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ANALYSIS OF ENERGY RETROFIT RENOVATION PROJECTS AND EUROPEAN UNION'S RECOMMENDATIONS TOWARDS A METHODOLOGY FOR THE ASSESSMENT OF LOCAL RENOVATION STRATEGIES

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ANÁLISIS DE LOS PROYECTOS DE REHABILITACIÓN ENERGÉTICA Y RECOMENDACIONES DE LA UNIÓN EUROPEA PARA UNA METODOLOGÍA DE EVALUACIÓN DE LAS ESTRATEGIAS LOCALES DE REHABILITACIÓN

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Abstract - Energy retrofit of existing buildings is one of the main keys to achieve European Union's decarbonising objectives defined in the European Green Deal. In order to proceed into them, European policy has been adapted and several research projects are developed. The aim of this paper, on the one hand is to analyse the assessment methodology of the research projects, setting up the overview of the assessed fields and the criteria followed to carry out and evaluate each project; and on the other hand, to contrast these processes with the evaluation framework established by the European Union (EU). As working methodology 18 projects have been studied, firstly characterising by the main parameters and afterwards analysing the assessment followed by each one. This analysis is decomposed into five parameters: the assessment scope, reflecting the fields covered by the project's assessment; data source, the nature of the data; verification, use of data verification strategies; and implementation of life cycle thinking in the assessment methodology. Finally, the projects' evaluation methods are decomposed into evaluation indicators in order to analyse the level of similarity between the projects' assessment and the evaluation framework provided by the EU. The research shows that although the projects have their bases in the EU energetic targets they also cover a wider scope, assessing many fields and combining many sources of data. However, despite the large knowledge already defined by many projects, there is a lack of global and complete roadmap to be followed.

Resumen - La rehabilitación energética de los edificios existentes es una de las principales claves para alcanzar los objetivos de descarbonización de la Unión Europea (UE) definidos en el *European Green Deal*. Para proceder a ellos, se ha adaptado la política europea y se han desarrollado varios proyectos de investigación. El objetivo de este trabajo es, por una parte, analizar la metodología de evaluación de los proyectos de investigación realizados, estableciendo la visión general de los campos evaluados y los criterios seguidos para realizar y evaluar cada proyecto; y por otra, parte contrastar estos proceidimietos con el marco de evaluación porpuesto por la UE. Como metodología de trabajo se han estudiado 18 proyectos, caracterizando en primer lugar los principales parámetros y analizando posteriormente la evaluación seguida por cada uno de ellos. Este análisis se descompone en cinco parámetros: el ámbito de la evaluación, que refleja los campos cubiertos por la evaluación del proyecto; la fuente de datos, la naturaleza de los mismos; la verificación, el uso de estrategias de verificación de datos; y la aplicación del concepto de ciclo de vida en la metodología de evaluación. Finalmente los métodos de evaluación son descompuestos indicadores de evaluación analizando el nivel de similitud entre el marco de evaluación porpuesto por la UE y el de los proyectos analizados. La investigación muestra que, aunque los proyectos tienen sus bases en los objetivos energéticos de la UE, también cubren un ámbito más amplio, evaluando muchos campos y combinando muchas fuentes de datos. Sin embargo, a pesar de los amplios conocimientos ya definidos por muchos proyectos, falta una hoja de ruta global y completa a seguir.

1. Introduction

Buildings are responsible of about the 40% of the energy consumption and the 36% of greenhouse gas emissions of the European Union, taking into account all the stages of the buildings' life; that make them one of the biggest responsible of the greenhouse effect. In response for this, improving the energy efficiency is an important playground in order to achieve the European Green Deal by 2050, the goal of carbon-neutrality [1].

According to the European Commission, around the 75% of the EU building stock is inefficient, and only the 0.4%-1.2% of them are renovated per year. Higher renovation rates could make a big reduction of energy composition and greenhouse gas emissions, and here is one of the big deals, so in order to achieve the climate and energy objectives this rates should be at least doubled [1].

1.1. Energy policies in Europe

The EU has prepared and updated the legislative framework with the revision of the Energy Performance of Buildings Directive (EPBD) 2010/31/EU and the Energy Efficiency Directive (EED) 2012/27/EU in 2018, as part of Clean Energy for all Europeans package [1].The EPBD directive was adopted in 2002 to promote the improvement of energy of buildings and in 2010 was updated, with new aspects including the Recommendation List of Measures (RLM) for renovation of existing buildings [2].

The main objective of the directives is to increase the energy in the scale of EU by 2030, and as linked objective, to use renewable sources at least in the 32 % of the energy. In the 2a article of the EPBD is established that member states must ensure a highly energy-efficient and decarbonized national building stock by the use of Long-Term Renovation Strategies (LTRS), with milestones every 10 years, until 2050 [3]. Moreover, the EPBD and EED directives recommend to use measurable indicators to assess the process, related to many aspects that can bring many benefits: clean energy transition, economic stimulation, contribution in comfort, health and wellbeing of the residents and reduction and control of energy poverty. [1]

1.2. Situation in Spain and EU politic implementation

In the case of Spain, in 2014 was submitted the first LTRS for energy renovation in building field [4] and in 2017 was updated [5]. They provided strategies for the renovation programs, based on the work of GTR ("Grupo de Trabajo sobre Rehabilitación") [6][7]. In this strategy the residential building stock was classified into different groups according to the energy efficiency and building typology; and provide information about renovation measures can be done to improve the energy efficiency. The building stock data for this study was collected from the census and the energy efficiency data from IDAE ("Instituto para la Diversificación y Ahorro de la Energía") and the Sech-Spahpusec project [8].

Despite this LTRS were well recognised in Europe the implementation of it is very difficult, and the following years the deep building renovation rate in Spain was very low. In 2014 the deep renovation rate in Spain was only a 0.08% [9]. According to the EPDB (EU) 2018/844 the recommended rate is 3% [10].

To unblock this situation was proposed a new model of public policies by a report that analysed the residential building renovation [11]. Municipalities would be the base and they should define local strategies following the LTRS, following ate the same time the European Directives.

1.3. Municipal strategies in Europe

In the Spanish state housing competencies are transferred to the Autonomous Community, for example in the Basque Autonomous Community, in 2015, 69% of the housing budget corresponded to the Autonomous Community, and the rest to the Spanish State. [12]

A recent report of GTR studied that local authorities (Autonomous Communities and Municipalities) could implement policies for the promotion of the renovation of residential buildings [13]. But nowadays there is no global mechanisms to direct these typo of policies in a uniform and coordinated way to achieve the goals defined by the European directives.

According to this study there are several causes for the difficulty of making a methodology that could answer to the need of a global roadmap that could be followed by the communities and mostly the municipalities. The main ones are the lack of information, the possible bad economic situation of residents, users' awareness [14] and the lack of enough financing programs.

For this, the first step is to develop a strategy by identifying the relevant actors and having information about the residential building stock according to the Building Performance Institute of Europe, BPIE [15]. In order to achieve this, different stakeholders should have enough information. Moreover, after implementing a strategy and a plan, it's necessary assess the process using the monitoring by indicators [16].

It's very important to be clear that the role of local public institutions has a key role as the United Nations clearly recognised in the Sustainable Development Goals of 2015 [17]. But they suggested it's necessary to provide planning tools, establishing the required strategy like decarbonisation plans [18].

1.4. Assessment system

Following the main objective of developing the evaluation and assessment system for local strategies for housing renovation, the project will be based in two main assessment methods: The Multi-Criteria evaluation systems and the methodology of Life-Cycle thinking.

Firstly, the Multi-Criteria evaluation system consists in providing a comprehensive assessment of the sustainability of the proposed renovation that allows developers striving for improved performance to gain an objective basis for calculating their efforts [19]. This method it is not standardized, so it is possible to have different results [20].

Secondly, the methodology of life cycle thinking evaluates all the stages pf the life-cycle of a products, process or system. It is a ruled and normalized methodology by the International Organization of Standardization (ISO), stablishing a standard for the Life Cycle Assessment (LCA) for the environmental sustainability assessment [21]. There are also standards focused in determinate fields such as for the building sector that defines the criteria to assess all the stages of the buildings with a life cycle thinking [22]. Moreover, this methodology doesn't only consider the environmental field, it also takes into account the social and economic fields, like the

standard EN 16627, developing and standard to assess the building sector focusing in the economic performance [23]. Nowadays, the best methodology to assess the economic and environmental impacts and performance is the LCA method according to the European Commission [24]. In the social field, there is also an standard for the building sector, assessing also the impacts and performance but this time in the social aspect [25]. According to all this, this methodology brings an opportunity to make a complete assessment and that's why more and more studies are using it in the building sector, prioritizing this methodology among others [26].

2. Objectives

The aim of this study is to set up the overview of assessment methodologies followed in the performance and evaluation of building energy retrofit research projects linked to the European Green Deal. This analysis will reflect the criteria and the roadmap of the projects' assessment in terms of the covered field, data management and the extension of each project's evaluation procedure. Furthermore, it is also followed the analysis of the targets and recommendations pointed by the EU, building the whole picture of the current trends in assessment of energy retrofit projects of buildings.

The research has been focalized in order to attend in the LocalREGEN national project, that consists in defining a multi-criteria methodology with a life cycle thinking perspective for the evaluation and assessment of the progress of the local strategies for housing renovation, based on progress indicators that are broad enough to encompass the specificities of different territories of Spain.

3. Methodology

As working methodology, energy retrofit projects have been analysed, focusing in the assessment methodology followed. The chosen projects are research projects directly linked with the European Green Deal [1] and the Directives that rule the targets to achieve them in the field of existing buildings [10]. The analysed projects have been limited to 18, making possible to have an extended view with diverse feature projects; alike, the chosen projects are performed in the period of 2012-2022 (some of them aren't still finished). The complete study is based in the information published by the projects, as official reports and deliverables, and scientific articles and conference communications linked to the projects.

The study has been developed the following three stages:

1- Characterization of European energy retrofit research projects
2- Analysis of projects' assessment methodology
3- Comparison between projects' assessment indicators and the evaluation framework recommended by the European Union

Characterization of European energy retrofit research projects – The projects have been characterised according to the main parameters, making possible to describe each of them: *type of project, scale, period, research program, coordination entity* and the *budget* of each project (see Table 1). Three types of projects have been chosen, (*methodology development, energy action plan* and *tool development*) representing the picture of European energy retrofit research projects of the last years.

