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Towards Zero Energy Settlements – A brief note on commissioning and POE within the EU ZeroPlus Settlements

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Abstract. Ambitious goals for the upgrade of construction aimed at energy conservation may quite often bounce due to different barriers, from design and detailing, through construction, to commissioning and behavioural ones. To overcome these, this paper focuses on the missing link of the construction process – the Informative Commissioning, the pre and post occupancy monitoring, and the POE, all integral parts of the ZeroPlus EU project. Limitations, barriers and other considerations and complexities encountered through the project's stages will be presented, alongside the formation of the methodology and some preliminary results of the first case studies to be commissioned.

1. Introduction

For most people, buildings – homes - are probably the most expensive commodity they will buy during their lifetime. Additionally, as buildings become more complex in terms of their passive and active systems, operating them appropriately becomes more complicated. Thus, it seems strange that it is assumed that building users will intuitively know how to operate and maintain their buildings and it would be reasonable to expect that relevant procedures would become more common in order to ensure the latter's proper use. Such procedures would include Informative Commissioning, i.e. presenting building users with the special features and peculiarities of their buildings; pre and post occupancy monitoring aimed at identifying potential discrepancies between the building performance without the user, and the latter's interaction with the former; and Post-Occupancy Evaluation (POE), i.e. surveying, monitoring, and analysing the building-user interaction to identify design or behavioural barriers induced failure or malfunction and, not least, specific and overall user satisfaction.

In come Nearly Zero Energy Buildings (NZEBs) and Zero Energy Buildings (ZEBs), which have become part of the contemporary scientific and planning-architectonic discourse [1]. Yet, more-often-than-not, the limitations of single buildings to both fend for themselves energy-wise and be economically compatible with conventional ones, hinder their becoming widely common.



In 2015 the Horizon2020 framework of the EU accepted an ambitious proposal by a consortium of 16 partners from 8 countries, aiming at surpassing such barriers by moving one scale up – from single buildings to communities and settlements [2]. Thus, by capitalizing on synergies alongside economy of scale, four case studies have been designed and are currently being constructed and commissioned in four of the consortium partner countries – Cyprus, Italy, France and the UK, thus covering four geo-climatic regions [3], alongside different construction technologies and common practices, as well as different typologies of residential buildings, ranging from villas to social housing apartments [4].

This paper focuses on the missing links of the construction process – the Informative Commissioning, the pre and post occupancy monitoring, and the POE, all integral parts of the ZeroPlus (ZP) EU project. Limitations, barriers and other considerations and complexities encountered through the project's stages are presented, alongside the formation of the methodology and some preliminary results of the first case studies to be commissioned.

2. The ZeroPlus Project - A brief description

ZP lays out and undertakes the design and construction of residential settlements within a collaborative prototype framework, involving technology providers, energy efficiency and renewable energy experts, and developers, collaborating from the earliest design stages. The goal is to create a market-ready innovative, yet readily implementable system for Near Zero or Positive Energy settlements which will significantly reduce their costs. Settlement level analysis highlights benefits by capitalizing on synergies and economy of scale, as opposed to individual buildings. The aims of ZP settlements exceed the state of the art by setting performance objectives requiring improvement relative to other energy efficient buildings:

- Operational energy reduction to an average of 0-20 kWh/m² per year.
- Generation from renewable sources at a minimum of 50 kWh/m² of renewable energy per year.
- Investment cost reduction by at least 16%, compared to a regular NZEB.

However, ambitious as these may be, the project has set a number of additional targets aimed at ensuring that the building design and systems incorporation, construction, commissioning, actual operation and pre and post occupancy phases, all are part of the overall framework, protocols and fine tuning. This in itself is a very ambitious innovation, since it comes to ensure that the circle design-construction-occupancy has feedback mechanisms incorporated in it, allowing for a continuous learning and improvement process, so vital in the construction industry [5]. The following chapters describe exactly these steps in the project as integral parts of ZP (Figure 1).

3. Commissioning

The ZP project involves the implementation of a number of innovative technologies, which are integrated in buildings and settlements in four case studies in Europe. Some of these technologies are already available in the market, but for most this is the first implementation in a construction project. The technologies implemented in each case study were selected based on an optimization of the design. An optimization program was developed for this purpose, through which the optimal configuration (e.g., type, number, and position) of technologies could be selected in order to minimize the initial costs of the system, while maintaining requirements regarding energy efficiency [6].

