MedZEB: a new holistic approach for the deep energy retrofitting of residential buildings

padula@itc.cnr.it
picenni@itc.cnr.it
r.malvezzi@certimac.it
l.laghi@certimac.it
jms@us.es
francisco.flor@uca.es
cmateo@five.es
lsoto@five.es
masim@phys.uoa.gr
karlessith@phys.uoa.gr

Marco Padula, Francesca Picenni, National Research Council of Italy, Institute for Construction Technologies
Roberto Malvezzi, Luca Laghi, CertiMaC
José Manuel Salmeròn Lissén, Francisco José Sanchez de la Flor, Universidad de Sevilla, Spain
Carolina Mateo-Cecilia, Laura Soto-Francés, Intituto Valenciano de la Edificaciòn
Maragarita-Niki Assimakopoulos, Theoni Karlessi, National and Kapodistrian University of Athens

Abstract. The MedZEB (Mediterranean Zero Energy Building) approach aims at stimulating the market uptake of energy deep and beyond retrofitting of existing buildings of the Mediterranean. Its holistic nature implies the evaluation and integration of a range of relevant factors and the effective support to the retrofitting supply chain, also with the help of an ICT platform. Main concern of the approach are residential buildings within a framework dealing with High TRL levels and with already on the market technologies to be combined to create Med-specific cost-optimal Packages of technical Solutions, linked to a Voluntary Certification Scheme. The triggered creation of trust and information exchange will pave the way to new investments and strengthen the Med deep and beyond retrofitting network.

Keywords: MedZEB, Energy retrofitting, Holistic approach, Cost-optimal solutions, ICT platform

Introduction

The research & experimentation project described here tackles the reduction of EU building stock energy consumption by introducing a new holistic approach: The MedZEB (Mediterranean Zero Energy Building)[1]. It aims at stimulating the market uptake of energy deep-and-beyond retrofitting of existing buildings of the Mediterranean areas which, with respect to other EU countries, are characterized by many peculiarities: coupling of heating and cooling challenges (BPIE, 2011), prevalence of private ownership, unbalanced income ratio between elder and younger social groups (within the €-area, this holds for Greece, Italy, Spain and France)[2], prevalence of old and modern (up to 1990) buildings (86%). While EU is still facing a low renovation rate (just around 1%) Med countries, on their turn, show a significant gap in the policy evolution of energy savings target at 2020 (almost 5.7%), rising up to 9.6% with reference to the residential stock (E. Tritopoulou, C. Nychtis, ELIH-MED. Med countries face also a delay in the nZEB performance definition (BPIE, 2015), in the introduction of smart solutions for the urban development, as confirmed by the smart cities EU ranking[3], and in the private investments in smart grids (JRC, 2017). Figg. 1-3 show a synthetic review of EU strategies concerning Energy Efficiency of Buildings (EEB); the weaknesses detected correspond to some of the main key issues identified by this project for unlocking the deep-and-beyond retrofitting market.

MedZEB approach definition

The project individuates the Med space as a "catchment area" where common transnational measures can be activated to enable the achievement of general objectives s. a.:

- **reconnecting** the fragmented value chain in the retrofitting market;
- **rebuilding** a framework of trust around the deep and beyond retrofitting market;
- **increasing** the overall convenience and appeal of the retrofitting interventions.

Core of the project is the development of a holistic, transparent and adaptive approach (MedZEB) focused on the residential built stock (private and public) and aimed at providing a generally valid cost-optimal renovation strategy for individual buildings. Main features of the "MedZEB approach" are:

1. **Holistic**. It will encompass and integrate all the most relevant elements of the retrofitting supply chain:

- **Technological aspects**: optimization of available technologies (from TRL 9 to already-in-the-market solutions), to compose cost-optimal packages of solutions according to a "one-stop shop" logic; the set will include passive or natural solutions for energy efficiency, ICT solutions for consumers' awareness energy saving, and smart solutions both at the building (smart monitoring) and at the district (smart grids) scale.
- **Financial aspects**: testing of available innovative financial solutions essential for unlocking the deep retrofitting market uptake. Several solutions (i.e. guarantee and solidarity funds, credit transfer mechanisms, etc.) and models (i.e. ERDF funds, ESCO, mixed models, etc.) will converge into a single tool for identifying proper financing paths. Initiatives s. a. the EU Project "Energy Efficient Mortgages Action Plan" (EeMAP) will be taken into account. Improvements of the current regulatory frameworks will also be proposed.
- **Engagement and training actions**: knowledge transfer and behavioural upgrade for final users (owners and inhabitants), direct training activities for building professionals, entrepreneurs, workers and policy makers.