Analysis of projects' assessment methodology – The assessment methodology used by each project is analysed according to four parameters: *assessment scope, data source, verification* and *use of life cycle methods* (see Table 2). The assessment scope defines the extension of the projects' evaluation methodology, classifying into different fields to assess: e*nergy, environment, economy, social, wellness & health* and *heritage*. The data source defines the origin of the data used to measure each assessment scope, classified into three types: *Real Data* (directly measured, monitored, by samples etc.), *Estimated Data* (by simulation, interpolation, data-bases etc.) and *Perceptive Data* (by surveys, interviews etc.). The verification checks the use of data verification strategies (*Yes/No/no data*) in each assessment scope of each project. Finally, the use of life cycle analysis checks the use of the life cycle thinking (*Yes/No/no data*) in the performance and evaluation of the projects the case of environmental, economic and social scopes (the three fields studied by the Life Cycle Assessment methodology).

Comparison between projects' assessment indicators and the evaluation framework recommended by the European Union – Finally, the indicators used in the assessment methodology of each project are analysed by comparing them with the list of recommended indicators published by the EU in the Commission Recommendation (EU) 2019/786 of 8 May 2019 on building renovation [27]. First of all, on the one hand, the indicators used by each project are identified by the documentation published, and listed numbering them; and on the other hand, the indicators recommended by the European Union are listed. Afterwards, the list of indicators of the projects and the list of indicators of the EU are compared, checking the use of each EU's indicator in each one of the project, and making the connection between the indicator used in the project and the indicator of the list of the EU. It has been considered that if two indicators are evaluating the same concept, characteristic, or impact they do have the connection even if the measurement method or the unit is not exactly the same. To show this comparison, the recommended indicators of the EU are listed, checking the use of these indicators in each project and specifying the connected projects' indicator or indicators by a number; the indicators of each project are listed and numbered so it is possible to identify and make the connection between EU's indicators and each projects' indicators.

4. Results and Discussion

4.1. Characterization of European energy retrofit research projects

Many types of renovation projects have been done, with different scale, aim and criteria, involving different disciplines and entities. In order to follow a normalized characterization, the projects have been classified according to main parameters: type, scale, period, program it belongs, entity is in charge of the coordination and budget (see Table 1).

TABLE 1. RENOVATION PROJECTS' REVIEW

Project name	Type	Scale	Period	Program	Coordination entity	Budget
ENERPAT {[28][29]}	Methodology development	Europe	2016-2019	Interreg SUDOE	SUDOE	1,89 M€
EFFESUS {[29]}	Methodology development	Europe	2012-2016	Seventh EU Framework	Tecnalia, Fraunhofer-Intitute	6,79 M€
ALDREN {[30][31][32] [33] [34]}	Methodology development	Europe	2017-2020	*Horizon 2020*	Centre Scientifique et Technicque du Batiment	1,98 M€
REFURB {[35][36][37]}	Methodology development	Europe	2015-2018	Horizon 2020	Flemish Institute for Technological Research	2,07 M€
RenoZEB {[38]}	Methodology development	Europe	2017-2021	Horizon 2020	Solintel M&P SL	8,71 M€
REVALUE {[39]}	Methodology development	Europe	2015-2019	Horizon 2020	Bax Innovation Consulting	1,57 M€
mPOWER {[40][18]}	Methodology development	Europe	2018-2022	Horizon 2020	Univeristy of Glasgow	2,00 M€
REPLICATE {[41][42]}	Action Plan	Europe	2016-2021	Horizon 2020	Municipality of Donostia	29,30 M€
GrowSmarter {[43]}	Action Plan	Europe	2015-2019	Horizon 2020	Stockholms Stad	35,80 M€
RemoUrban {[44] [45]}	Action Plan	Europe	2015-2020	Horizon 2020	Fundación Cartif	24,75 M€
STEEP {[46][47]}	Action Plan	Europe	2016-2020	Seventh EU Framework	Municipality of Donostia	2,63 M€
OptEEmAL {[48][49][50]}	Tool development	Europe	2015-2019	Horizon 2020	Cartif Technology Centre	4,24 M€
EASEE {[51][52]}	Tool development	Europe	2012-2016	Seventh EU Framework	Rina Consulting SPA	7,68 M€
Paradis {[53][54]}	Tool development	National	2016-2019	Revalue Research Program	Aarhus University	n/d
ENERSI {[55]}	Tool development	National	2013-2017	Spanish Nat. Research Plan	ARC Engineering and Architecture La Salle	n/d
Plan Zero CO_2 {[56]}	Action Plan	Territorial	2018-2021	Horizon 2020	Alokabide	n/d
AGREE {[57][58]}	Methodology development	Territorial	2020-2022	Horizon 2020	Basque Government	0,56 M€
HEREVEA {[59]}	Tool development	Territorial	2015	Feder Andalucía	University of Seville	n/d

The *TYPE* of the project defines the nature of the project, most of times determined by the outcome of the project, and can be classified into three different types: *Methodology Development*, *Energy Action Plan* and *Tool Development*. Most of projects analysed are based in the *Methodology Development*, researching in the applicability of renovation strategies, but focusing in different working areas and purposes. The project ENERPAT [28][29] and EFFESUS [29] are based in the eco-renovation solutions of the housing of historic centres, experimenting

on networks of cooperation. ALDREN is based in the utility of the Building Renovation Passport (BRP) [30][31]. With a different working field, the REFURB [35][36] project proposes different renovation packages based not only in energy, also in the features and needs of the dwelling and dweller creating a methodology. Furthermore, BIM (Building Information Modelling) based methodologies are also developed, like RenoZEB project [38], researching in new renovation constructive solutions using prefabricated elements. Another type of project is the development of an *Energetic Action Plan* for cities, the projects REPICATE [41][42], GrowSmarter [43], ReemoUrban [60], and STEEP [46][47]; they follow a similar schedule with three main working areas being one of them the improvement of energy efficiency of existing buildings. *Tool development* research projects also have been analysed, focusing in different working areas and systems but all of them based in the use of a software to attend energy retrofit renovation projects, like OptEEmAL [48][49], based on different energy conservation measures in to perform the energy use at building and district scale; EASEE [51][52] focused in innovative envelope solutions; Paradis [53][54], which generates and assesses optimal renovation scenarios; and ENERSI [55], a multi-disciplinary data management tool.

The *SCALE* defines the influence area of the research, most of times according to the institutions involved in the project. Three main scales have been determined: European, National and Territorial. European projects are more directly linked to the targets of the European Directive previously mentioned, and most of them are based in the cooperation between different entities from different countries, and in this study all these projects are funded (the entire of part of it) by the European Union. National projects aren't so common, and there are only two national projects analysed here, both of them tool developments; the main feature of these projects is that are focused in the building typology of the country. Finally, the territorial projects could be the final part of the chain of renovation projects, acquiring knowledge from bigger scale projects and applying in more specific scenarios.

The *PERIOD* defines the time when the project but in this is more important the time covered (all of them are linked to the European directives targets, so it's not relevant the time location). It has been seen that almost all the projects 3-4 years, even with different type, scale and budget.

The *PROGRAM* and the *COORDINATION* define the belonging research program and the main funder, and defines the entity in charge of the management. All the European scale projects and most of territorial projects belong to the main research European programs: "Interreg SUDOE" (abbreviation of Cooperation Programme Interreg V-B Southwest Europe), "Interreg Europe", "Seventh Framework Programme for Research and development" and "Horizon 2020 Research and Innovation Programme". The difference is made by the national scale projects, belonging to national research programs. However, the coordination is always carried by national or territorial entities, even in European scale, but based in the coordination of many entities.

4.2. Analysis of projects' assessment methodology

As mentioned before, all the projects are linked to the targets of the European Green Deal [1], following the same main objectives but using different assessment and evaluation methodologies. In this section the assessment methodology followed by each project is analysed according to four parameters (see Table 2 and Annexe 1 for more details):
Assessment Scope: *Energetic* scope, *Environmental* scope, *Economic* scope, *Social* scope, scope related to *Wellness & Health*, and scope related to *Heritage*.
Data Source: *Real* (by direct measurement, monitoring), *Estimated* (by calculation, simulation, interpolation or from data-bases), and *Perceptive* (by surveys, interviews)
Verification: *Yes, No, n/d* (no data); Use of data and result verification strategy.
LCA: *Yes, No, n/d* (no data); Use of life cycle thinking assessment or methodology in the case of Environmental scope, Economic scope and Social scope.

TABLE 2. PROJECTS' ASSESSMENT METHODOLOGY

Project	Assessment Scope	Data Source	Verification	LCA
ENERPAT	Energy	Real + Estimated	Yes	-
{[28][29]}	Environment	Estimated	No	Yes
	Economy	Estimated	No	Yes
	Social	Perceptive + Estimated	No	n/d
	Wellness & Health	Real + Estimated	Yes	-
	Heritage	Real	-	-
EFFESUS	Energy	Estimated	No	-
{[29]}	Environment	Estimated	No	Yes
	Economy	Estimated	No	Yes
	Wellness & Health	Estimated	No	-
	Heritage	Real	-	-
ALDREN	Energy	Real + Estimated	Yes	-
{[30][31][32][33][34]}	Economy	Estimated	No	Yes
	Wellness & Health	Real + Estimated	Yes	No
REFURB	Energy	Estimated	No	-
{[35][36][37]}	Economy	Estimated	No	No
	Social	Estimated	No	No
	Wellness & Health	Estimated	No	-
RenoZEB	Energy	Real + Estimated	Yes	-
{[38]}	Environment	Estimated	No	n/d
	Economy	Estimated	No	No
	Wellness & Health	Real + Estimated	Yes	-
REVALUE	Energy	Estimated	No	No
{[39]}	Economy	Estimated	No	Yes
	Wellness & Health	Estimated	No	-
mPOWER	Energy	Estimated	No	-
{[40][18]}	Environment	Estimated	No	No
	Economy	Estimated	No	No
	Social	Estimated	No	No
REPLICATE	Energy	Real + Estimated	Yes	-
{[41][42]}	Environment	Estimated	No	No
	Economy	Real + Estimated	Yes	No
	Social	Perceptive + Estimated	Yes	No
GrowSmarter	Energy	Real + Estimated	Yes	-
{[43]}	Environment	Estimated	No	No
	Economy	Estimated	No	No
	Wellness & Health	Real + Estimated	Yes	-
RemoUrban	Energy	Real + Estimated	Yes	-
{[44] [45]}	Environment	Estimated	No	No
	Economy	Estimated	No	No