Commissioning is a systematic process that ensures that all building systems perform according to the contract documents, the design intent, and the owner's operational needs [7]. It usually spans the entire design and construction phases of a new building, and ideally should begin at the design phase. The main purpose of the commissioning plan in this project was to provide key guidelines and support both the construction companies and the owners of each case study when they prepare a detailed commissioning process, in order to ensure the proper implementation of the selected innovative technologies and help them in navigating through this complex process. Since the plan addressed only the technologies mentioned above, and not the other conventional systems in which they are integrated (such as the electrical system), it complemented the building commissioning processes that would in any case be implemented by the case study owners.

The plan provided detailed information on proposed actions that are implemented in the assembly, installation, and pre-occupancy phases of the project. The general sequence in which these actions are carried out is as follows:

1. Developing and connecting a Web-GIS platform to each building to record test results. Further information on this platform is provided in Section 4 of this paper.
2. Commissioning of each ZP technology.
3. Building diagnostics.
4. Monitoring of the ZP system during the pre-occupancy phase.

For the assembly and installation phases, basic checklists were provided for the commissioning of each ZP technology. For the pre-occupancy phase, building diagnostics and systems tests were defined for measuring and verifying the performance of the different technologies, as well as actions for testing the monitoring system that is implemented and for guiding the building users.

3.1. Production, assembly, and installation of the ZP technologies.

Basic checklists were defined for the commissioning of each ZP technology during its assembly and installation. Additional checklists describe the performance tests to be carried out and the parameters to be checked after completing the installation of each system separately and as a stand-alone scenario. Given the different dates at which each technology and building system is installed, the performance of each technology should be tested by itself. The additional simultaneous testing of all the technologies in the pre-occupancy phase of each project is described in the next section.

The checklists and a comparison of the installation plans with as-built data of the technologies allow the owners of each case study to check the implementation of each technology and to detect, as far as possible, deficiencies while construction is taking place and before the pre-occupancy phase. This allows deficiencies to be properly resolved within the construction's tight schedule.

3.2. Pre-occupancy system tests.

A variety of tests are executed in between the completion of construction and pre-occupancy of the settlements, to ensure that all the systems in each case study are performing (simultaneously and separately) according to the project's goals, under full and partial load conditions. The usage tests together with the measurement of energy flows provide a measure of initial performance. This phase is important because any problem that is detected can be handled before the buildings are occupied.

Monitoring protocols were defined for measuring and verifying the energy savings and energy production provided by the different technologies and include the parameters that need to be measured for each technology. In most cases, the measurement equipment installed to assist the commissioning and testing process, such as heat meters and energy meters, will later be used to monitor the performance of the technologies during the use phase. It is thus important to record the results of these tests for the following two reasons:

1. The results of the tests verify proper installation and functioning of the technologies.
2. The tests provide monitored performance results, which will serve as an indication of initial performance for the following monitoring process.

3.3. Building diagnostics.

A number of different tests are carried out after the completion of the construction to evaluate the physical performance of the building envelope for heat loss. In case deficiencies are found during these tests, they must be fixed prior to handover. Of the different tests that are recommended, air permeability – infiltration - and u-value tests are required to be carried out in any case, to ensure that calibrated building energy simulations can be executed in the pre-occupancy phase.

3.4. System testing.

Before the buildings are occupied a number of tests are carried out which measure energy generation, energy end uses (regulated and unregulated), indoor and outdoor environmental conditions (air

temperature, relative humidity, CO₂, etc.). As mentioned above, the tests and their results are linked to the monitoring system. These results constitute a baseline for the consequent monitoring process after the buildings are occupied.

3.5. Further guidance.

The performance of the technologies depends, in addition to the suppliers who manufacture and supply the systems and the contractors who install them, on the building occupants and on those maintaining the systems. Due to the innovativeness of all the technologies, the users in each case study are well informed and guided on the proper use of the different systems. The training procedure in each case study varies depending on the configuration of the technologies and on the owner's requirements. However, in all of the cases a fully detailed operations and maintenance manual is provided, after its translation, where necessary, to the relevant local language for each case study.

Many problems may occur in the first year of occupation. To deal with those, a Problem Identification Procedure was prepared, which includes a protocol of steps that are suggested to be followed and implemented by a Rescue Team that is formed for each case study.

Finally, Informed Consent Forms and Welcome Packages were prepared for the building occupants in the relevant languages. The Welcome Package is a non-technical user guide introducing the occupants to the innovative technologies and monitoring equipment installed in their residence and settlement. The document contains basic information about the technologies and the monitoring equipment that have been installed. Guidance on how to access the Web-GIS platform, where the monitored data will be collected and stored, is also provided in the document. Further details are given in Section 6 below.

