Les-Energy Seed and Health. From School to Home. Towards a Model to Raise Awareness about the Benefits and Co-benefits of Energy Retrofitting in the Residential Buildings.

Eva Crespo Sánchez[1, a)], Belen Onecha Pérez [2], Oriol Pons Valladares [1], Carlos Marmolejo-Duarte [3]

[1] *Escola Tècnica Superior d'Arquitectura de Barcelona, SMArT – Sustainability and Metabolism in Architecture and Technology. Universitat Politècnica de Catalunya, Av. Diagonal 649, 08028, Barcelona, Spain*
[2] *Escola Tècnica Superior d'Arquitectura de Barcelona,*
REARQ – Rehabilitació i Restauració Arquitectònica, Universitat Politècnica de Catalunya
[3] *Escola Tècnica Superior d'Arquitectura de Barcelona,*
CPSV – Centre de Política de Sòl i Valoracions, Universitat Politècnica de Catalunya.

[a)] Corresponding author: eva.crespo@upc.edu

Abstract. Project LES (Energy seed and health. From school to home), co-financed by *Educació científica, cultura científica i divulgació a la recerca* program has the aim to promote education, culture and scientific dissemination to the citizenship or specific group of people that are not specialized in this area. This project is seen as an opportunity to show to future generations that the applied science (experimental workshops) is a decisive strategy to activate the renovation building plan which successfully and comprehensively deals with the climate emergency. The culmination of this project is the sum of results of past research projects in theoretical, descriptive and experimental fields that are previously accomplished avoiding to stay on the Death Valley. As an example, EnerValor2 project has provided evidence about the limited awareness of society in the face of benefits and co-benefits emanating from energy retrofits at houses, especially in the well-being, health and user productivity realms. Giving visibility to the role of science in our context is the opportunity to present the architecture research as an essential key to mitigate the climate change and improve people's health. The goal of this research is to arrive the major range of people, but the main receptor and driver is students between 8 and 10 years old and then it will be available to seed the energy and environmental conditioning concepts and the interrelations with strategic performance in buildings. The awareness is achieved throughout scientific workshops implemented in primary schools which exhibiting energy and quality air deficiencies and opportunities of their schools and also extrapolated to housing. The success of energy knowledge transmission and awareness in the project is evaluated through the surveys made before and after the workshops, which allow tracing the quantitative and quality stage through the sessions and their energy and health concepts. Reaching adult people throughout our children is the main challenge, but also is the main key to obtain a successful final result. The project diffusion and the awareness to society are not only attained to primary students of the two schools selected for the project, but also the entire educational community (students, teachers, families and the whole of society). Regarding the experimental material (8 scientific briefcases), it will be loaned to the administrative educational headquarter, and the energy educational contents (instruction manuals of the workshop, quality air measurements values and also energy teaching material) developed during the project will be available in a website. The project seeks to raise awareness regarding benefits about energy efficiency actions at houses and, accordingly, a wider interest to start energy rehabilitation (since actually there is only among 0,4% and 1,2% of building refurbishment) of our residential area that contributes to relieve climate change. Indeed, the decision to select two schools situated in different socioeconomical districts (vulnerable and middle-income families) allows to provide details and statistics about the different perception about energy benefits in both school's families. This evidence contributes to establish an energy path as well as action policies to activate a massive deep energy residential renovation.

INTRODUCTION

Multiple projects concerning energy consumption of buildings try to captivate future generations to be aware of their own actions. These projects have the aim to consolidate a good pattern of energetic behavior in schools that encourage its implementation at homes and therefore contribute to climate change mitigation [1]. A benchmark for citizen awareness through students is EURONET 50/50 project, led from Rubi and replicated nationally in Madrid and Valencia as well as other European cities. Other projects (e.g. ZEMedS) [2][3] have their scientific focus their attention on measuring energetic and economic impacts in deep energy rehabilitation actions from a technical and design perspective. These projects aware the entire education community: not only students but also the directive team, professors, maintenance and cleaning staff, etc.

In spite of the efforts, the society's perception of the environmental, economic and social benefits about energy intervention in residential areas is very low [4-7]. One of the surveys carried out in EnerValor1 project shows that people is willing to renovate minimally their home to improve the functionality and the aesthetic of their homes. It also mentions *Lameba, Grau i Pastor* study [8] in which the surveys conducted reflect that 70% of respondents recognize to implant sustainability criteria because of regulatory requirements and not for personal interest. Only 17,6% accomplished the measures in this field because of interest in energy benefits.