Project	Assessment Scope	Data Source	Verification	LCA
	Social	Perceptive + Estimated	No	No
	Wellness & Health	Real + Perc. + Estim.	Yes	-
STEEP	Energy	Real + Estimated	Yes	-
{[46][47]}	Environment	Estimated	No	Yes
	Economy	Estimated	No	No
	Social	Estimated	No	No
	Wellness & Health	Real + Estimated	Yes	-
OptEEmAL	Energy	Real + Estimated	No	-
{[48][49][50]}	Environment	Estimated	No	No
	Economy	Estimated	No	Yes
	Social	Estimated	No	No
	Wellness & Health	Estimated	No	-
EASEE	Energy	Real + Estimated	Yes	-
{[51][52]}	Environment	Estimated	No	No
	Economy	Estimated	No	Yes
	Wellness & Health	Real + Estimated	Yes	-
Paradis	Energy	Estimated	No	-
{[53][54]}	Economy	Estimated	No	No
	Wellness & Health	Estimated	No	-
ENERSI	Energy	Estimated	No	No
{[55]}	Economy	Estimated	No	No
Plan Zero CO_2	Energy	Real + Estimated	Yes	-
{[56]}	Economy	Estimated	No	No
	Social	Real + Perc. + Estim	No	No
	Wellness & Health	Real + Perc. + Estim	Yes	-
	Accessibility	Real	-	-
AGREE	Energy	Estimated	No	-
{[57][58]}	Economy	Estimated	No	No
	Social	Estimated	No	No
	Accessibility	Real	-	-
HEREVEA	Energy	Real + Estimated	No	-
{[59]}	Environment	Estimated	No	Yes
	Economy	Estimated	No	No

(*) *Indicators and topics performed in the assessment methodology of each project are indicated in the Annex 1*

4.2.1.Assessment Scope

Despite all the projects are linked to the EU energetic and environmental targets [1] each one follows a different criteria in their development, assessment and decision making, covering different fields named as "Assessment Scope". The "Assessment Scope" indicates the evaluation fields performed by each project in their development and evaluation, by specific indicators in order to assess the specific fields defined in this paper (*energy, environment, economic, social, wellness & health* and *heritage*). This indicators and topics assessed by each project are indicated in the Annex 1.

In the Figure 1 it can be appreciated the number of the projects assessing each "Assessment Scope". Whereas, as mentioned before, the European policies recommend the assessment of many aspects like clean energy transition, economic stimulation, contribution in comfort, health and wellbeing of the residents and reduction and control of energy poverty [1] not all of them are taken into account. This also can reflect the feasibility and easiness to assess each field. The energetic scope is the most assessed together with the economic field, the *Energetic scope* because is the base of all the projects and the *Economical scope* because the economic factor is always one main conditional to make feasible the operation. The next most assessed field is the *Wellness & health scope*, showing the importance of this factor and also the one of the main

targets of the European Directives [1], making a good opportunity for the assessment methodologies. The *Environmental Scope* shows clearly the weakness of the nowadays energy retrofit assessment methodologies, when covers the main final targets of the European Green Deal [1], included in 11 of 18 projects. So does the *Social scope*, being one of the targets recommended in the Directives and performed in half of the studied projects (9 of 18). Finally, the *Accessibility* and *Heritage* scopes play a minor role, becoming secondary targets followed by this projects.

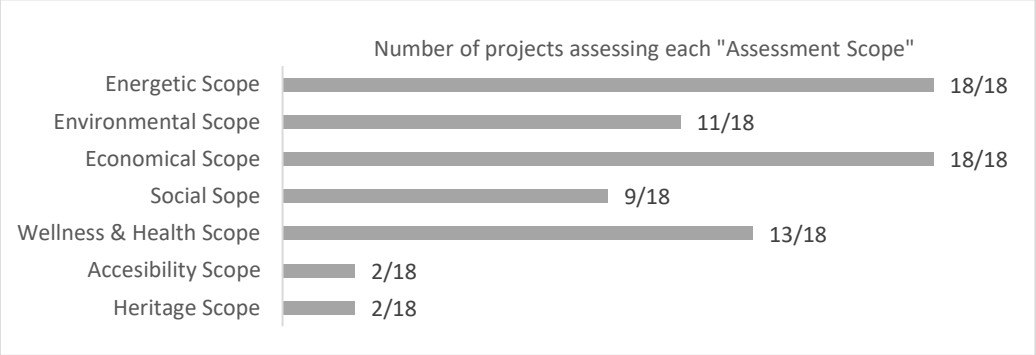

Fig. 1. Percentage of projects assessing each "Assessment Scope"

As all the projects are directed to the improvement of energy efficiency of existing buildings, the *Energetic scope* is the main assessed field and the core of all the projects, but each one is based in different techniques using several disciplines. Indicators used in the Energy Performance Certificates (EPC), introduced for first time in 2002 by the EPBD (Directive 2002/91/EC) [61] and updated in 2018 by the Directive 2018/844 [10], are used in all the projects, like primary energy consumption and energy demand among others [62]. Furthermore, covering a wider evaluation, the embodied energy, energy related to the material and intervention energetic costs [63], is also taken into account in ENERPAT [29], EFFESUS [29], OptEEmAL [49] and HEREVEA [59].

Whereas all these projects are linked to environmental objectives, not all of them have a specific assessment in *Environmental Scope*, performing it in 11 of 18 projects. Most of the projects specifically assessed in the environmental field use the indicator of Greenhouse Gas (GHG) emissions or equivalent CO_2 emissions, linked to the main target of the EU of decarbonising the existing building stock *[1]. One of the most complete evaluations performed are the ones based the Life Cycle Assessment (LCA) thinking, used in* ENERPAT [29]*,* EFFESUS [29] *and STEEP* [47]*; this method evaluates the impact of each project with an overall view* [21], explained in the head *3.2.4. Life Cycle Analysis. As a similar approach, HEREVEA* [59] *uses the Ecological Footprint (EF) method* [64]*, that "assesses the amount of land that would be required to provide the resources (grain, feed, firewood, fish, and urban land) and absorb the emissions (CO_2) of humanity"* [59]; in this projects the standard UNE-EN15978 [23] was used to assess the project in the environmental impact.

The *Economical scope* has a specific evaluation in all the projects but by different indicators and calculation methods. As a complete economic assessment, ALDREN [30], REVALUE [39], OptEEmAL [49] and EASEE [51] have used life cycle thinking methods, the Life Cycle Cost method (LCC) [65], for their economic calculations. With a similar treatment, ENERPAT *and* EFFESUS *use the* Circular Economy (CE) [29] bases, in this case also evaluating the whole life cycle in terms of economy [29]; further, *they are focused* in the local economy, enhancing the use of local material and techniques to boost local business and logistic easiness [29]. REPLICATE [42] and

STEEP [47] have also analysed the opportunity to wider the local economy and benefit for local businesses. Otherwise, as a detailed economic study, AGREE is focused in the financial support and viability to attend stakeholders in the economic evaluation of energy retrofit projects, concentrated in the territorial framework [58].

The *Social scope* englobes many indicators recommended by the European Directives [27] but in the analysed projects takes a minor place as it is assessed in half of the projects (10 of 18). In these projects, the most evaluated aspect is the "energy poverty" or the "fuel poverty"; Foster et al. defined fuel poverty when "its energy consumption does not meet basic energy needs" [66]; furthermore, Perez-Bezos et al. proposed an energy vulnerability assessment method for prioritizing the retrofitting of residential buildings [67]. In this research seven projects assessed the energy poverty: ENERPAT [29], REPLICATE [42], RemoUrban [44], STEEP [47], OptEEmAL [49], Plan Zero CO_2 [56] and AGREE [58]. OptEEmAL [49] project defined inhabitants suffering "energy poverty" when 10% of their incomes are used to pay energy bills [68]. As a more general aspect, in addition to energy poverty, more aspects about the "social vulnerability" are also assessed by REPLICATE [42], Plan Zero CO_2 [56] and AGREE [58].

Wellness & health parameters describe comfortable and healthy indoor conditions, and it's necessary to understand them together with thermal performance of the building in order to reach good conditions of wellness & health and reduce the energy demand [69]. Nevertheless, it is not assessed in all the projects, in 13 of 18 projects. Indoor thermal conditions are assessed all these 13 projects (ENERPAT [29], EFFESUS [29], ALDREN [30], REFURB [36], RenoZEB [38], REVALUE [39], GrowSmarter[43], RemoUrban [44], STEEP [47], OptEEmAL [49], EASEE [51], Paradis [53] and Plan Zero CO_2 [56]). In the case of GrowSmarter [43] standardized evaluation is applied by ISO-7730 [70] and ISO-7726 [71] International Standards. Covering a wider field, Paradis [53] and Plan Zero CO_2 [56] apply the Standard EN-15251 [72].

Accessibility issues are also an important field to assess as it is defined in one of the three diagnosis topics in the study of performance indicators to prioritise multi-family housing renovations of Monzón and López-Mesa [73]. In the research 2 of 18 projects have a specific assessment for accessibility, both of them in territorial scale: AGREE evaluates the accessibility degree in the building and also inside the dwelling [58]; besides, the Plan Zero CO_2 performs it in four parameters: the accessibility to the entrance on the building, vertical accessibility, sensorial accessibility (identification, orientation and communication) and analysis of adapted housing [56].

Heritage preservation is also a field to perform in energy retrofit projects, as built heritage has architectural and cultural value, and also mirrors the people, the territory, the productive activity, and the culture that created it [74]. In the analysed projects 2 of 18 count with a specific assessment of heritage preservation, EFFESUS and ENERPAT , projects based in the renovation of the housing heritage of the historic centres [29].

4.2.1.Data Source

For the assessment it is necessary to quantify and qualify different parameters and indicators by using data. In this paper data sources have been classified into three types: *real*, *estimated* and *perceptive*. As it can be defined in the Table 2, most of the assessment is made by estimated data, thus, data obtained by calculation, simulation, interpolation or by using data-bases or indirect measurements.

