Tools and techniques supporting new nZEB design methodologies in Mediterranean climate

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Abstract. The paper refers to the final phase of the Smart Case research project "Innovative solutions for the optimization of multi-functional primary energy consumption and indoor living conditions in the Building System". The aim of the research was to develop tools and methodologies to support and orient the design of new buildings in the Mediterranean area, with regard to the selection of envelope technologies for the best overall energetic and environmental performance of the building system. Further research developments on the topic may concern actions aimed at moving from the Nearly Zero Energy to the Plus Energy model. The interaction between the building and the smart grid will be one of the main aspects to be investigated with a systemic perspective towards smart cities.
Keywords: nZEB, Energy efficiency, Building envelope, Smart building/grid

Scenario

The current debate on the need to express the energy-environment-development trinomial with the aim of safeguarding the planet, saving resources, guaranteeing comfort and safety conditions, highlights the need to identify appropriate design strategies and methods of intervention able to seize the opportunity to set up new built spaces.
The components to be considered in a process of transformation towards a smart city are complex and numerous; they concern the development and implementation of new technologies, new practices and governance procedures, such as the definition of new energy policies, land management, transport and services, but also aspects related to emerging areas such as green and low-carbon economy, mitigation and adaptation strategies to climate change, social inclusion and local development, environmental protection and resilience of the built environment (Claudi, 2014).
In this scenario, the paper refers to the final phase of the Smart Case research project[1] "Innovative solutions for the optimization of multi-functional primary energy consumption and indoor living conditions in the Building System" (PON R&C 2007-2013) developed within the STRESS Scarl Consortium, a high technology District for sustainable buildings, which has represented a research path in which the technology transfer process, in the sense of transmission of knowledge and skills, has conveyed a technological innovation based on advanced aggregation methods and on "networking" capability between the business world and research structures.
The research areas have focused on topics in which some technical inadequacies related to the current design and construction practices are critically considered, aiming at the use of new and more efficient technologies for the performance improvement, not only oriented towards the optimization of the energy aspects, but also to the overall quality of the building system. This is possible through integrated design interventions aimed at overcoming a linear concept of the design process and through the ability to prefigure and verify the effectiveness of the transformations in projects simultaneously carried out on multiple levels and by multiple actors (Claudi; Musarella, 2016).

The Smart Case research: goals, methodology and results

The contribution of the researchers of the Department of Architecture of the University Federico II of Naples, lied in the identification of design strategies for the optimization of primary energy consumption and indoor livability in relation to new buildings, aiming to reduce building energy demand.
The research started from the assumption that the current state of knowledge is based on the awareness that the energy efficiency of buildings is determined to a large extent by the envelope performance[2], the efficiency of plants and the passive control systems for summer and winter comfort. The objective was therefore to develop support and orientation tools and methodologies for new construction interventions in the Mediterranean area, with regard to the selection of envelope technologies for the best overall energetic and environmental performance of the building system.
The work intended to create a system of data, design parameters and significant aspects typical of the Mediterranean climate, useful for the implementation of the architectural concept; in particular, the aim was to investigate to what extent the topics for the project of nZEB in Mediterranean climate - such as the orientation, the shape of the building, the mass and the insulation of the envelope, the use of high performance materials, the solutions for the mitigation of solar irradiation and its related thermal load, the natural ventilation, shading and passive cooling systems - represent key elements to maximize the overall performance of the residential unit, leading to the achievement of the set goals.
In this context, the design of a demonstrator building near completion in Benevento has represented an opportunity for implementing design, construction and plant innovative methodologies for the integrated design and construction of a Net Zero Energy Building (nZEB) (Fig. 1).
The demonstrator building, intended to accommodate students of the University of Sannio, aims to meet short/medium term housing needs. The identified dwelling type - single family house - is directly related to the identified users and requires innovative responses to the changed contemporary conditions of living in architectural, technological, plant and environmental terms[3].
An approach based on parametric environmental design was introduced at an advanced stage to support the design of the demonstrator building, using lighting simulations related to the incident solar radiation on glazed elements as tools for the evaluation, correction and optimization of the design solution[4].
This methodology was aimed at optimizing the quantity and

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01 | Demonstrator building, Benevento.
Study render

quality of the internal natural lighting and therefore the factors related to energy saving combined with the indoor comfort of future users.

The first phase of the research has focused on the recovery of all the climatic data of the study site, the city of Benevento, in order to analyse different solutions in the most accurate way possible.