In terms of energy efficiency, people have some daily conscious habits (e.g. lighting management or ventilation), but their bond with environment conditioning and benefits is not yet known nor replicated, and even less in some social sites (especially in vulnerable neighborhoods or people with different culture because of their country of origin) [9, 10]. Sun protection is a key factor in energy consumption, because of the technology applied and its way of control, being the one that provides more benefits. In fact, many schools from the 1960s and 1970s manifest physical impairment that make them dysfunctional. *Noves proteccions solars tibades per a tallers d'arquitectura escolar sostenible (New solar projections stretched by architecture school sustainable workshops)* project lead by a team member is a clear example of the educational role of architecture [11].

In parallel to this issue, studies in relation to building conditioning and their impact in health and users' productivity started to active years ago. On account of the appearance of Covid-19, many articles certify impacts related to air quality, mainly in offices and schools, as well as housing [12-16].

Environmental, economic and social benefits and co-benefits go beyond environmental improvement or energy bill reduction, which are invaluable effects for vulnerable households. Therefore, efforts are being done on policies and tools that will allow prioritizing areas of rehabilitation [17].

An example of co-benefits is the improvement of indoor air quality of spaces, not only in CO_2. CO_2 emissions from the atmosphere are described as greenhouse gas pollutants (GHG, causing climate change), but there are also other air pollutants not associated with GHG -such assolid particulate matter (PM), nitrogen dioxide (NO_2) or sulfur dioxide (SO_2)-that are linked to hospital admissions and lead to winter mortality and morbidity [18].

These health-related co-benefits are particularly relevant in low-income households. There are families used to long exposure to temperatures below 18ºC, a situation that can cause both physical discomfort and mental illnesses; or the presence of high humidity concentrations that cause respiratory problems such as asthma; or the presence of pollutants and microorganisms in indoor air that affect lung diseases (*Programa de Malaltia Pulmonar Difusa Intersticial, Hospital Clínic, UB*) or are associated with premature death [19].

Taking data from the *Enervalor* project, the second phase shows that consumers show interest in undertaking energy improvement actions in their homes when they are informed of the social, economic and environmental benefits. The majority of the population can be included within a medium socioeconomic level with a basic energy consumption and are able to activate some kind of architectural improvement in their buildings. However, it is necessary to continue working on raising awareness and informing society.

Consequently, it is considered a priority to continue investing efforts in the education of our children in the field of environmental awareness thanks to the contribution of science. Some projects have started to work in this method of energy knowledge transmission [20-23]. This awareness can be developed not only with actions to improve habits of use but also with actions to improve the envelope and its facilities, and thus address the problem of climate emergency and the reduction of energy demand through the basic energy parameters of a building. At the same time, ensuring the conditioning of homes at hygrothermal and air quality levels, will report benefits in health and productivity.

Finally, the economic support of European funds and local governments [24] have activated state and local energy rehabilitation plans that are a perfect complement to activate the dynamism of society and fuel energy improvement actions in their homes. Moreover, public awareness of the impact on health of parameters such as the hygrothermal

behavior of a building and the quality of indoor air are a perfect tandem to encourage society to mobilize to comply with actions to improve the living conditions of their homes.

PROJECT CHALLENGE

The project was born from the need to give visibility to science and its impact on society together with the need for an action plan to combat climate emergency and the minimization of diseases linked to energy and environmental deficiencies in the building sector. Also, adding the economic aid plan to activate the energy rehabilitation is the perfect contextual framework to develop Project LES "Energy seed and health. From school to home".

Project LES "Energy seed and health. From school to home" aims to increase the scientific awareness of society regarding the improvement of energy efficiency and the environmental conditioning of the built environment through the seed sown in the students. The articulation of the scientific results of 5 research projects meets two challenges: first, bringing together science (as a concept), technique (as a procedure) and technology (as a tool) and second, contributing to the socio-economic valuation of research results by overcoming the barrier of the valley of death.

Scientific objective

Project LES "Energy seed and health. From school to home" aims to contribute to a society with greater scientific awareness focused on the field of energy efficiency and environmental conditioning and their benefits and co-benefits on the well-being, health and productivity of the users (hygrothermal behavior and indoor air quality).

