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Development of net zero energy settlements using advanced energy technologies

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Abstract

The research activities described in this paper focus on the development and implementation of a comprehensive and cost-effective system for Net Zero Energy (NZE) settlements. The system is composed of innovative solutions for the building envelope, for building energy generation, and for energy management at the settlement level. The developed solutions will be implemented in 4 different demonstration projects throughout the EU, with varying climates and building types. The results of their implementation will be monitored, analyzed. The target is to achieve a reduction of operational energy usage to 0-20 kWh/m2 per year through a transition from single NZE buildings to NZE settlements, in which the energy loads and resources are optimally managed. In addition, investment costs will be at least 16% lower than current nZEB costs. In this paper, the methodology that was developed in order to optimize the energy, environmental and cost plans of the four case studies through the best integration and combination of the selected innovative energy technologies with excellent architectural and engineering design is described. In addition the evaluation of the four NZE settlements in terms of energy, environmental and cost performance is presented.

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Keywords: "net zero energy communities; sustainable energy technologies; real life case studies; energy; environmental and cost performance"

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1. Introduction

Buildings and settlements are nowadays increasingly expected to meet higher and potentially more complex levels of performance. They should be sustainable, use zero-net energy, be healthy and comfortable, grid-friendly, yet economical to build and maintain. The European Union (EU) has adopted the new 2030 Framework for climate and energy [1] which goes beyond the 2020 targets and aims at:

- a 40% cut in greenhouse gas emissions compared to 1990 levels
- at least a 27% share of renewable energy consumption
- at least 27% energy savings compared with the business-as-usual scenario

Furthermore, the EU has even more ambitious targets for 2050, as defined the 2050 Roadmap, aiming at drastic reductions in domestic greenhouse gas (GHG) emissions of 80% by 2050 compared to 1990 levels [2] and climate change targets as defined by the EU strategy on adaptation to climate change which sets out a framework and mechanisms for taking the EU's preparedness for current and future climate impacts to a new level [3].

The EU building stock is responsible for a major percentage of energy consumption (40%) and GHG emissions (36 %). Although the renovation of existing building stock presents a large potential, there are several limitations (technical, legal etc.) preventing them to achieve very high performances. On the contrary, more than one quarter of the 2050s building stock is still to be built. The energy consumption and related GHG emissions of those new buildings need to be close to zero in order to reach the EU's highly ambitious targets. The concept and obligation of Net Zero Energy Buildings (NZEBs) has become increasingly more important as the recast of the European Performance of Buildings Directive (EPBD) requires all new buildings to be "nearly zero energy" buildings (nZEB) by 2020, including existing buildings undergoing major renovations. The EPBD defines a nearly Zero-Energy Building as follows: "A nearly Zero-Energy Building is a "building that has a very high energy performance… [ ]. The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby." Acknowledging the variety in building culture and climate throughout the EU, the EPBD does not prescribe a uniform approach for implementing nearly Zero-Energy Buildings and neither does it describe a calculation methodology for the energy balance [4]. The notion of cost effectiveness is also very important as the recast EPBD stipulates that the EU Member States shall ensure minimum energy performance requirements for buildings to be set 'with a view to achieving cost-optimal levels. Achieving a ZEB includes apart from minimizing the required energy through efficient measures and covering the minimized energy needs by adopting renewable sources, a series of optimized and well balanced operations between consumption and production coupled with successful grid integration [5, 6].

Net zero energy communities are the next frontier in energy efficiency and sustainability paving the way for the development of future smart cities. NZE Settlements with a reduced carbon footprint will play a key role in fulfilling the previously mentioned EU's ambitious targets. Achieving net zero at the settlement scale presents unique challenges as well as opportunities. NZE settlements should be places of advanced social progress and environmental regeneration, as well as places of attraction and engines of economic growth based on a holistic integrated approach in which all aspects of sustainability are taken into account. They will also support the efficient use of natural resources, economic efficiency and the energy efficiency in new and existing buildings [5, 7]. Santamouris (2016) [8] supports that innovating the built environment of Europe to zero assumes a minimization of the energy consumption of buildings, eradication of the energy poverty and mitigation of the urban heat island and the local climate change and that such an objective is an unequivocal choice that will create substantial opportunities for future growth. The main shortcomings in the current roadmap towards NZE Buildings and Settlements are:

- Large discrepancies in targets and fulfillments among EU Member States [9]
- The use of energy efficient technologies in combination with the various energy production technologies (solar, wind and other sources of energy) to attain nearly zero-energy behavior result to a significant cost burden for the building/ settlement [9, 10]

- Delays in smart/micro grid integration that can be considered as a modern electric power grid infrastructure for enhanced efficiency and reliability, thus ensuring effective optimization of resources at neighbourhood and district level.

Significant efforts have been put into quantifying and bridging the energy, financial and environmental gaps that exist between the cost optimal combinations of energy technologies and NZEB. The aforementioned efforts show that while various innovative passive and active smart and even low cost technologies are available, their successful and optimal integration is still missing. Furthermore, although there are now some examples of NZEBs already built, which show that they are achievable there exist very few cases in Europe demonstrating the NZE concept at distinct level.