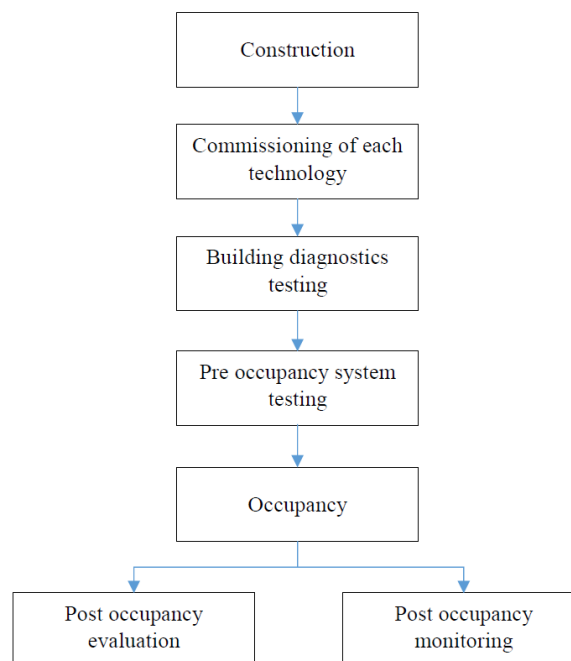


Figure 1. ZP Construction-to-POE flow chart.

4. Web-GIS platform

A Web-GIS platform has been created in order to support effective monitoring of the ZP case studies. On the platform, the following categories of data are recorded: (a) Indoor Environmental Quality of the buildings; (b) Energy consumption of the buildings; (c) Energy consumption at district level; (d) Energy production; (e) Settlement meteorological conditions. The monitoring consists of four levels as depicted in Figure 2.

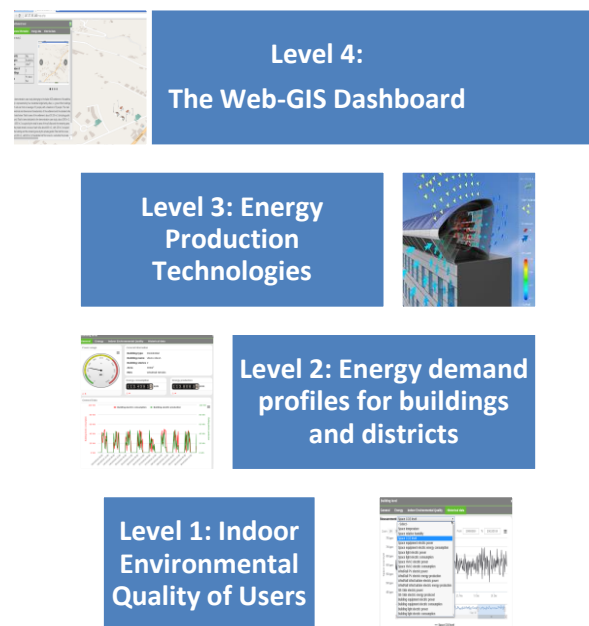


Figure 2. The four levels of the Web-GIS platform for each ZeroPlus case study.

The general schematic representation of the long-term monitoring devices and data acquisition units at building and settlement level, along with their interconnection to the Web-GIS platform, is depicted in Figure 3.

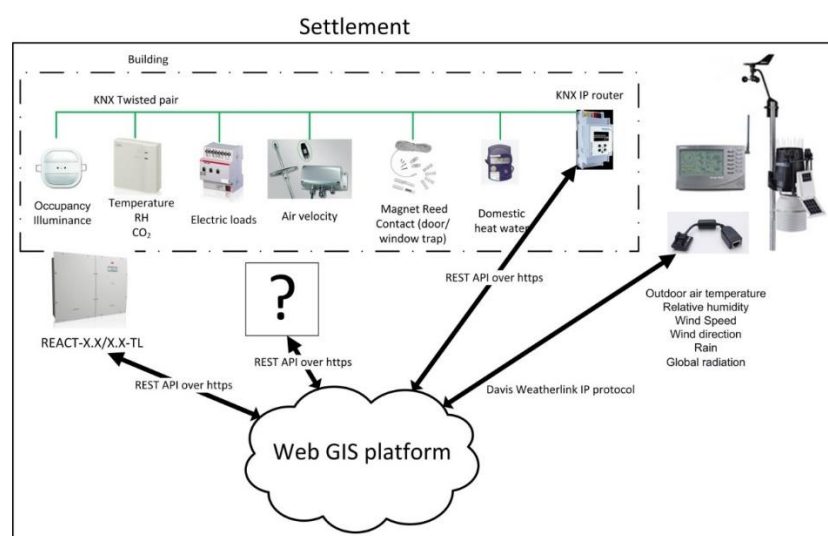


Figure 3. The monitoring equipment schema and connection to the platform.

