Pathways to ZEED

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Abstract. The EPBD, 2010/31/EU directive on the energy performance of buildings, introduces the concept of Nearly Zero-Energy Building (nZEB) supporting the transition towards Zero Energy Emission Districts (ZEED) and potentially transforming cities perspectives in order to reduce human impact on the environment. The EPBD revision in course aims at decarbonising the building stock also taking into account ICT facilities and smart readiness for better knowledge, management, and efficiency both at building and at district level. Most of Italian buildings were built before the 80es' and more than 25% with specific architectural constraints. Thus the transition towards nZEBs could be extremely difficult, owing to the low new construction rate and to the feasibility of single buildings renovation. The main objective of this paper is to investigate whether the nZEBs could be the only pathway in promoting transition towards ZEEDs, or not, and, in the former case, which would be the benefit to promote transition thanks to Energy-efficient Interactive Building.

Keywords: nZEB, Smart Buildings, ZEED

Introduction

Directive EU/31/2010 (EPBD) has introduced the nZEB concept requesting detailed definitions and national nZEB Plans in Member States. In Italy the EPBD transposition was concluded in June 2015[1], providing a new energy performance (EP) calculation methodology, stricter EP minimum requirements (including nZEB requirements), and the rules for taking into account the use of energy from renewables. In Italy a nZEB is «a building characterized by a very high energy performance in which the very low energy demand is significantly covered by renewable sources, produced within the building system boundaries»[2], meaning "on-site" and not also "nearby" as expected in the original EPBD definition.

The Italian Plan for nZEBs (called PanZEB)[3] calls for all new or deeply renovated buildings to be nZEB s from 2021 (2019 if public buildings), but some regions have set earlier targets, notably Lombardy (from 2016) and Emilia Romagna (new public buildings from 2017 and all new others from 2019).

The EPBD is currently being updated as part of the "Clean Energy for All Europeans" package[4].

The upcoming revised EPBD will boost long-term planning of energy efficiency renovations, facilitate access to financial tools, enable public authorities to invest in well-performing buildings and improve monitoring of the building stock performance. Data from EPBD energy certification (EPC) and technical system inspections will be complemented by that available from ICT integration, such as smart metering and building automation and control systems, to guide effective actions.

Smart buildings will be addressed for the first time and a *Smart Readiness Indicator (SRI)* is currently being developed within a study tendered by the European Commission.

Smartness will enable the ability of occupants and the building itself to react to comfort or operational requirements, take part in demand response and contribute to the optimal operation of the different energy systems and district infrastructures to which the building is connected.

The smartness indicator should cover flexibility features, enhanced functionalities and capabilities resulting from more interconnected and built-in intelligent devices being integrated into the conventional technical building systems. It will open to third-party systems such as the electricity grid and district, heating network, electric vehicle infrastructure and demand-response aggregators, aiming at ensuring compatibility in communications, systems control and relevant data or signals transmission[5].

Mobility will be part of the new EPBD prescriptions, encompassing pre-cabling and recharging points for electric vehicles in new parking areas.

The signs for a wider scope that encompasses other elements of the whole energy system were also evident from the European Parliament report of the proposal last October, that suggested «minimum requirements for the overall energy performance of buildings to a whole district instead of to a single building, to allow an integrated approach to the district's energy and mobility system within the scope of a holistic refurbishment scheme»[6].

In Italy, standards for second-generation smart meters for electricity, gas and water have been set in 2016[7]. The Italian main DSO is planning to install 13 million second generation meters by 2019 and another 28 million over a period of 15 years. They will also act as a smart network sensor, enabling continuous grid quality-of-service monitoring, near real-time identification of network faults and renewable micro-generation.

Italian built environment overview

In Europe, urban areas expansion rate is higher than the population growth: in the last twenty years, indeed, there has been a 20% expansion of the building areas against a population growth of only 6%[8]. In Italy a similar urbanization of agricultural lands is not proportional to the population growth that is almost limited, on the contrary. To limit further urban development and the related land-take phenomenon, the achievement of significant energy savings requires the massive renovation of existing buildings. Listed or protected historical centres, that are around 18,000 all over the country (Repellini, 2003), have relevant architectural value and their structure cannot be drastically altered; therefore, improved energy management can be envisaged as an effective alternative solution.

74% of all the residential buildings (more than 12 million totally) were built before the 80's and only 32% of these are in an "excellent" state of preservation[9]. Moreover, it is to be considered that the seismic regulations date back to 1974[10] and the first law for energy savings in buildings dates back to 1976[11].

As for the widespread edification, most of the buildings in Italy consist of single duplex houses, whereas buildings with at least 9 dwellings represent less than 5% of the total.