In the case of the energetic scope assessment, all the analysed projects use estimated data. Some of them, REFURB [36] and REVALUE [39] are based on the EPC, so they only make use of *estimated* data sources, as EPC-s are based in estimation of energy demand [75]. However, certain projects also evaluate their project by using *real* data sources, obtained by direct measuring, monitoring or by samples. In RenoZEB, façade integrated sensors are used to monitoring data in real time, including the measurement of solar radiation [38].

Environmental and *Economic* scopes' indicators are not easy to measure to get real data; for instance, in the RemoUrban uses Digest of UK Energy Statics to calculate savings in carbon emissions [44]. In the *economic* field only REPLICATE use real data, measuring incomes and costs related to the intervention [41].

In the *Social* and *Wellness & Health* aspects perceptive data is also used, by non-technical indicators obtained by surveys or interviews; it can be a determinant data source as in the study of Jimenez-Bescos and Oregi, were they used a questionnaire to reinforce the energy computation estimation [76]. In ENERPAT, participation of stakeholders and citizens was an important pillar against the energy poverty and following the citizen acceptance [29] working on the *social* field. Besides in RemoUrban made surveys and interviews to occupants collecting data about satisfaction, comfort and problems [44], in this case also performing both *social* and *wellbeing & health* assessment scopes. In addition, Plan Zero CO_2 counts with occupants' participation strategies, working also in both *social* and *wellbeing & health* fields [56], and also REPLICATE do so assessing the *social* scope [41].

4.2.2.Verification

Finally, it is taken into consideration the application of Life Cycle Assessment (LCA) thinking methods, a methodology that brings the opportunity to make a complete assessment of the impact caused by the project in the performed scope, taking into consideration the environmental, social and economic fields; that's why more and more studies are using it in the building sector, prioritizing this methodology among others [26]. Among the analysed projects four of them used a life cycle thinking in their environmental assessment scope, and another four in their economic scope.

As the most complete life cycle environmental assessment, ENERPAT carries out a complete LCA, by a specific study on the whole system [29]. Besides, in EFFESUS, life cycle was only focused in the characterization of the solutions and material, in the environmental field [29]; and in the case of STEEP also assess the impact taking into account the entire life cycle but in limited parameters [77]. Furthermore, HEREVEA counts with the evaluation of the projects' impact in all the stages of the life cycle but using the previously mentioned *Ecological Footprint (EF)* [64] *method, that despite it's not the same as LCA, it has the perspective of assessing the complete impact of the an intervention in all its life stages* [59].

In the economic field the most used method is the Life Cycle Cost (LCC) method, and was applied by ALDREN [30]*,* REVALUE [39]*,* OptEEmAL [49] *and EASEE* [51].

4.3. Comparison between projects' assessment indicators and the evaluation framework recommended by the European Union

In order to compare the current trends of European research projects in the field of energy retrofitting of buildings, the assessment indicators used by each project are compared with the list of recommended indicators published by the EU as Commission Recommendation (EU) 2019/786 of 8 May 2019 on building renovation [27]. For this, the indicators used by the assessment methodology of ach project are identified, listed and numbered, organized in the scopes or chapters according to each project (Annex 2: Indicators by the European research projects' assessment methodology). These projects' indicators are compared with the list of recommended indicators by the EU, checking the connection between them. This comparison is reflected in *the Table 3. Comparison between EU recommended indicator list and the projects' assessment indicators* (pages 16-19), by listing the EU recommended indicators and specifying the connection with the indicators of each analysed project by numbers; the numbers make reference to the list of indicators by the European research projects' assessment methodology of the Annex 2. The indicators by the EU are also numbered, in this case with a letter (A-L) referring the scope and a number referring the indicator.

The list of indicators provided by the EU in the Commission Recommendation (EU) 2019/786 of 8 May 2019 on building renovation [27] are organized in certain chapters according to the role of each indicator. The list of indicators and its organization has been carried out following the Article 2a of the EPBD, located in the paragraphs 1 and 3 [10]. As it can be appreciated in the analysis done by the comparison between the assessment indicators of the 18 studied project and the list of indicators recommended by the EU, not all the indicators are used in the projects, and some of the chapters aren't applied in any of the projects. It is an important point to underline taking into account that several types of projects have been analysed with the aim of making reference to the whole picture of building energy retrofit research project, all of them following the targets defined by the same Directive as the recommended assessment framework, the EPBD [10].

Instead, some chapters and indicators are very used, and this could be the signal of very usable or very accessible indicators, in terms of difficulty of application, in a similar way as in the previous chapter of the study, with the most assessed scopes (4.2. Analysis of projects' assessment methodology). In the *Fig. 2. Number of projects assessing the most used indicators by the EU* it can be appreciated the most assessed recommended indicators by the 18 analysed projects, the ones used in at least a quarter of the projects, ergo, the indicators by the EU used in five or more projects' assessment methodologies.

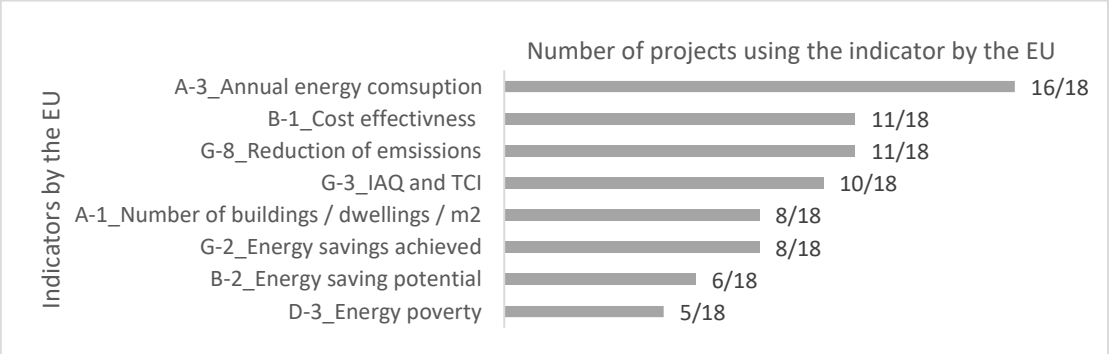

Fig. 2. Number of projects assessing the most used indicators by the EU

TABLE 3. COMPARISON BETWEEN EU RECOMMENDED INDICATOR LIST AND THE PROJECTS' ASSESSMENT INDICATORS

SCOPE	INDICATOR	EFFESUS	ENERPAT	ALDREN	REFURB	RenoZEB	REVALUE	mPower	Replicate	GrowSmarter	RemoUrban	STEEP	OptEEmAL	EASEE	Paradis	ENERSI	Plan Zero CO2	AGREE	Herevea
INDICATORS by Commission Recommendation (EU) 2019/786. Following the EPBD Article 2a [27]																			
A- OVERVIEW	1- Number of Buildings / Dwellings / m2 (Building type, age, size, climatic zone)	18,19	18,19	1, 3, 9,7	19,20	-	5	-	-	-	-	-	-	1,3	-	2, 3 5	-	-	13,14 18
	2- Annual energy consumption (by Building type, End Use)	16	16	31	27	-	9	11	2	1-3	17,18	6,10	2, 7	8,11	1	1	3,5	-	1
	3- Annual % renovated (by Building type, Building sector)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4- Renovated m2 (by Building type, size, age)	-	-	-	-	-	-	-	11	-	-	11	-	-	-	-	-	-	-
	5- Number of EPCs (by Building type, Energy class)	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-
	6- Number /m2 of NZEB (by Building sector)	-	-	-	-	-	-	-	-	-	-	-	40	-	-	-	-	-	-
B- COST-EFFECTIVENESS	1- Cost-effectiveness of main renovation measures	5	5	44-46	-	-	19-29	-	-21	61-65	-	-	33-35	13	6	6	-	-	2
	2- Total energy saving potential	-	-	-	-	-	30	-	20	-	2	-	31	14	-	-	-	4	-
C- PUBLIC POLICIES	1- Proportion of buildings undergoing deep and NZEB renovation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2- Public incentives for deep renovation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3- Public and private investments in deep renovations	-	-	-	-	-	-	5	-	-	53	-	41,42	-	-	-	-	1	-
	4- Energy savings from deep renovations	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

INDICATORS by Commission Recommendation (EU) 2019/786. Following the EPBD Article 2a [27]		**EFFESUS**	**ENERPAT**	**ALDREN**	**REFURB**	**RenoZEB**	**REVALUE**	**mPower**	**Replicate**	**GrowSmarter**	**RemoUrban**	**STEEP**	**OptEEmAL**	**EASEE**	**Paradis**	**ENERSI**	**Plan Zero CO2**	**AGREE**	**Herevea**
SCOPE	**INDICATOR**																		
D- POLICIES ABOUT SOCIAL SCOPE	1- Public investments in policy addressing social issues	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2- % of rented houses with EPCs below a certain performance level	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
	3- Energy poverty	-	22	-	-	-	-	-	51	-	20,30	-	36	-	-	-	23	-	-
	4- % of buildings in lowest energy classes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E- POLICIES IN PUBLIC BUILDINGS	1- Renovated public buildings in m2 (Building type, age, size, climatic zone)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F- INNOVATION IN BUILDINGS	1- No. of b. with building energy management systems (BEMSs) or similar smart systems	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-	-
	2- Public and private investments in smart technologies (including smart grids)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3- Citizens participating in energy communities	-	-	-	-	-	-	-	23,52	57	52	-	-	-	-	-	-	-	-
	4- No of graduated students related to energy efficiency	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	5- No of installers skilled in new technologies and working practices	-	-	-	-	-	-	2,3	-	-	-	-	-	-	-	-	-	-	-
	6- Budget of national research programmes in the field of building energy efficiency	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-
	7- Participation of national universities in in-ternational scientific research projects (e.g. H2020) on energy efficiency in buildings-related topics	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