The long-term monitoring equipment installed in the buildings and district follows the KNX technology, a bus system for building automation and control based on the predecessor systems EIB, EHS and BatiBUS [8]. KNX is a standardized protocol internationally documented through the following: ISO/IEC 14543-3, (International); CENELEC EN 50090, (Europe); CEN EN 13321-1 and EN1332-2 (KNXnet/IP), (Europe); GB/T 20965, (China); ANSI/ASHRAE 135, (USA).

Effectively, all components connected to the KNX bus are KNX certified thus ensuring that all products selected can meet the specifications without encountering communication or interconnection issues. Furthermore, a KNX bus does not require centralized control. The decentralized structure guarantees the functionality of the system even if one of the devices fails [8-9].

In the buildings, a KNX IP router gathers the measurement data from the various measuring equipment installed in the buildings using the KNX protocol. The KNX IP router transfers the measurements to the Web-GIS platform via a secured REST API [10].

The buildings' dashboard is depicted in Figure 4, whereas Figure 5 presents a reading of Key Performance Indicators for the specific case study.



Figure 4. Initial screen when a building is clicked.

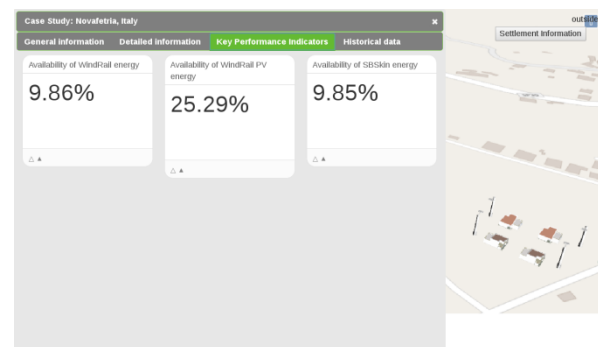


Figure 5. Key Performance Indicators for the case study.

5. The experience of the Italian demonstration case study

Granarolo dell'Emilia, Bologna (Italy) is the location where the first Net Zero Energy Settlement has been built by following the ZP guidelines in temperate Mediterranean climate. The demonstration case study consists of two adjacent single-family villas of about 240 m² gross floor area located into an approximately rectangular ground sub-lot of about 800 m² (Figure 6) [11]. The two villas have been built by the construction company Contedil by implementing the following systems:

- Building integrated energy conservation systems, such as high-performance insulation, smart energy management system and home automation, as well as other advanced envelope components aiming to achieve the first ZP performance objective of 0-20 kWh/m² per year as maximum energy consumption.
- Renewable energy production systems, such as PV panels and energy storage, at both building and settlement level, connected by an integrated energy resources management system to achieve the second ZP performance objective of 50 kWh/m² per year as minimum energy production.

The final configuration of technologies and materials is the result of the ZP design optimization carried out by the case study supporting team (University of Perugia) in collaboration with the construction company Contedil and all technology providers, always respecting the national regulations. Life Cycle Cost (LCC), Life Cycle Analysis (LCA), and numerical simulations have been performed at building and settlement level to achieve the optimal ZP design.



Figure 6. The two demonstration villas in the Italian Net Zero Energy Settlement in Granarolo dell'Emilia, Bologna.

Upon the completion of the construction phase of the two villas, and before their occupancy, building diagnostics and pre-occupancy tests and monitoring were performed by the case study supporting team together with the construction company, with the aim to verify the effective operation of the building envelope, vis-à-vis the design and the simulated performance.

The building diagnostics consisted of a drawings review ('as designed' vs. 'as made'), air permeability test (Figure 7), U-value test (Figure 8), targeted infrared thermography (Figure 9), and co-heating test (Figure 10). The co-heating test was performed by switching on the heating system for a number of days in both villas, taking indoor and outdoor spot air temperature measurements [12].

Pre-occupancy tests consisted of walkthrough survey, short-term indoor/outdoor environmental monitoring (Figure 11-15), and metering/sub-metering (Figure 16). The indoor portable microclimatic stations were equipped with sensors able to measure the following parameters: air temperature, relative humidity, mean radiant temperature, air velocity (turbulence), CO₂ and VOC, vertical radiant asymmetry, and heat flow. The outdoor portable microclimatic station was equipped with sensors able to measure the following parameters: air temperature, relative humidity, surface temperature, wind speed, CO₂, global solar (and reflected) radiation, and light intensity (lux meter).