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Combining nZEBs should lead to ZEED districts, but the Italian urban configuration does not reach the large population density that is the main requirement for a ZEED to be economically sustainable. The largest cities are concentrated on a small area (that represents only 8% of the national territory) which is about 27,000 km² while medium-size cities extend for 1/4 of the Italian area: the rest of the national territory, that is about 67,4%, is occupied by small local housing systems[12].

The Italian territory is also subject to hydrogeological risk: Italian towns with at least one area classified as high hydrogeological risky are 7,145 (i.e. 88% of the total) corresponding to about 15.8% of the Italian territory[8]; that imposes land saving and urban regeneration first, rather than random interventions on single buildings[13].

Since 1992, in the framework of urban regeneration, several Urban Recovery Programs were established[14]; these are public/private integrated programs with a total funding of 10 billion euros assigned to 76 exemplary cases in many cities. A similar initiative should be repeated to rehabilitate districts to updated energy efficiency standards.

In this context we believe Smart buildings are key to achieve ZEEDs where existing building constraints and their density should not allow the single nZEB conversion and the successive transition to ZEED districts.

nZEBs: level of knowledge and diffusion

Apart from few experienced countries with centralised data management systems in place, availability of information on energy performance of the building stock is lacking. The European Commission has launched the *EU Building Stock Observatory* in November 2016, and further efforts to know and act on energy performance progress and notably on nZEBs are ongoing[15]. Actually, even less understanding is available on implementation of ZEEDs in the EU!

Many initiatives are being born to appraise the spread of nZEB in Italy, but data are hardly accessible at the moment and some rough estimates are only available so far (Chiesa, 2017).

Within a research financed by the Ministry of Economic Development in order to monitor and improve national and regional policies, in 2017 ENEA has established a national Observatory, "Osservatorio nazionale nZEB" (Costanzo, 2017), that investigates nZEB number, typology, technologies and their driving factors such as incentives, skills, targeted research and innovation.

nZEB number is growing fast, with a percentage of nZEBs out of total issued energy performance certificates increased by 70% in Lombardy, but also, by average 10%, in other regions where mandatory legislation has not been enforced yet. In the period January 2016 - September 2017, in the four regions (Lombardy, Piedmont, Marche and Abruzzo) firstly analysed in ENEA Observatory, almost 350 nZEBs have been built complying with current standards in force, mostly new and residential buildings (more than 80% of total nZEBs).

As an estimate extended to the whole Country, nZEBs could nowadays count 0.005% of the existing national building stock. In Lombardy the rate of nZEB built in the 2016-2017 biennium is 20% of new built, a good percentage if we consider the licence and construction process scheduling.

Most of censed nZEB show a limited variety of technologies: highly insulated envelope, electric heat pumps (mostly air-water) coupled with a PV system or condensing boiler joined to solar thermal panels for domestic water heating (DWH). Half the cases have mechanical ventilation systems with heat recovery whereas use of DH in urban contexts or biomass systems in urban environments is quite absent.

Installed building automation systems and smart technologies are not trackable through energy performance certificates nowadays. Dimmers for lighting, control for heating, cooling and mechanical ventilation, monitoring and control services are present in the very small sample observed in detail. In the residential sector only some prototype and public buildings take advantage from the installation and operation of control (thermal flow, humidity, temperature) and management systems.

Yet the cost-effectiveness of these systems appears to be interesting. In the tertiary sector building technical control and management systems potential is being explored by ESCOs and aggregators while it is estimated that in the residential sector widespread implementation of demand response can save up to 10-15% of potential grid costs and 10-40% reduction of consumers' electricity bill.

The imminent publication of the nZEB Observatory on the ENEA web should allow expert users to register and feed the database with more details on existing nZEBs, related energy and comfort services (including smart technologies) and impacts.

The main Italian incentives for renovation of private (65% tax deduction scheme) and public buildings (thermal account) "encourage" the installation of intelligent metering and active control systems according to EPBD article 8[2] but initial investment to attain the nZEB standards have produced less than two dozen nZEBs so far[16]. As for multi-family building, the 2017 Financial Law extended the tax deduction scheme to end 2021, increasing the relief to 70-75% for major renovation measures that comply to stricter requirements, notably minimum energy performance of the building envelope towards "deep renovations". In seismic zones, in the case the renovation should result into a lower structural risk the relief is increased to 80-85%, with higher eligible costs limits. A mechanism to promote major renovation in multifamily building-blocks with low-income consumers was also introduced to solve the problem of the initial investment bar-

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rier (Credit transfer). The credit can be transferred to renovation suppliers, to enterprises or organizations, to single persons. Financial institutes are not involved in this mechanism, so far.
Only three are the Italian regions that aim at nZEB standard in their invitation to tender for renovation of public buildings funded by EU Structural funds 2014-2017: anyway the introduction of building automation and control systems are among the eligible measures and their installation will be monitored in the next phase of the ENEA nZEB Observatory.
Finally, national and EU research in Italy is concentrating on cost reduction of nZEBs[17] but results in terms of paybacks and investments are extremely contradictory, going from average 14% additional cost for transforming an existing building into a nZEB (compared to standard deep renovation) to additional investment costs of about 3%, that represent a benefit for the occupants of about 67% of their operational costs, with an economic payback of about 6 years (if analysing the life cycle cost of the investment).