In the framework of the EU project called ZERO PLUS: "Achieving near Zero and Positive Energy Settlements in Europe using Advanced Energy Technology" a comprehensive, cost-effective modular system for Net Zero Energy (NZE) settlements is being developed, implemented and demonstrated in a series of case studies across the EU. In this paper, the energy, environmental and socioeconomic objectives of the ZERO-PLUS project are presented as well as the methodology to achieve these objectives. The case studies and technologies involved are described. In addition the energy, environmental and cost analysis performed at building and settlement level is presented as well as the preliminary results that will form the basis for the integrated design and the optimization of the zero energy settlements. The ZERO-PLUS project [11] is coordinated by the National and Kaposistrian University of Athens.

2. Energy, environmental and socioeconomic objectives

The goal of the ZERO-PLUS project is to provide the market with an innovative, yet readily implementable system for NZE residential neighborhoods that will significantly reduce their costs. In effect, the project has the following six main objectives:

1. Reduce the operational energy usage in residential buildings to an average of 0-20 kWh/m2 per year, compared with the current average of 70-230 kWh/m2energy per year. The reduced energy consumption will be attained through the application of a number of technologies, including highly efficient insulation, heating and lighting, as well as automated Building Energy Management Systems (BEMS) in four selected case studies.
2. Generate at least 50kWh/m2 renewable energy per year, on average, in the NZE settlement. This objective will be attained through the integration in the settlement of innovative energy production technologies such as Linear Fresnel Reflectors, advanced building integrated photovoltaics (biPV) and advanced wind driven energy production systems.
3. Reduce the cost of NZE settlements by at least 16%, compared with current costs. This cost reduction will be achieved through a strategy of mass customization. To achieve this objective, a modular building system will be developed that is customized and optimized according to the specific requirements of each building and settlement, yet is implemented through cost-effective industrialized processes.
4. Transit from single NZE buildings to NZE settlements, in which the energy loads and resources are optimally managed. This objective will be attained through the application of solutions for the distribution network, energy storage and micro grid control on a district level, as well as through an optimum climatic management of the open spaces in the settlement.
5. Achieve a market uptake of the solutions developed in ZERO-PLUS by the year 2018. This will be achieved through the demonstration of the solutions in four different real-life case studies across the EU under different climatic conditions, and through the dissemination and exploitation of the results of these case studies, based on a comprehensive market analysis and business plan.
6. Support the shift towards resource-efficient, low-carbon and climate-resilient buildings and districts, by enhancing the role of Europe's construction industry in the reduction of the EU's carbon footprint by almost 77kgrCO2/m2 with a total 408 tonnes CO2 offset for all ZERO-PLUS case studies.

3. Overall approach and methodology

The challenge of significantly reducing the costs of NZE settlements will be achieved through the implementation of three parallel strategies:

- Increasing the efficiency of the components directly providing the energy conservation and energy generation in the NZE settlement.
- Reducing the "balance of system" costs through efficient production and installation processes.
- Reducing operational costs through better management of the loads and resources on a district scale rather than on the scale of a single building.

In order to achieve the objectives described in the previous section a work plan has been set up including the following activities:

- State of the Art on NZE and Positive Energy Settlements: Initial Preparation and Collection of Data in the Four Demonstration Sites
- Development of an innovative Process Information Modelling (PIM) approach which will be implemented for the planning, simulation and optimization of the off-site production and onsite assembly activities and for the integration of innovative building envelope components
- Design and optimization of solutions applied on the building scale, for on-site and nearby-generation of renewable energy, for energy conservation systems, for building energy management systems and for highly efficient heating ventilation and air conditioning systems
- Design and optimization of solutions for net-zero energy neighbourhoods at the district scale.
- Integrated Design and Optimisation of the Zero Energy Settlements providing integrated solutions based on the outcomes of the three previous activities,which are adapted to the local climate and site, using energy optimisation techniques and Life Cycle Assessment (LCA) approaches
- Verification of the performance of the solutions through a building commissioning process and their implementation in demonstration projects.
- Monitoring of the settlements and verification of the energy performance, development and implementation of solutions for automated and cost-effective maintenance of the installed equipment, and an analysis and minimization of the differences between predicted and actual energy performance
- Accelerating significantly the speed at which NZE buildings and their systems are taken up by the market and end users.

These activities will be implemented by an international consortium, composed of 16 partners from the academia and the industry, who will work together in a number of areas.

4. The ZERO PLUS technologies

The ZERO-PLUS system is an optimized, integrated, readily implementable system for cost-optimal NZE settlements constituted by a number of advanced, beyond the state of the art, energy technologies (Figure 1).System components are customized and optimized for each case-study. Standardized interfaces allow for flexibility of the system and optimized collective performance, as different components can be interchanged or adjusted. The energy technologies composing the ZERO-PLUS system are divided into the following five main categories:

Envelope Components. Innovative, composite cool- thermal insulating material based on the new generation of extruded polystyrene (XPS) will be installed on the building envelope. The component provides, through one light composite material, improved vapour permeability (lower water vapour diffusion resistance factor μ) and cool materials properties which contribute to lowering the demand for cooling, GHG emissions and mitigating the UHI. The final layer is either a) a ceramic tile (for flat surfaces) with high solar reflectance and either high or low emissivity coefficient that makes it appropriate for a variety of climatic conditions or b) a coating with high solar reflectance (for vertical surfaces), infrared emittance and photocatalytic properties that apart from the cool material benefits has also self cleaning properties. Thus, the material is lighter and is suitable for new and existing buildings; it minimizes the construction costs because of the decrease in the required layers and the easier construction method.