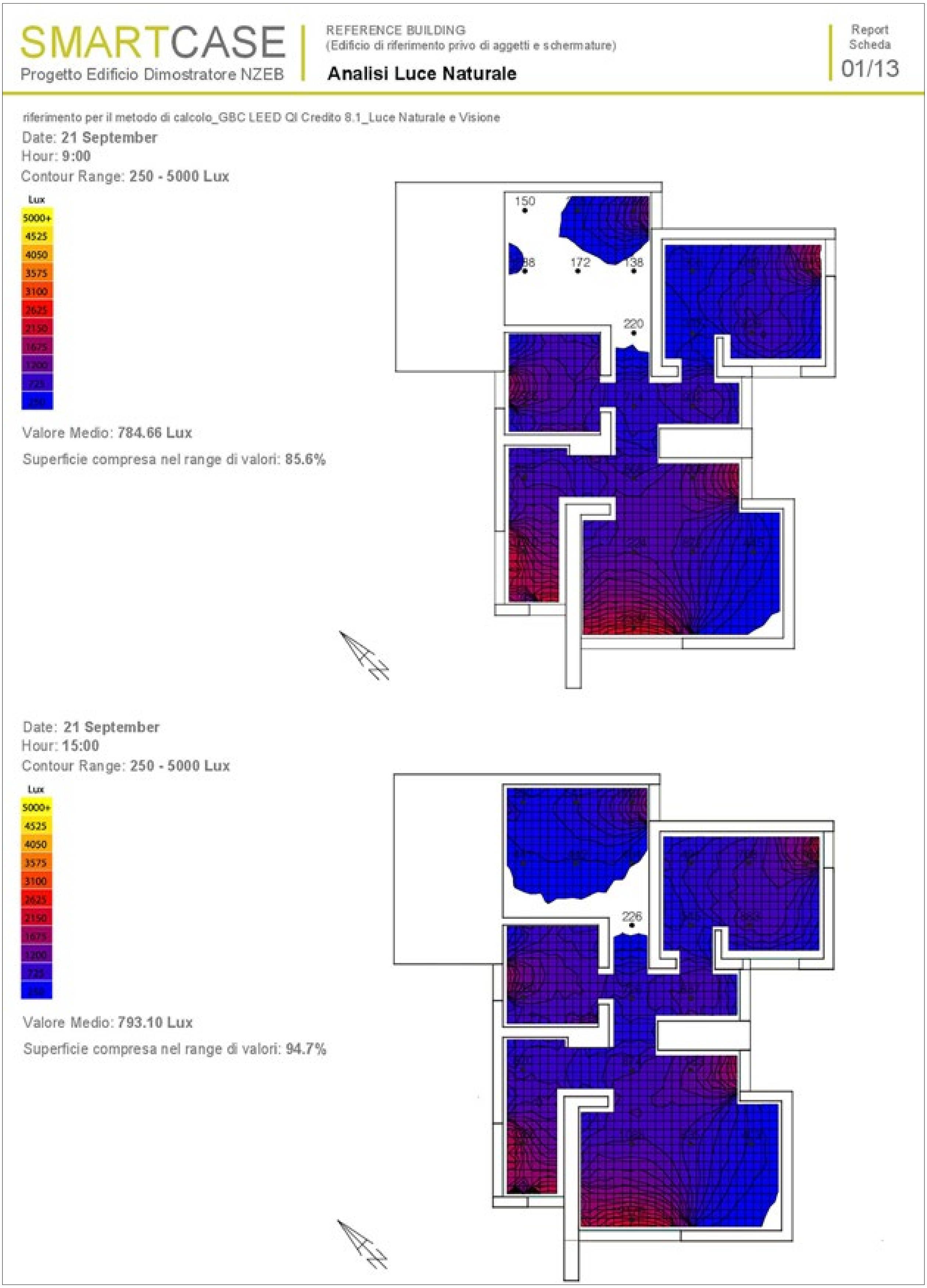
Subsequently, two different calculation models were produced through the simulated based design: one for the *Reference Building* (namely the project building deprived of any projection or shielding), the other for the *Design Building* (namely the building in progress), setting a series of comparisons based on the ranges of values (250-5000 lux) and on the calculation methods (simulations at 9:00 am and at 3:00 pm on September 21st and March 21st) proposed by the GBC LEED protocol with regard to Indoor Environmental Quality. From this set of simulations it was found that the Design Building did not reach the pre-set natural light benchmarks. At the same time, the summer irradiation values on windows were analysed, with the aim of reducing them by at least 40%, comparing the reference building to the design building, in order to find the right balance between the amount of light and the solar radiation and avoid indoor overheating.