The awareness actions of the project intend to transmit to students between 8 and 10 years old the contribution of science in energy and environmental conditioning concepts and their interrelation with strategic actions to the school and residential building stock, focusing on the building envelope, the conditioning installations and the introduction of renewable energy sources as the key to achieve the final success of the energy actions.

At last, there is the aim to demonstrate that the promotion of scientific culture is a basic pillar to activate business markets such as refurbishment of the housing stock and encouraging actions that guarantee plausible improvements in two points: the reduction of energy demand, consumption and CO_2 emissions and the optimization of environmental quality, hygrothermal and pollutants.

Socio-generational objective

The second objective of the project is an individual action with a social impact. The intention of the project is therefore to raise the awareness of the students, as they are the channel of transmission in the social sphere through different generations.

Another purpose is to show future generations the importance of science and research in our society. Science has different application models: historical, descriptive and experimental. The project aims to show that applied science (with experimental workshops) is a seed that makes it possible to activate a massive building renovation plan that addresses the problem of climate emergency in an extensive and successful way. It also unveils that this project has been achieved through the development of multiple theoretical, descriptive and experimental research projects. An example of this kind of strategy was the awareness program of selective urban waste collection that focused the awareness effort on children in order to reach the whole society.

Acquiring a concept, regardless of its complexity, is not just a matter of showing an attitude of interest and attention; for an effective understanding, assimilation and retention, active involvement of the subject through personal experimentation is necessary. For this reason, the project proposes different scientific workshops as an ideal format to guarantee a solid acquisition of knowledge by the students.

The dissemination of the project not only reaches the group of students (approximately 200, counting the two schools) but also made available the experimental material and the scientific content developed to the entire educational community and families throughout a web platform with guarantees of hosting and maintenance for two years after the end of the project.

METHODOLOGY

From the pedagogical point of view, the project is based on a multidirectional format to raise awareness of scientific culture and its application in the field of building. In the activities designed, children, teachers and families are the protagonists being the children the main backbone of the transmission of knowledge to society through their families.

The project's strategy to achieve maximum diffusion with the minimum economic investment is to carry out 2 demonstrations (in two schools in 2nd primary grades with two lines, to students between 8 and 10 years old) to validate the new methodology developed for this study (individual action). This model is physically reproducible in other schools (public, subsidized and private) with the help of 8 scientific briefcases accessible through the Consortium of Education of Barcelona and/or the Department of Education of the Generalitat of Catalonia to the whole society and with the support of user manuals incorporated in the web.

In order to guarantee the success of the knowledge transmission and awareness of the students to their families, an active training model is proposed through experimental scientific workshops which, complemented by monitoring, provide quantifiable evidence for each of the actions proposed in the workshops, which will be incorporated in different user manuals developed in the project. The purpose of these manuals is to collect the information gathered in the workshops and to be able to disseminate the replication of these on a large scale (first in Barcelona, followed by Catalonia and thus be able to reach a national or even international level).

The expected results of this action, measured qualitatively and quantitatively through surveys conducted in different phases of the project and to different people, will be the confirmation that the promotion of scientific culture is a fundamental pillar.

The scientific model is structured in three phases: a) Design of the experience, b) Experimental demonstration, and finally, c) Measurement and evaluation of the impact of the project as well as dissemination and validation of the objectives and results.

The project design phase is based on the creation of results from 5 projects developed by the project team:

1. *Nexo pobreza-energía-vivienda,*
2. *Smart rehabilitation 3.0*
3. *EnerValor 2. A nivel percepció de l'usuari de beneficis i co-beneficis*
4. *ZEMedS amb cost òptim de la rehabilitació energética*
5. *Noves protecciós solars tibades per a tallers d'arquitectura escolar sostenible.*

The UPC-Clima project is also added, which provides environmental quality data in 3 schools carried out within the climate emergency plan of the Polytechnic University of Catalonia.

The validation and consolidation of the format and final development considers the feedback from teachers and pedagogues of the two participating schools, as well as the Department of Education, the Consortium of Education, and also from institutions focused on research and technology transfer, such as EURECAT, as well as entities that are the backbone of energy efficiency in Catalonia and based in Barcelona: ICAEN, CEEC and COAC.