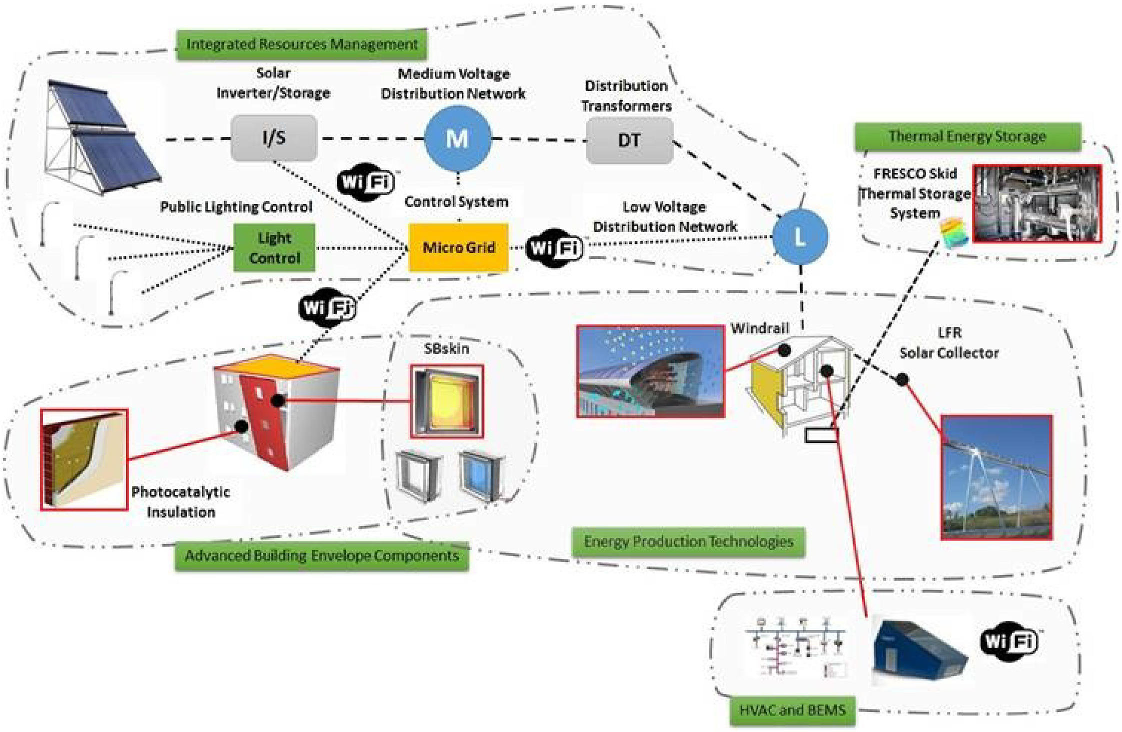


Fig. 1. Synoptic diagram of the components of the proposed system.

Heating Ventilation and Air-Conditioning. Compact solar thermal driven air-conditioning systems will be exploited to meet the cooling demand and, where possible, the heating demand of the buildings. This technology is based on a new solar Desiccant Evaporative Cooling concept. The smallest unit has a solar collector surface of about 2 m2, providing the necessary electricity to drive the system, and gives 2.7 kW of cooling power, while the maximum power absorbed is 150W. Furthermore, Wireless Sensors Networks coupled with model based predictive control algorithms will enable indoor comfort management by the building occupants but also the interconnection with the integrated resources management component.

Energy production. Three innovative energy production technologies will be considered for the ZERO-PLUS system. The first energy technology is precast, dry-assembled and pre-stressed translucent biPV glass components made of Dye Sensitized Solar Cells (DSC) capable of performing as an active and passive system simultaneously. These cells will be applied to translucent building façades and roof installations. The second technology is a compact Linear Fresnel Reflector (LFR) for polygenerative applications based on solar energy concentration. The possibility of a tight coupling of flat PV panels on the reverse side of the mirrors allows for flexibility in energy generation. Finally,WindRail®, a building-based modular wind turbine system will be considered. The system efficiently harnesses the energy of the wind, by exploiting the pressure differences around the building and the solar radiation to generate electricity. WindRail® modules are designed to also enable integration of other building based technical solutions such as HVAC systems.

Thermal storage. A complete and integrated solution for the storage of heat coming from high performance solar fields and its transformation into cold by absorption chillers will also be part of the system. A thermal storage system composed of pressurised oil storage, temperature sensors, inverter pumps and 3way valves will be used to help manage the temperature and to maximize the storage efficiency. The system is designed to increase the overall efficiency of the whole system and to control the hot fluid feed into the chillers according to the quantity of available energy. An integrated control system verifies the density of energy stored and gives the signals to control the solar collector tracking system.