2. **Transparent**. It will be characterized by three main elements:

- **MedZEB protocol**: guarantee scheme for the good execution of the retrofitting process along the whole value chain; all subjects involved are enabled to cooperate according to shared quality principles and procedures.
- **MedZEB Voluntary Certification Scheme (VCS):** integration of existing EPC schemes referred to relative savings classes, and based on staged renovation pathways. The VCS's scope is to testify the compliance of the interventions with the MedZEB

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protocol and to introduce further quality indicators to create added value for the investments.

- **ICT open platform**. Assisted digital marketplace for matching demand and offer within the Med energy retrofitting market and along the whole value chain, for re-creating and enhancing trust among owners and investors, and for increasing the overall attractiveness of such market.

3. **Adaptive**. Buildings are elements of a wider context with which they interact at many levels, which will be addressed by focusing on:

- **persons: care for well-being**. Increased well-being of closed spaces is an added value for convincing people to undertake renovation interventions, as discomfort is often associated to multiple pathologies (e.g. Sick Building Syndrome, breathing disease, allergies). A modification of the current metabolic standards will be proposed as well, by taking into account the actual values of metabolic rate for females (B. R. M. Kingma, 2015). A MedZEB multi-layer ICT smart control system will be defined (e.g. based on inner and outer temperature, natural lighting and shading, humidity, presence of people, etc.), for the (self)monitoring of consumptions and behavioural enhancement.
- **Resources: step-by-step renovation approach**. Such an approach, already tested in other EU projects[5] and proposed by technical references (BPIE, 2016b), divides the deep renovation process into self-standing interventions on basis of minimum savings and Return on Investment (Fig. 4). In this way, the overall investment can be split along a wider time span with multiple advantages: i) reduced financial intensity; ii) higher grip on savings monitoring; iii) reduction of the perceived risk; iv) mitigation of shortcomings. This approach is mostly suitable in the absence of incentives for deep renovation, but it could effectively target all situations where no one-step intervention is possible. To this extent, every building can be associated to a Renovation Individual Roadmap (RIR, based on the BPIE "building passport"), which will include the cost/benefit analysis of all the renovation steps. Financial and regulatory proposals proposals will be studied in order to support investors to proceed after the first step, by mitigating the "decreasing return law" for reaching the highest standards.
- **Situations: alternative investment options**. Not all buildings, especially in the Med area, have the potential to reach high energy standard; in these cases, MedZEB proposes an alternative investment based on the use of RES. This RESALT concept could be pursued e.g. for fulfilling the last step (= towards nZEB) of a renovation pathway, whenever this is not economically feasible. Alternative investments can be aggregated in joint initiatives at the urban district, thus stimulating the rise