After evaluating the simulations and comparisons results, a third calculation model was developed for an *Upgraded Design Building* to get as close as possible to the goal of illuminating 75% of indoor surface by natural light, as required by LEED credit (USA), and reducing by at least 40% the summer irradiation values compared to the reference building.

The changes have concerned the definition of a new form for the roof projections in order to intercept a greater amount of natural light without increasing the amount of solar radiation on the envelope. The Upgraded Design Building is simply a new version of the Design Building, as far as possible, "optimized" on the pre-set benchmarks, and it condenses the set of factors that can be taken into account to rethink the whole or part of the initial building (Figures 2, 3, 4).

The data-sheets related to the different calculation models have represented effective tools to detect any problem or advantage of a solution compared to another; the obtained data set was translated into new design guidelines that led to an improved building, in part different from the initial one, that, in its final form, has optimized the natural light factor while controlling the excessive summer irradiation of the transparent envelope. After checking all the variables and selecting the technological and formal solutions for achieving the nZEB performance, everything has been translated into the project, producing two-dimensional and three-dimensional graphics for its implementation and communication.

The study shows that in Mediterranean climates the tools and methodologies supporting nZEB design have to relate to design strategies characterized by a strong respect for the context, with particular attention to recurring architectural forms and typologies, to prevailing technological solutions, to materials, textures and colours connoting the buildings developed over the centuries which today identify homogeneous geographical and cultural areas. A design oriented to contain energy consumption and to housing comfort, able to take advantage of local natural



02 | Simulations for the optimization of the relationship between the shape of the building and the levels of natural lighting and reduction of the thermal load on the transparent envelope

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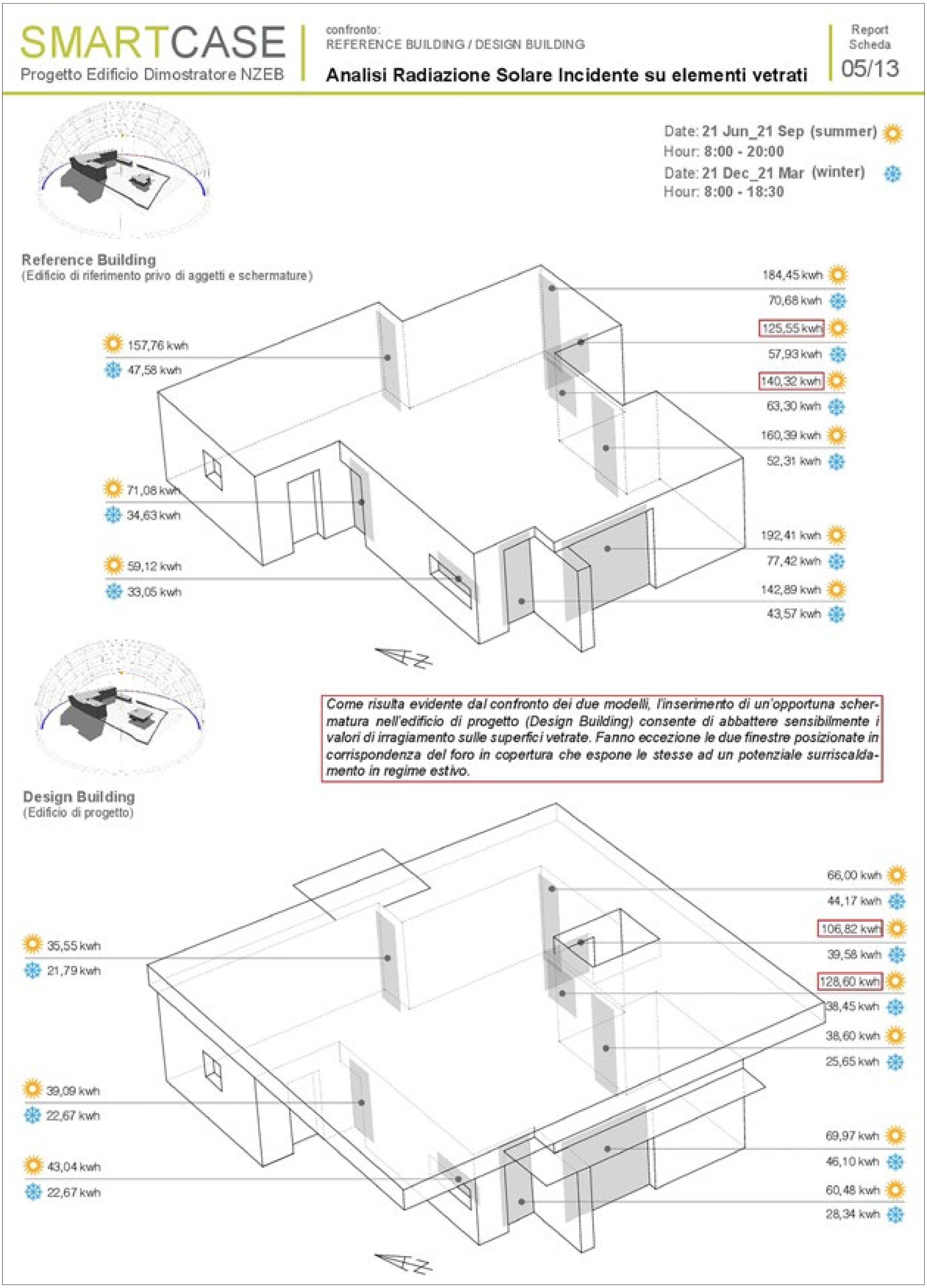