INDICATORS by Commission Recommendation (EU) 2019/786. Following the EPBD Article 2a [27]		**EFFESUS**	**ENERPAT**	**ALDREN**	**REFURB**	**RenoZEB**	**REVALUE**	**mPower**	**Replicate**	**GrowSmarter**	**RemoUrban**	**STEEP**	**OptEEmAL**	**EASEE**	**Paradis**	**ENERSI**	**Plan Zero CO2**	**AGREE**	**Herevea**
SCOPE	**INDICATOR**																		
G- ENERGY, HEALTH, SAFETY	1- Reduction in energy costs per household (average)/decrease in energy poverty	-	22	-	-	-	30	-	-	-	-	-	-	18	-	-	-	-	-
	2- Actual energy savings achieved	12	12	31	-	-	30	-	19	-	2	-	-	14	-	-	-	4	-
	3- Average/aggregate indoor air quality in-dices (IAQIs) and thermal comfort index (TCI)	7-10	7-10	35-41	-	-	31-33	-	-	19-21	10,11	-	20,23	15	3-5	-	17-19	-	-
	4- Cost of avoided illnesses/reduction in health costs attributable to energy efficiency measures	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-
	5- Reduction of whole life carbon	-	2,3	-	-	-	-	-	-	-	-	1	27	-	-	-	-	-	1
	6- Disability Adjusted Life Year (DALY)/Quality Adjusted Life Year (QALY) improvements attributable to the improvement of building stock and living conditions	-	-	-	-	-	-	-	-	-	-	-	-	-	9-10	-	29	-	-
	7- Labour productivity gains from better working environment and improved living	-	-	-	-	-	-	-	-	-	-	-	-	17	-	-	-	-	-
	8- Reduction of emissions	16	16	-	-	-	-	-	30	4-6 53	13	1	27	16	-	-	2	7	1
	9- Employment in the building sector (No of jobs created per EUR million invested in the	-	24	-	-	-	-	-	22	-	34	-	-	20	-	-	-	-	-
	10- GDP increase in the building sector	-	-	-	-	-	-	17	57	-	27	-	-	-	-	-	-	-	-
	11- % energy imports for the Member State (energy security measures)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12- Removal/prevention of accessibility bar-riers for persons with disabilities	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13,14	9	-

INDICATORS by Commission Recommendation (EU) 2019/786. Following the EPBD Article 2a [27]	**EFFESUS**	**ENERPAT**	**ALDREN**	**REFURB**	**RenoZEB**	**REVALUE**	**mPower**	**Replicate**	**GrowSmarter**	**RemoUrban**	**STEEP**	**OptEEmAL**	**EASEE**	**Paradis**	**ENERSI**	**Plan Zero CO2**	**AGREE**	**Herevea**
SCOPE - INDICATOR																		
H- Aggregation of projects, including by investment platforms or groups, and by consortia of small and medium-sized enterprises, to enable investor access as well as packaged solutions for potential clients. No of integrated/aggregated projects	-	-	-	-	-	-	-	-	-	51	-	-	-	-	-	-	-	-
I- Reduction of the perceived risk of energy efficiency operations for investors and the private sector. Perceived risk of energy efficiency operation (survey-based)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
J- Use of public funding to leverage additional private-sector investment or address specific market failures; Public investments as percentage of total investments in energy saving Public-private partnership initiatives	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
K- Guiding investments into an energy efficient public building stock, in line with Eurostat guidance. Investment in energy efficiency renovation on the public building stock	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6,10	-
L- Accessible and transparent advisory tools, such as one-stop shops for consumers and energy advisory services, on relevant energy efficiency renovations and financing instruments. Perceived risk of energy efficiency operation (survey-based)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	-	-

(*) *Indicators of each project are listed and numbered in the Annex 2.*

5. Conclusion

The paper presents the analysis of energy retrofit research projects in buildings linked to the EU energetic targets, based in the improvement of the energetic performance, in order to build an overview of the working fields treated and the criteria followed to perform and evaluate each project.

Despite all the projects are linked to the same energetic aims, all of them cover wider scopes but with a different roadmap and measurement techniques. On the one hand, there are projects of many types and scale, so they have different aims in addition to the energetic field. However, even in projects with similar typology and scale don't have a common roadmap in the assessment: in the case of the European scale energetic action plans (REPLICATE [42], GrowSmarter [43], RemoUrban [44] and STEEP [47]), follow the same scheme in the planning scope, but they do not follow the same roadmap in the assessment methodology, performing and evaluating each project under different scopes, indicators and data sources. Moreover, in the case of tool developments, although they have several applications, the common assessment scopes use completely different criteria. On the other, in terms of the energetic assessment, even though all the projects have certain indicators in common, the key assessing elements and data sources have different origins.

In terms of environmental assessment, life cycle thinking is only implemented in four of the eighteen analysed projects, ergo, only these four projects try to evaluate the whole environmental impact, were the final main objectives of Directives are fundamentally the environmental impact *taking into account all the stages of the buildings' life [1].*

In conclusion, it does exist a big knowledge of energy retrofit renovation projects by methodologies, tools and action plans, but there is a lack of a global roadmap to be followed in order perform and assess the retrofit of existing buildings.

The continuation on this research, by the Project LOCAL-REGEN will be focused to fulfil these lacks, towards a global roadmap to be followed and proceed in the main objective of the "European Green Deal".

6. Further research lines

The study is part of the research project LOCAL-REGEN (PID2019-104871RB-C22), funded by the Ministry of Science and Innovation. State Research Agency/10.13039/501100011033. The project consists in defining a multi-criteria methodology with a life cycle thinking perspective for the evaluation and assessment of the progress of the local strategies for housing renovation, based on progress indicators that are broad enough to encompass the specificities of different territories of Spain. This way, the project will follow the analysed data of this study towards a methodology for the assessment of local renovation strategies.

Furthermore, in the same line of LOCAL-REGEN research project, a Phd project has been proposed in order to proceed the research and develop a catalogue of residential building energy renovation solutions, based on life cycle assessment and with a holistic assessment, answering to the requirements determined by European policies. Firstly, possible scenarios will be analysed by representing the diversity of residential buildings and users with their diversity of needs through the characterisation indicators. Secondly, different technical solutions applicable to the scenarios will be evaluated according to measurable progress indicators. Finally, the Life Cycle Analysis will assess the environmental impact of the building and the possible interventions and also the economic feasibility, taking into account all the stages of the life of the building.

7. Diffusion of work

The main part of this study have been presented in the *CONECT* international scientific conference and published as an article in *Environmental and Climate Technologies* scientific journal (ISSN 16915208 (paper) and 2255-8837 (online)) as “Analysis of Energy Retrofit Assessment Methodologies in Buildings by European Research Projects”.

Environmental and Climate Technologies scientific journal impact:

Impact factor (SJR) year 2020: 0.323
103/220 (Q3) in the category “general environmental science” (SJR ranking)
Cite Score (2020): 2.3

ANNEX

Annex 1: Topics assessed by projects' classified by "Assessment Scopes"

TABLE 3. TOPICS ASSESSED BY PROJECTS CLASSIFIED BY "ASSESSMENT SCOPES"

Project	**Assessment Scopes and assessed indicators and topics**		
ENERPAT {[28][29]}	**Energetic Scope**	**Environmental Scope**	**Economical Scope**
	- ECM (Energy conservation measures) - Embodied energy - Monitoring of energy performance	- Life Cycle Analysis application. - Use of local materials. - Environment conditions	- Application of circular economy - Local material and techniques to boost new local business - Economic return
	Social Scope	**Wellness & Health Scope**	**Heritage**
	- Energy poverty - Citizen acceptance	- Indoor environmental conditions	- Different solution filtered according to heritage impact
EFFESUS {[29]}	**Energetic Scope**	**Environmental Scope**	**Economical Scope**
	- ECM (Energy conservation measures) - Embodied energy	- Life Cycle thinking in use of materials - Use of local materials	- Application of circular economy - Local material and techniques to boost new local business and logistic easiness - Economic return
	Wellness & Health Scope	**Heritage**	
	- Indoor environmental conditions	- Different solution filtered according to heritage impact	
ALDREN {[30] [31] [32] [33] [34]}	**Energetic Scope**	**Economical Scope**	**Wellness & Health Scope**
	- Non-renewable energy use - Energy performance by hourly energy simulation	- Global cost: energy, maintenance, replacement, Ghg, revenues. - Economical risk. - Economical value: rental value, rental growth, discount rate.	- TAIL system assessing the Thermal environment; Acoustic environment; IAQ (indoor air quality); Luminous environment.
REFURB {[35][36][37]}	**Energetic Scope**	**Economical Scope**	**Social Scope**
	- EPC indicators - Energy saving by %	- Annual investment cost - Cost efficiency indicator	- User typology and solutions according to the user (dweller)
	Wellness & Health Scope		
	- Basic assessment of comfort by checking which renovation package gives a plus in comfort		
RenoZEB {[38]}	**Energetic Scope**	**Environmental Scope**	**Economical Scope**
	- Energy savings - Equipment performance - Monitoring in real time: solar radiation, light, heat transfer)	- GHG emission savings	- Financial conditions analysed - Market opportunities and barriers analysed.
	Wellness & Health Scope		
	- Thermal Comfort	- IAQ	- Illuminance
REVALUE {[39]}	**Energetic Scope**	**Economical Scope**	**Wellness & Health Scope**
	- EPC indicators - Energy performance index	- Life Cycle Cost - Incomes (rental housing), cost and market approach.	- Thermal comfort - IAQ - Risk of mould - Sound protection
mPOWER {[40][18]}	**Energetic Scope**	**Environmental Scope**	**Economical Scope**
	- RES (renewable energy source) % installed - HDD (heating degree days) & CDD (cooling degree days) - HEF (hidden energy flows)	- Total primary energy footprint - GHG emissions	- GDP (gross domestic product)

