energy Policy, 55*, 261–270. https://doi.org/10.1016/j.enpol.2012.12.006

Carbon Hub, Z. (2013). Closing the gap between design and as-built performance new homes interim progress report zero carbon hub interim progress report: Closing the gap between design and as-built performance. www.zerocarbonhub.orgwww.zerocarbonhub.org.

Chantrelle, F. P., Lahmidi, H., Keilholz, W., Mankibi, M. E., & Michel, P. (2011). Development of a multicriteria tool for optimizing the renovation of buildings. *Applied Energy, 88*(4), 1386–1394. https://doi.org/10.1016/j.apenergy.2010.10.002

Fernández-Galiano, L. (2021). *Lacaton & Vassal : 1991–2021*. AV Monografías, Arquitectura Viva.

Foucquier, A., Robert, S., Suard, F., Stéphan, L., & Jay, A. (2013). State of the art in building modelling and energy performances prediction: A review. *Renewable and Sustainable Energy Reviews, 23*, 272–288. https://doi.org/10.1016/J.RSER.2013.03.004

García Vázquez, C. (2015). La obsolescencia de las tipologías de vivienda de los polígonos residenciales construidos entre 1950 y 1976: Desajustes con la realidad sociocultural contemporánea. *Informes De La Construcción, 67*(1), m020–m020. https://doi.org/10.3989/ic.14.045

García-Pérez, S., Oliveira, V., Monclús, J., & Díez Medina, C. (2020). UR-Hesp: A methodological approach for a diagnosis on the quality of open spaces in mass housing estates. *Cities, 103*, 102657. https://doi.org/10.1016/j.cities.2020.102657

García Vázquez, Carlos., & Valero Ramos, E. (2016). I*ntervención en barriadas residenciales obsoletas : manual de buenas prácticas*. Abada.

Guerra-Santin, O., & Tweed, C. A. (2015). In-use monitoring of buildings: An overview of data collection methods. *Energy and Buildings, 93*, 189–207. https://doi.org/10.1016/j.enbuild.2015.02.042

Hernández-Valencia, M., López-Martín, E., Potter, J., & Domínguez-Saborido, F. J. (2014). *Intervención en espacios comunes de edificios plurifamiliares de promoción pública. Actuaciones Accesibles en Arquitectura, 78–91*. Ed. Pencil.

Herrera-Limones, R., Millán-Jiménez, A., López-Escamilla, Á., & Torres-García, M. (2020). Health and Habitability in the Solar Decathlon University Competitions: Statistical Quantification and Real Influence on Comfort Conditions. *International Journal of Environmental Research and Public Health, 17*(16), 5926. https://doi.org/10.3390/ijerph17165926

Hess, D. B., Tammaru, T., & van Ham, M. (2018). *Housing Estates in Europe: Poverty*. Springer.

Instituto Juan de Herrera DUyOT, & Ministerio de Fomento. (2016). Síntesis metodológica general del Catálogo de Barrios Vulnerables e Indicadores Básicos de Vulnerabilidad Urbana. https://cdn.mitma.gob.es/barriosvulnerables/static/adjunto/Sintesis_metodologica_general_catalogo_bbvv.pdf

León-Rodríguez, Á. L., Suárez, R., Bustamante, P., Campano, M. Á., & Moreno-Rangel, D. (2017). Design and performance of test cells as an energy evaluation model of facades in a mediterranean building area. *Energies, 10*, 1816.

Millán-Jiménez, A., Herrera-Limones, R., López-Escamilla, Á., López-Rubio, E., & Torres-García, M. (2021). Confinement, comfort and health: Analysis of the real influence of lockdown on University students during the COVID-19 pandemic. *International Journal of Environmental Research and Public Health, 18*(11), 5572. https://doi.org/10.3390/ijerph18115572

Monteys, X. (2011). Rehabitar entrar por el balcón [7]. http://cataleg.upc.edu/record=b1396436~S1*cat

Pardo-Bosch, F., Cervera, C., & Ysa, T. (2019). Key aspects of building retrofitting: Strategizing sustainable cities. *Journal of Environmental Management, 248*, 109247. https://doi.org/10.1016/j.jenvman.2019.07.018

Penna, P., Prada, A., Cappelletti, F., & Gasparella, A. (2015). Multi-objectives optimization of Energy Efficiency Measures in existing buildings. *Energy and Buildings, 95*, 57–69. https://doi.org/10.1016/j.enbuild.2014.11.003

Pizzorni, R. M. (Reginaldo M. . (2000). Malos tiempos para la lirica... (Esperanza y des-esperanza en la Europa de las posguerras). https://dadun.unav.edu/handle/10171/23487

Power, A. (2008). Does demolition or refurbishment of old and inefficient homes help to increase our environmental, social and economic viability? *Energy Policy, 36*(12), 4487–4501. https://doi.org/10.1016/j.enpol.2008.09.022

Sambricio, C. (2003). *Un siglo de vivienda social: 1903–2003*. Madrid: Nerea.

Sendra, P. (2016). Infrastructures for disorder Applying Sennett's notion of disorder to the public space of social housing neighbourhoods. *Journal of Urban Design, 21*(3), 335–352. https://doi.org/10.1080/13574809.2015.1133223

Vartholomaios, A. (2017). A parametric sensitivity analysis of the influence of urban form on domestic energy consumption for heating and cooling in a Mediterranean city. *Sustainable Cities and Society, 28*, 135–145. https://doi.org/10.1016/j.scs.2016.09.006

Wassenberg, F. (2013). *Large housing estates: Ideas The Bijlmermeer and beyond*. Ios Press.

Yoshino, H., Hong, T., & Nord, N. (2017). IEA EBC annex 53: Total energy use in buildings—Analysis and evaluation methods. *Energy and Buildings, 152*, 124–136. https://doi.org/10.1016/j.enbuild.2017.07.038

Zhou, Z., Zhang, S., Wang, C., Zuo, J., He, Q., & Rameezdeen, R. (2016). Achieving energy efficient buildings via retrofitting of existing buildings: A case study. *Journal of Cleaner Production, 112*, 3605–3615. https://doi.org/10.1016/j.jclepro.2015.09.046