Figure 7. The Blower-Door test for the air permeability – infiltration - evaluation.



Figure 8. The U-value test for the thermal transmittance and heat flow evaluation.

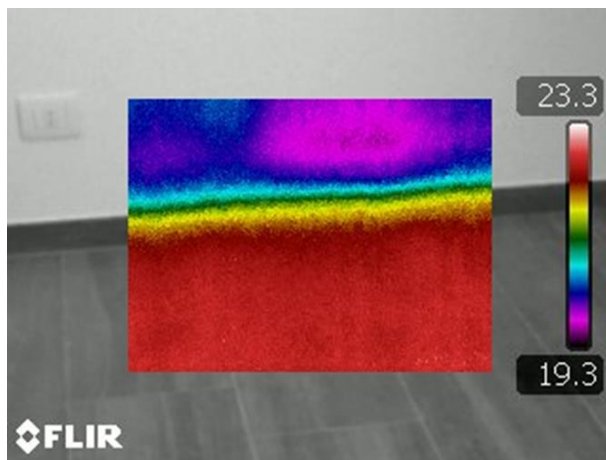


Figure 9. Example of a thermal image made to compare the surface temperature between floor and external wall.



Figure 10. Tinytag probe for indoor air temperature monitoring used during the co-heating test.



Figure 11. Portable microclimatic station for short-term outdoor monitoring located in an open space close to one of the two villas.



Figure 12. Continuous spatial monitoring in the outdoor area of the settlement through an equipped helmet.

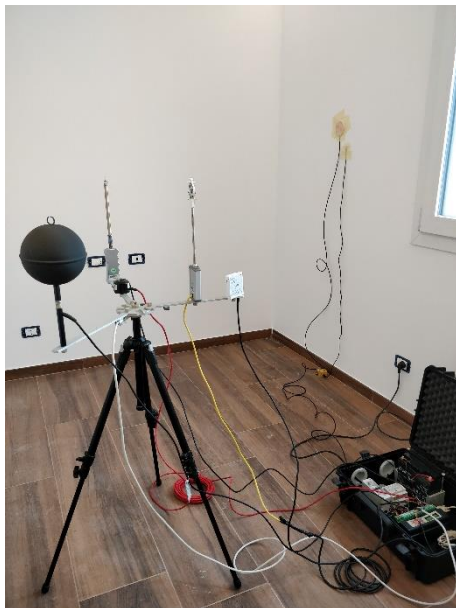


Figure 13. Portable microclimatic station for short-term indoor monitoring located in the middle of a villa's room.



Figure 14. Tinytag probe for indoor air temperature and relative humidity measures used for the short-term monitoring.



Figure 15. Short-term monitoring of the external walls surface temperature performed with Tinytag probes.

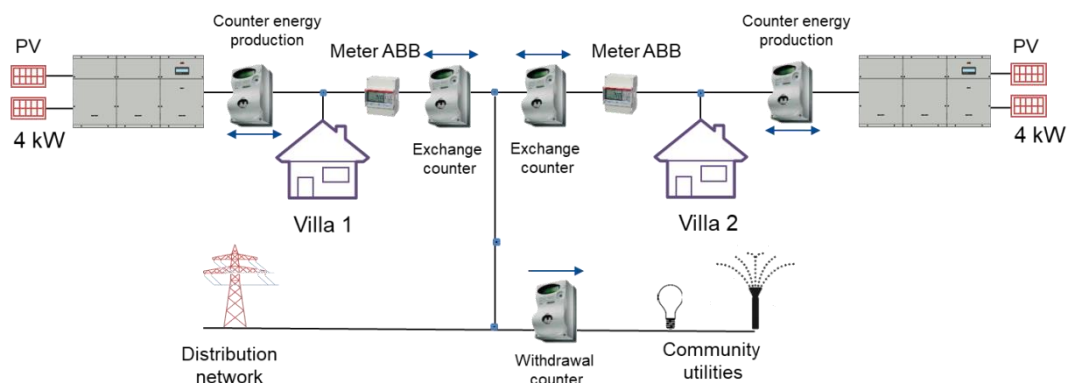


Figure 16. Integrated Smart Energy Resources Management system designed for the Italian NZE settlement showing all metering and sub-metering devices.