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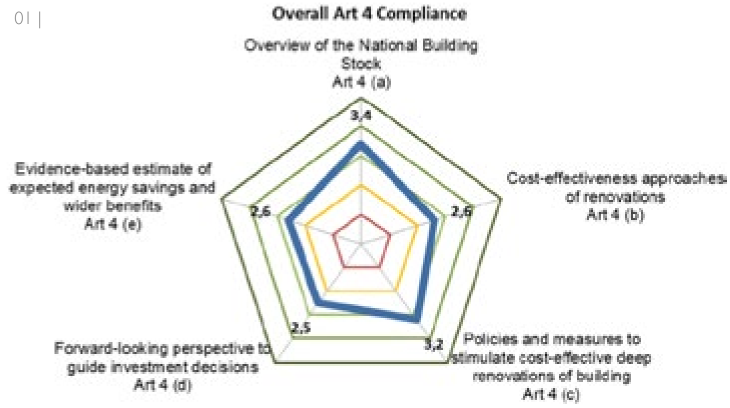
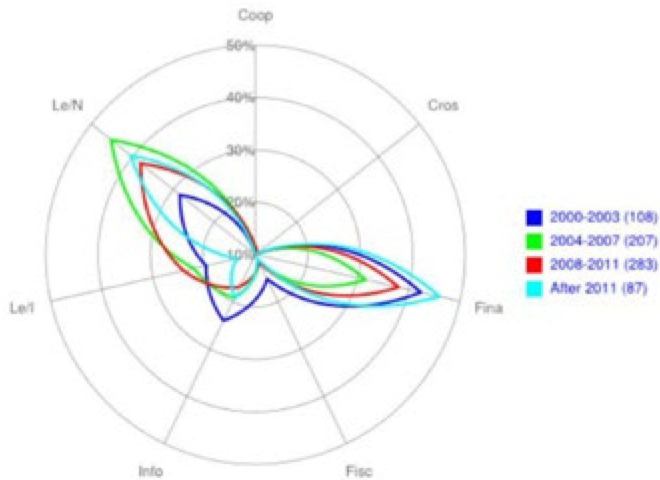


01 | Overall compliance of all EU Member States with the EPBD recast (Energy Performance of Building Directive) Art. 4 (BPIE, 2016)

02 |



02 | Changes in policy mix in terms of number of measures introduced by type and by period of time[4] (Odyssee-Mure, 2015)

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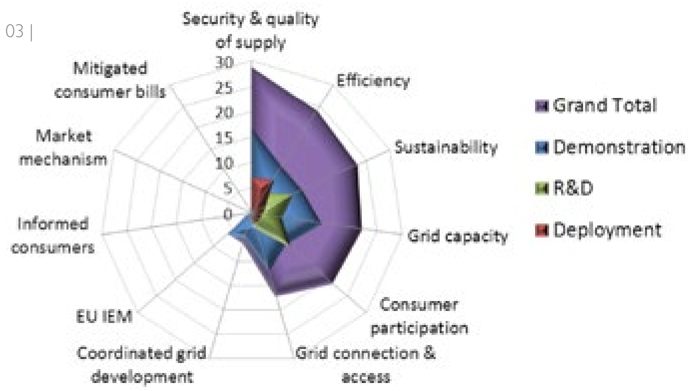

03 | Cumulative benefits effects of smart grids projects across EU (JRC, 2011)

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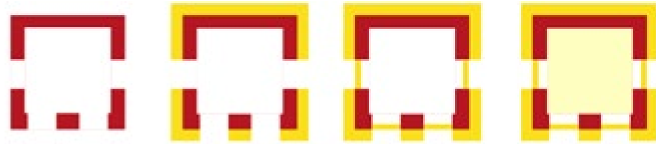

04 | Step-by-step retrofitting concept (EUROPHIT, 2015)

of energy aware communities, such as Local Energy Cooperatives (LECs). RESALT concept complies with the most recent trends on RES integration in the nZEB standard (JRC, 2016).

- **Contexts: smart integration**. The integration of systems across sectors is achieved by assuming a smart grids approach aimed at producing significant energy savings when combined with building management systems. At the building level, a smart monitoring system can cut the annual household consumptions up to 10% in Europe (OECD, 2017). The achievement of ZEB standards requires the integration in the grid of bioclimatic design, EE technologies and RES, as well as the consideration of the following aspects:
  - installation of smart metering;
  - demand response and users' engagement;
  - technical distribution infrastructure;
  - interoperability criteria (D. Kolokotsa, 2016).