AUDIENCES

Interdisciplinarity of the team and collaborating institutions

The interdisciplinary nature of the agents involved focuses on the continuous interaction and relationship throughout the project between agents from the architecture, education, energy and humanities sectors (participation is noted in the timeline) and all institutions with strong policies on gender, sustainability and internationalization.

Infrastructures and schools

The content to be transmitted must be adapted to a certain cognitive and developmental capacity of the students. Therefore, this call is focused on the age range of 8 to 10 years old, which corresponds to the middle cycle of primary education. This educational stage has been chosen because it is the time that combines the development of skills such as oral expression and comprehension, socialization, and also curiosity and logic. According to Piaget's theory, between the ages of 7 and 11, children begin to use logical thinking in certain situations, although they have not yet developed fully abstract thinking. In this period, they begin to handle spatial, temporal and numerical concepts essential to assimilate the content that is intended to reach through this project. Children also begin to ask questions

and predict the consequences of an action, as well as to consolidate their sense of responsibility and understand how different phenomena are related, ideal skills for the success of a scientific activity (e.g., they are able to understand the effects of climate change).

Likewise, the structure and methodology of the project is designed to be reproducible in all courses, it will only be necessary to readapt the contents to each didactic model according to the age group.

In line with this new educational model, scientific and technological studies, research and innovation are a perfect ingredient to activate the curiosity and involvement of students, regardless of age. It has an even greater purpose if the subject matter/knowledge imparted can be linked to the interests of families and society in general.

The key to success is to provide tools and illustrate with audiovisual examples the impact of energy improvement actions in schools and homes from a scientific approach that allows to provide rigor and measurable data, beyond theoretical concepts. The scientific promotion contributes to eradicate erroneous perceptions that often lead to the discouragement of the society in front of this type of strategies.

The support staff are university students (in subjects related to the Department of Architectural Technology of the ETSAB) that contribute to pre-validate the workshops, minimizing the risk of unforeseen events of the real demonstrations, ensuring the success of the proposal, both in the scientific-technical field and in the format of collaborative, inclusive and safe education.

GENDER AND INTERCULTURAL PERSPECTIVES

Gender perspective

The aim is to reach society regardless of gender. In the public educational environment (85% of primary schools nationwide), students with specific educational needs (according to SEN a probable ratio of 2 people per classroom) and students with a female single-parent family nucleus (high probability, both in the Eixample and Nou Barris districts) are included. For this reason, it is considered appropriate to try to ensure that the leadership of the workshop is played by a female role and thus show the students that research and science can be a possible career opportunity, fun and committed to society. In addition, specific indicators have been designed in the surveys and on the website that allow the comparison of the impact of the project on both men and women in terms of participation and involvement. In the district of Nou Barris there is a conservative predominance regarding the figure of women, for this reason the project aims to address this aspect and project female researcher figures to the students.

A award is awarded to recognize the contribution of women in a sector dominated by men. It is an award for women linked to the construction and energy efficiency sector, specifically in the field of the execution of actions applied to energy saving at the envelope level or installations and renewable energies.

Intercultural perspective

The choice of districts was based on income but also on the percentage of foreign presence in order to provide an intercultural perspective. Precisely, Barcelona is a city remarkable for its multiculturalism of nations. The district of Eixample has the highest percentage of foreign population with 18% (mainly from Italy, China and France, but also from the other four continents). The district of Nou Barris has 9.1% of foreign population (mainly from Honduras, Ecuador, Bolivia and Pakistan).

In the school of Nou Barris, which has an open enrollment model that makes possible a high turnover of students throughout the year, the workshop is offered in Catalan to contribute to the teaching of this language (adapted with occasional translations and understandable expressions and vocabulary).

ECOSOCIAL TRANSMISSION FORMAT

Since the aim is that students can measure the knowledge acquired and consolidate the most decisive concept of their training in this area, a dual format for the transmission of scientific knowledge with an ecosocial perspective is proposed: face-to-face (through workshops) and telematic (through the web).

The on-site model is the application of the scientific workshops, whose material in the form of scientific briefcases is made available to the Education Consortium and the Teaching Department so that it can be reused by the rest of the schools that wish to participate in the proposal. In order to minimize the impact of CO2 emissions, two measures are

carried out: on the one hand, the research team travels to the schools by public transport, since the schools are close to it. On the other hand, a reduced workshop schedule is proposed in order to minimize the number of possible trips.

