SER4SC

SEISMIC AND ENERGY RENOVATION FOR SUSTAINABLE CITIES
CONFERENCE PROCEEDINGS

1st to 3rd February 2018
University of Catania
Department of Civil Engineering and Architecture

EDITORS
Giuseppe Margani
Gianluca Rodonò
Vincenzo Sapienza

EdicomEdizioni

DICAR
Dipartimento Ingegneria Civile e Architettura

UNIVERSITÀ degli STUDI di CATANIA

PROCEEDINGS OF THE

SEISMIC AND ENERGY RENOVATION FOR SUSTAINABLE CITIES

SER4SC

INTERNATIONAL CONFERENCE
CATANIA, FEBRUARY 1-3, 2018

Edited by
Giuseppe Margani
Gianluca Rodonò
Vincenzo Sapienza

EdicomEdizioni

Published by EdicomEdizioni

Monfalcone (Gorizia)
Tel. 0481 484488
Fax 0481 485721
e-mail info@edicomedizioni.com
www.edicomedizioni.com

ISBN 978-88-96386-56-9

Patrons

Friends

Organizing Committee

Stefano Cascone • Dario Distefano • Melania Lombardo • Manuela Marino
Giuseppe Margani • Attilio Mondello • Gianluca Rodonò • Vincenzo Sapienza

Scientific Committee

Giuseppe Alaimo	*University of Palermo*	*Italy*
Salvatore Caddemi	*University of Catania*	*Italy*
Carlo Caldera	*Politecnico di Torino*	*Italy*
Ivo Caliò	*University of Catania*	*Italy*
Santi Maria Cascone	*University of Catania*	*Italy*
Amir Causevic	*University of Sarajevo*	*Bosnia-Herzegovina*
Massimo Cuomo	*University of Catania*	*Italy*
Giuliano Dall'Ò	*Politecnico di Milano*	*Italy*
Pietromaria Davoli	*University of Ferrara*	*Italy*
Marco D'Orazio	*Università Politecnica delle Marche*	*Italy*
Valter Fabietti	*University of Chieti-Pescara*	*Italy*
Giovanni Fatta	*University of Palermo*	*Italy*
Corrado Fianchino	*University of Catania*	*Italy*
Alberto Fichera	*University of Catania*	*Italy*
Marco Filippi	*Politecnico di Torino*	*Italy*
Luca Finocchiaro	*Norwegian University of Science and Technology*	*Norway*
Emil-Sever Georgescu	*Nird Urban-Incerc*	*Romania*
Aurelio Ghersi	*University of Catania*	*Italy*
Riccardo Gulli	*University of Bologna*	*Italy*
Paolo La Greca	*University of Catania*	*Italy*
Rosario Lanzafame	*University of Catania*	*Italy*
Raffaella Lione	*University of Messina*	*Italy*
Paulo B. Lourenço	*University of Minho*	*Portugal*
Giuseppe Margani	*University of Catania*	*Italy*
Luigi Marletta	*University of Catania*	*Italy*
Emanuele Naboni	*The Royal Danish Academy of Fine Arts*	*Denmark*
Maurizio Nicolella	*University of Naples Federico II*	*Italy*
Masa Noguchi	*University of Melbourne*	*Australia*
Francisco Hipólito Ojalvo	*University of Extremadura*	*Spain*
Luis Palmero Iglesias	*Universitat Politècnica de València*	*Spain*
Emilio Pizzi	*Politecnico di Milano*	*Italy*
José Ignacio Sánchez Rivera	*University of Valladolid*	*Spain*
Antonello Sanna	*University of Cagliari*	*Italy*
Angelo Salemi	*University of Catania*	*Italy*
Adolfo Santini	*Mediterranea University of Reggio Calabria*	*Italy*
Vincenzo Sapienza	*University of Catania*	*Italy*
Enrico Spacone	*University of Chieti-Pescara*	*Italy*
Marius Voica	*Ion Mincu University*	*Romania*

Introduction to the Conference Proceedings

1-3 February 2018, University of Catania, Catania, Italy

One of the main challenges of the twenty-first century is to increase the sustainability level of our cities.
This requirement is mostly associated to environmental issues, and a great effort has been made in the past years to build a low-carbon society. However, a town, to be considered sustainable, must, above all, be safe, particularly against natural hazards, which in Europe are mostly related to climate changes (e.g., hurricanes, floods, storms, and landslides) and seismic events (earthquakes). Unfortunately, sustainability is still not a prerogative of most European cities, especially those placed in seismic countries such as Italy, where at least 50% of the residential stock is earthquake-prone, while over 80% of the same stock is highly energy-consuming and carbon dioxide-emitting, thus contributing to trigger hazards related to climate changes. In this context, renovation actions, which combine both energy and seismic issues, are strongly needed. This assumption has to be promoted for the following main reasons: energy renovation alone will be worthless if an earthquake destroys the building; to prevent life losses and damages; to avoid several costs otherwise duplicated (costs for building-site setup and scaffolds, claddings, plasters and other finishings, etc.).
Nevertheless, several barriers considerably limit the real possibility to extensively undertake combined retrofit actions, especially for multi-owner housing and high-rise buildings. These barriers are of different kinds: (i) technical (e.g., unfeasibility and/or ineffectiveness of conventional retrofit solutions, and need of regulatory simplification); (ii) financial (e.g., high renovation costs, "split-incentive"/"landlord–tenant dilemma", and insufficient incentives and subsidies); (iii) organizational (e.g., temporary alternate accommodation for occupants, consensus to the retrofit expenditure by condominium ownerships, and excessive time to obtain building permits); and (iv) cultural/social (insufficient information and skills, and lack of adequate policy measures to promote renovation actions).
The Seismic and Energy Renovation for Sustainable Cities - SER4SC 2018 Conference, held in Catania, 1st to 3rd February, aims to overcome these barriers and to bridge the gap between sustainability and safety, with a link that may conserve both human and environmental resources.
This edition contains 56 papers arranged by theme into 6 thematic sessions.
Each submission received reviews from at least two different Scientific Committee members and we would like to express our thanks to all the reviewers that provided detailed comments and feedback on all the submitted papers.
The selected papers were organized into sessions for the oral presentation, according to the key topics of the conference.

1st Session

Urban vulnerability and sustainable cities
Sustainability and safety of cities. Description of the vulnerability and/or energy performance scenario of any region or town. Tools and methods for assessing the urban vulnerability to natural hazards and for determining the scale of intervention to adequately reduce this vulnerability. Cost evaluation for the improvement of the urban resilience to natural hazards. Scenarios of possible financial incentives.