  To this extent, MedZEB will draw from the SMART GEMS project, where a large number of case studies (at the building and district level) have been assessed in order to analyse the following aspects of smart grids: improvement of reliability, mitigation of security risks, increase of EE and integration of smart monitoring and control. The iterative approach was based on a three-phase cycle expansion:
  - the users/consumers aspects, mainly focused on smart and zero energy buildings analysis;
  - the smart grids penetration at district and city level;
  - optimization of smart grids operation, enhancement of skills and collaboration (Karlessi et al., 2017).
- **Environments: district scale design**. According to the MedZEB approach, the energy saving starts from the very outside of the building. Indeed, Med cities are well known hot spots: urban heat island effect raises the temperature of big cities by 1 to 3°C. There is an increasing convention that the absence of vegetation and natural shadings, presence of asphalt, concrete, buildings, and other surfaces disrupting the natural cooling effect are the most relevant heat island effect factors in Med climates (Gomez, Salvador & Dominguez, 1998). Basing on this, the MedZEB approach will take into account the following design aspects (also by drawing from the RepublicMed project):
  - **Micro-climatic analysis**: mapping of existing Land Use on GIS platform, and a climatic sub-regioning to identify building energy requirements;
  - **Shading by greening**: reducing the summer exposition through a careful design of the green. Vegetation has a cooling effect of between 1-4,7 C° in 100-1000m (Schmidt, 2006; Norton et al., 2013) and trees shadow on façades and roofs reduces the demand for refrigeration. This means up to 25% of the building energy saving (Nichols Consulting Engineers, 2012) and the improvement of human health and perception of health (EPAOAP, 2008).
  - **Reducing heat islands** by choosing the right pavement. Although there is no consensus definition, cold pavements are those that have less surface temperature and accumulate less heat than traditional pavements through different properties, mainly related to a high albedo and high emissivity (EPAOAP, 2008). Among these, vegetated or non-vegetated pavements allow for a higher permeability of soils.
  - **Natural ventilation at district level**. Urban geometry affects directly urban heat island effect. The most well-known effect is the urban street canyon effect, occurring if a relation H/W>1 exists; it is classified according to the usual relations of H/W and Sky View Factor (SVF) (Ali-Toudert & Mayuer, 2006). The ideal situation for main streets would be east-west orientation, and small connections with north-south orientation, blocking solar radiation with appropriate vegetation (Brophy, et al., 2000). In hot areas such as Med, an H/W ratio>0.5 is recommended to reduce the solar incidence during the day (Shishegar, 2013). A proper design of the outer space can also increase natural air movements, due to the formation of delta pressures between different parts of a neighbourhood.

Tailored	Transparent	Holistic	Adaptive
MedZEB approach	HAPPEN Platform	Engagement &Training	to persons: focus on well-being
		Financing & Regulation	to resources: step-by-step approach
	MedZEB protocol		to situations: alternative investments
		Optimal solutions	to contexts: smartness
			to environments: district scale design

Tab. 1 | MedZEB Approach main features

Tab. 1

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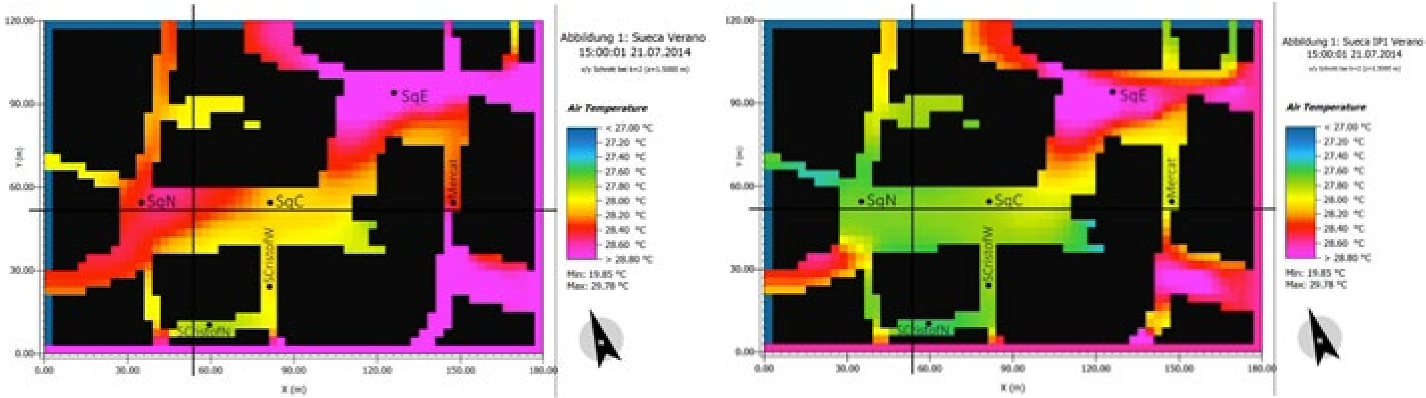