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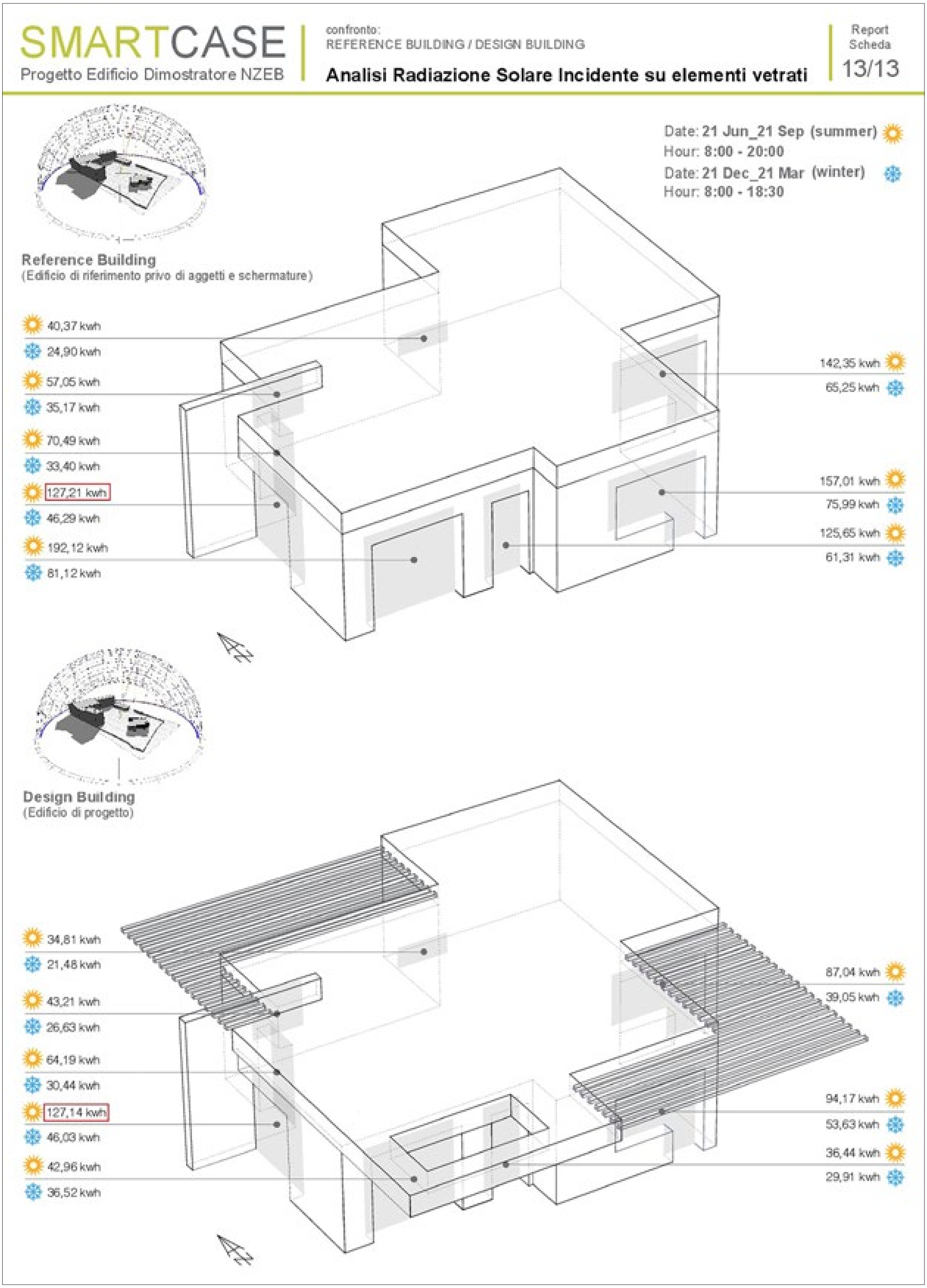