	Social Scope		
	- HDI (human development index)		
REPLICATE {[41][42]}	**Energetic Scope**	**Environmental Scope**	**Economical Scope**
	- Annual final energy consumption - RES % energy consumption	- CO_2 emissions - PM10 concentration - Noise pollution - Wastes and recycling rate - Water consumption	- GDP - Median dispensable income
	Social Scope		
	- Population dependence ratio - High education degree ratio - Affordability of housing - Fuel poverty	- Public participation - Unemployment rate - Jobs created - Degree of satisfaction	
GrowSmarter {[43]}	**Energetic Scope**	**Environmental Scope**	**Economical Scope**
	- Reduction of energy use - Energy demand (kwh/m2), heating, DHW, lighting, HVAC) - Measurement standard (IPMVM)	- Reduction of CO_2 emissions	- Affordability indicators: Financial net present value (ENPV), Economic Rate of Return (ERR), Benefit/cost ratio (B/C ratio) - Assessment for economic sustainability
	Wellness & Health Scope		
	- Thermal indoor environment (ISO 7730, ISO 7726)		
RemoUrban {[44][45]}	**Energetic Scope**	**Environmental Scope**	**Economical Scope**
	- Energy savings - Measurement standard (IPMVM)	- Saving in CO_2 - Reduction of environmental footprint	- Capital value of houses
	Social Scope	**Wellness & Health Scope**	
	- Surveys to occupants - Reduction of fuel poverty	- RH (relative humidity) and temperature - Percentage of Hours Properties Met Thermal Comfort Targets. - Occupants perception by post-retrofit surveys: comfort, physical health and emotional wellbeing. - Air quality · Natural light	
STEEP {[46][47]}	**Energetic Scope**	**Environmental Scope**	
	· Primary Energy Consumption: the whole life cycle. · Reduction of energy consumption - Increase of RES energy	- Concentration of contaminants - Waste and Recourses; Air quality: Water; Biodiversity and ecosystems; Noise; Landscape and Townscape; Soil and Land; GHG emission reduction; embedded carbon in extraction; manufacturing and transport; predicted lifetime emissions, emissions of deconstruction and re-use; opportunities for carbon sequestration.	
	Economical Scope	**Social Scope**	**Wellness & Health Scope**
	- Return of capital - Opportunity to wider local economy and benefit for local businesses	- Political and institutional support analysed. - Equality - Community cohesion	- Increase of residents' health and comfort
OptEEmAL {[48][49][50]}	**Energetic Scope**	**Environmental Scope**	**Economical Scope**
	- Primary energy consumption - Embodied energy	- Global warming potential GWP - GWP investment - GWP reduction	- LCC, life cycle cots - Operational energy cost - Investments - Return of investment - Payback period
	Social Scope	**Wellness & Health Scope**	
	- Energy poverty measured as % on inhabitants that use more	- Local thermal comfort - Percentage Outside Range - IAQ	

	than 10% of their incomes to pay energy bills	- Visual Comfort	
EASEE {[51][52]}	**Energetic Scope**	**Environmental Scope**	**Economical Scope**
	- Energy consumption	- Reduction of CO_2 - Reduction of waste	- Economic impacts: cost effectiveness during the life cycle.
	Wellness & Health Scope		
	- Comfort levels		
Paradis {[53][54]}	**Energetic Scope**	**Economical Scope**	**Wellness & Health Scope**
	· Energy consumption (reduction) · Energy frames defined in BR18	- Investment cost analysis	- Indoor thermal comfort and IAQ (EN 15251) - Discomfort hours - Degree of Satisfaction - Health and Wellbeing (indoor thermal comfort, IAQ and their effects on diseases)
ENERSI {[55]}	**Energetic Scope**	**Economical Scope**	
	- EPC indicators	- Cost & Return on investment analysis	
Plan Zero CO_2 {[56]}	**Energetic Scope**	**Economical Scope**	**Social Scope**
	- Following the targets of 2010/31/UE - EPC indicators - Heating system - Energy consumption - No Renew Prim Energy consumption - Air tightness (N50)	- Optimum cost methodology. Using simulation calibrated with real data.	- Vulnerability and Energy poverty. - Incomes of occupants. - Occupants profile (family type, age, conflicts).
	Wellness & Health Scope	**Accessibility Scope**	
	- Indoor hygrothermal comfort, PMV & PPD (EN-15251). - Indoor air quality	- Accessibility to the entrance - Vertical accessibility (lift) - Sensorial accessibility (identification, orientation) - Adapted housing	
AGREE {[57][58]}	**Energetic Scope**	**Economical Scope**	**Social Scope**
	- Energy efficiency	· Big study about financial support and viability	- Social vulnerability (economic situation, house typology…) - Census tract size
	Accessibility Scope		
	- Accessibility analysis in the dwelling and the building		
HEREVEA {[59]}	**Energetic Scope**	**Environmental Scope**	**Economical Scope**
	- Energy from bills - Embodied energy	- EF-Ecological footprint (instead of LCA) in all the life cycle. - EN-15978 standard, Sustainability of construction work.	- Economical data from bills - Economical cost of the project, per m^2

Annex 2: Indicators by the European research projects' assessment methodology

Project	Scope	Indicator
ENERPAT {[28][29]}	(without a specific classification of indicators by scopes)	1_Enviornmental conditions 2_Embodied Energy 3_Operatonal energy 4_Economic return 5_Economic feasibility: Cost 6_Constraints: Impact on historic significance (Visual); Impact on historic significance (Physical); Impact on historic significance (Spatial) 7_Habiability: Impact on thermal comfort. ISO 7730 (PMV, PPD etc) 8_Habiability: Impact on visual comfort. Illuminance level, uniformity of illuminance. 9_Habiability: Impact on acoustic comfort 10_Habiability: Impact on indoor air quality. Temperature and humidity level, CO2 concentration, particulate matter, VOC etc. 11_Habiability: Impact on electrical energy saving 12_Energy saving estimation, in terms of percentage reduction of the demand 13_Air change (winter) 14_Windows: frame area; G-value; Shading factor 15_Roofs, walls: U value 16_Energy consumption / CO2 emissions 17_Number of storeys 18_Gorund floor area 19_Year of construction 20_Principale use 21_Percentage of openings: presents the opening area (m2) of the building divided by the total wall and roof area (m2) of the building 22_Energy Poverty 23_Logistic easiness 24_Socio-economic development 25_Citizen acceptance
EFFESUS {[29]}	(without a specific classification of indicators by scopes)	1_Enviornmental conditions 2_Embodied Energy 3_Operatonal energy 4_Economic return 5_Economic feasibility: Cost 6_Constraints: Impact on historic significance (Visual); Impact on historic significance (Physical); Impact on historic significance (Spatial) 7_Habiability: Impact on thermal comfort. ISO 7730 (PMV, PPD etc) 8_Habiability: Impact on visual comfort. Illuminance level, uniformity of illuminance. 9_Habiability: Impact on acoustic comfort 10_Habiability: Impact on indoor air quality. Temperature and humidity level, CO2 concentration, particulate matter, VOC etc. 11_Habiability: Impact on electrical energy saving 12_Energy saving estimation, in terms of percentage reduction of the demand 13_Air change (winter) 14_Windows: frame area; G-value; Shading factor 15_Roofs, walls: U value 16_Energy consumption / CO2 emissions 17_Number of storeys 18_Gorund floor area 19_Year of construction 20_Principale use 21_Percentage of openings: presents the opening area (m2) of the building divided by the total wall and roof area (m2) of the building 22_Energy Poverty 23_Logistic easiness 24_Socio-economic development 25_Citizen acceptance

Project	Scope	Indicator
ALDREN {[30][31] [32][33] [34]}	BUILDING PICTURE	1_Building category 2_Use 3_Year of construction 4_Year of last renovation 5_Bearing structure 6_Location: country, city, province, PC, address, latitude, altitude, land parcel no. 7_Weather data: climate locality and climatic zone 8_HDD and CDD 9_Geometry: reference floor area 10_Geometry: volume 11_Geometry: shape factor A/V 12_No. of floors 13_Characteristics of the spaces of the building (no. of rooms, corridors, offices…) 14_Envelope characteristics (external wall, windows, floor, roof) 15_Envelope elements' U value 16_Type of heating system 17_Heating system efficiency rate 18_Heating system energy label 19_Heating system age 20_Heating system power 21_Type of cooling system 22_Cooling system efficiency rate 23_Cooling system energy label 24_Cooling system age 25_Cooling system power 26_Type of ventilation system 27_Ventilation system efficiency 28_Lighting system characteristics (no. of different types of lamps) 29_Renewavle energy characteristics 30_Metering system characteristics 31_Electric vehicle charging characteristics
	ENERGY RATING AND TARGETS	31_Energy Performance scale calculated by hourly energy simulation. 32_Non-Renewable primary energy use (a- a) with only the self-used PV electricity produced on-site taken into account or (b) including also the export to the grid (the main energy performance indicator)
	COMFORT AND WELLBEING TAIL index (Thermal env., Acoustic env., Indoor air quality, Luminous env.)	33_Thermal environment: Air temperature 34_Acoustic environment: Sound pressure level 35_Indoor Air Quality: CO2 35_Indoor Air Quality: Ventilation rate 36_Indoor Air Quality: Air relative humidity 37_Indoor Air Quality: Visible mold 38_Indoor Air Quality: Benzene 39_Indoor Air Quality: Formaldehyde 40_Indoor Air Quality: PM2.5 41_Indoor Air Quality: Radon 42_Luminous environment: Daylight factor 43_Luminous environment: Illuminance
	ECONOMICAL COST, VALUE AND RISK	"44_Economical Costs: Global costs/life cycle costs (Global costs calculation: Business as usual + renovation scenarios): Energy Costs and revenues, Maintenance costs, Other running costs, Replacement Costs, GhG costs" 45_Economical Risks: Sustainability-risks rating (Risk rating: from current building and local market outlooks) "46_Economical Value: Investment worth (Discounted cash flow calculation: business as usual + renovation scenarios) Rental value, Rental growth, Discount rate, Vacancy and relating costs, Occupation rate (hotels), Room price (hotels)"
REFURB {[35][36][37]	DWELLER CHARACTERISTICS	1_Stage of life 2_Time to manage