05 | Current Summer State of a real Urban Space (Sueca, Spain) and design scenario, where trees are to be used in the principal square to provide shading and evapotranspiration (Source: Republic Med project)

Research structure

The project goes through a "one-time-last-time" process for producing the most suitable solutions for unlocking the retrofitting market in the Med space. This process encompasses two main parts (Fig. 5):

- **Background Work** (research part): it is aimed at producing a flexible set of integrated solutions tailored for the Med residential built stock; in particular, the work will consist of: 1) an accurate review of the most relevant and up-to-date solutions and 2) an extensive optimization action aimed at producing a flexible set of integrated technical solutions for the Med residential built stock and at defining financial and regulatory aspects tailored for the Med market;
- **Pilots Testbed** (experimental part): the solutions will be tested on real Med pilot case studies, which will also support the incubation of wider partnerships and the increase of exploitation opportunities. Figure 6 reports the expected impacts of MedZEB pilots in the short (2020) and long (2030) term. Living Labs (LL) will be activated in the pilot to support the innovation process, thus de-fragmenting the supply and value chain at local level and supporting the knowledge raising of inhabitants and workers. LL will engage four main target stakeholders (companies, users, public organisations and researchers) in real-world context activities which, according to the 5 Living Lab components (Ståhlbröst and Holst, 2012) will be facilitated by ICT embedded in the HAPPEN platform. ICT will offer new ways of cooperating and co-creating in each Living Lab, as well as across all the activated ones, thus giving access to a multi-contextual environment. A holistic monitoring of the pilots at the home (self-monitoring of the inhabitants), building (aggregated monitoring) and district (smart grids) level will be carried out.

Optimum analysis methodology

Taking into consideration both the cost optimal Life Cycle Cost (LCC) and the holistic impact, the MedZEB holistic approach will identify, for each reference building and in each representative climate in MED countries, an integrated set of renovation measures considering the country specific peculiarities, combined actions on the building envelope, technological systems (including passive solutions), RES integration and measures applied at district level. In order to define such Packages of Solutions (PoS) an optimization methodology, i.e. SEDICAE (Aparicio Ruiz et al., 2014), allows the exact solution to be reached in a very low CPU time. The optimization procedure aims at obtaining the minimum global cost in the life cycle of the building but also the best, i.e. the cheapest, combinations (Pareto Front) for their final energy consumption.

To obtain the optimum solution, the proposed methodology is based on different steps. Conditioning demands, energy consumption and global cost of the initial case are assessed by a detailed software tool and then by a simplified one. A first adjustment of the simplified method is defined. The adjusted simplified method is both fast and accurate and is used for building the Pareto Front (Fig. 7) to determine the best combination of life cycle cost versus energy consumption. In order to identify the Pareto Front, 6 different cases are evaluated, i.e. initial case {1}, minimum global cost case {4} and minimum energy consumption with the initial global cost {6}. The proposed method allows the optimum solution to be found with only 7 detailed simulations: the 6 Pareto Front characteristic cases and the new optimum. Its accuracy is guaranteed by the adjustment and re-adjustment steps of the procedure. By applying this procedure to Spanish reference buildings located in different climate zones (A3-Cadiz to E1 Burgos), it was possible to demonstrate that a 60% energy saving (i.e. deep renovation) may be achieved on primary energy consumption.