Resolution of organizational and practical problems
Strategies to overcome different organizational and practical problems, which considerably limit the real possibility to undertake retrofit actions, especially for multi-owner housing and high-rise buildings: consensus to the retrofit expenditure by condominium ownerships, excessive duration of renovation works and temporary alternate accommodation for occupants, split-incentive/landlord-

tenant dilemma, excessive time for getting construction permits, need of regulatory simplification, etc.

Economic and financial policies to promote renovation measures
Economic and financial tools, measures and policies to promote renovation activities.

Strategies for promoting the social sensitivity to prevention actions
Development of new policies to promote the awareness of the disastrous consequences of inadequate or insufficient prevention actions. Strategies to disseminate, among interested stakeholders, technical skills and competences on retrofitting measures, as well as to highlight the economic convenience of undertaking combined seismic and energy renovations. Training activities.

2nd Session

Construction techniques of historic and recent buildings
Description of construction techniques adopted for historic buildings (i.e. built before 1950) and recent buildings (i.e. built from the 1950s to the 1980s). Relationships between construction techniques and seismic or energy performance of buildings.

3rd Session

Seismic and energy regeneration strategies at district and urban scale
Urban regeneration strategies for the reduction of seismic vulnerability and/or energy dependence. Integrated land use and transport planning to reduce energy consumption due to private means of transportation.

4th Session

Design, monitoring and management tools
Novel tools for design, monitoring and management of existing buildings (e.g. BIM, parametric design, form finding, sensor grids, building management systems, etc.), with particular reference to renovation and post-renovation activities.

Retrofit optimization through prefabricated systems
Development of prefabricated systems to accelerate seismic and/or energy renovation activities, in order to reduce costs and inconvenience to the occupants.

5th Session

Technical solutions, materials and methods for seismic and energy renovation
Technical solutions, materials and methods for the seismic and/or energy renovation of historic and/or recent buildings.

6th Session

Decision support tools for the selection of the optimal retrofitting scenario
Development of user-friendly decision support tools to select the best seismic and/or energy renovation scenario, in terms of effectiveness, efficiency, costs, available incentives and subsidizes, safety, inconvenience to the occupants, etc.10. Resolution of organizational and practical problems.

Diagnostic techniques and numerical models to assess seismic vulnerability and energy performance
Development of novel diagnostic techniques and numerical models to determine the seismic vulnerability and/or the energy performance of historic and/or recent buildings.

Despite the different disciplines and viewpoints represented at the conference, all participants agreed that the challenge of combining energy renovation actions ad seismic upgrades are urgent and represents today a prevention action that is becoming more and more necessary to increase the sustainability level of our towns.
Seismic and energy renovation of buildings will allow reaching very relevant benefits, at environmental, social and economic levels.
Consequently, wide engagement actions, at both local and European level, are fundamental to raise awareness of the social, environmental and cultural relevance of prevention actions, and to achieve consensus and behavioural change towards decisional strategies for both energy efficiency and seismic safety.
Prevention is essentially a matter of mindset and culture. Since European countries have a great tradition and culture, the basic premises for developing a prevention attitude are all there.
In this context, schools, universities and research institutes play a crucial role, stimulating institutions and political forces to strongly promote the upgrade of the building stock.
This virtuous circle is possible, as well shown by the movement for the restoration of historic cities that has originated in Europe and afterwards has reached brilliant results of urban rebirth, which are clearly evident in Italy as well as in many other countries
This conference has engaged expertise and experiences of scientists, scholars, professionals and decision-makers from different countries, in order to find new effective, affordable and holistic solutions, which may positively contribute to enhance the sustainability level of our towns. In other words, this conference has aimed to become a hub, where people can discuss and start developing new robust renovation strategies for sustainable cites.

Acknowledgements:

We would like to thank our sponsors for their invaluable help for the success of the conference. We especially thank the Department of Civil Engineering and Architecture of the University of Catania (DICAR), the Order of the Engineer of Catania, the Foundation of the Engineer of Catania, the National Association of Building Constructors of Catania (ANCE Catania) for their attention to the issue of sustainable urban renovation, and their action of spreading the culture of risk mitigation.

Giuseppe Margani
Vincenzo Sapienza
Gianluca Rodonò

Contents

Introduction

1st Session

2nd Session

3rd Session

4th Session

5th Session

6th Session

6th Session

Decision support tools for the selection of the optimal retrofitting scenario

Diagnostic techniques and numerical models to assess seismic vulnerability and energy performance

SEISMIC AND ENERGY RENOVATION FOR SUSTAINABLE CITIES

Tectonic Sustainable Building Design for the Development of Renovation Scenarios – Analysis of ten European renovation research projects

Aliakbar Kamari[a,b]*, Rossella Corrao[a], Steffen Petersen[b], Poul Henning Kirkegaard[b]

[a]*Department of Architecture, University of Palermo, Palermo 90128, Italy*
[b]*Department of Engineering, Aarhus University, Aarhus 8000, Denmark*

Abstract

The investigation of 10 European building renovation research projects presented in this paper demonstrates that recent research in this field is currently centralized around quantifiable objectives i.e. development of energy efficient renovation scenarios, whereas the more qualitative objectives in renovation projects such as aesthetics, identity and/or social dimensions are rarely addressed. Furthermore, the result of this investigation together with the recent researches about the current practice of building renovation indicates that many of renovated buildings, which now are claimed to be sustainable are not addressing all aspects of a conventional definition of sustainability. Lastly, through the lens of tectonic architectural theory, there seems to be little use of design methodologies that includes all project stakeholders (i.e. architects, engineers, clients) in identifying truly sustainable solutions in a holistic perspective. To address these identified shortcomings in current approaches to sustainable building renovation, we propose the use of a design framework called 'Tectonic Sustainable Building Design', which draws upon the concepts Tectonics (an architectural articulation theory), Sustainability (the use of holistic design objectives) and a Holistic Multi-Methodology for Sustainable Renovation (an integrated design methodology). 'Tectonic Sustainable Building Design' deals with renovation projects as an architectural transformation, and intents to enable designers to form a strategy that establishes a link between the intentions of an architectural transformation and the way it is perceived by the user/owner of buildings. Once this is established, the framework is intended to serve as a platform for refining and improving the contemporary building industry seen in the light of sustainability, by supporting the decision-making in the development of holistic renovation scenarios.

Selection and peer-review under responsibility of SER4SC2018 Scientific Committee.

