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Inter-ActiveHouse: users-driven building performances for Nearly Zero Energy Buildings in Mediterranean climates

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ABSTRACT
Building simulations rely on fixed assumptions and mathematical models to describe a specific building scenario, overlooking the building occupants' component. Almost 40% of in-home energy use is due occupants interacts with the building systems. The goal of this paper is to understand the magnitude of the performance gap when applied to two case studies in a Mediterranean climate. A set of scenarios are simulated assuming both a typical building usage and possible variations given by the users' interactions with shading, ventilation and cooling systems. Results show that the magnitude of the effects with a negative impact is bigger if compared to actions that might have a positive influence, this means that simulated results with standard usage assumptions are not an average of the possible effects but they reflect an optimistic outcome given by the optimal equipment usage.

KEYWORDS
Users interactions, energy efficiency, occupants behaviour, building simulation.

INTRODUCTION
Buildings sustainability standards usually focus on passive strategies to reduce the energy consumption by improving the envelope and system performances (Rodriguez-Ubinas et al., 2014). Considering the operational phase, several studies (Fabi et al., 2013; Shuqin et al., 2015; Martinaitis et al., 2015) attest a deep performance gap between simulated/predicted and real data, quantifiable towards, e.g.: the 56% offices' electrical request for lighting during non-working hours (Masoso and Grobler, 2010); the 200% increase in energy bills (Fabi et al., 2012). This gap clearly relates buildings' performances to the occupants' misuse of buildings systems that often does not follow the designed assumptions (Hale, 2018). Actually, virtual simulations take into account standard conditions of use, neglecting the big influence of users and reducing their interactions to a fixed system of defined schedules. Whereas some software integrate users-related variables, often their predictions fail because the working hypotheses do not properly reflect real conditions. The real human action drivers can contribute to model a reliable algorithm of interaction between users and buildings. A driver is anything that pushes an occupant to perform either an action or an interaction with the building system, affecting also the energy consumptions. The interactions between occupants and the construction system could be related to a combination of several drivers, both external and internal (Schweiker and Shukuya, 2009; Boerstra et. Al, 2013, Hellwig, 2015; Lou et al., 2016). The main objective of the study is to assess the magnitude of the users' impact on buildings behaviour in relation to outstanding examples of sustainable architecture. The analysis is performed on certified case studies of Mediterranean Active House, in order to exclude any possible bias of non-optimised design. Active House (AH) is a holistic approach

to building design aimed at promoting sustainability. AH is supported by a network of research centres and construction companies (namely AH Alliance), among which Politecnico di Milano is delegated to adapt the vision to Mediterranean climate. This analysis is part of the preliminary research done in this field. The analysis concerns the cooling season, since a hot-warm climate characterises the weather clusters of the Mediterranean region (Peel et al., 2007). Here, winter is a mild season, while summer offers a large daily range of temperature (Causone et. Al, 2014), requiring a dynamic approach and proving to be more relevant to the definition of the design resilience in Mediterranean region.

METHOD

The proposed analysis performs several sets of dynamic simulation scenarios in the software tool TRNSYS17 (http://www.trnsys.com/), starting from the typical usage assumptions, and implementing possible interactions with (i) cooling, (ii) shading and (iii) ventilation systems.

Case studies

The dynamic simulations are performed on two outstanding examples of sustainable and high energy-efficient buildings, designed and validated according the AH principles (www.activehouse.info): SVEVAH and VELUXlab[1]. While SVEVAH virtual model represent an example of applied design strategies for a Mediterranean building project, VELUXlab is a real building prototype, whose virtual model has been set and calibrated according to the real use and measured energy consumption (Imperadori et al., 2013).

Table 1. Main features and technical characteristics of the two case studies.

		VELUXlab	SVEVAH
Project data	Location	Milan	Rome
Roof	Transmittance (W/m^{2}K)	0,133	0,117
	Damp effect (h)	10,5	10
Envelope	Transmittance (W/m^{2}K)	0,124	0,137
	Average FLD (%)	5,7	5
Transparency	Transmittance (W/m^{2}K)	1,1	1,1

Baseline scenario

The buildings are equipped with a fully automated system that controls heating and cooling, as well as natural ventilation and shading systems. It operates as follows: i) cooling is switched on only when the indoor temperature T_i is above the AH overheating thresholds[2]; ii) natural ventilation is allowed when outdoor temperature T_e, is above 22°C and T_i>T_e; iii) windows facing north are never shaded; iv) windows are shaded when outdoor temperature is above 24°C, T_i>T_e, and the irradiance on the glass overcomes 140W/m^2 (Reinhart, 2001); v) East and West facing windows are shaded only if the condition in iv) is met during morning/afternoon time. Following the performance rating method of ASHRAE 90.1 §G1.2, these assumptions have been used to create a baseline scenario, within which the simulated performances represent the baseline for further results from different user-driven scenarios.