The virtual model, through a web platform made within the UPC server, incorporates the informative material of the project: the audiovisual manuals of the workshops and the results of the surveys and air quality measurements. This will bring a wide visibility to the project, not only locally but also internationally. The entity or company that will support the development of the informative and audiovisual material will be linked to the field of social and solidarity economy (SSE) in Barcelona with the aim of promoting new entrepreneurial strategies and enhancing local and nearby employability.

The stages of the implementation of the transmission model, fully reproducible, will be:

- **Basic theoretical content**. To complement the scientific concepts transmitted in the workshops with technical guides that 1) focus on priority technical concepts and 2) introduce figures that relate the economic impact with energy and environmental conditioning of space. The purpose of this stage is to favor a greater assimilation of the content and the link with real life.

- **Description of the scientific procedure**. To allow the verification of the parameters previously defined through the different instruments contained in the case 1, as well as its user's manual. The purpose of this stage is to increase the guarantees of replication of the workshops in the rest of the educational centers, assuring a greater consolidation of knowledge in all students.

- **Application of the scientific procedure**. To follow the scientific procedure with the measurement techniques through the different workshops, the results and the experiences that can be shared through the web. The purpose of this stage is to promote scientific culture through cooperation and transmission of experiences between students and schools. It is a way to encourage, stimulate or motivate students and schools by making them the protagonists of a reference channel.

- **Basic gamification tool**. To contribute to the dissemination of knowledge and allow participants to validate the acquisition of theoretical concepts on science, technology and innovation in the field of energy efficiency and environmental conditioning of buildings. The purpose of this stage is that students can measure the knowledge acquired and consolidate the most important concepts of their training in this field.

SCIENTIFIC WORKSHOPS

The on-site model consists of experimental scientific workshops with the purpose of transferring the knowledge to the students and students to their families. Depending on their duration, the workshops are divided into:

- Long duration workshops: short performances but with extended monitoring time.
- Short duration workshops: immediate cause-effect actions.

The following table 1 explains in detail the five workshops that are carried out in the schools based on the expected results, the indicators for evaluating the results and the activities proposed to the students.

TABLE 1. Scientific workshops at schools.

	Expected results	Energy concept	Proposed activities
W1	↓ of heating consumption favored to combat the fact that the interior space does not lower its operating temperature excessively in the coldest periods. Visualization of how the conductivity of a wall influences the comfort temperature value and the relationship with energy consumption.	Thermal: - Insulation - Inertia - bridging	Outside, an activity is prepared where the students have to run twice, with and without their coats on. In this way they will understand the concept of thermal insulation. With three buckets (one new, one with a hole and one with many holes), calculate the time it takes to empty the holed buckets to understand the concept of thermal bridging. With different materials (metal, brick, wood), calculate the temperature they acquire by placing them on the radiator and thus understand what thermal inertia and conductivity is.

	Expected results	Energy concept	Proposed activities
W2	↓ of the heating consumption in facilitating solar radiation input. Variability of the temperature and in relation on solar incidence. Enhancing natural light indoors. Preservation of the visual relationship between indoors and outdoors.	Solar protections	Replacement of blinds with solar shades that allow to stop solar radiation but not the entry of natural light, as well as the eradication of thermal bridging. Raise and lower at times with different solar incidence and measure the variation of temperature (ºC) and illumination level (Lux).
W3	↓ of heating consumption by reducing the transfer of hot air indoors to outdoors in winter and vice versa in summer. Control of indoor air pollutants due to the composition of outdoor air. Urban environments but also allergenic particles from rural areas.	Voluntary ventilation (air renovation) + Involuntary ventilation (infiltrations)	Open and close windows and observe the quality of the air and its composition (voluntary ventilation). Locate air infiltrations (unwanted ventilation) on the various facade surfaces using sticky notes (post-it).
W4	↓ heating consumption (RES) and increased cooling consumption. Relationship between occupancy and variation of indoor air pollutants, temperature and humidity.	Occupancy impact	With a temperature sensor, the occupancy impact is evaluated in three states: classroom empty-one person-classroom full. And also, with the students at rest (sitting), in high-motion (walking) and in motion (running).
W5	↓ of energy bills and equivalence of CO_2 impact.	Renewable energy sources (RES)	The workshop consists of testing the operation of a fan from a photovoltaic plate. Placing the plate under solar radiation, the operation of this element will be observed.