Keywords: Tectonics; Sustainability; Design methodology; Building renovation; Renovation scenarios, Tectonic Sustainable Building Design (TSBD)

1. Introduction

Today buildings are responsible for 40% of energy consumption and 36% of CO_2 emissions in the EU [1]. Most of these buildings will still be in use by the year 2050; reducing their consumption and

* Corresponding author. Tel.: +45 3151 8280
E-mail address: ak@eng.au.dk or aliakbar.kamari@unipa.it

emissions through renovations is therefore a key objective to meet the European Union's long term energy and climate goals [2]. Recent investigations into the practice of building renovation reveal different types of challenges and barriers [3] where economic, technical, and behavioural barriers seem to be dominating [4]. There are several reasons for these barriers including variety of stakeholders involved in the process (clients, tenants, contractors, municipalities, consultancies etc. – see [5]) and their interests, a massive range of available renovation solutions (insulation approaches, window replacement, HVAC systems etc. - see [6]), and broad number of objectives/criteria [or sub-criteria] (e.g. regarding energy efficiency, spatial quality, investment cost etc.) that needs to be addressed. Acre et al [7] state that the evidence of a holistic renovation influence of an energy renovation (use of pure technically designed renovation scenarios[†]) is that many of the measures taken in energy renovation, which affect architectural quality and social aspects, are not necessarily related to energy concerns (or pure technically designed renovation scenarios). In particular the substantiation of the objectives/criteria itself is a highly complicated task due to the variety of stakeholder expectations. Some objectives are considered engineering issues such as improvement of energy efficiency, and others are architectural issues such as increasing of spatial quality or liveability of buildings [7]. In a broader perspective, the challenges for building renovation can basically be categorized as socio-technical, socio-economical and socio-environmental issues just as the three pillars of the 'sustainability development paradigm'; *society*, *economy*, and *ecology* [8] and their interfaces. That, in fact, emerges the importance of sustainability objectives, and how effectively the complexity mentioned above can be reduced if the essential sustainability objectives/criteria for building renovation are identified and targeted early in the design stage ahead of further investigation and fulfilment.

The significant components to perform the design process of a holistic renovation can rationally be addressed throughout the following questions and their relevant descriptions:

- *Why to do a renovation?* (key focus: elaboration on sustainability objectives)

  Buildings are renovated to make changes. There are a wide array of advantages that can be obtained as an outcome of a holistic and sustainable retrofitting. The motivation for making these changes should embark on sustainability objectives/criteria in its full sense.

- *What to do for renovation?* (key focus: elaboration on renovation approaches)

  There are a broad range of renovation approaches that together creat a renovation scenario and can be applied for the renovation of existing buildings.

- *How to develop a comprehensive renovation scenario?* (key focus: elaboration on design methodologies)

  The renovation design process and selection of the renovation approaches needs to use of an equipped methodology, which is able to deal with the complexity of "soft" and "hard" criteria that are involved in the renovation projects as well as to cope with different decision makers and their different priorities in the design process. Decision-making in building renovation is influenced by a number of non-technical stakeholders.

Nevertheless, by exploring and accessing a comprehensive descriptions and answers to above questions, the fundamental and in our understanding finest potential of architecture to invite us to be

[†] The term "renovation scenario" used in this study means a selection and combination of different renovation technologies/actions (i.e. insulation of the external walls or replacement of the windows are each a renovation action) that together build alternative renovation scenarios/packages and subsequently is applied in a renovation project.

together or to contemplate in solitude by addressing the human scale, what we have chosen to describe as the ability of architecture to 'gesture' us, is oppressed [9]. Handling the "hard" objectives/criteria (measurable criteria such as energy consumption or energy generation) often relies on the use of rational quantitative methods whereas the handling of the "soft" objectives/criteria (i.e. identity, spatial, sociality, aesthetic etc.) often requires different methods. To cope with these "soft" criteria there must be an extra layer of evaluation principles that investigates how improvements of the "hard" objectives/criteria affect the "soft" objectives/criteria. It is the question of how a renovation also influence the experience of the built environment (or how to blow a soul into the buildings). Consequently, existing buildings cannot simply be renovated, but must undergo a transformation to comply with all objectives/criteria in a holistic approach. Conceiving a holistic renovation scenario is thus not only a technical 'principle' but also a spatial 'gesture' revealing various architectural potential through this transformation, which inevitably makes building renovation a question of *tectonics* [9].

The Danish research project RE-VALUE[‡] (Value Creation by Energy Renovation, Refurbishment and Transformation of the Built Environment, Modelling and Validating of Utility and Architectural Value) has been initiated to develop a more holistic approach to the assessment of value creation in building renovation projects. The aim of this paper is to contribute to the part of the RE-VALUE project which focuses on the development of a conceptual framework for methods that supports decision making on various levels of the renovation process. The conceptual framework is entitled 'Tectonic Sustainable Building Design' (hereafter referred to as TSBD). The potential of this framework is demonstrated through the evaluation of 10 European renovation research projects. According to [10], European building sector has become decomposed and not yet able to offer efficient solutions for holistic renovation. Developing and promoting TSBD influences the current practice of building renovation significantly. To this end, section 2 provides brief descriptions of sustainability, tectonics, and holistic multi-methodology as concepts. Section 3 presents the analysis of 10 European renovation research projects. The results from this analysis and the descriptions in section 2 inform section 4 where the proposed TSBD framework is described. Finally, section 5 provides a short conclusion and further research work.

2. 'Sustainability', 'Tectonics', and 'Holistic design methodology'

2.1. Sustainability

The term *sustainability* is an autotelic term, which means it is hailed as a priori goal in itself. It can be described as incontestable development of society and economy on a long-term basis within the framework of the carrying inclusion of the earth's ecosystems [11]. Nevertheless, sustainable development refers to a dynamic process from one state towards another that means there is no exact definition about it – nor is this necessary [12]. Sustainable development is to meet the needs of the present without compromising the ability of future generations to meet their own needs [8]. S*ustainability* is based on the modern information and communication systems [13]. As such, it is of special interest to verify the need for the deep understanding of *sustainability* as the pattern with the agglomerated set of indicators defined by the respective criteria [14]. Today, there is a significant range of methods accessible for appraisement of *sustainability* and its relevant criteria in this sector[15]. Many of the existing assessment methods and methodologies have been developed for the design of the new buildings, but can be applied to renovation projects as well, and some are particularly intended or adapted for building renovation

[‡] Participated by Brabrand Housing Association – with energy renovation in the Aarhus suburb of Gellerup – as well as DEAS, an administration company on the private rental housing market (for more info: http://www.revalue.dk)

context [16]. BREEAM[§] (by British Research Establishment), LEED[**] (by US Green Building Council), ATHENA (by ATHENA Sustainable Material Institute in Canada)[††], DGNB[‡‡] (by German Sustainable Building Council), DGNB-DK[§§] (by Green Building Council Denmark), BEAM Plus[***] (by Hong Kong Green Building Council), and EcoEffect[†††] (by Royal Institute of Technology in Sweden) are some examples of these methods. However, Jensen et al [16] argue that most of the methods and tools that mentioned above have a narrow environmental or energy focus, whereas the most recent tools attempted to evaluate environment, economy and social relations in an equal circumstances, i.e. DGNB-DK.