The post-occupancy monitoring of the two villas has not started yet and will be performed thanks to a long-term monitoring system integrated within the two villas and in the common areas of the settlement with the aim to verify the performance of the buildings during the use phase. The entire monitoring system will continuously record indoor and outdoor environmental data, energy consumption, and energy production. The monitoring system for the indoor ambient includes sensors for air temperature, relative humidity, CO₂ concentration, door/windows open/close, room presence and luminance (Figure 17 and Figure 18), while for the outdoor ambient a wireless DAVIS vantage pro2 plus meteorological station (Figure 19) is included, installed on a mast in a common space. All the recorded information will be then transmitted by the KNX IP router to the Web-GIS platform that will analyse and visualize the data in a form of report. Access to the report will be provided by using a personal case study account on the Web-GIS platform. The Web-GIS platform will be useful also in

identifying possible sensor malfunction, as well as in generating a 15-day report for problem identification and informing towards predictive maintenance needs.

After one year of continuous monitoring, the real performance in terms of annual energy consumption and annual energy production will be compared with the first two performance objectives of the ZP project.

Furthermore, in order to supplement the environmental monitoring with the occupant's feedback, a comprehensive Post-Occupancy Evaluation (POE) will be carried out in both villas.

Each phase of the project has required a substantial and continuous coordination and collaboration of all interested partners of the consortium ZP. In the next phase, during the POE, the involvement of the villas' owners will be required for the success of the project and to this aim specific informative documents and a dedicated supporting team will be made available.



Figure 17. Air temperature, relative humidity, and CO₂ concentration sensor located in the living room to monitor the air quality.



Figure 18. Room presence and luminance sensor integrated on the ceiling of the living room.



Figure 19. Weather station for climatic data collection by DAVIS.

6. Post-Occupancy Evaluation (POE)

POE is the last stage of diagnostics undertaken once the building user has moved in. Its main purpose is to verify the usability of both building and systems, identify design or behavioural barriers which often cause malfunction, and eventually point to necessary modifications both in the existing building and in future design and construction processes. It comprises both quantitative and qualitative data – spot measurements, surveys, questionnaires administered to building users, statistical analysis of their replies, as well as evaluating their qualitative responses. These last ones need to be carefully registered

by generic groupings on the basis of sex, age, health condition, as well as additional personal attributes, which may affect evaluation of environmental parameters on the basis of subjective needs, evaluation, expectations or cultural dictates and norms [5]. Following are some of the questions to illustrate the details the survey aims at identifying:

- *Sex / Age / Health.* Metabolic differences, or needs, preferences and expectations stemming from age (e.g., babies, older people need a warmer environment) or health condition, may well affect the perception of the indoor environment, thus also change the operational patterns of heating/cooling systems. This, naturally, affects the energy consumption, but may as well create a subjective perception of uncomfortable environment, which projects on both the user's satisfaction and the project's image.

- *Country of origin / If not born in this country, how long have you been living here?* The purpose of these questions is to help clarify climatic adaptation. It should be obvious that the thermal expectations and needs of a person born and raised in a specific environment (e.g., the UK) may be very different from those of a recently arrived immigrant (e.g., from a subtropical region). Thus, the surveys aim at understanding the framework within which specific micro-climatic conditions are identified as comfortable or not [13],[14].

- *Education / Occupation.* Such questions aim at identifying and understanding possible barriers hindering the proper operation of building details (e.g., openable windows, operable shutters) and systems (e.g., thermostats, mechanical ventilation, heat recovery) [15],[16]. Usability is one of the main targets of good design, all the more so in the case of ambitious energy conservation targets such as those of ZP.

Complex as such research may be, the ZP project exacerbates complexity, not least due to different and often contradicting considerations, among them cultural and language specificities in the four distinctly different case studies, both on the national and the socioeconomic background of building users; ethical issues and privacy protection vs. small sample groups; different occupation commencement in the case studies; and many more. Thus, appropriate procedures, protocols, and documents have been prepared and are about to be put in use in the first case study to be lived in (Section 5). Some of these are described below:

- **Informed Consent Form.** Before moving into their ZP home the occupants will be informed about all aspects of the monitoring process and measures taken for the protection of their personal data. This information is included in the informed consent statement and is written in plain language that participants can understand. Once the occupants are certain that they understand these aspects, they are asked to give their written consent at the end of the Informed Consent Form.
- **Welcome Package.** Its purpose is to serve as a non-technical user guide that will introduce the occupants to the innovative technologies and monitoring equipment installed in their residence and the settlement. Each case study owner and/or supporting team is responsible for adjusting the template to the requirements of the respective case study. All documents have been translated from English to the local language (Greek, Italian, and French). Each Welcome Package introduces the Rescue Team for the respective case study. The role of the Rescue Team is to provide clarifications and support to the occupants when required. The Rescue Team is composed of members from the case study owner and case study support team (e.g., academics).
- **POE questionnaire.** This has been translated from English to the other three languages, has been fine tuned for linguistic and cultural specificities, and has been developed in both hard-copy format to be administered by an interviewer, and in a digital format accessible on an Internet site secured via SSL. No logs will be kept in order to avoid any leakage of personal information such as IP address, location etc. No email or other personal information (IP, exact time stamp of participation) will be associated with the answers. Only the consortium partners responsible for the POE will have access to the data using their login credentials. Thus, they can create, edit, and export questionnaires and the responses. In all cases, data will be encoded