Integrated Energy Resources Management. Medium Voltage (MV) and Low Voltage (LV) distribution networks with micro grid capabilities will be combined with public lighting control and solar inverter/storage. This integrated system will provide the capacity to safely integrate more renewable energy sources, smart buildings and distributed generators into the network; deliver power more efficiently and reliably through demand response and comprehensive control and monitoring capabilities; use automatic grid reconfiguration to prevent or restore outages (self-healing capabilities), and enable users to have greater control over their electricity consumption and to actively participate in the electricity market

5. The ZERO PLUS settlements

The ZERO-PLUS system will be developed, implemented and demonstrated in four case studies across the EU. The settlements have varying climates, micro-climates and building types thus maximising the possible impact on the building industry and market uptake of the solutions. The four case studies are described below:

Fig. 2. ZERO-PLUS case studies in a) Cyprus, b) France, c) Italy, d) UK.

Peyia, Cyprus. The settlement is situated on the outskirts of Peyia a village in the south-west region of Cyprus. The site is a hillside adjacent to a pine forest and very close to the Sea. The residential part of the development includes 123 autonomous plots spread in 323,608m^2 of total land area. In the framework of ZERO-PLUS two autonomous plots of approximately 1,700m^2, including individual houses with an area of about 500m^2, will be constructed and monitored. In parallel, the main open spaces of the settlement and in particular the main square and the area around it will be constructed to improve microclimatic conditions.

Voreppe, France. The French case study is located in Veroppe, a small town15 km North-West of Grenoble. The ZERO-PLUS case study is an apartment building of around 1400 m² of inhabited area consisting of 20 dwellings for social renting. It is integrated in a larger program including 28 additional dwellings for social selling.

Novafeltria, Italy. The Italian settlement is located in a residential- commercial area of Novafeltria in the Rimini province. The total area dedicated to the Italian NZE settlement, including public spaces, is approximately of 30,000 m2. This area will include four residential single-family villas of total gross area of 130 m^2 each distributed into an approximately rectangular ground sub-lot of more than 400 m^2.

Derwenthorpe, York, UK. Derwenthorpe is a mixed tenure community in the outskirts of York which when complete in 2019, will consist of around 500 new family homes. The scheme is being built in four phases; the first phase of 64 homes was completed in 2013. Through ZERO-PLUS three properties will be transformed into near zero energy homes. The properties will be located in Phase Four of the development, and will demonstrate the next generation of low energy and low carbon homes.

6. Energy, environmental and cost performance of the ZERO PLUS settlements

This section describes the design and optimization of the energy and environmental performance of the four case studies at building and settlement scale using advanced simulation techniques. The implementation of the ZERO PLUS technologies is considered and evaluated. Microclimate analysis and optimization of the case studies is conducted. Furthermore a cost assessment of the four case studies has been carried out in order to estimate their cost compared with current NZEB costs. The aim is to bridge the gap between single building scale and the settlement scale analysis and optimization, from thermal-energy, environmental and sustainability perspectives. Their technical and financial optimization in a whole and integrated way will be carried out in the next step of the design phase of the four case studies.

6.1. Optimisation of the energy and environmental performance at building scale

This subsection describes the efforts undertaken in order to optimize the expected energy and environmental performance of selected energy production and energy management technologies, singly and in combination, in individual residential building typologies across the four case studies described earlier. The following activities have been implemented in order to achieve the overall aim:

1. Design, testing and optimization of the the expected energy and environmental performance of building-level wind and solar energy systems (for electricity generation), solar concentrators (for production of hot water, heating and cooling), HVAC and thermal storage systems for different types of residential buildings across the four case studies, using simulation tools.
2. Design, testing and optimization of the expected energy and environmental performance of internet based home energy management and (lighting) control systems using simulation tools.
3. Integration and optimization of the energy and environmental performance of building energy production and energy generation technologies to achieve NZE buildings.

In the framework of the first activity, the annual baseline energy use, energy generation and environmental performance of eight representative residential typologies (by building form, construction and occupancy) across the four case studies were assessed in detail in terms of space heating, hot water, cooling, lighting and appliances, using advanced dynamic thermal simulation techniques (such as IES Virtual Environment, energy Plus etc.). Secondly, demand for space heating, hot water and cooling (if necessary) were minimised by deploying best-practice energy efficiency measures, and thirdly, the contribution from proposed solar/wind energy collectors were modelled to achieve the Zero Plus targets of net-regulated energy use $\leqslant$ 20 kWh/m2 per year and renewable energy production of $\geqslant$ 50kWh/m2 per year.

As part of the second activity, in the energy models of the eight residential typologies (across four case studies), improvements in energy and environmental performance (in terms of thermal comfort) were simulated for the proposed home energy management systems, for different types of occupancy schedules (24-hour occupancy, weekend-evenings). Energy savings from advanced lighting control systems (combining daylight and occupancy sensors) were also modelled using advanced simulation techniques at high spatial (individual room level) and temporal resolution (hourly) to create a range of load profiles for different occupancy patterns.