2.2. Tectonics

The term tectonic derives from the Greek word 'tekton', which signifies a carpenter or builder, and has gradually come to denote construction in general [17]. The poetic connotation of the term first appears in Sappho (in the seventh century BC) where the 'tekton' [the carpenter] assumes the role of the poet. This meaning undergoes further evolution as the term passes from being something specific and physical, such as carpentry, to a more generic notion of making, in the poetic sense. Sekler [18] describes it as "the noble gesture which makes visible a play of forces, of load and support in column and entablature, calling forth our own empathetic participation in the experience" [18]. In this description, the author has established a link between a 'structural concept' and how it influences the experiencing subject through spatial 'gestures' once the structural principle is manifested, or realized, through concrete 'construction'. Hvejsel et al [9] propose that Sekler's terms can be used as a vocabulary to articulate not 'only' the "visible play of forces", but the implications of technical interventions on the perceived spatial quality in a broader sense. In this explanation, *tectonics* can be referred as the art of construction. According to Beim [19], Tectonic Visions in Architecture is discussed as "visionary investigations into new materials, technologies, structures, and practices of construction, as means to construct (new) meaning in architecture". In connection to this, Nilsson [20] argues that the full *tectonics* potential in every building comes, according to Frampton [17], from its capacity to articulate both the poetic and the cognitive aspects of its substance. Frampton [17] makes, with reference to Semper's [21] distinction between symbolic and technical aspects of building, an interesting distinction between the representational and ontological aspects of *tectonics* form. Nilsson [20] states that, this dichotomy is something in constant need of reformulation in the creation of architectural form, since every building type, technology, topography and temporal circumstances give different cultural situations and conditions. Concentrating on "poetry" characteristic of architecture, Christiansen [22] defines *tectonics* as a fusion between the expression of form and the way it is created. The author states that when materials are processed with adequate technical awareness and insight, it is possible to create a specific form that communicates something that cannot possibly be communicated in any other way – whatsoever [22].

2.3. Holistic Multi-Methodology

The word 'methodology' was originally used to describe 'the science of method', which technically makes the concept of 'a methodology' meaningless. However, Checkland [23] distinguished this

[§] http://www.breeam.org
[**] http://www.usgbc.org
[††] http://www.athenasmi.org/
[‡‡] http://www.dgnb.de/en/
[§§] http://www.dk-gbc.dk/
[***] https://www.hkgbc.org.hk/eng/BEAMPlus.aspx
[†††] https://www.ecoeffect.se

traditional meaning of ‘a methodology’ towards a new one including different sets of principles. He addressed ‘methodology’ as “a body of methods used in a particular activity” [23], i.e. making a crucial distinction between ‘methodology’ and ‘method’. As the structure of the word indicates, ‘methodology’ in this situation leads to selection of some certain ‘methods’, in the form of the specific approach or process adopted for the specific situation. Currently, there is a huge diversity of methodologies for dealing with “objective” or “subjective”, “soft” or “hard”, and “quantitative” or “qualitative” problems. They have been categorized in two types including Soft Systems Methodologies - SSM and Hard Systems Methodologies - HSM [23]. Cross [24] addressed them and their differences between design and science contexts. Cross [25] distinguished between Scientific Design concept (attached to HSM) and Design Science concept (attached to SSM)and considers use of the two concepts (SSM beside HSM) in analysing design activity and link it to the works of Simon [26], Schön [27,28], and Dorst [29]. This leads to the appreciation of the complementary strengths of the two different paradigms for gaining an overview of the whole range of activities within the design domain [25]. Mingers et al [30] contributed to the discussion by stating that to deal with the richness of the real world, it is desirable to go beyond using a single (or, on occasions, more than one) methodology. They argue that it is possible to combine several methodologies - in whole or in part – which stem from different paradigms. In this paper, the term holistic multi-methodology has assigned to the mentioned concept. As such, a holistic multi-methodology is developed and equipped by mix of SSM and HSM approaches [31] to cope with complexity of the problems to include both “soft” and “hard” objectives in parallel.

Building renovation can be regarded as a problem-solving activity terminated by a solution deemed satisfactory. In doing so, there are various stakeholders who are involved in the process, the sustainability objectives/criteria (including “soft” and “hard” criteria) are considered, targeted and evaluated, and ultimately an appropriate renovation scenario is developed. To succeed in this field, an efficient integrated design methodology is required that can cope with complexity of the mentioned components.

3. Analysis of 10 European building renovation research projects

The building renovation process usually involves multiple separated disciplines, which leads to additional costs and risk of failure. Many customers see high operating costs and poor environment as an acceptable alternative to the time-consuming, disruptive and risky renovation process. Despite remarkable number of recently finished or yet ongoing renovation research projects, Moseley [10] argued that the European building sector has become fragmented and not yet able to offer holistic solutions for deep renovation at acceptable cost and quality. For this reason, a list of 10 recent European building renovation research projects have been analysed (see Table 1). The aim is to evaluate what and why the recent researches have been established and targeted. It leads to realize about possible gaps regarding their outcomes for the future of the renovation field in practice.