to avoid identification of interviewees. The data bank will be password protected to avoid unauthorized access. Once data have been processed and analysed, the original data bank shall be erased/shredded.

Needless to say that all relevant planning, protocols and procedures, and documents are being scrutinized and authorized by the Helsinki Monitor in three countries for each case study – the country of the specific case study (Cyprus, Italy, France, and UK), the country of the institution responsible for this task of the project (Israel), and the country of the project's coordinating institution (Greece). Thus, checks and balances are ensured and maintained.

To ensure a comprehensive understanding of the indoor environment and how it affects the users such surveys have to be carried out under different weather and season conditions.

Finally, the data acquired and processed through the ZP POE task will allow the team to identify potential design, construction, commissioning or building/user interface flaws which will provide correcting feedback at the different project levels, thus ensuring the improvement of principles and practices towards better, usable, environment and user friendly buildings. All this is summarized in the flow chart presented in Figure 20.

7. Summary

This paper attempted to highlight the link still missing from most projects – that of a feedback mechanism aimed at enhancing the learning process in the construction industry. It is obvious that most projects constructed around the world lack such mechanisms for various reasons, among them the obvious lack of appropriate legislation, standards, assessment tools, procedures and protocols, and not least enforcement of these, as well as public awareness. This last component should not be dismissed since it has the power to both allow for the efficient use of buildings, but also to move processes speeding up necessary legislation and implementation. Without a combination of all of these it will be difficult to bring the needed upgrade of one of the most conservative industries.

ZP has undertaken the task of conceiving, designing, building and monitoring a comprehensive energy conserving, usable project incorporating not only efficient building design and systems, but also the appropriate commissioning, diagnostics and monitoring, POE and feeding back into the decision making mechanism the conclusions of all of the above [17]. We look forward to presenting further ongoing results in one of the future papers.