QUANTITATIVE AND QUALITATIVE IMPACT OF THE PROJECT

Individual experimentation is what guarantees that students and teaching staff acquire and consolidate the concepts, which is why they are the reason for study. Dissemination is carried out through the web, which allows access to the academic community in charge of transmitting knowledge to their families.

In the short term, the impact is achieved in:

- The target audience: sensitization of students and teaching and management staff of the schools.
- The support staff: undergraduate, master's and doctoral students of the university. Also, additional staff hired to support the coordination work between scientific, didactic and digital material.
- Support agents: Teaching Department, Education Consortium, ICAEN, CEEC, ICE, CESIRE, COAC, ETSAB, etc.

In the medium term, the impact is achieved in the awareness of the families of the target audience and support staff.

In the long term, the impact is achieved with the activation of energy rehabilitation at society level.

In order to know the starting point of the people involved in the project in relation to the contribution of science, technology and innovation in terms of the improvement of environmental, social and economic vectors, and to know the evolution of this knowledge and its impact on real social actions, the quantitative and qualitative impact is evaluated from the web and the surveys carried out.

The website has a user measuring mechanism that allows to have a count of the users that visit the website and the duration of such visit, this allows to have a control of the quantitative impact. In addition, the website contains a section for the transmission of experiences between centers and a basic gamification tool, which controls the qualitative impact.

The surveys are structured in 3 different formats to validate the success of the project and its quantitative scope. They are formulated according to each profile of the citizens involved: (1) the students, (2) the management and teaching staff of the selected schools and (3) the families of the students and teachers. Qualitatively, the aim is to have

an individualized interaction with the project participants. It is also considered appropriate to conduct the surveys in three distinct phases: a first phase conducted before the scientific workshops, a second phase conducted after the scientific workshops, and finally, a third phase conducted one year after the implementation of the project. In this way, it is possible to know in a quantitative way which are the concepts ‘a priori’ and ‘posteriori’ of the actions carried out and if measures have been taken with respect to awareness and knowledge in the field of science, energy efficiency and environmental conditioning.

CONCLUSION

The key of the Project LES "Energy seed and health. From school to home” is, as its title indicates, to plant the seed of energy awareness in the youngest strata of society, an action that is extremely necessary in the current context of climate emergency, health debacles and geopolitical crises.

A replicable methodology is applied, consisting of: previous questionnaires to establish the level of knowledge in the field of energy efficiency, scientific workshops on the strategic parameters to improve the energy performance of buildings and subsequent questionnaires to determine to what extent the corresponding knowledge has been expanded and consolidated. The material used, the procedure and the results will be made available to the Education Consortium and the Department of Education to facilitate and promote the replication of the experience in other centers.

The Project is its implementation phase, so there is a lack of results for the moment, but it is intended to achieve the following results (from the seed...):

- To increase children's knowledge and awareness of strategies to improve the energy performance of buildings.
- Consequently, that this effect is also produced in teachers and families, so that they can develop more efficient behaviors at home and apply for financial aid or make small investments in their homes.
- Promote science as a professional field of the future, especially for girls, whose absence in scientific university careers is notable.
- Promote social commitment from childhood, as a result of the understanding of the high impact of energy efficiency measures on the climate emergency.

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REFERENCES

1. C. Cosmi. *Schools4energy: A living laboratory for energy awareness in schools*. Proceedings of the Research and Innovation Conference Proceedings, 2018.
2. N. Gaitani. Paving the way to nearly zero energy schools in Mediterranean region-ZEMedS project (Energy Procedia, 2015), pp. 78.
3. E. Crespo Sanchez, J.R. Dacosta Diaz and K. Kampouropoulos. *Novel architectural strategies to support an nZEB Mediterranean school*. (IOP Publishing, 2019), Vol. 603. No. 4.
4. D. Ürge-Vorsatz. *Measuring the co-benefits of climate change mitigation*. (Annual Review of Environment and Resources 39.1, 2014), 549-582.
5. R. Chapman. *Retrofitting houses with insulation: a cost–benefit analysis of a randomized community trial*. (Journal of Epidemiology & Community Health 63.4, 2009), pp. 271-277.
6. C. Marmolejo-Duarte, A. García-Hooghuis and A. García-Masià. *How much and why are we willing to pay for energy-efficient homes? A stated preferences analysis in Barcelona*. (ACE: Arquitectura, Ciudad y Entorno, 2020).
7. E. Crespo Sanchez. *Perceived benefits of energy efficiency in the Spanish residential market and their relation to sociodemographic and living conditions*. (Applied Sciences 11.2, 2021), pp. 875.
8. A. Lambea Rueda, M. A. Grau Ruiz and G. Pastor Albaladejo. *La sostenibilidad de la vivienda: Razones para incentivar su desarrollo en España*. (REVESCO: revista de estudios cooperativos 133, 2020), pp. 61-70.