The research projects listed in table 1 have been selected due to their scale, history, the involved countries, and their funding that underlines their importance (see Appendix 1). The analysis have classified them in three levels including *moderate* or *ordinary*, *deep* renovation, and *Near Zero Energy Building* (NZEB). The mentioned terms have been extracted from the projects themselves. In this classification, *moderate* is attached to features expected about recently retrofitted buildings and solutions; NZEB refers to application of exceedingly advanced solutions which lead to develop renovation scenarios with very high energy performance; and lastly *deep renovation that* refers to implementation of wider range of sustainability criteria for renovation purpose. We have also considered them for details level which they have provided for renovation actions thorough 1) low numbers of identified renovation actions + low amount of provided technical properties (referred as *low*); 2) Low numbers of identified renovation actions + high amount of provided technical properties (referred as *moderate*); 3) High numbers of identified renovation actions + low amount of provided technical properties(referred as *high*); and 4) High numbers of identified renovation actions + high amount of provided technical properties (referred as *very high*). The analysis demonstrates that the first priorities in almost all of the projects are related to energy efficiency and cost. The amount of projects dealing with the variety of renovation approaches is promising. However, only one project has included the validation and verification of the selected scenarios after construction process. There are no "soft" criteria such as spatial quality in any of the projects. None of the projects consider the design process for generating renovation scenarios, and consequently do not describe how to cope with the various stakeholders involved throughout the process. Overall, it can be concluded that none of the projects deals with the *sustainability* (see section 2.1) in its full sense. This calls for new actions including research about converging and combining the outcomes out of the analysed projects in Table 1 while broadening their scope to encompass the full definition of *sustainability*, hereafter, demonstrate the new definition under a unified and simplified platform.

Table 1. Analysis of 10 European building renovation research projects

Project Name	Renovation level			Renovation project phase											Building function			Case study evaluation (renovation)	Focus on specific climate zoon	Focus on building elements for renovation purpose	Major considered criteria									Development of a digital tool
	Moderate	Deep	NZEB	Energy auditing and Renovation assessment	Identification of the renovation actions (level of details)				Enhancement of renovation actions	Creation of renovation actions	Generation of renovation scenarios	Site implementation	Validation and Verification	Monitoring	Residential buildings	Public/Commercial/Office buildings	Historical buildings				Energy consumption	Renewable energy	CO2 emission	Water consumption	Indoor comfort	Payback period	Cost	Occupant behaviour	Renovation process	
					Low	Moderate	High	Very high																						
iNSPiRe		+		+		+			+	+	+	+		+	+	+		+	+	+	+	+	+		+		+			
EcoShopping						+										+					+	+			+		+			
HERB		+			n/a	n/a	n/a	n/a	+	+	+	+		+	+			+		+	+	+	+			+	+			+
REFURB		+	+		n/a	n/a	n/a	n/a			+	+	+		+			+			+		+				+	+	+	
READY			+			+				+				+	+	+			+	+	+	+	+	+			+		+	
3ENCULT				+				+	+		+			+			+	+			+				+				+	
MORE-CONNECT		+	+			+				+					+	+	+			+	+				+					+
BuildHeat	+				+				+	+	+				+			+		+	+							+	+	
NeZeR	+	+	+			+			+	+					+			+	+		+	+					+		+	
RePublic_ZEB			+	+				+	+	+	+					+		+	+	+	+	+	+				+		+	

Note: Further information about the selected research projects have been provided in Appendix 1.

4. Tectonic Sustainable Building Design - TSBD for building renovation

TSBD relies on the idea from the goal-directed integrated design process (International Energy Agency-IEA task 23)[‡‡‡]. Identifying and targeting the sustainability objectives/criteria and renovation approaches is therefore a key point to that. In addition, it is paramount to TSBD to also evaluate how a renovation scenario may influence the experience of the built environment. As such, the TSBD framework relies on the following:

- ***Sustainability*** is considered as the most desired value for renovation of the existing building stock. For expanding of the holistic sustainability objectives/criteria in building renovation, the recent research by Kamari et al [32] about development of a new holistic sustainability decision-making support framework, has been used. The study was inspired by a number of sustainability assessment methodologies [33] using Soft Systems Methodologies - SSM [23] and Value Focused Thinking [34]. The product was a sustainability Value Map for building renovation consisting of three categories – Functionality, Accountability, and Feasibility – with a total of 18 sustainable value-oriented criteria (see Table 2) and 118 sub-criteria. The procedure for development of the Value Map has been a consensus-based process. The major part of the criteria in the Functionality category are quantifiable while the qualitative criteria have been listed in other category named Accountability. From other side, Feasibility category contains a mix of quantitative (i.e. cost criteria) and qualitative criteria such as advantages in using an efficient renovation process where it influence the key stakeholders.

Table 2. List of sustainable value oriented criteria for building renovation (adapted from [32])

FUNCTIONALITY	ACCOUNTABILITY	FEASIBILITY
Indoor comfort	Aesthetic	Investment cost
Energy efficiency	Integrity	Operation & maintenance cost
Material & waste	Identity	Financial structures
Water efficiency	Security	Flexibility & Management
Pollution	Sociality	Innovation
Quality of services	Spatial	Stakeholders engagement & education

- ***Tectonics*** theory of architecture is used to articulate a linkage between technically motivated alterations and the spatial experience of a building for renovation purpose. In order to expand the *tectonics* principles for this reason, the recent studies by Jensen et al [35] about development of a vocabulary between 'technical concept', 'construction', and 'spatial gestures', together with study by Hvejsel et al [9] about development of a tectonic approach to energy renovation in a Danish context, have been used. Both the studies have re-read the *tectonics* theory throughout the spatial and methodological conceptions of the term that is specific to, and link, the works of Semper [21], Sekler [18], and Frascari [36]. They conclude that *tectonics* holds the potential to equip us with a detailed spatial view and in depth structural understanding of buildings, which considers significantly fitted for building renovation projects.

- ***Holistic Multi-methodology for Sustainable Renovation*** - HMSR is used in TSBD as a holistic multi-design methodology for development of the renovation scenarios according to the recent studies by [4,5,37]. The authors identify the retrofitting as a highly complex and socio-technical

[‡‡‡] http://task23.iea-shc.org/integrated-design-process

system and subsequently investigate and address the concept of Holism (including cultural and technological changes) in this field. Ultimately, the study is wrapped up by producing a multi-methodology based on a mix of SSM and Multiple Criteria Decision Making – MCDM [38] methods, which includes 23 steps/actions. The part of HMSR also proposes application of a Decision Support Systems – DSS [6,39] for generation of the renovation scenarios concerning "hard" criteria towards addressing "soft" criteria in the next steps. As such, HMSR can serve as a mean to structure retrofitting problems in accordance with the sustainability in its totality, support the decision-making, and help to develop and select the most appropriate retrofitting alternatives. It has been structured in three levels (see Figure 1) and the decision-making on third level is considered as the integrated design process implementation and evaluation for sustainable renovation and entitled scientific decision-making.