06 |

HAPPEN POTENTIAL IMPACT EVALUATION																				
		LEVEL 1. Direct pilot impacts (within the duration of the project - 2020)											LEVEL 2. Expected pilot impacts (2030)							
		FRONTRUNNER PILOTS (FP)			THEMATIC/PERSPECTIVE PILOTS (T/PP)						TOTAL level 1		REPLICATION POTENTIAL (RP)						TOTAL level 2	
	A	B	C	D	E	F	G	H	I	L			M	N	O	P	Q	R		
	Country	ES	FR	IT	SI	HR	HR	GR	GR	CY			ES	FR	IT	SI	HR	HR		
	Partner	EIG	EPA	H&D	ZRM	IRE	IRE	UoA	AEG	CEA			EIG	EPA	H&D	ZRM	IRE	IRE		
raw	Frontrunner pilots + Support pilots	Castellon de la Plana	Mars.	Milan	Brezno	Buzet	Rasa	Athens	Lesvos Paros	Strovo-los			Castellon de la Plana	Mars.	Milan	Slovenia (*)	IRENA (**)	Labin stan LoS (***)		
1	*PPI-A:* Building area involved [m^2]	3 698	2 100	4 000	350	1900	829	830	1175	5007	19 889	m^2	239 446	32 040	115 500	1 000 000	221 111	29 876	1 637 973	m^2
2	*PPI-B:* N° of buildings involved	1	6	2	1	1	1	1	6	2	21	buildings	73	89	75	1 500	96	70	1 903	buildings
3	N° of dwellings	36	34	40	6	-	-	-	-	3	119	dwellings	2 338	535	1 650	17 500	-	529	22 552	dwellings
4	Average area per dwelling [m^2]	103	60	100	58.3	-	-	-	-	-			102	60	70	57	-	56		
5	Energy Performance (EPC scheme) [kWh/m^2year]	179	198	220	182	84	237	108	150	384			179	204	230	330	156	85		
6	Estimated energy consumption [MWh/year]	662	417	880	63.7	159.41	196.14	89.64	176.25	1921.9			42 861	6 536	26 565	330 000	34 463	2 539		
7	Energy consumption reduction - MedZEB [%]	60	70	60	60	60	60	60	60	60			60	60	60	60	60	60		
8	***PPI-E: Energy Savings triggered [MWh]***	***397***	***292***	***528***	***38.22***	***95.646***	***117.68***	***53.784***	***105.75***	***1153.1***	*2.78*	*GWh*	***25 716***	***3 922***	***15 939***	***198 000***	***20 678***	***1 523***	*265.78*	*GWh*
9	***PPI-F: RES triggered [MWh]***	***132***	***62***	***176***	***12.74***	***31.882***	***39.228***	***17.928***	***35.25***	***384.37***	*0.89*	*GWh*	***8 572***	***1 307***	***5 313***	***66 000***	***6 893***	***508***	*88.59*	*GWh*
10	*PPI-H:* Greenhouses Gas Reduction [$tonCO_2$]	134	98	178	12.9	32.3	39.7	18.2	35.7	389.4	939	$tonCO_2$	8684	1324	5382	66858	6982	514	89 744.49	$tonCO_2$
11	*PPI-D:* Cumulative Investments by EU stakeholders [M€]	2.22	0.34	2.00	0.10	1.24	0.05	0.10	0.10	0.23	6.38	M€	11.10	5.00	38.50	300.00	44.22	5.13	403.95	M€

06 | MedZEB pilots' impacts

ICT Platform The development of the HAPPEN platform, a critical factor of this research, will go through four phases, with the aim of delivering a highly usable and target-oriented digital marketplace:

- **scouting/analysis/exploitation**: capitalisation of existing open solutions, with particular attention to those developed by EU funded projects, which will undergo a multi-viewpoint selection process made by energy efficiency, finance, economics, ICT and market experts to identify matches with target users expected needs. As a result, an entry-level platform providing basic functionalities will be delivered as a basis for the co-design activities.
- **Customisation through the Living Labs**: participants give feedback on the general user experience, new functionality desired and other requirements of the entry-level prototype.
- **Co-design sessions**: transnational representatives of the entities taking part in the research and those leading the Living Labs will meet each six months to discuss the implementation of the gathered feedbacks, review and fine-tune the platform's contents and features.
- **Beta-testing with final users**: competent subjects will carry out a beta-testing phase interacting directly with the platform management team through a specific area of the platform itself.