Towards a ZEED example in central Italy

Within the scope of the ZEEDs, the goal is not the achievement of the energy efficiency of the single building but of a network of these, so the problem cannot be addressed only by reducing the energy demand thanks to the adoption of increasingly efficient systems or components, but must be dealt with a wider vision that takes into account the management of buildings and their interaction.
For the new buildings, including nZEB, it is necessary to ensure that the energy supply is synchronized with the actual demand, in order to avoid useless waste that could reduce or nullify the efficiency of systems.
This need is even more urgent for obsolete buildings where, due to the greater energy demand, a gap between demand and supply causes more substantial energy loss.
For this reason, transforming or designing smart buildings can be a first step in achieving the goal of creating zero-energy districts. The starting point is to equip the buildings with sensors, actuation and data transmission systems: a centralized diagnostics and optimization system that allows energy and economic savings with low costs, being mainly based on automation and ICT infrastructure. This approach has become possible on a large scale thanks to new technologies available at increasingly competitive costs, e.g. wireless sensors and IoT platforms.
Considering a network of buildings allows to compare energy behaviours and therefore identify in real time any anomalous trends with the same operating conditions, to understand on which buildings a redevelopment intervention is a priority and more competitive, and finally ensures the verification and maintenance of energy performance of recently renovated buildings.
Generally, considering a network of buildings has the effect of rationalizing and simplifying the management of single buildings, because the supervision function is carried out from a single remote location, reducing operating and maintenance costs. If structured, this supervisory system is able to implement consumption optimization strategies by acting on the control systems installed in the buildings, without penalizing user comfort. Moreover, real time monitoring and knowledge of the real behaviour of buildings allows developing predictive models of demand, allowing to reduce loads in cases where it is requested by the energy supplier both for emergency reasons and because a possible reduction of the request for energy concurrently with anticipated peaks can be rewarded by the same supplier. The ad-

vantages of this management are reflected both on the supplier that ensures greater system security and lower infrastructure costs, and on users, who are guaranteed with lower costs, thanks to the possibility of choosing to consume energy when it costs less, reduce the power used, accumulate or generate energy on their own.

ENEA, at its Research Centre in the north of Rome, has realized a network of 10 smart buildings with a total area of about 10,000 square meters (Clerici et al., 2015) (Fig 1).

These buildings have been equipped with sensors, implementation systems and data transmission for real time communication with the supervision system that is able to monitor consumption, diagnose and report malfunctions, identify incorrect behaviour of users, optimize the energy consumption of end users (air conditioning, lighting) in relation to a series of targets such as comfort, energy saving, energy expenditure and maintenance. Different levels of monitoring and control details have been adopted in these buildings, which correspond to a different number of installed instruments and costs:

- at the building level, the total electrical energy and the fraction for lighting, the driving force and the fans are monitored. Also in the HVAC plant, the electrical energy absorbed by the various components, as well as the thermal energy, is accounted.
- At zone level, electricity is monitored separately for different end uses. In this case the lights and the fans can be controlled remotely by operating the switchgear and disabling the lines in the absence of personnel.
- At the single room level, sensors, thermostats and infrared motion detectors have been installed. At this level the set point of the thermostats can be controlled according to the presence of the occupants and the external climatic conditions, while, thanks to the presence of the installed sensors, the lights are switched off in the absence of the user or sufficient ambient light level.

The control logics tested in the demonstration realized in Casaccia refer to two strategies:

- Energy on Demand: Provide the energy at the time and place where it is required, avoiding unnecessary waste (e.g. operation and ignition of plants outside of working hours).
- Optimization: Adaptive control that allows to modulate the energy demand over time in view of the variation of multiple parameters, i.e. weather, actual presence of people, any variations in the cost of the energy carrier, without sacrificing user comfort.

It has been found that the achievable saving coefficient is influenced by the following factors:

- level of control and energy performance of the original building
- behaviour of the user
- percentage of incidence of controlled uses on general consumption.

In fact, the savings coefficients are higher if the intervention is carried out on more obsolete buildings without any control system, where users have not developed their own energy awareness.

In relation to the general consumption of buildings, from the experimentation conducted, it was found that a more punctual control (at the single room level) corresponded to more substantial savings around 35%, while management at the zone level (at the level of a single electrical cabinet) or the entire building savings are reduced to less than 20%.