In the framework of the third activity, the energy and environmental performance of building energy production and energy generation technologies were integrated and optimised to achieve near zero energy buildings, i.e. achieve the Zero Plus targets of net-regulated energy use ⩽ 20 kWh/m2 per year and renewable energy production of ⩾ 50kWh/m2 per year. The performance of the proposed systems were also tested and optimised for current and future climate (e.g. 2030s, 2050s, and 2080s) as indoor temperatures and solar insolation are expected to increase with climate change.

As a result of the analysis, the following technologies were recommended for the four case study settlements:

- Cyprus: Advanced insulation, solar air-conditioning, high concentration PV CHP, building energy management system (BEMS)
- France: high concentration photovoltaic CHP, building integrated PV, combined solar and wind system, BEMS
- Italy: Advanced insulation, combined solar and wind system, BEMS
- UK: Advanced insulation, combined solar and wind system, BEMS

All case study dwellings met the Zero Plus net-regulated energy and renewable energy production targets. However the Cypriot case study's regulated energy consumption was found to be lower than recommended under the Zero Plus targets; therefore it is expected that during the cost optimisation phase of the project, this reduction may be scaled back. Also the Italian case study was found to be generating renewable 40% more energy above the required target; again this may require a scale back during cost optimisation.

Modelling for future climate showed that:

- Most case studies will retain their status of meeting the Zero Plus targets.
- Though the building mean figure for the French case study meets the target for all climate change scenarios, higher consuming flats may need to explore additional passive solar measures to reduce cooling demand beyond 2050s to retain a net regulated below the Zero Plus target.
- Where solar radiation change was available, the case studies showed a slight increase in renewable energy generation.

6.2. Design and optimization of the NZE Technologies to be implemented at the settlement scale

This subsection describes the main efforts undertaken in order to design and optimize the solutions for net-zero energy settlements at the district scale. More in details, three main activities have been carried out. The first one concerned the outdoor energy technologies and renewable systems at NZE settlement including energy and environmental details about innovative solutions to be implemented in common areas. Therefore, a first careful analysis of the technologies described above and other technologies considered as suitable for the implementation into the case studies were identified and their technical performances with varying possible boundary conditions and constraints of the Zero-Plus neighborhoods were examined (Figure 5). Additionally, a first draft of an integrated calculation tool for mutual optimization of the renewable plants combined with the energy needs and natural resources availability was operated by means of a dedicated new tool developed in this project. Therefore, a preliminary analysis of the microclimate models was performed, to be further investigated.

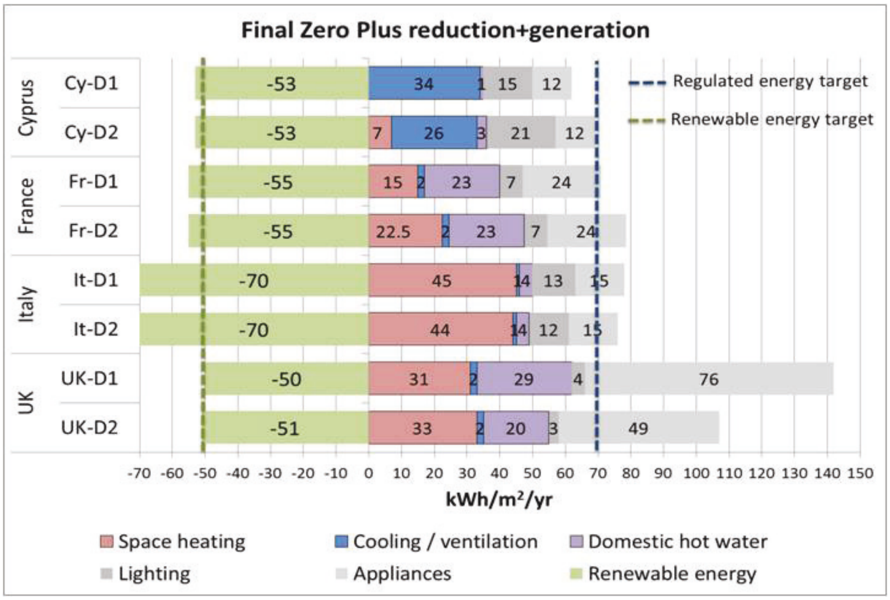


Fig. 3. Energy consumption and production for the ZERO-PLUS case studies.