Project	Scope	Indicator
		3_Expected period to own the house
		4_Age of dweller
		5_Energy use patterns
		6_Home occupation pattern
		7_Type of decision maker
		8_Renovation need
		9_ Access to information
		10_General knowledge level
		11_Technocal knowledge level
		12_Male / Female
		13_Financial possibilities
		14_Owner status
		15_Willingness to invest in energy efficiency
		16_Intentions to renovate
		17_Environmental values and attitudes
	DWELLING CHARACTERISTICS	18_Neighbourhood type
		19_Dwelling type
		20_Construction era
		21_Construction type
		22_Historical value
		23_Urgency for renovation
		24_Inconvenience linked with the renovation
		25_Inconvenience and defects
		26_Value of the house
		27_Energy Performance
RenoZEB		(not enough information, project still in progress)
REVALUE {[39]}	KPIs USED FOR MARKET APPROACH	1_Transaction Date: Date of signed purchase
		2_Location: Macro location (Town, Region); Micro-Region (district, area); Property
		3_Limitations to use: Easements, servitudes, etc.; site occupancy index
		4_Quality of Plot: Parking spaces, etc.
		5_Building type: size, age. Building aesthetics, number of apartments within the building
		6_Dwelling / Layout: Layout of dwelling, size, number os storeys, number of rooms, level of dwelling in the building
		7_Builing standards: Evaluation of the building standard in relationship to the relevant comparable and market segment based on market specific criteria, e. g. (poor, average, good, very good)
		8_Technical specifications: Type of heating system (central, decentralized), Type of ventilation, Presence of elevator, Presence of renewable energy production, Other
		9_Energy performance: EPC rating (A, B, C, D, E, F, G); Energy demand; Energy performance index
		10_Building Condition: maintenance status; Implemented refurbishment and retrofitting intervention; Remaining life span, age
		11_Legal (houses and apartments for rent): type of tenure; limitations on use
		12_Additional Income from Renewable Energy Sources (RES)
	KPIs USED FOR INCOME APPROACH	13_Gross income: Achievable net rent6 (including service charges, etc.); Voids, bad debts, etc.; Revenues from energy production
		14_Development of gross income: Increase of the net rent over time; Tenant turnover; Vacancy, Defaults
		15_Running costs: Costs for heating and DHW production based on consumption of the previous year; Property tax, assurances, etc.; Building cleaning, waste disposal, etc.; Common electricity.
		16_Operating costs: Costs for maintenance and repair (regular and irregular); Management costs; Running costs for vacant apartments.
		17_Economic and technical lifetime (Building age; Qualities of the location; Status of maintenance and refurbishment; "Currentness" of layout (dwelling or building); EE-performance (EPC / individual components)

Project	Scope	Indicator
		18_Discount rate / yield: Interest rates for capital, opportunity; Projected Inflation; Opportunity cost for equity; Risk adjustment for specific property or type; Expected interest rates, etc.; Yield for comparable properties
	KPIs USED FOR COST APPROACH	"19_Land value: Value of the building plot / land value based on market value for land with consideration of: - Limitations to use (site occupancy index, etc.) - Quality of plot (parking spaces, etc.)" 20_Technical specifications: Type of heating system (central, decentralized), Type of ventilation, Presence of elevator, Presence of renewable energy production, Other 21_Energy performance: EPC rating (A, B, C, D, E, F, G); Energy demand; Energy performance index 22_Building Condition: maintenance status; Implemented refurbishment and retrofitting intervention. "23_Constructional Costs: - Infrastructural costs; - Construction costs of the comparable building with consideration of building type, building standard and specifications: Costs for building envelope, structural work; Costs for fit-outs, etc.; Costs for building technics (HVAC system, electrical system, etc.); Costs for outdoor facilities, etc." 24_Additional Building Costs: Architectural, engineering, permitting, certifications and other additional costs 25_Depreciation of Estimated Building Costs: Building age; Building type; Remaining life span with consideration of implemented refurbishment and retrofitting interventions. 26_Cost Adjustment to Specific Condition: Maintenance condition; Defects and damages 27_Market Correction for Location: Macro location (Town, Region); Micro-Region (district, area); Building type 28_Additional Income from Renewable Energy Sources (RES)
	GENERAL ECONOMICAL KPIs	29_Life Cycle Costs 30_Cost of saved energy
	STANDARD IMPROVEMENT EVALUATION	31_Thermal comfort 32_Usability 33_Air quality 34_Risk of mold 35_Sound protection
mPOWER {[40][18]}	(without a specific classification of indicators by scopes)	1_Validity of the gathered data: Indicates the level of knowledge of public energy employees on municipal energy issues. 2_Municipal campaigns: Indicates the number of campaigns that city has create in order to boost energy transitions. 3_ Staff on energy Staff 4_Staff on transition Budget 5_Budget for transition 6_RES percentage 7_Installed RES 8_RES production 9_Plans for RES investment 11_Total energy consumption 12_Total Primary Energy Supply 13_Total Primary Energy Footprint 14_Hidden Energy Flows (HEF) 15_GHG emissions 16_Human Development Index (HDI) 17_Gross Domestic Product (GDP) 18_Heating Degree Day (HDD) and Cooling Degree Day (CDD) 19_Inhabitants
REPLICATE {[41][42]}	PROJECT LEVEL: TECHNICAL KPI	1_Total final energy generation – Heat & electricity separately 2_Total final energy consumption – Heat & electricity separately 3_Total fuel consumption - per energy carrier 4_Renewable Energy Production - Heat & electricity separately 5_Degree of energetic self-supply by RES - Heat & electricity separately

Project	Scope	Indicator
		6_Degree of energetic self-supply by CHP (Cogeneration Heating Plant) - Heat & electricity separately
		7_Number of buildings connected to the DH
		8_Total heat supplied to the buildings connected to the district heating network
		9_Degree of heating supply by DH
		10_Final energy demand of the buildings
		11_Number of refurbished buildings
		12_Number of final users involved – Services and Networks separately
	PROJECT LEVEL: ENVIRONMENTAL KPI	13_Total primary energy consumption related to heating and electricity consumption
		14_Total greenhouse gas emissions related to heating and electricity consumption
	PROJECT LEVEL: ECONOMIC KPI	15_Total investment per intervention. Excl. VAT
		16_Total municipal grants per intervention
		17_Local cost ratio per intervention (related to total costs)
		18_Energy production cost - Heat & electricity separately
		19_Energy bill - Heat & electricity separately
		20_Total energy cost per year
		21_Payback Period per intervention
	PROJECT LEVEL: SOCIAL KPI	22_Direct total and local jobs created
		23_Number of citizens involved in the study
		24_Degree of satisfaction per intervention
	CITY LEVEL: CITY DESCRIPTION INDICATORS	25_Population of the city
		26_Population increase rate
		27_Tourism intensity
		28_Climate Koppen Geiger classification
		29_Population Density
	CITY LEVEL: ENERGY and ENVIRONMENT	30_Carbon Dioxide emissions
		31_PM10 concentration
		32_Noise pollution
		33_Annual final energy consumption
		34_Green Electricity purchased
		35_Renewable electricity generated within the city
		36_Renewable heat generated within the city
		37_Smart energy meters
		38_Refurbished buildings improving energy performance
		39_Number of connections to a district heating network
		40_Municipal solid waste per capita
		41_Recycling rate
		42_Liters of water used per capita
		42_Water losses
	CITY LEVEL: GOVERNANCE	43_Climate resilience strategy
		44_Existence of local sustainability plans
		45_Existence of Smart Cities strategies
		46_Existence of an Agenda 21
		47_Signature and compliance of the Covenant of Mayors
	CITY LEVEL: SOCIAL	48_Population dependence ratio
		49_Number of high education degrees per 100,000 population
		50_Affordability of housing
		51_Fuel poverty
		52_Open public participation
	CITY LEVEL: ECONOMY and FINANCE	53_City's unemployment rate
		54_Expenditures by the municipality for the transition towards smart city
		55_Incentives for final users for low carbon measures (RE, Energy Efficiency, mobility)
		56_Share of green public procurement
		57_Gross Domestic Product
		58_Percentage of the ICT sector on GDP
		59_Median disposable income

Project	Scope	Indicator
GrowSmarter {[43]}	(related to ENERGY, COMFORT and ENVIRONMENT)	1_Heat energy required (kWh) per year and month normalized for climatic conditions 2_Cooling energy required (kWh) per year and month normalized for climatic conditions. 3_Electric energy required (kWh) per year and month 4_CO2 emissions due to heating energy demand (kt/year) 5_CO2 emissions due to cooling energy demand 6_CO2 emissions due to electric energy demand 7_District heating (space heating and hot water) 8_Purchased electricity 9_Total purchased energy 10_Hot water circulation losses 11_Heat pump electricity consumption 12_Produced solar energy 13_Hot water usage 14_Energy recovered from data centre 15_Air leakage in air flow l/s at 50 Pa 16_Air leakage in air changes per hour at 50 Pa (ACH50) 17_U Value of windows (incl. frame) 18_Solar gain coefficient (%) 19_PPD of overall thermal environment evaluated at reference point of window 20_PD of local thermal comfort (draught, radiant asymmetry, vertical air temperature difference) 21_Sensible air temperature of the reference apartments according to relevant standards (e.g. ISO 7726, 7730) 22_Energy saving from waste heat recovery. 23_DHW heating demand during one year. 24_Temperatures of the delivered DHW 25_Temperatures of the incoming water mains. 26_Energy use for DHW, annual consumption. 27_Annual DHW use 28_Energy use for DHW per person in building 29_Energy use for DHW per square meter 30_Heat recovery ratio 31_Effectiveness of the heat recovery system (i.e. overall COP of the system) 32_Average seasonal performance factor 33_Infiltration flow rate ($m^3/s \cdot m^2$ envelope area) at 50 Pa. 34_Infiltration losses (cooling and heating) (kWh/m^2 floor area). 35_Reduction of energy use compared to baseline (kWh/m^2 floor area) 36_Lighting intensity 37_Annual electric energy use 38_Electricity consumption 39_U Value of windows (incl. frame) 40_U Value of facades 41_Relevant overall thermal environment evaluated at reference point. 42_If required (based on user survey), PD of local thermal comfort (draught, radiant asymmetry, vertical air temperature difference). 43_Sensible air temperature of the reference buildings. 44_Energy demand and consumption by heating (Gas) 45_Energy savings (primary energy) 46_Equipment performances 47_Average electric energy demand of lighting system and other electricity uses 48_On-site electricity production 48_Share of RES in heating cooling and electricity supply. 49_Solar energy production on a monthly basis 50_Building electricity load on a monthly basis 51_Electricity purchased from the grid on a monthly basis 52_Self-sufficient fraction of the electricity consumption of the building 53_Reduced CO2 emissions due to renewable energy contribution 54_ Recycling rates 55_Waste generation 56_GHG/Capita