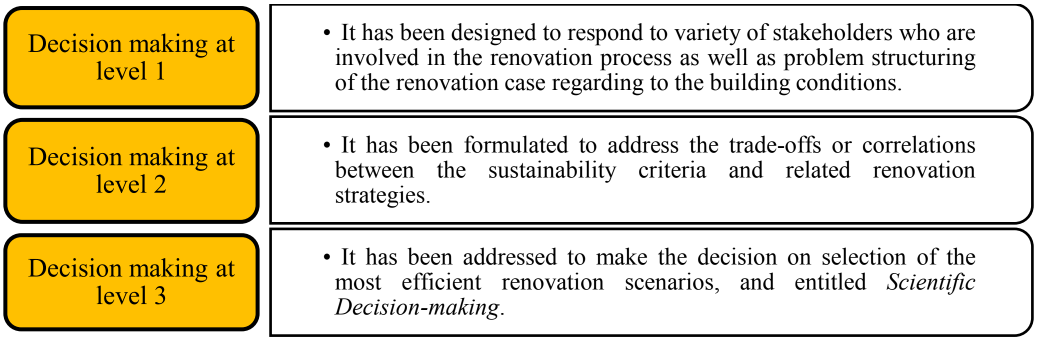

Figure 1. Three levels of decision-making for building renovation (adapted from [37])

It may be difficult to recognize the correlation between *sustainability* and *tectonics* in building renovation. For more clarification on synthesizing the concept of *sustainability* with *tectonics,* the research "Towards a Tectonic Sustainable Architecture" by Danielsen et al [40] which explores "Can tectonic thinking form a basis for new strategies for contemporary sustainable building practices?", is propounded and unfolded. Danielsen et al [40] considered in what manner the paradigm of *sustainability* influences the realm of the *tectonics*. They started to unpack architecture using an ancient theory by Marcus Vitruvius Pollio (in the first century AD) including firmitas (durability), utilitas (utility), and venustas (delight). In this framework, the authors defined two principles of *tectonics* with reference to Semper [41] as a result of conscious artistic work, and the material properties and the design of constructions, whereas the functional dimensions of architecture are paid less attention (according to [19]). However, they stated that Semper's downsizing of functional aspects is important to be aware of when approaching the research-question stated above, which concerns how *tectonics* may affect sustainable solutions (also being functional). Consequently, *tectonics* thinking was defined as "a central attention towards the nature of the making, and the application of building materials (construction) and how this attention forms a creative force in building constructions, structural features and architectural design (construing) – can be used to identify and refine strategies for improving a contemporary sustainable building industry" [40]. This demonstrates the value of using *tectonics* for articulation of architectural principles to perform a building renovation alongside with sustainability objectives/criteria. In our understanding, however, the authors' view about *sustainability* in the research by Danielsen et al [40] is not comprehensive enough. For TSBD framework presented in this paper (see Figure 2), as stated earlier, *sustainability* is referred to the studies by Kamari et al [32], Butters [12], International Living Future Institute [42], or SPeAR by Arup Group Limited Arup [43] including more holistic objectives/criteria. That makes the *sustainability* in TSBD framework as the most desired and ultimate value, for issuing out the objectives/criteria in the design process towards application of certain renovation approaches to achieve them. Subsequently *tectonics* theory principles tailors them into each other. The result enhances both "hard" and "soft" objectives/criteria of renovation in parallel. Finally yet importantly, it is use of an efficient design methodology (here refers to use of HMSR) that eventually makes it all possible.

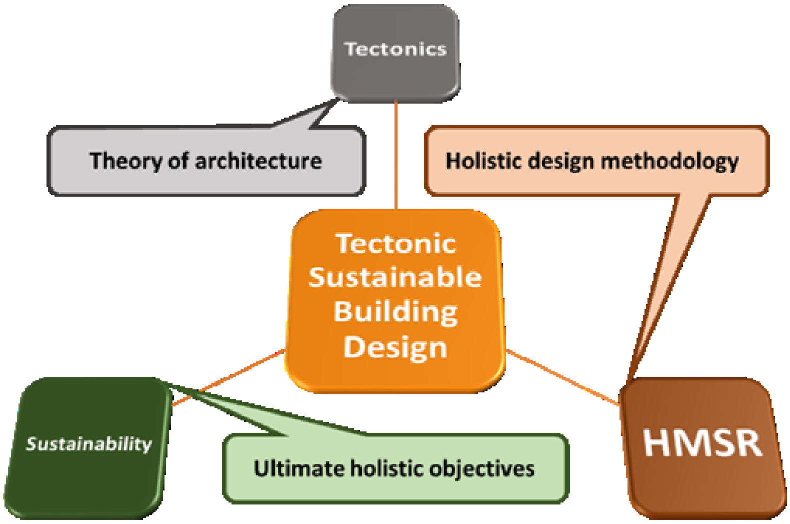

Figure 2. Tectonic Sustainable Building Design conceptual framework for building renovation

5. Conclusion and Further studies

5.1. Conclusion

This paper set out the findings regarding to the evaluation of 10 European renovation research projects into development of a conceptual framework under the topic of TSBD - Tectonic Sustainable Building Design. TSBD seeks for interaction between architecture, sustainability objectives and an equipped design process. It is therefore attached to the *tectonics* (refers to architectural articulation theory), the *sustainability* (refers to the holistic objectives), and a holistic multi-methodology - HMSR (refers to the integrated design methodology). By focusing on TSBD thinking in the field of building renovation, one forms a strategy of establishing a link between the intentions embedded in the architectural transformation and the way these are perceived by the user/owner of the building, what refers as articulation of architecture theory using *tectonics* principles. It hence influences the experience of the built environment in human scale. Furthermore, it can serve as a means to unify the platform for renovation strategies for refining and improving the contemporary building sector seen in the light of sustainability, and supporting the decision-making ahead of developing renovation scenarios as holistically as possible. Above all, it provides a clear focus in the design process and a common language among the stakeholders who are involved in the process, which leads to improve the current practice of renovation.

5.2. Further studies

Rise of new paradigms such as *sustainability* and its development during the last two decades has led to increase the level complexity consisting of broad range of objectives/criteria and expectation in AEC sector. To cope with the increased level of complexity, new approaches to building design, and the methods and tools that support them must be preceded by new ways of imagining and thinking. The complexity of issues within the domain should be explored through broader perspectives and hence the traditional design approaches should be re-considered and equipped to become enable to deal with its level of complexity and multifaceted nature. The study in future concerns expanding of the TSBD framework for Building Design in general. That means move from building renovation to design of new buildings. For this reason application of digital tools through framework of BIM (Building Information Modelling) is proposed and structured as an integrated design methodology (following the concept: BIM is a Methodology neither tool nor method). It hence is replaced with the HMSR in this paper. In this regard, BIM's notion needs to be addressed as a methodology and then it should get processed and equipped by use of both Soft Systems Methodologies - SSM (where a design problem is able to be formulated) and Hard Systems Methodologies - HSM (use of decision support systems and simulation tools) through an effective design process (from conceptual design to detail design stages) for developing a holistic sustainable building design. Further research can also explore the notion of *tectonics* through *sustainability* and vice versa; as well as the effects of recent technologies and digital tools on *tectonics* expression (known as algorithmic *tectonics*).