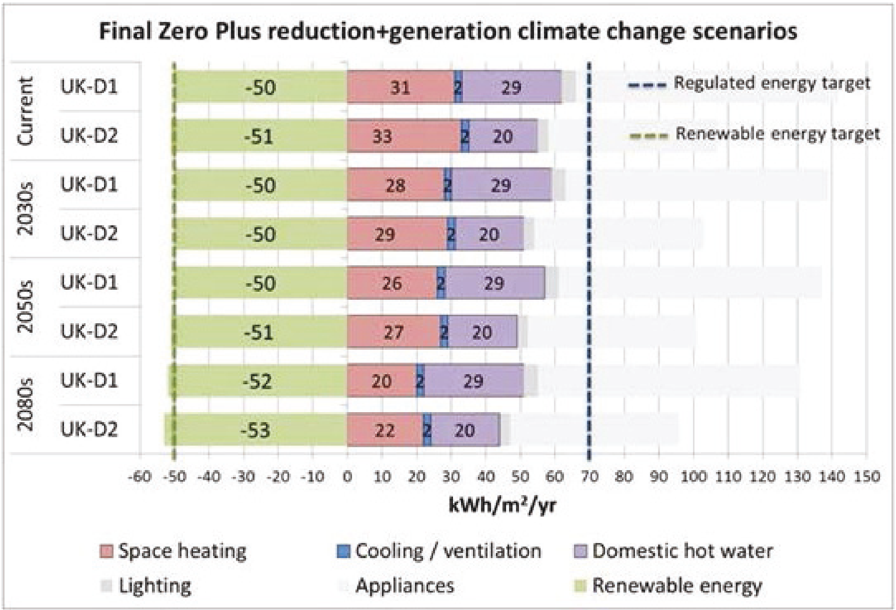


Fig. 4. End use consumption for each climate scenario considered for the UK case study.

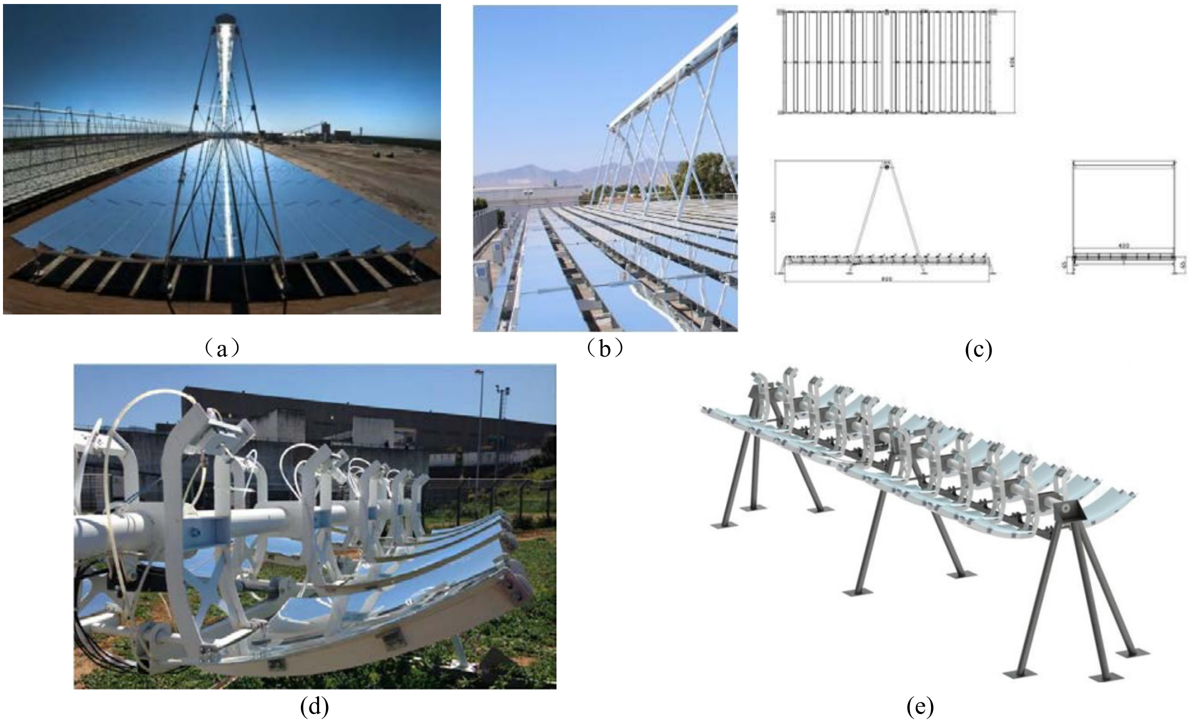
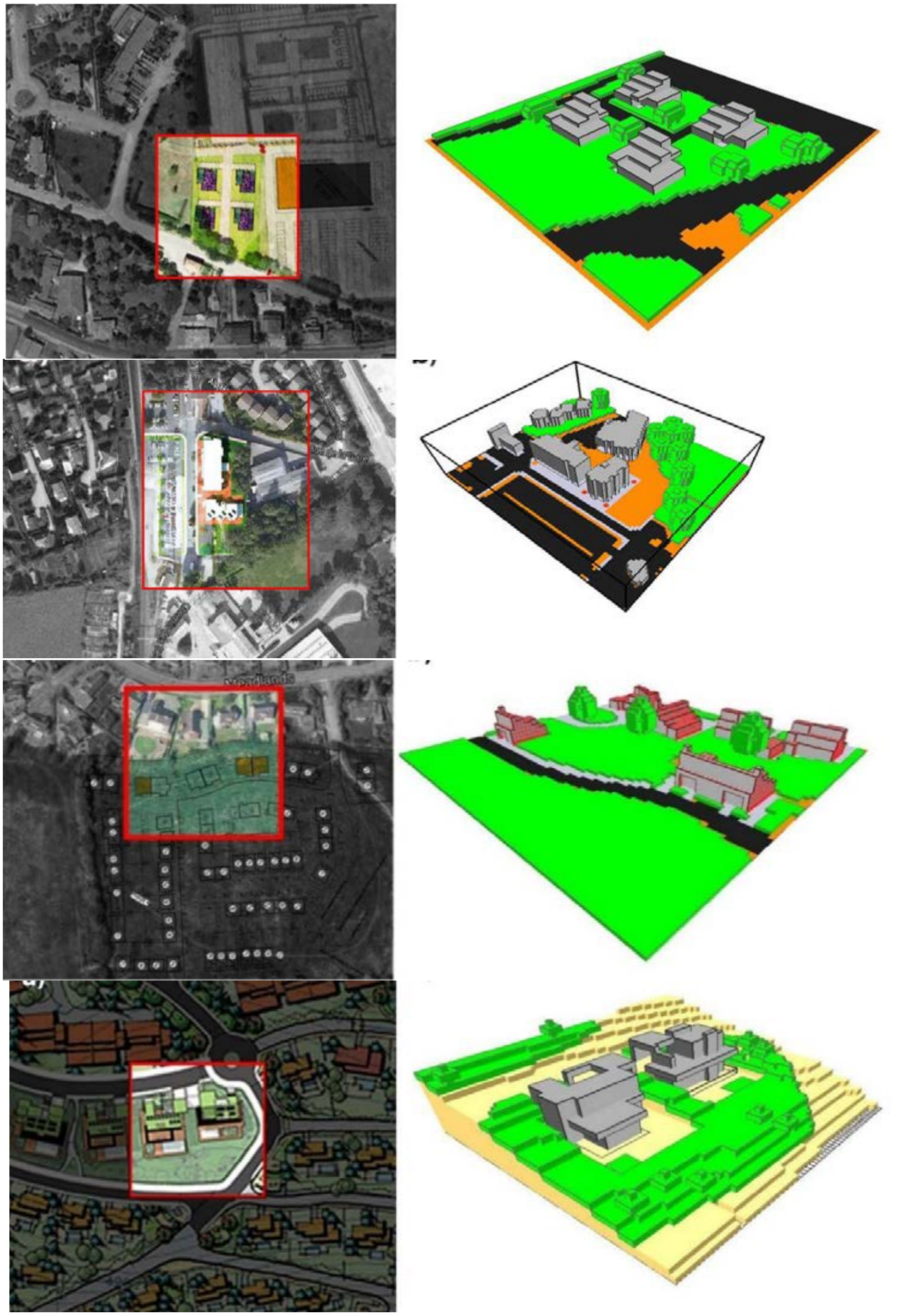