04 | Simulations for the optimization of the relationship between the shape of the building and the levels of natural lighting and reduction of the thermal load on the transparent envelope

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05-06 | Demonstrator building, Benevento. Construction phases: assembly of X-Lam panels (Cross Laminated Timber) and stratification of the external walls. The choice of the Fibertherm Flex 180 panel contributes to ensure a good thermal inertia thanks to its mass, making it suitable for the reference climate context

resources and climate, is generally based on a bioclimatic approach, aiming at controlling three levels at the same time: climate-environmental, typological and technical-executive (Lavagna, 2010).

An original aspect of the research lies in the use of a systemic approach, based on tools that incorporate modelling and simulation in relation to requirements related to the reference context, to the intended use and to the typological aspects (as well as to the containment of energy consumption), studying how and to what extent the envelope design will have to be adjusted or misaligned by the "passive house" energy standards designed for the Central European climate.

In this regard, it is reaffirmed that the Passivhaus model, born in the climatic, cultural and constructive context of Central Europe, makes little sense if applied in the Mediterranean area, where the main parameter to take into account is perhaps the flexibility of the solutions, that have to be adjusted to different climatic summer and winter conditions, with mild intermediate seasons in which ventilation and lighting topics prevail over the strictly thermal ones, not to mention the cultural and social values (Sala, 2012) (Figures 5, 6).

Some experiences carried out in different geographical areas have shown that there are no standardized solutions valid for any latitude, that architectural optimization is no less efficient than plant optimization, that the choice of materials cannot exclusively depend on their level of ecologicality, that the simple implementation of eco-efficient system devices does not automatically make the building they are part of sustainable, that the assessment of the building energy performance cannot be separated from a thorough post-occupancy verification (Russo Ermolli, 2013).

The main output of the research activity, beyond the methodological and the skills integration aspects that have characterized the whole process, is related to the experimental verification applied to the demonstrator building. Thanks to the sensors for monitoring the confined space environmental conditions (sensors for detecting temperature and humidity, air quality, occupancy and illumination) and the thermal performance of the opaque and transparent envelope (surface temperature values, solar radiation, infrared radiation) it will be possible, through the effective use of the building and the systemic organization of the collected data, to intervene for subsequent corrective solutions while continuing to optimize indoor well-being of the users performance (Figures 7, 8).

The need to develop exemplifying cases also originates from the consideration that the European directives on sustainable design and energy efficiency, as transposed at national level, are scarcely observed in the current design practices.

Future developments, integration between building and smart grid

Further research on this topic may concern actions aimed at the transition from the Nearly Zero Energy, to the Net Zero Energy, up to the Plus Energy model, for which the integration of renewable energy sources in architecture is strategic. The interaction between the nZEB building and the smart grid will be one of the main aspects to be investigated with a systemic perspective towards the smart cities. In this sense, cities must push the extensive use of systems for generating and accumulating energy sources and the development of smart grids, for a flexible and adaptable distribution over time.