This structured process will bring to the definition of three different usage environments mirroring the research holistic features:

- **How does it HAPPEN?** educational tools and training materials on the deep retrofitting and the MedZEB approach to let non energy-expert users build a preliminary knowledge.
- **What HAPPENs?** cost optimal packages of solutions identified through the research in object will be uploaded to be interactively accessed.
- **Make it HAPPEN!** innovative financial solutions, incentive systems and business model descriptions tested in the Mediterranean space mapped on a Geographical Information System (GIS).

A user configuration tool will guide users through these environments, helping them in the choice of the most suitable technical and financial energy efficient solutions and paving the way for direct contacts with local operators. This platform will incorporate, process and render in a more interactive, usable and inclusive way the results and outputs of the research. Therefore, it will be brought to the market to support matchmaking and decision making processes of both inexperienced and specialists in the deep and beyond retrofitting market of the Med area, thus becoming the EU reference portal for Med Energy deep retrofitting.

Conclusions In this paper, the essential concepts and methodologies for the construction of a holistic MedZEB approach in EEB have been illustrated. Such endeavour will be carried out in the next three years; its final aim is to activate a Med-scale retrofitting market, based on the awareness that common issues can be addressed

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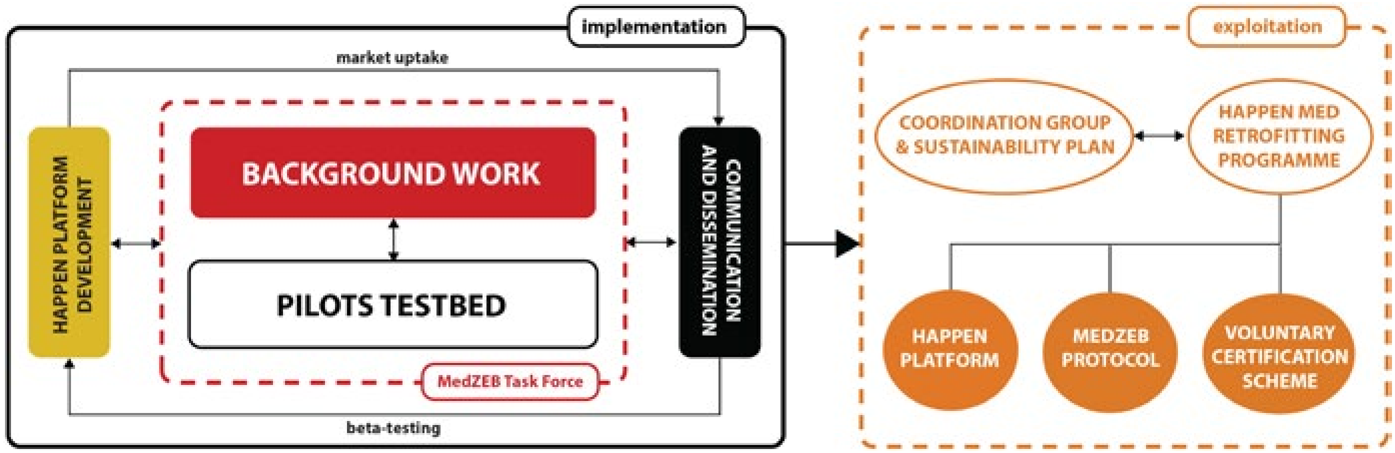

07 | Project Rationale

properly only by assuming shared approaches and solutions.
Collaboration and trust become the leading key-words of the MedZEB path by putting men and their living sphere at the core of the renovation market. In this sense, communities, more than consuming individuals, value-chains, more than isolated operators, and neighbourhoods, more than single buildings, are regarded as the proper realms for unlocking the uptake of best practices and high impacts. A pilot testbed will be developed across the Med countries, supported by the HAPPEN platform; acting as a backbone of the project, providing a proper experimentation field for the research outputs and for the construction of MedZEB-inspired networks. On this basis, it will be possible to scale-up the MedZEB approach into a real Med-scale retrofitting programme, where all the results and achievements obtained will nurture the roll out of further opportunities, according to the project motto: "this is the way to make it HAPPEN!"