Acknowledgements

The authors of the paper would like to show their gratitude to the Danish Innovation Foundation for financial support through the RE-VALUE research project.

References

[1] EC - European Commission. Energy-Efficiency Buildings, Energy Union and Climate; 2014, Retrieved from https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings/.

[2] Joint Research Centre [JRC] Institute for Energy and Transport Luxembourg. Energy Renovation: The Trump Card for the New Start for Europe; 2015, Retrieved from https://setis.ec.europa.eu/newsroom/news/energy-renovation-trump-cardnew-start-europe.

[3] BPIE - Buildings Performance Institute Europe. Europe's buildings under the microscope; 2011, Retrieved from http://bpie.eu/wp-content/uploads

[4] Kamari A, Jensen SR, Corrao R, Kirkegaard PH. A Holistic Multi-methodology for Sustainable Renovation. *International Journal of Strategic Property Management* 2017; Manuscript has been submitted for publication.

[5] Kamari A, Jensen SR, Corrao R, Kirkegaard PH. Towards a holistic methodology in sustainable retrofitting: Theory, Implementation and Applications. In: *WSBE 2017 (World Sustainable Built Environment) conference, Hong Kong, China* 2017, p. 702-708. Retrieved from http://www.wsbe17hongkong.hk/download/WSBE17%20Hong%20Kong%20-%20Conference%20Proceedings.pdf

[6] Kamari A, Corrao R, Kirkegaard PH. Towards the development of a Decision Support System (DSS) for building renovation: Dependency Structure Matrix (DSM) for sustainability renovation criteria and alternative renovation solutions. In: *SER4SE 2018 (seismic and Energy Renovation for Sustainable Cities) conference*. Catania, Italy; 2017. Manuscript has been submitted for publication.

[7] Acre F, Wyckmans A. Spatial quality determinants for building renovation: a methodological approach to the development of spatial quality assessment. *International Journal of Sustainable Built Environment* 2014; **5(3)**:183–204.

[8] Brundtland GH. *Report of the world commission on environment and development: Our common future. World Commission on Environment and Development*. Oxford, U.K.: Oxford University Press; 1987.

[9] Hvejsel MF, Kirkegaard PH, Bundgaard S. Towards a Tectonic Approach – energy renovation in a Danish context. *Nordic journal of Architectural Research* 2015; **27**:35-60.

[10] Moseley P. Practical Approaches to the Building Renovation Challenge. In: *European Commission EASME* 2016; p. 1-13. Retrieved from https://ec.europa.eu/easme/sites/easme-site/files/practical_approaches_to_the_buildings_renov_challenge.pdf

[11] *United Nation - UN. Sustainable Development Challenges.* New York: Department of Economic and Social Affairs (DESA); 2013. Retrieved from https://sustainabledevelopment.un.org/content/documents/2843WESS2013.pdf

[12] Butters C. Sustainability Value Map. In: *Building and urban development in Norway*; 2014, p. 34-39. Retrieved from http://www.universell-utforming.miljo.no/file_upload/idebank%20article%20chris%20butters.pdf

[13] Afgan NH, Carvalho MG. Multi-criteria assessment of new and renewable energy power plants. *Energy* 2002; **27**:739–755.

[14] Afgan NH. Sustainability paradigm: intelligent energy system. *Sustainability* 2010; **2**:3812–3830.

[15] Haapio A, Viitaniemi P. A critical review of building environmental assessment tools. *Environmental Impact Assessment Review* 2008; **28**(7):469–482.

[16] Jensen PA, Maslesa E. Value based building renovation – A tool for decision making and evaluation. *Building and Environment* 2015; **92**:1-9.

[17] Frampton K. *Studies in tectonic culture: The poetics of construction in nineteenth and twentieth century architecture*. Cambridge, Mass.: MIT Press; 1995.

[18] Sekler EF. Structure, construction, tectonics. *Aufbau* 1964; 89-95.

[19] Beim A. *Tectonic Visions in Architecture*. Copenhagen: Kunstakademiets Arkitektskoles Forlag; 2004.

[20] Nilsson F. New Technology, New Tectonics? - On Architectural and Structural Expressions with Digital Tools. In: *Tectonics - Making Meaning* conference 2007. Retrieved from https://publications.lib.chalmers.se/records/fulltext/165235/local_165235.pdf

[21] Semper G. *Style in the technical and tectonic arts, or practical aesthetics*. Los Angeles: Getty Publications; 2004 [1861].

[22] Christiansen K. *Tectonics: the meaning of form*. Aarhus: Systime; 2015.

[23] Checkland P. Soft systems methodology: a thirty year retrospective. *Systems Research and Behavioral Science* 2000; **17**:11–58.

[24] Cross N. Designerly Ways of Knowing: Design Discipline Versus Design Science. *Design Issues* 2001; **17(3)**:49-55.

[25] Cross N. *Designerly ways of knowing*. London: Springer-Verlag; 2006.

[26] Simon HA. *The Sciences of the Artificial*. Cambridge: MIT Press; 1969.

[27] Schön D. Designing: Rules, types and words. *Design Studies* 1988; **9(3)**:181–190.

[28] Schön D, Wiggins G. Kinds of Seeing and their Functions in Designing. *Design Studies* 1992; **13(2)**:135-156.

[29] Dorst K. Describing Design: a comparison of paradigms. PhD. Faculty of Industrial Design Engineering, Delft University of Technology, The Netherlands; 1997.

[30] Mingers J, Brocklesby J. Multimethodology: Towards a Framework for Mixing Methodologies. *Omega, International Journal of Management Sciences* 1997; **25(5)**:489-509.

[31] Mingers J. *Systems Thinking, Critical Realism and Philosophy: A Confluence of Ideas*. London: Taylor and Francis; 2014.