The cornerstones to be pursued are those that will cut down and progressively eliminate harmful climate-altering emissions over time, moving from nZEB - *Nearly Zero Energy Building* model to nZEA - *Net Zero Energy Architecture* model, which surpasses the building scale to achieve a strong interaction and exchange between architecture and urban dimension, to nPEA - *Net Positive Energy Architecture* model; the latter marks the definitive transition not only to the self-production of the energy needed by the architectural or urban organism, but also to the surplus of produced energy that focuses on the new frontier theme of the dynamic management of the total amount of energy, generated and distributed according to users needs, contexts and moments of the day or season of the year (Tucci, 2017). In this direction, to support the development of the "intangible" performance of an energy-efficient, responsible and sustainable settlement, the planning and experimentation contributions offered by the use of smart grids are increasingly important and significant, as systems capable of intelligently integrate the actions of the connected users - producers and consumers - in order to distribute energy in an efficient, sustainable, economic, and safe way (Boeri et al., 2017).

In the context of energy, environmental and social emergency of cities, such a laboratory of innovation can become a benchmark and a reference model for urban regeneration interventions that put smart buildings on the grid, connecting users, tracing consumption profiles, planning the energy production and redistributing the surplus.

The interaction between the building and the smart grid is therefore a key aspect for the future research in which ICTs will play a decisive role. The integration of sensors and control units will allow the acquisition of aggregated data from multiple buildings, allowing a better configuration of the grids as a function of an energy demand no longer assessed only at individual level but also at building and/or district scale, according to a smart building/smart city logic (Dassori Morbiducci, 2013).

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07 | Demonstrator building, Benevento.
nZEB near completion

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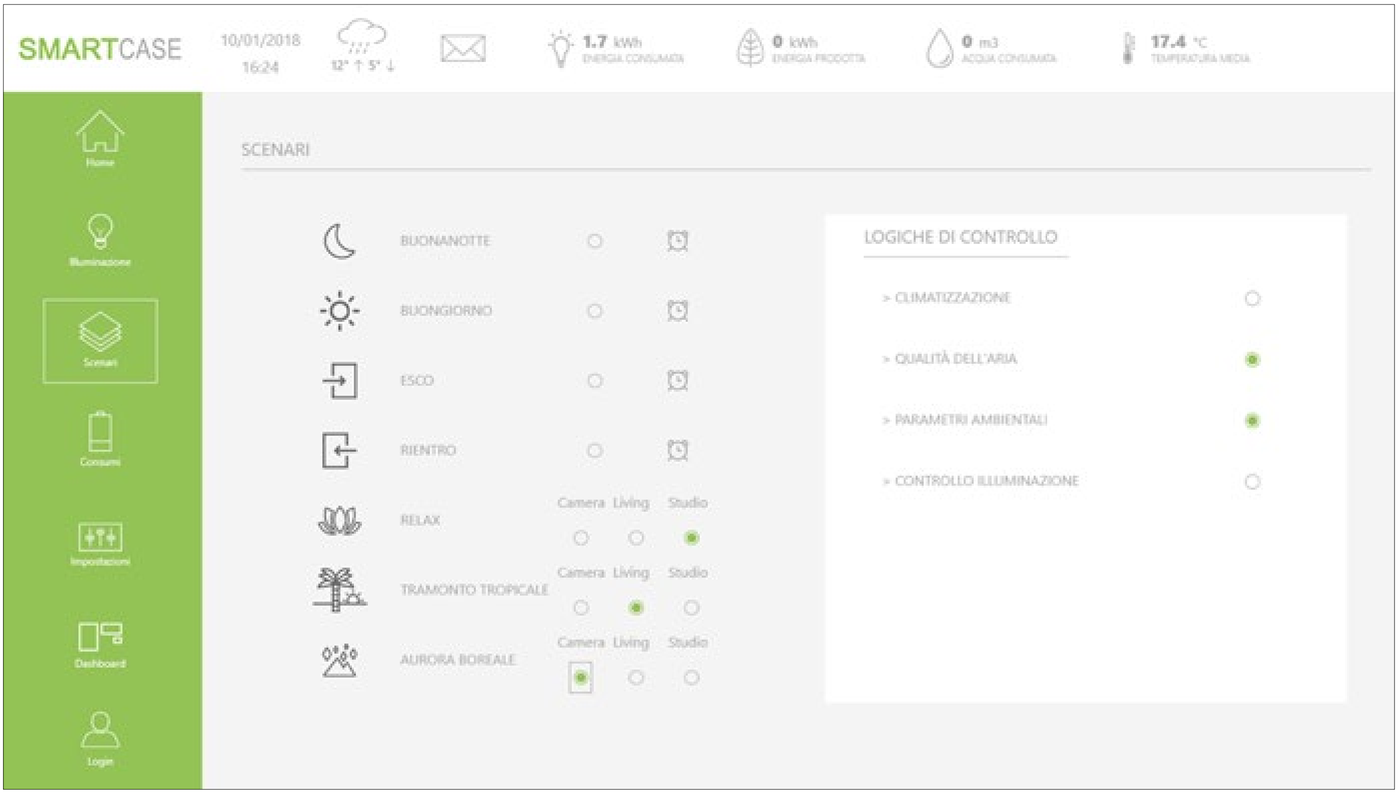