Fig. 5. Pictures & schemes of some Zero Plus technologies and their integration into the settlements. a-b) FRESCO Solar LFC (PV/ST compact Linear Fresnel Collector for polygenerative applications) (left) design and (right) experimental application on a rooftop in Cyprus and (c) geometry details. d-e)FAE HCPV (High Concentrating Photovoltaic systems exploit the property of optics to focus the sun radiation impacting a wide area on a small area occupied by one or more high efficiency PV cells in order to generate electricity.) (left) design and (right) pilot system.

The second activity involved the development of microclimate models of all the settlements as they were conceived by the designers' team of each project (Figures 6). Then, possible microclimate improvement strategies were proposed. Those strategies consisted of (i) greenery design for taking advantage of passive cooling effect in summer and wind shading effects in winter conditions, when and where needed, and (ii) cool paving strategies for reducing surface temperatures of the district and passively cooling the building boundaries for further benefits at indoor level. Both these strategies were then combined in order to produce optimum scenarios. Based on those optimum scenarios and through an iterative interpolating process, the numerical data of typical summer and winter days were used to develop new weather files for building simulation taking into account the microclimate improvements. Therefore, the final simulated settlement energy performance of building energy need was able to consider possible thermal-energy benefits due to the microclimate improvements, thanks to the abovementioned strategies, representing a key result of the project, since a real settlement-scale optimization was carried out at this stage.

The same microclimate models were integrated into a new calculation tool that was developed in Matlab with the final purpose also to optimize the positioning of the renewables by taking into account the microclimate boundaries and the relative solar and wind availability around each settlement (Figure 7).

The final activity implemented concerns the environmental assessment by means of acknowledged LCA techniques and LEED assessment protocols. This still on-going phase of the Zero Plus project will compare the proposed designed net zero energy settlements with standard net zero energy buildings which are designed without the Zero Plus further step consisting of the settlement optimization. Additionally, the LEED protocol pre-assessment procedure will be implemented in each case study, with further economic benefits also for the construction companies taking advantage of such added-value characterizing LEED certified interventions within the market.



A

B

C

D

Fig. 6. Site location (left) and ENVI-met models (right) for the Italian (A), French (B), UK (C) and Cypriot (D) case study.