In general, in order to quantify the contribution to active energy efficiency from the management and control of technical building systems (such as: heating, air conditioning and lighting) we can refer to the standard UNI EN15232[18]. The standard establishes the potential savings in thermal and electrical energy that can be achieved through the introduction of specific automation functions of the plants, indicated by the standard itself, belonging to a higher class of energy efficiency (A, B, C).

The standard deals with the assessment defining "a priori" the types of intervention on the automation devices rather than on the overall intelligence of the system.

The analysis of the implemented methods can be transferred to buildings network, with particular reference to the tertiary ones (offices, schools, business centres, public agencies).

Conclusions

A high rate of energy consumption is due to unpredicted and unmetered uses. Where other solutions are not possible or too expensive, acting on such consumption component is a valuable alternative to transition towards ZEEDs.

Smart buildings are not a requirement of the present EPBD but the legislative and regulatory context is changing, opening the way to integration of the wider energy system level.

In the long term, an assessment for smartness may be integrated with the assessment for energy performance in the Energy Performance Certificates. New tools (e.g. smart metering, building automation and control systems, Smart Building Network, Smart Home Network, …) and pricing systems, financing models, new technologies for smart energy districts are now requested by, and rapidly penetrating, the markets.

There is an emerging tendency among consumers to invest in smart innovative services (assisted living, demand-response, energy consumption optimization) and private energy generation. Disruptive change is expected from the technology sector that will probably lead the way, provided it is accompanied by a prompt legislative adaptation to the new EU provisions.

Smart Buildings will propose an innovative architecture for the energy management of the building that takes into account its operating conditions and the surrounding energy system. In perspective, a new generation of smart buildings, energy-efficient interactive buildings, will play a key role in the energy balance of the network system, optimizing its energy management, interacting with the network, providing flexibility of its energy demand and optimizing the availability of renewables and taking advantage of local or distributed storage. This is in our opinion a valuable alternative to pave the pathway towards ZEEB.

NOTES

[1] Interministerial decree 26th June 2015 - "Minimum requirements of Energy Performance in Buildings".

[2] Law n. 90/2013, converting Decree 63/2013 "Transposition of Directive 2010/31/UE on Energy Performance of Buildings (Official Journal of the Italian Republic, general n.181, August 2013).

[3] "Piano d'azione nazionale per incrementare gli edifici a energia quasi zero (PAnZEB- National action plan to increase nZEBs)", approved by the interministerial Decree 19 June 2017.

[4] COM/2016/0765 final: Proposal for a directive of the European parliament and of the Council amending Directive 2010/31/EU on the energy performance of buildings. Last 19th December a political agreement has been reached between the European Parliament, the Council and the Commission and its publication is imminent.

[5] https://smartreadinessindicator.eu/.

[6] (COM(2017)0660 - C8-0394/2017 - 2017/0294(COD)) Committee on Industry, Research and Energy.

[7] Authority for electricity, gas and water, Deliberation 87/2016.

[8] Minutolo, A. and Zampetti, G. (2017), *Ecosistema Rischio, Monitoraggio sulle attività delle amministrazioni comunali per la mitigazione del rischio idrogeologico*, Legambiente.

[9] Annuario statistico italiano - dati 2017.

[10] Law No. 64/1974 National seismic regulations.

[11] Law 373/1976 "Regulations to limit energy consumption for building space heating".

[12] "Forme, livelli e dinamiche dell'urbanizzazione in Italia", 2017- ISTAT.

[13] As suggested in the DDL (project of Law) No. 2039 (2014) "Containment of land consumption and reuse of built land".

[14] Law N. 179/1992 (art. 16), and Law 493/93.

[15] Building Stock Observatory 2017 update and "Comprehensive study of building energy renovation activities and the uptake of nearly zero energy buildings in the EU" (2017/S 192-392561), in course.

[16] Tax deductions (relief) introduced by the Italian 2007 Financial Law, are key drivers of energy efficiency improvements in the housing sector. They consist of 65%-75% reductions of IRPEF (personal income tax) and IRES (corporate income tax) granted to cover expenses incurred for the overall energy performance upgrade of the building, major and minor renovations, including installation of BACS. 32 Billion EUR investments stimulated so far (from 2007) and 3,3 Billion EUR investments in 2016, amounting to nearly 0,10 Mtoe/year savings in 2016. 360,000 eligible applications for 65% tax deductions received in 2016.

[17] National studies: RdS PAR 2015 reports 120-121-122, Edifici a energia quasi zero (nZEB), Project D.2.1: Research on energy renovation of public building (public schools, hospitals, office buildings), Report RdS/PAR2013/114 (2014) and Chiesa, V. et al. (2017), *Energy Efficiency Report*, Polytechnic of Milan, EU H2020 Call EE-13-2016-2017 - Cost reduction of New nZEBs, CON-ZEBs and A-ZEB projects.

[18] European standard EN 15232-1:2017 on "Energy efficiency in buildings - Influence of Building Automation and Control and Building Management".

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