[1] Designed as the demo-house ATIKA, by ACXT/IDOM studio for VELUX, in 2011; retrofitted by Atelier2 – Valentina Gallotti and Prof. Marco Imperadori – Politecnico di Milano

[2] According to the AH Specifications, 2nd edition (2013) (www.activehouse.info), the maximum operative temperature limits follow the AH ranking: 1. $T_{i,o}$ < 25.5°C; 2. $T_{i,o}$ < 26°C; 3. $T_{i,o}$ < 27°C; 4. $T_{i,o}$ < 28°C, with an outside T_{rm} ≥12°C. Beyond the set threshold of 26°C, the automated control system activates the floor cooling system.

Cooling set point variation scenarios

The set of simulation scenarios (Table 2) compares the several static set point (a) with a complex modulation (b, c) that reflects the real conditions of use, and an adaptive setup (d), which assures the lowest adaptive category of comfort (UNI EN 15251:2008). Only for this analysis, the reference scenario adopted is the one with cooling system set at 26°C, as it reflects the standard cooling set point temperature in Mediterranean climate.

Table 2. Set of scenarios defining the users' action of changing the cooling set point

SCENARIO			TIME	SET POINT (°C)
Sp_(set point)	(a)	Static set point	0-24	from 24 to 28 with 1°C step
sp_night	(b)	Night set back	8-20 (20-8)	26 (28)
sp_c	(c)	Daily combination	8-20 (20-23) 23-6.30 (6.30-8)	26 (28) off (28)
sp_a	(d)	Adaptive opportunity	8-23 (23-8)	0,33Trm[3]+20.8°C (off)

Shading system variation scenarios

Buildings users interact with the shading system as a reaction to sun position and solar radiation intensity and depth (Reinhart, 2001), even if indoor daylight supply is lower than the comfort threshold. In order to represent the effect of different drivers, several scenarios are scheduled (Table 3), differing in duration (all day, AM, PM) and interaction between users and MAS (Multi Agent Systems).

Table 3. Set of actions scenarios for the interactions with the shading system.

SCENARIO	MAS ON	MAS OFF (time) control modification
Base_s	-	(0-24) 80% shading (no ref. on external conditions)
Base_n	-	(0-24) Not shaded
PM_i	0-13 and 18-24	(13-18) 80% shading if irradiance > 250W/m^2
PM_s	0-13 and 18-24	(13-18) 80% shading (no ref. on external conditions)
PM_n	0-13 and 18-24	(13-18) Not shaded
AM_i	0-8 and 13-24	(8-13) 80% shading if irradiance > 250W/m^2
AM_s	0-8 and 13-24	(8-13) 80% shading (no ref. on external conditions)
AM_n	0-8 and 13-24	(8-13) Not shaded

Ventilation scenarios

Ventilation interactions are set according to different time schedule of natural ventilation. (Herkel et al., 2009). Scenarios are shown in Table 4. Ceiling fans are not considered, since the prime design strategies of the buildings did not account them.

Table 4. Actions scenarios for the interactions with the ventilation system.

SCENARIO	MAS[4] ON	MAS OFF (time) control modification
Base_o	-	(0-24) open
Base_c	-	(0-24) close
PM_o	0-13 and 18-24	(13-18) open
PM_c	0-13 and 18-24	(13-18) close
AM_o	0-8 and 13-24	(8-13) open
AM_c	0-8 and 13-24	(8-13) close
Day_o	0-8 and 18-24	(8 and 18) open
Day_c	0-8 and 18-24	(8 and 18) close

[3] Trm is the running mean external temperature, as defined by UNI EN 15251:2008

[4] MAS (Multi Agent Systems) applied to ventilation systems manages natural ventilation through the automatic opening/closing of windows, according to the external and internal temperatures and CO_2 concentration.