Project	Scope	Indicator
		57_Relative awareness (survey based)
	(related to ECONOMY)	58_Initial investment 59_Replacement costs 60_Operating costs 61_Financial net present value – FNPV (C) - and financial rate of return – FRR(C) - on investment 62_Financial net present value – FNPV (K) - and financial rate of return - FRR (K) - on national capital 63_Economic Net Present Value (ENPV) 64_Economic Rate of Return (ERR) 65_Benefit/cost ratio (B/C ratio)
RemoUrban {[44][45]}	ENERGY SAVINGS	1_Energy savings per home 2_Percentage of energy savings 3_Dwelling numbers per building 4_Archetype (building) Energy savings 5_CO2 savings
	IMPROVEMENTS IN WELLBEING	6_Relative Humidity Thresholds 7_Dry temperature (per season: winter, spring/autumn, summer)
	INCREASED PROPERTY VALUES	8_Increase od capital value of houses according to the EPC rating improvement
	SUSTAINABILITY INDICATORS. URBAN ORGANIZATION. BUILDING AND HOUSING	9_Average Building Energy demand 10_Thermal Comfort 11_Indoor Air Quality Comfort 12_Environmental Certified Buildings
	SUSTAINABILITY INDICATORS. ENVIRONMNET AND RESOURCES	13_Air quality: CO2 emissions 14_Air quality: NO2 air pollution 15_Air quality: PM10 air pollution, P2.5 air pollution 16_Air quality: Noise pollution 17_Energy: Final energy consumption 18_Energy: Primary energy consumption 19_Energy: Renewable energy penetration rate 20_Energy poverty 21_Water consumption 22_Potable Water Supply Service 23_Wastewater Treatment 24_Sanitation Services 25_Urban Solid Waste 26_Solid Waste Treatment
	SUSTAINABILITY INDICATORS. CITIZENS and SOCIETY	27_GSP, Gross Domestic Product 28_Employment Rate 29_Disposable Income 30_Population Living in Poverty 31_R&D Expenditure 32_Labour Productivity 33_Gender Income equity 34_New Business 35_New Patents 36_Adult Literacy Rate 37_Secondary Education Competition Rate 38_Higher Education Degrees 39_Access to Basic Health Care 40_In-patient Hospital Beds 41_Emergency Service Response Time 42_Population Dependency Ratio 43_Average Life Expectancy

Project	Scope	Indicator
		44_Suicide Rate
		45_Crime Rate
		46_Internet Access Rate
		47_Voter Participation
		48_Open Public Participation
		49_Innovate/Green Public Procurement
		50_Open Data
		51_Incentives to Promote Sustainable Actions
		52_Awareness Initiatives
		53_Investment in SCC Project
		54_Climate Resilience Strategy
STEEP {[46][47]}	ENERGY SCOPE	1_CO2 emissions
		2_Use of total electrical energy per capita
		3_Green electricity
		4_Smart meters
		5_Buildings constructed under the EPBD standard
		6_Power consumption of the public sector
		7_Renewable energy
		8_Green public procurement
		9_PM10 Emission
		10_Use of total electrical energy per sector
		11_Buildings renovated with the improvement of energy efficiency beyond the EPBD requirements
		12_Percentage of lighting points with energy saving system
	SCOPE OF EXPLOITATION OF OTHER RESOURCES	13_Production of solid waste per capita
		14_Percentage of recycled solid waste
		15_Percentage of losses in the water network
		16_Percentage of waste waters receiving treatments of secondary and tertiary level
		17_Number of containers for organic matter
		18_Kg of annually waste produced per inhabitant
		19_Use of the fifth container (organic matter)
	ECONOMY AND FINANCE SCOPE	20_Number of PPP and EPC contracts
		21_Assessed value of commercial and industrial properties
		22_Incentives for the end users to implement energy efficiency
		23_Debt service ratio
		24_City's unemployment rate
	SOCIAL SCOPE	25_Population of the city
		26_Number of city users per year
		27_Percentage of school aged population enrolled in schools
		28_Number of high education degrees per 100.000 population
OptEEmAL {[48][49][50]}	ENERGY INDEX	1_Energy demand
		2_Final energy consumption
		3_Peak load and profile of electricity demand
		4_Peak load and profile of thermal energy demand
		5_Degree of energetic self-supply
		6_Net fossil energy consumed
		7_Total energy use per capita
		8_Total residential electrical energy use per capita
		9_Energy demand covered by renewable sources
		10_Total residential natural gas energy use per capita
		11_Total residential butane gas energy use per capita
		12_Energy consumption of public buildings per year
		13_Energy use from District Heating
		14_Energy use from Biomass
		15_Energy use from PV
		16_Energy use from Solar Thermal
		17_Energy use from Hydraulic
		18_Energy use from Mini-Eolic

Project	Scope	Indicator
		19_Energy use from Geothermal
	COMFORT INDEX	20_Local thermal comfort 21_Local temperature deviation from set point 22_Percentage outside range 23_Indoor air quality 24_Visual comfort
	ENVIRONMENTAL INDEX	25_Global Warming Potential - GWP (kg CO2) 26_GWP investment 27_GWP reduction 28_Primary energy consumption 29_Embodied energy of refurbishment scenarios 30_Energy payback time
	ECONOMIC INDEX	31_Operational energy cost 32_Investments 33_Life cycle cost 34_Return on investment 35_Payback Period
	SOCIAL INDEX	36_Energy poverty measured as % of inhabitants that use more than 10% of their incomes to pay energy bills
	URBAN INDEX	37_Percentage of buildings compliant with EPBD standard 38_Percentage of buildings compliant with Passivhaus standards 39_Percentage of buildings compliant with EnerPhit standards 40_Percentage of buildings compliant with nZEB standards
	GLOBAL INDEX	41_Kwh energy saved / euro invested 42_C02 saved / euro invested
EASEE {[51][52]}	(without a specific classification of indicators by scopes)	1_Floor area 2_Total volume 3_Net lettable area 4_Max. Occupancy 5_Capital Cost 6_Peak heating 7_Peak Cooling 8_Annual Heating 9_Annual Cooling 10_Annual lighting 11_Annual small power 12_Running cost 13_Net present value 14_Reduction in energy consumption 15_Comfort and indoor climate (winter and summer season) 16_Reduction of CO2 17_Improvement of productivity for companies involved in new diversified business 18_Annual economical savings 19_Payback period 20_Job creation
Paradis {[53][54]}	(without a specific classification of indicators by scopes)	1_Energy consumption 2_Energy frames defined in BR18. Renovation classes (I and II) 3_Indoor thermal comfort % in class I, II, III according to EN-15251 4_Discomfort hours above 27 and 28 ºC 5_Indoor Air Quality. % out of Class III according to EN-15251 6_Investement cost 7_DF - Daylight Factor 8_Daylight requirements according to BR18 9_Degree of satisfaction. % regarding effects of building space and thermal and luminous environments on satisfaction with Indoor Environment Quality 10_Health & Well-being. % regarding Energy improvement, indoor thermal comfort, air quality and their effects on Asthma, Allergy, and Eczema diseases

Project	Scope	Indicator
ENERSI {[55]}	(without a specific classification of indicators by scopes)	1_EPC indicators: Primary energy consumption; CO2 emissions 2_Geopraphic information 3_Census data 4_Building technical inspections data 5_Cadastre data 6_Costs and Return of investment
Plan Zero CO_2 {[56]}	AN EFFICIENT RESIDENTIAL STOCK. REDUCTION OF ENERGY CONSUMPTION	1_EPC energy label 2_CO2 emissions 3_Energy consumption in Heating 4_Type of heating system: energy source (gas, electricity); individual/centralized 5_Energy consumption in DHW 6_RES production percentage 7_Capacity for installation of RES: space, solar exposition, user revenues 8_Capacity for self-consumption 9_State of conservation (Aesthetic deficiencies, Risk to habitability, Risk of healthiness, Risk for users) 10_Operational costs (maintenance/IPES/expenses) 11_Community fee 12_Degree of Compliance Preventive Plan
	HEALTH AND WELL-BEING OF USERS. ENSURING HEALTHY AND COMFORTABLE HOMES	13_Degree of physical accessibility in the building (lift, entrance, circulation) 14_Degree of sensorial accessibility in the building (adapted lighting, signals) 15_Adapted housing provision 16_Provision of Heating system 17_RH - Relative Humidity 18_IAQ - Indoor Air Quality by CO2 concentration 19_Indoor temperature 20_Economical incomes of users 21_Household profile / usage profile /energy needs profile 22_Cohabitation 23_Energy poverty
	ADVANCED MANAGEMENT. INTEGRATED MANAGEMENT OF SOCIAL RENTING	24_Energy Self-management, percentage of implantation 25_Energy consulting 26_Degree of BIM modelling / Digitisation of the residential park 27_Implementation of asset management platform 28_Implementation of measuring devices 29_Impact of the plan on the users (impact of the consulting, impact on the comfort, accessibility and habitability, satisfaction degree, economic savings related to energy) 30_Impact of the plan on ALOKABIDE 31_Impact of the plan on the Government
AGREE {[57][58]}	(without a specific classification of indicators by scopes)	*(project still in progress: it is possible that not all the indicators used to perform the assessment are still published)* 1_Sustainable energy investments generated (in the territory of the participating entities) by AGREE 2_Total funding requested 3_Leverage factor 4_Energy savings 5_Sustainable energy investment projects and innovative financing solutions and/or schemes 6_Demonstrator of innovative and replicable investment finance solutions, documenting feedback/captures from potential replicators 7_Reduction of greenhouse gas emissions (in tCO2-eq/year) and air pollutants (in kg/year) 8_Social vulnerability 9_Accesibility in the dwelling and the building 10_Financial support and viability
HEREVEA {[59]}	MAIN ASSESSMENT INDICATORS	1_EF - Ecological Footprint (taking into account the life cycle perspective, using the standard EN-15978) 2_Economic cost

Project	Scope	Indicator
	ECONOMICAL EVALUATION	3_Renovation economical cost
		4_New construction economical cost
		5_R Cost: Cost of the renovation work of project with respect to a new construction. R_cost = (Ren_cost)/Cons_cost)
		6_Z Cost: statistical value of the cost
		7_N Cost: Normalized economical cost
	ENVIRONMENTAL EVALUATION	8_Renovation EF
		9_New construction EF
		10_R EF: EF of the renovation work of project with respect to a new construction. R_EF = (Ren_EF)/Cons_EF)
		11_Z EF: statistical EF
		12_N EF: Normalized EF
	CHARACTERIZATI_ ON INDICATORS	13_Date of construction
		14_Area
		15_Number of floors
		16_Number of dwellings
		17_Construction characteristics: foundation, structure, roof, installations
		18_Georefenced data
		19_Damage degree in construction elements: foundation, structure, roof, installations

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