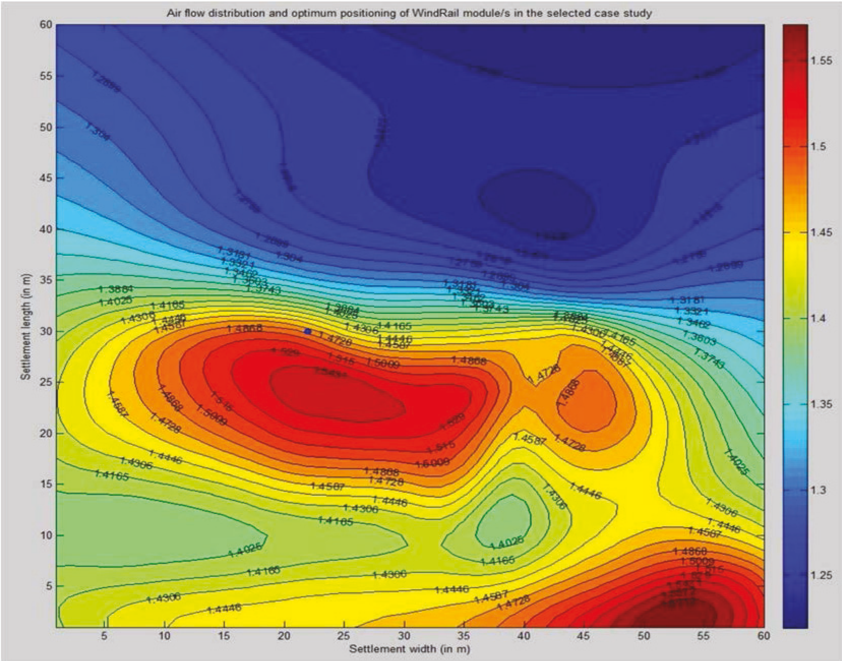


Fig. 7. Screen shot of the Matlab-tool for the Cypriot case study results with 1 Windrail module and 1 FAE module: Air flow distribution and optimum positioning on the building roofs.

6.3. Cost assessment of the ZERO PLUS case studies

One of the main objectives of the Zero Plus project is to reduce the cost of nZE settlements by at least 16% compared with current costs through a strategy of mass customization. A bespoke methodology has been developed for the assessment of the cost reduction of the Zero Plus building. The cost considered in the methodology is the cost for acquisition, supply and installation.

Three building scenarios are considered in the methodology for cost assessment:

1. **Conventional Building**: a building conforming to the minimum energy requirements as set by the local building regulations.
2. **Zero Energy Reference Building**: an nZEB designed with conventional technologies (e.g. conventional PVs) having the same energy and environmental performance as the Zero Plus Building.
3. **Zero Plus Building**: anZEB that uses energy efficient technologies to reduce energy consumption and achieves the target of producing renewable energy of at least 50kwh/m2 per year by using building integrated RES plus:

- the energy produced by settlement RES
- the energy reduction from using the advanced energy management systems
- the energy reduction from advanced building envelope components
- the energy reduction from improved microclimate.

The methodology for the cost assessment is consisting of the following steps:

1. Full and detailed definition of the characteristics and performance of the three considered building scenarios.

2. Computation of the extra costs for the Zero Energy Reference Building elements and components compared to the Conventional Building.
3. Computation of the extra costs for the Zero Plus Building elements and components compared to a Conventional Building.
4. Calculation of the cost difference between the Zero Plus Building and the Zero Energy Reference Building resulting from the innovative technologies and techniques both at building and at settlement level.

For each of the Zero Energy Reference and the Zero Plus initial building design the additional costs for the innovative elements and components have been calculated and compared against the cost of the same elements and components of the conventional building.

The analysis showed that, against a Zero Energy Reference building that has the same energy and environmental performance, the Zero Plus buildings manage to maintain a lower cost.

Case study dwellings in Italy, France and the UK meet the cost reduction target of 16%, while for the Cypriot case study the cost reduction is 12.4%. Further improvements in the energy performance and in the overall cost of the settlements are expected in all four settlements from the improvement of the microclimate, the incorporation of innovative facade components and the finalization of the design of the advanced energy management systems. In addition, the initial design components will undergo technical and economical optimization.

7. Conclusions

At present and during the following years the building design community and building professionals in general will be challenged by mandatory codes and standards that aim to improve the buildings energy, environmental and cost performance. The ZEB principle is anticipated to contribute significantly towards the achievement of the future smart cities, envisioned by the European Union and promoted through its regulatory framework. The Horizon 2020 project "Achieving near Zero and Positive Energy Settlements in Europe using Advanced Energy Technology" (Acronym: ZERO-PLUS) described in this paper, meets the challenge to develop a comprehensive, cost-effective modular system for Net Zero Energy (NZE) settlements to implement and demonstrate it in four real life case studies across the EU. The analysis conducted during this first design and optimization phase performed at building and settlement scale shows that the four settlements are able to achieve the target of having a net-regulated energy use $\leqslant$ 20 kWh/m2 per year and renewable energy production of $\geqslant$ 50kWh/m2 per year and therefore be considered as zero energy settlements. Moreover, the initial cost analysis shows a reduction of at least 16% compared with current NZEB costs indicating the cost effectiveness of the projects. The next steps include the optimization from the technical and economic point of view, of the integrated architectural and engineering design developed for each one of the four involved settlements, using full and detailed simulation of the energy and environmental performance of each settlement and LCC analysis regarding the specific contribution of each of the selected innovative components in order to estimate the optimum economic sizing.

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