[32] Kamari A, Corrao R, Kirkegaard PH. Sustainability focused Decision-making in Building Renovation. *International Journal of Sustainable Built Environment* 2017; Manuscript has been accepted ahead of publication. doi:10.1016/j.ijsbe.2017.05.001

[33] Jensen SR, Kamari A, Strange A, Kirkegaard PH. Towards a holistic methodology in sustainable retrofitting: Theory, Implementation and Applications. In: *WSBE 2017 (World Sustainable Built Environment) conference*. Hong Kong, China; 2017, p. 702-708. Retrieved from http://www.wsbe17hongkong.hk/download/WSBE17%20Hong%20Kong%20-%20Conference%20Proceedings.pdf

[34] Keeney RL. *Value-Focused Thinking*. Cambridge: Harvard University Press; 1992.

[35] Jensen SR, Hvejsel MF, Kirkegaard PH, Anders S. Renovation of social housing – a tectonic dialogue between past and present? In: *NAF 2017 Symposium: Reflecting Histories and Directing Futures*. Oslo, Norway; 2017. Manuscript has been accepted ahead of publication.

[36] Frascari M. Tell the tale detail. *Via* 1984; **7**:22–37.

[37] Kamari A, Corrao R, Petersen S, Kirkegaard PH. Sustainable Renovation Framework: Introducing three levels of Integrated Design Process Implementation and Evaluation. In: *PLEA 2017 conference*. Edinburgh, UK; 2017, p. 781-788. Retrieved from http://nceub.org.uk/PLEA2017/proceedings/PLEA2017_proceedings_volume_I.pdf

[38] Triantaphyllou E, Shu B, Nieto SS, Ray T. Multi-Criteria Decision Making: An Operations Research Approach. *Encyclopedia of Electrical and Electronics Engineering* 1998; **15**:175-186.

[39] Nielsen AN, Jensen RL, Larsen TS, Nissen SB. Early stage decision support for sustainable building renovation: A review. *Building and Environment* 2016; **103**:165–181.

[40] Danielsen C, Beim A, Christiansen K, Bundgaard C, Jensen TB, Madsen US. *Tectonic Thinking in Architecture*; 2012, KADK School of Design, Retrieved from https://issuu.com/cinark

[41] Semper G. *Die Vier Elemente der Baukunst. Ein Beitrag zur Vergleichenden Baukunde*. Braunsweig; Friedrich Vieweg und Son; 1851.

[42] International Living Future Institute. Living Building Challenges; 2014, Retrieved from https://living-future.org/wpcontent/uploads/2016/12/Living-Building-Challenge-3.0-Standard.pdf

[43] Arup Group Limited - ARUP. SPeAR – Handbook; 2012. Retrieved from https://www.oasys-software.com/media/Manuals/Latest_Manuals/SPeAR_Manual.pdf

Appendix 1 – Further information about analysed renovation research projects

Project name	Year	Countries involve	Total cost	EU program
iNSPiRe Development of Systemic Packages for Deep Energy Renovation of Residential and Tertiary Buildings including Envelope and Systems	2012 - 2016	Spain, Germany, Sweden, Austria, Italy, France, United Kingdom, Belgium	EUR 10 841 678,29	FP7
http://cordis.europa.eu/project/rcn/104743_en.html http://inspirefp7.eu/				Links to Project
EcoShopping Energy efficient & Cost competitive retrofitting solutions for Shopping buildings	2013 - 2017	Germany, Spain, Austria, Portugal, Croatia, Poland, Italy, Spain, United Kingdom, Turkey, Taiwan, Hungary	EUR 5 929 338,01	FP7
http://cordis.europa.eu/project/rcn/109127_en.html http://ecoshopping-project.eu/index.html				Links to Project
HERB Holistic Energy-efficient Retrofitting of residential Buildings	2012 - 2016	Greece, United Kingdom, Italy, Portugal, Germany, Switzerland, Spain, Turkey, Poland, Netherlands	EUR 8 606 892,87	FP7
http://cordis.europa.eu/project/rcn/105487_en.html http://www.euroretrofit.com/				Links to Project
REFURB REgional process innovations FOR Building renovation packages opening markets to zero energy renovations	2015 - 2018	Belgium, Netherlands, Denmark, Slovenia, Estonia, Germany	EUR 2 074 875	FP7
http://cordis.europa.eu/project/rcn/194628_en.html http://go-refurb.eu/about-refurb/				Links to Project
READY Resource Efficient cities implementing ADvanced smart citY solutions	2014 - 2019	Denmark, Sweden, Lithuania, Austria, France	EUR 33 340 202,60	FP7
http://cordis.europa.eu/project/rcn/197826_en.html http://www.smartcity-ready.eu/				Links to Project
3ENCULT Efficient ENergy for EU Cultural Heritage	2010 - 2014	Denmark, Germany, Austria, UK, Spain, Italy, France, Netherlands, Czech Republic, Belgium	EUR 6 704 955,74	FP7
http://cordis.europa.eu/project/rcn/97086_en.html http://www.3encult.eu/en/project/welcome/default.html				Links to Project
MORE-CONNECT Development and advanced prefabrication of innovative, multifunctional building envelope elements for MOdular REtrofitting and CONNECTions	2014 - 2018	Netherlands, Latvia, Estonia, Portugal, Denmark, Czech Republic, Switzerland	EUR 5 557 263	H2020
http://cordis.europa.eu/project/rcn/193236_en.html http://www.more-connect.eu/links/				Links to Project
BuildHeat Standardized approaches and products for the systemic retrofit of residential Buildings, focusing on HEATing and cooling consumptions attenuation.	2015 - 2019	Italy, Belgium, Germany, Austria, Spain, United Kingdom	EUR 9 136 072,50	H2020
http://cordis.europa.eu/project/rcn/198377_en.html http://www.buildheat.eu/				Links to Project
NeZeR Promotion of smart and integrated NZEB renovation measures in the European renovation market.	2014 - 2017	Finland, Netherlands, Sweden, Romania, Spain	Co-funded	H2020
https://ec.europa.eu/energy/intelligent/projects/en/projects/nezer#partners http://www.nezer-project.eu/2.1f96676d145d7c93741c57.html#.WLVrXDsrJPY				Links to Project
RePublic_ZEB Refurbishment of the Public building stock towards nZEB	2014 - 2016	Greece, Romania, United Kingdom, Croatia, Hungary, Slovenia, Portugal, Italy, Bulgaria, Spain, Macedonia	Co-funded	H2020
https://ec.europa.eu/energy/intelligent/projects/en/projects/republiczeb http://www.republiczeb.org/index.jsp				Links to Project

SER4SC

9 788896 386569

~~euro 10,00~~ copia omaggio