9. A. B. Onecha, M. Bosch, M. Bosch, C. Cornadó, E. Crespo, J. Martí. *4 X 4: Methodology to design a set of 4 moocs between 4 entities under the same topic – erasmus + smart rehabilitation 3.0 project*. (Edulearn2022).
10. A. B. Onecha Pérez. *Accompanied self-renovation: A massive online course to meet the need of a professional rehabilitation expert in people-centered and low-cost renovations*. (ICERI2021 Proceedings, 2021).
11. S. Habibi, O. Pons Valladares and D. Peña. *New sustainability assessment model for Intelligent Façade Layers when applied to refurbish school buildings skins*. (Sustainable Energy Technologies and Assessments 42, 2020).
12. P. V. Dorizas, M.N. Assimakopoulos, and M. Santamouris. *A holistic approach for the assessment of the indoor environmental quality, student productivity, and energy consumption in primary schools*. (Environmental monitoring and assessment 187.5, 2015), pp. 1-18.
13. K. Sepideh Sadat, A. Montazami, and D. Mumovic. *Perceived indoor air quality in naturally ventilated primary schools in the UK: Impact of environmental variables and thermal sensation*. (Indoor air 31.2, 2021), pp. 480-501.
14. A. Merabtine. *Building energy audit, thermal comfort, and IAQ assessment of a school building: A case study*. (Building and Environment 145, 2018), pp. 62-76.
15. S. Roy. *Making IAQ better with COVID-19 in the air: How can building HVAC systems be modifed to provide a safer environment in new and renovated spaces?* (Consulting Specifying Engineer 57.9, 2020), pp. 16-20.
16. J. Huertas Cardozo and M. Hernández Luna. *Towards Post-COVID classrooms: work in progress*. (Studies 2.5, 2020), pp. 16.
17. S. Ugarte. *Energy efficiency for low-income households*. (2016).
18. D. Ürge-Vorsatz. *Measuring the co-benefits of climate change mitigation*. (Annual Review of Environment and Resources 39.1, 2014), pp. 549-582.
19. M.A. Calvo-Torras, N. Casquero-Modrego, J. Sellares, F. Hernández-González, E.L. Arosemena. *The Role of Apartment Layout in the Incidence of Indoor Microorganisms and How They May Affect Occupants with an Interstitial Lung Disease*. (In Proceedings of the 16th International Conference on Indoor Air Quality and Climate, INDOOR AIR, Seoul, Korea 2020).
20. J. Wang. *How do parents and children promote each other? The impact of intergenerational learning on willingness to save energy*. (Energy Research & Social Science 87, 2022) 102465.
21. M. Nils Peterson, K.T. Stevenson, and D.F. Lawson. *Reviewing how intergenerational learning can help conservation biology face its greatest challenge*. (Biological Conservation 235, 2019), pp. 290-294.
22. J. Castor, K. Bacha and F. Fuso Nerini. *SDGs in action: A novel framework for assessing energy projects against the sustainable development goals*. (Energy Research & Social Science 68, 2020), 101556.
23. H. Pearce, L. Hudders and D. Van de Sompel. *Young energy savers: Exploring the role of parents, peers, media and schools in saving energy among children in Belgium*. (Energy Research & Social Science 63, 2020), 101392.
24. J. Dolšak, N. Hrovatin, and J. Zorić. *Factors impacting energy-efficient retrofits in the residential sector: The effectiveness of the Slovenian subsidy program*. (Energy and Buildings 229, 2020), 110501.