Night_o	8-18	(0-8 and 18-24) open
Night_c	8-18	(0-8 and 18-24) close

RESULTS

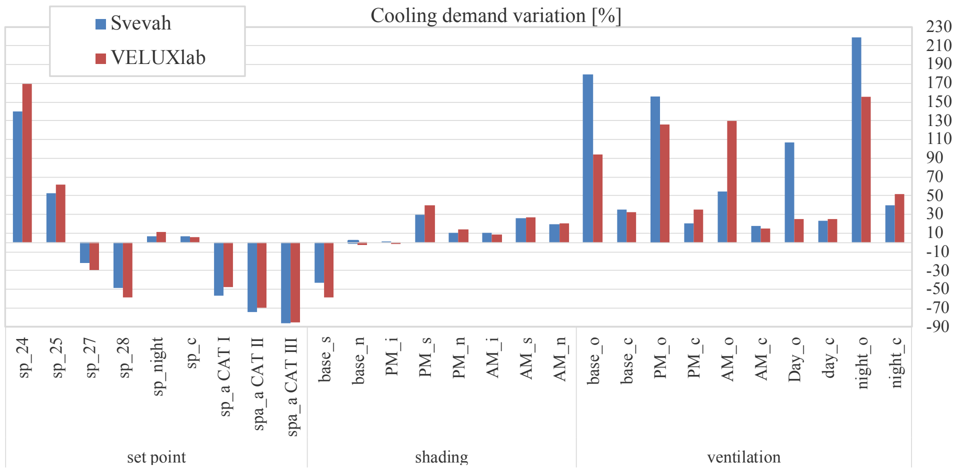

Figure 1. Variation of cooling demand in the different scenarios compared to the baseline, expressed as percentage.

Figure 1 shows that some scenarios improve the final energy performance up to 90% less; others instead increase it up to almost 230%. The first important observation concerns the asymmetry of the variations: this is particularly clear in the cooling set up scenarios, where a 1°C variation in the setpoint temperature causes different effects on energy consumption. In fact, a 1°C reduction in setpoint temperature increases the cooling demand by approximately 60% above the baseline, while a 1°C increase in setpoint temperature reduces cooling demand of 20% below baseline. This tendency is even clearer when a 2°C variation is taken into account. This means that the cooling demand variation and the set point variation are not proportional and, therefore, the energy efficiency can drastically change if lower setpoint temperatures are considered (SP 24°C 150% more in cooling demand if compared to SP 26°C). Generally, it is possible to notice that the set of scenarios with shading interactions has less influence on the energy demand. This is due to the resilient design of the case studies, which integrate architectural features to prevent summer overheating, such as enclosed shape and internal shaded patio (VELUXlab) and smaller openings to South (SVEVAH). Another interesting consideration involves the influence of different outside scenarios, between the two case studies: although the observed tendency is the same, VELUXlab prove to be more sensible to setpoint changes, while it is more resilient to variations in the ventilation management system. The background reason stands in the different climate: Rome is a warmer city if compared to Milan, meaning that natural ventilation and external air infiltration are more critical. On the opposite side, when cooling is relying only on mechanical air conditioning, the relative influence is lower, due to the already higher cooling demand.

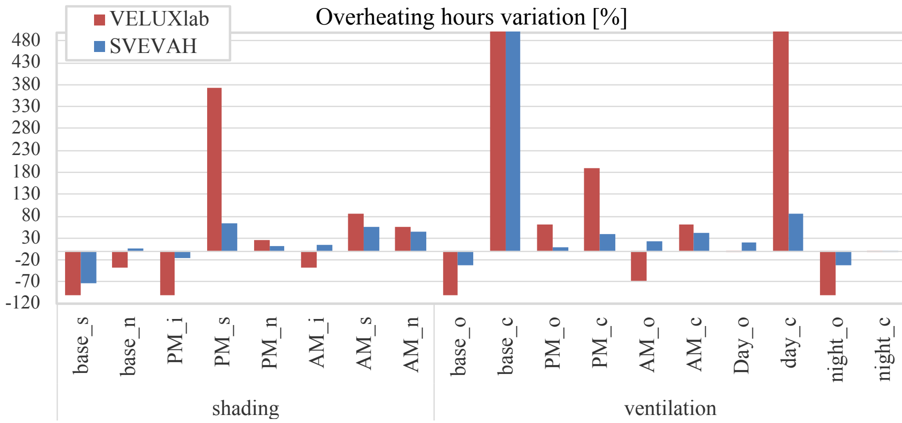

Figure 2. Variation of overheating hours in percentage, calculated according to AH Specifications, 2nd edition (2013) (www.activehouse.info) and compared to baseline scenario.

Figure 2 shows the overheating hours for the scenarios with interaction on the shading and ventilation systems. Similar ventilation and shading scenarios have comparable effects on the comfort point of view -in contrast with previous results. The highest number of overheating hours is detected when no ventilation is allowed, this means that the buildings are unable to dissipate the internal heat gains and the overheating is mainly internally driven. These results confirm that modern efficient buildings are less sensitive to external stress, due to their engineered envelope with optimized performance, but also less resilient to indoor increasing heat gains.