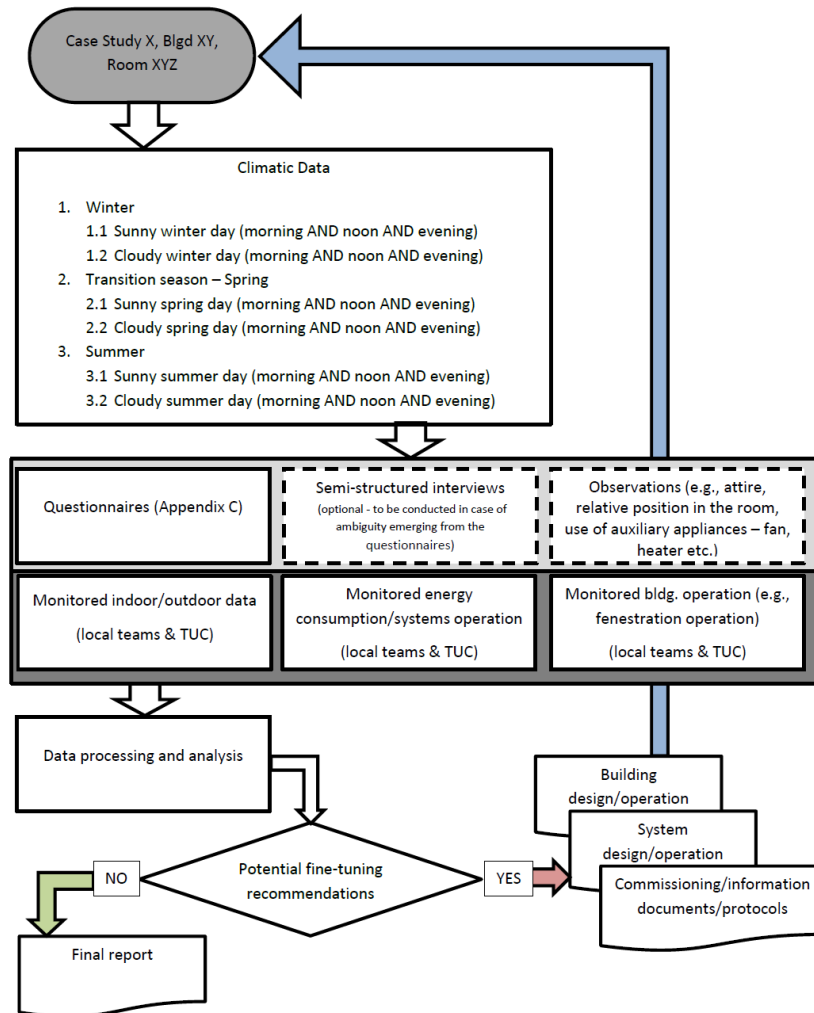


Figure 20. Generic protocol for POE.

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References

- [1] A. Hermelink, S. Schimschar, T. Boermans, L. Pagliano, P.Zangheri, R. Armani, K. Voss, E. Musall (2012) Towards Nearly Zero-Energy Buildings. Definition of Common Principles Under the EPBD. Final report. Ecofys by order of the European Commission, Köln.

- https://ec.europa.eu/energy/sites/ener/files/documents/nzeb_full_report.pdf
- [2] Artopoulos G, Pignatta G, Santamouris M, 2018, 'From the Sum of Near-Zero Energy Buildings to the Whole of a Near-Zero Energy Housing Settlement: The Role of Communal Spaces in Performance-Driven Design', *Architecture_MPS*, vol. 14. 10.14324/111.444.amps.2018v14i3.001
 - [3] Ibid, pp.147-150.
 - [4] M. Santamouris (2016) Achieving near Zero and Positive Energy Settlement in Europe using Advance Energy Technology. Booklets 1-2. National and Kapodistrian University of Athens, Athens. http://www.zeroplus.org/pdf/ZERO-PLUS_Booklet.pdf ; http://www.zeroplus.org/pdf/ZERO-PLUS_Booklet2.pdf
 - [5] I.A. Meir, Y. Garb, D. Jiao, A. Ciclesky (2009) Post-Occupancy Evaluation: An inevitable step towards sustainability. *Advances in Building Energy Research* 3(1): 189-220.
 - [6] Shubin, S., Isaac, S. and Rabinowitz, G. (2017)."Control and optimization tools for the incorporation of innovative technologies in Net Zero Energy settlement design", 34th International Symposium on Automation and Robotics in Construction, Taipei, Taiwan.
 - [7] Mills, E. (2011). Building commissioning: a golden opportunity for reducing energy costs and greenhouse gas emissions in the United States. *Energy Efficiency*, 4(2), 145-173.
 - [8] www.knx.org
 - [9] KNX (2016) A History of KNX. The worldwide Standard for home & building control. https://www.knxuk.org/images/pdf/A_History_of_KNX.pdf
 - [10] Richardson L, Ruby S. (2007) RESTful web services. O'Reilly Media, Boston etc.
 - [11] Pisello, A. L., C. Piselli, G. Pignatta, C. Fabiani, F. Ubertini, F. Cotana, and M. Santamouris. "Net Zero Energy Settlement in Europe: First Findings of the ZEROPLUS Horizon 2020 Project". Proceeding from the 16th CIRIAF National Congress. Assisi, Italy, April 2016
 - [12] G. Bauwens, S. Roels (2014) Co-heating test: a state of the art. *Energy and Buildings*, 82 (2014), pp. 163-172.
 - [13] R.J. de Dear (1998) A global deatabase of thermal comfort field experiments. *ASHRAE Transactions: Symposia* 104, ProQuest Central 1141-1152.
 - [14] M. Fountain, G. Brager, R. de Dear (1996) Expectation in indoor climate control. *Energy and Buildings* 24(3): 179-182.
 - [15] R. Gupta, M. Kapsali (2016) Evaluating the 'as built' performance of an eco-housing development in the UK. *Building Services Engineering Research & Technology* 37(2): 220-242.
 - [16] I.A. Meir, M. Schwartz, Y. Davara, Y. Garb (2018) A window of one's own. A public office building Post-Occupancy Evaluation. *Building Research & Information* 38(1): 1-16.
 - [17] I.A. Meir (1999) "Spreading the Word": Toward a multiple layer program for information dissemination. In Szokolay S. (ed.) *Sustaining the Future: Energy-Ecology-Architecture*. Vol.2, Refereed Papers. Proc. 16th PLEA Int. Conf. (Brisbane, Sept.22-24), PLEA International & Dept. of Architecture, The University of Queensland, Brisbane, pp. 679-686.