08 | The monitoring and control system is mainly based on three "infrastructures": the first one, the Building Management System (BMS), regards measurement and control functions; the second one, the Living Lab, is a monitoring system for research and validation purposes; the third one concerns the software for the management and control of the hardware part, the functioning logics and the user interface.
The BMS provides the user with the ability to activate/plan a series of smart processes specifically designed to optimize the use of lighting and air conditioning systems. BMS information can also be accessed remotely through an App developed for Android devices that connects to the measurement database installed in the building's technical room. The functionality of the mobile app is mainly addressed to the user's control of some BMS features

NOTES

[1] The Smart Case research project, articulated in the period 2013-2017, has had the contribution of the University Federico II of Naples and the University of Sannio, Research Centers and industrial partners and the collaboration of local authorities and institutions that have provided important support to the research activity. The general scientific coordination is entrusted to prof. G.P. Vanoli of the Engineering Department of the University of Sannio, while the coordination for the STRESS Scarl Actuator is entrusted to Eng. F. De Falco. The Research Group within the Department of Architecture of the University Federico II of Naples consists of prof. A. Claudi de Saint Mihiel (coordinator and scientific manager), prof. M. Bellomo, U. Caturano, A. D'Agostino, P. De Toro, D. French, M. Losasso, A. Piemontese, with the contribution of: arch. E. Buiano, E.A. De Nicola, C. Filagrossi Ambrosino, C. Girardi, E. Porcaro, T. Venditto, C. Tomeo.

[2] It is important to underline that the scientific literature related to 2050 trends highlights the strategic role of the building envelope in terms of adaptability, integrability and efficiency to meet the needs of resilient buildings and cities.

[3] The cultural renewal induced by the affirmation of energy efficiency and sustainability of the interventions has begun to invest in recent times the residential sector, as well as the production for residential use. The research on the residence has undergone a major acceleration thanks to the promotion action carried out by the European regulatory provisions on energy saving and users comfort (Girardi, 2013). At the same time users have developed new needs to satisfy, in addition to the primary need of living (Arbizzani 2012).

[4] Simulation activities and the related 2D and 3D graphic restitution have been edited by the arch. E.A. De Nicola, winner of the scholarship "Applications of innovative methodologies for the integrated design of nZEB in reference to a scale demonstrator building and/or a refurbishment of a part of the existing building" - SMART CASE Research, coordinator: Prof. A. Claudi de Saint Mihiel.

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Among the different and qualified stakeholders who have given their contribution in specific ways and in different phases we mention: the vice-president of the Campania Region Fulvio Bonavitacola, who underlined how, thanks to the forthcoming phase of data monitoring and testing on the demonstrator building, the Campania Region will be able to use the obtained results to "instruct" the new Regional Piano Casa, aimed at the energy refurbishment of the existing building stock. Moreover, with regard to the large amount of both public and private buildings - of no historical and architectural value - built in the post-war period, the Region will operate through demolition and reconstruction interventions «observing the demonstrator so that the decision maker can decide well» in relation with design and plant solutions studied and adopted for its design and construction. The president of STRESS - high technology District for sustainable buildings - Ennio Rubino, remarked how The Smart Case project «has shown that it is possible to provide the territory with "concrete objects" as results of industrial research projects financed with European structural funds». The demonstrator building is an intervention of great experimental value for the definition of standards and guidelines for the construction of near zero energy buildings in Mediterranean climates. Vito Grassi, sole director of Graded and vice-president of the Unione Industriali di Napoli, has expressed his satisfaction for having contributed to the realization of what will become a permanent laboratory for testing the most advanced technologies in terms of building sustainability. The nZEB demonstrator represents the practical proof of the fact that the growth of our productive fabric necessarily passes through an ever closer collaboration between companies, the university system and the research world in tune with the national strategies for the promotion and activation of the "Digital Innovation Hub" foreseen by the Industry Plan (Piano Industria) 4.0.

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