DISCUSSIONS

The results clearly attest the outcomes of experimental and monitored experiences in literature (Fabi et al., 2013; Shuqin et al., 2015; Martinaitis et al., 2015): the users interaction with the building systems could create a significant gap between predicted and real performance.
The presented case studies are supposed to be at the forefront of a sustainability. However, final performances change completely when the simulation assumptions and parameters are modified. This result indicates that the actual energy efficiency standard should account for the criticism related to users' interactions, allowing a better calibration of the design strategies. At last, the simplified scenarios could represent a limitation of the study, which does not account for more complex interactions. However, this simplified approach, based on the one-at-a-time method, helps to separate possible correlations and to quantify the criticisms of each system in the Mediterranean climate. According to this approach, users' influence represents a big source of uncertainty in the final energy performance of Mediterranean sustainable buildings. Sometimes also positive: shading scenarios are controlled by irradiance (Reinhart, 2001) and decrease the energy consumption of the building: less irradiance would mean less solar gain, and thus, a reduction of overheating effect and cooling demand. These outcomes represent a first step towards a proposal for modification of the thresholds on efficiency in regulations and standards, which should clearly account for usage behavior.

CONCLUSIONS

The analysis is a preliminary step into the investigation of the interaction between users and building automation systems. According to the achieved results, the actual sustainability certification scheme can lead to biased conclusion on buildings final energy performance. The analysis in this paper is an additional contribution to the research on this issue and the case studies analysed show that the criticisms is not related only to low-performing buildings, but it is extended also to ambitious projects that claim outstanding performances.
Future

investigations of the presented project aim at defining a threshold acceptance boundary to account for misuse and interaction between MAS and users to be integrated into the future generation of sustainability standards.

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REFERENCES

Boerstra A., Beuker T., Loomans M., Hensen J. 2013. Impact of available and perceived control on comfort and health in European offices, Architectural Science Review, vol. 56:1, 30-41.

Causone, F., Carlucci, S., Pagliano, L., & Pietrobon, M. 2014. A zero energy concept building for the Mediterranean climate. Energy Procedia, vol. 62, 280–288.

Fabi, V., Andersen, R.V., Corgnati, S.P. et al. 2013. A methodology for modelling energy-related human behaviour: Application to window opening behaviour in residential buildings. Building Simululation, vol. 6, 415.

Fabi V., Andersen R.V., Corgnati S., Olsen B.W. 2012. Occupant's window opening behaviour: a literature review of factors influencing occupant behavior and models, Building and Environment, vol. 58, 188-198.

Hale, L.A. 2018. At Home with Sustainability: From Green Default Rules to Sustainable Consumption. InSustainability, vol. 10, 249.

Hellwig R.T. 2015. Perceived control in indoor environments: a conceptual approach. In: Building Research & Information, vol. 43:3, 302-315.

Herkel S., Knapp U., Pfafferot J. 2005. A preliminary model of users' behaviour regarding the manual control of windows in office buildings, 9th International IBPSA Conference, Building Simulation, Canada.

Imperadori M., Sauchelli M., Brambilla A., Falcone N., Zanello C. and Zorzi V. 2013. Comfort and Energy Assessment of the First Italian Nearly Zero Energy Building in a University Campu. In proceedings of PLEA. Munich, Germany.

Luo M., Cao B., Ji W., Ouyang Q., Lin B., Zhu Y. 2016. The underlying linkage between personal control and thermal comfort: Psychological or physical effects?, Energy and Buildings, vol 111, 56-63.

Martinaitis V., Zavadskas E. K., Motuzienė v., Vilutienė T. 2015. Importance of occupancy information when simulating energy demand of energy efficient house: A case study. In: Energy and Buildings, vol 101, 64-75.

Masoso O.T. and Grobler L.J. 2010. The dark side of occupants' behaviour on building energy use, Energy and Buildings, vol. 42, 173-177.

Peel, M. C., Finlayson, B. L., & McMahon, T. A. 2007. Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth System Sciences, 11(5), 1633–1644.

Reinhart C. 2001. Daylight availability and manual lighting control in office buildings - simulation studies and analysis of measurements, University of Karlsruhe, Germany

Rodriguez-Ubinas, E., Montero, C., Porteros, M., et al. 2014. Passive design strategies and performance of Net Energy Plus Houses. Energy and Buildings, 83, 10–22.

Schweiker M. and Shukuya M. 2009. Comparison of theoretical and statistical models of air-conditioning-unit usage behaviour in a residential setting under Japanese climatic conditions, Building and Environment, vol. 44, 2137–2149.

Shuqin C., Weiwei Y., Hiroshi Y., Mark D. L., Katy N., Adam H., 2015. Definition of occupant behavior in residential buildings and its application to behavior analysis in case studies. In: Energy and Buildings, vol. 104, 1-13

www.activehouse.info