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NOTES

[1] Approach to be developed by the project N. 785072 HAPPEN - Holistic APproach and Platform for the deep renovation of the med residential built ENvironment, Horizon 2020, Call EE-11-2017, April 2018-March 2021; Lead Partner: ITC-CNR.

[2] Eurostat: ilc_lvho02, 2014; ilc_li11, 2015.

[3] http://www.smart-cities.eu/ranking.html

[4] Legend: Coop=Cooperative measures; Cros=Cross-sectoral measures; Fina=Financial measures; Fisc=Fiscal measures; Inf=Information/education/training; Le/N=Legislative /Normative; Mark=New market-based instruments.

[5] See e.g. the results from EUROPHIT project (IEE).

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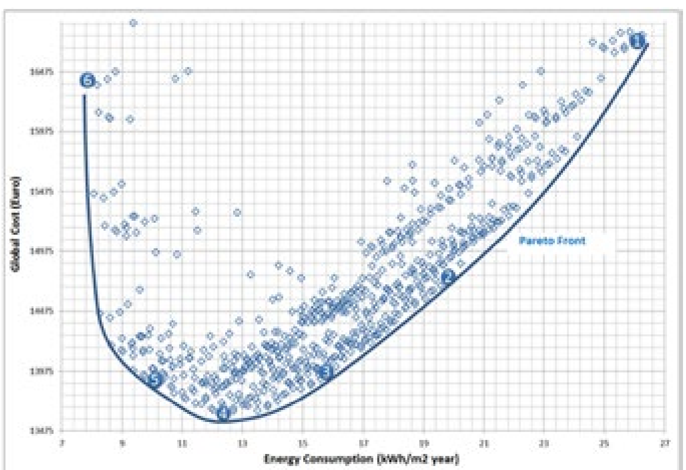

08 | Characteristics cases defining the Pareto Front (Global cost vs. Energy consumption)

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César Mifsut Garcia
Entitat Valenciana d'Habitage i Sòl (EVha)

EVha deals both public dwellings and lot development into Valencian Land territory, and currently covers the refurbishment of hundreds of social flats per year. EVha looks with special attention to the development of the MedZEB approach, as it pursues the awareness raising on energy efficiency criteria in a holistic development of refurbishment and building features, thus covering EVha's institutional interests: the definition of nZEB criteria addressing specifically the Med area, to be called for compliance treating to companies and professional formation on them, and the behavior re-education on those matters in collaboration with tenants and cultural and neighbourhood associations. EVha is also interested in assuming the research results, apply them within a first intervention and extend them to further locations. EVha believe that the greatest challenge in sharing these new MedZEB criteria is the exchange of knowledge among partners from the same geographic conditions in our Mediterranean area. To this extent, we think that the creation of the HAPPEN platform will be an indisputable added value of this experimentation.

Alexandre Sorrentino
Direction de la stratégie et de la prospective
Établissement Public d'Aménagement Euroméditerranée (EPAEM), Marseille

The target to be reached, also in the case of the energy renovation challenge of the Med built environment, must be that of establishing a contextual model that specifically takes into account climate, sociological, geo-graphic and social background of the population, as well as the characteristics of their houses. The way to achieve such recognition of a model or practices is to test together, to find answers to the price-quality-sustainability-comfort equation. This is exactly what MedZeb aims to do. As an urban planner, our practice is as much about new construction as renovation of old housing in Marseille, a 26-century-old city. Taking part in an experimental approach such as MedZEB should allow us to deal more effectively with the renovation of old buildings while preserving their architectural values. Working in this way will allow to engage the population not as a sum of consumers, but as a community, thus enabling the coupling of smart solutions with the enhancement of smart citizens, and activating district-scale effects. The diversity of partners of the MedZEB project is an asset for the success of this project with ambitions and common causes: find replicable solutions to the problems of energy renovation of old buildings in Mediterranean cities. It is a challenge and an imperative, at the same time, to ensure a transition towards a more sustainable urban living quality.

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