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Abstract—**This work analyzes the results of a monitoring campaign on seventeen nZEBs which was promoted by the Piedmont Region. The analysis of these buildings, distributed throughout the Piedmont territory, has allowed the verification of energy performances of the nZEBs, as well as the requirements of space heating and domestic hot water systems and the efficiencies of technologies that boost renewable energy sources. This analysis highlighted the advantages and criticalities of these buildings in terms of energy consumption, outlining a starting scenario for future incentive campaigns and new energy transition strategies. Not always the most used technologies for the building envelope or for the systems are the optimal choices; designers should choose the systems that works better for a certain building envelope taking into account how the building will be used, the winter and summer climatic conditions but also the solar exposure and the availability of other renewable energy sources.**

I. Introduction

In the northern part of Italy, the particular morphology of the Po valley, surrounded by the Alps where the 98 % of the piedmont population lives, determines critical air quality conditions, especially in its west side. A great impact about this environmental condition is given by the energy production for civil and transport sectors. In particular, the energy-uses related to space heating and cooling, domestic hot water, lighting and electrical appliances contribute significantly at these critical conditions and then should be reduced.

In Italy, the first Energy Performance Building Directive (EPBD, 2002/91/EC) was implemented with the Decree 192/2005; then, with the Ministerial Decree June 15th 2015 (DM 26/6/2015) it was updated to be compliant with the EPBD2 (2010/31/EU) in 2013 and the minimum performance standard and technical rules were tightened. In this Decree it was introduced the requirements of nearly Zero Energy Building (nZEB) and the obligation for new buildings to be nZEB from January 2019 for public buildings and from January 2021 for all others.

Also Piedmont Region, took some actions to reduce energy consumptions and pollutant emissions. With the application of the EPBD2 mentioned above and among the initiatives undertaken, the Piedmont Region has encouraged the creation of nZEBs in order to be able to monitor the real energy performance of these buildings. This initiative was called "Contributions for nearly zero energy buildings" (in Italian: D.D. 25/7/2011 n. 160, Legge Regionale 7/10/2002 n. 23 - Approvazione del "Bando regionale per la concessione di contributi per la realizzazione di edifici a energia quasi zero" e della modulistica relativa, in Italian).

In 2011 with this initiative, the Piedmont Region proves active towards the sustainable development of its territory through the realization of nZEBs, a starting point for the future energy efficient buildings. Moreover, the analysis of the characteristics of these real buildings highlights aspects on typical sustainable designs and critical issues on monitoring energy efficiency.

The buildings eligible for tender, had to prove very low thermal energy needs for space heating, space cooling and domestic hot water; also electrical energy for appliances and lighting was considered. It was mandatory for these buildings to meet the following minimum requirements:

- Energy need for space heating: $Q_{H,nd}/S \leq 15$ kWh/m^2/year.
- Energy need for space cooling: $Q_{C,nd}/S \leq 10$ kWh/m^2/year.
- Primary energy from renewable energy sources (RES): $EP_{tot,res}/EP_{tot} \geq 50\%$.

The energy needs $Q_{H,nd}$ and $Q_{C,nd}$ can be reached with an accurate design of the envelope of a building mainly limiting the heat loss by transmission and ventilation and controlling the solar contributions through shading devices. The third requirement considers the use of RES and efficient technologies to control the total primary energy of the building EP (considering space heating, space cooling, domestic hot water and lighting).

In this work the results of the monitoring campaigns of seventeen nZEBs are analysed comparing their design and real energy performances; this analysis starts from a previous research [1]. After an introduction to nZEB with a state of art paragraph, the case study of 17 nZEBs is presented with the analysis of measured and calculated data to evaluate their real energy performance.

II. STATE OF ART

A first definition of nZEB was hypotized after the energy crisis of the 1970s. In 1977, Esbensen & Korsgaard designed "zero-heating buildings" to face the problem of rising oil costs [2]. They described nZEB as "self-sufficient in heating and hot water production, insulated constructions equipped with heat-recovery and solar heating systems". More recently, many actions and regulations for better energy performance of buildings were achieved. In 2001 Parker et al. [3] introduced a new definition of nZEB, paying particular attention to the ability of these buildings "to generate their own power and guarantee to the users the right energy supply throughout the year". Furthermore, in 2008, in the International Energy Agency (IEA) report "'Towards Net Zero Energy Solar Building", Laustsen [4] promptly specified the non-use of fossil resources. However, nZEB acronym was officially introduced with the European Directive EPBD2 in 2010 within the strategies for a sustainable development; the nZEB was defined as “a building with very high energy performance. The very low or almost zero energy requirement should be covered very significantly by energy from renewable sources, including energy from RES produced locally or nearby".

The European Union did not give a univocal definition of nearly Zero Energy Building so as to delegate the member states on the basis of local specificities. Therefore, in Italy the referring legislation about nZEB is the Decree 26/6/2015 on minimal requirements for buildings (“Decreto Requisiti Minimi” in Italian) and the Decree 28/2011 on the use of renewable energy sources [5]. In this context it would be important to also consider the environmental impact of building materials and technologies in order to assess the impact of a building throughout its life cycle. For example, the use of bio-compatible local materials with high energy performance could really increase the sustainability of the buildings sector.

III. CASE STUDY

Twenty-five buildings were financed through the call for tenders from the Piedmont Region “Contributions for nearly zero energy buildings” and in this work we have chosen to analyze only seventeen buildings with complete data about design characteristics and monitoring campaigns. In Figure 1 it is possible to observe that nZEBs are located in small municipalities, mainly in the provinces of Cuneo, Torino, and Novara. The characteristics of these buildings, single-family residential houses, have been reported in Table 1. On average, they are located at an altitude of 378 m a.s.l. in plain areas, have a gross heated volume of 905 m^3, a useful heated area equal to 220 m^2 and a surface to volume ratio of 0.77 m^2/m^3.

The buildings were classified by the old regional energy performance certification adopting the evaluation index $EP_{L,TO}$ (energy performance index for space heating and domestic hot water for the city of Torino) and they were all in class A (D.G.R. August 4th 2009, n. 43-11965 Legge regionale 28 maggio 2007, n. 13 "Disposizioni in materia di rendimento energetico nell'edilizia", in Italian).

From Table 1, the energy performance of the 17-nZEB in Piedmont can be highlighted by their characteristics listed below:

- High level of thermal insulation of the opaque envelope with thermal transmittances $U_{op} \approx 0.15$ W/m^2/K; this value is about half that indicated by the Decree 26/6/2015 (0.20-0.26 W/m^2/K).
- High level of thermal insulation of the transparent envelope with triple glazing with $U_w \approx 1.0$ W/m^2/K and shading devices; this value is lower than the standard value of 1.4-1.6 W/m^2/K.
- Installation of a mechanical ventilation system with heat recovery and, possibly, a geothermal pre-heating and pre-cooling system.
- Production of thermal energy from renewable sources: solar thermal (ST) collectors for the production of domestic hot water (DHW) and a heat pump to supply energy for both heating and cooling seasons; the recurrent solution adopted is a combined system with an air-water heat pump (HP) associated with solar collectors and a low temperature emission system, like a radiant floor (RF).
- Contribution of the photovoltaic (PV) modules to supply the heat pump powered by electricity and other electrical appliances.
- Installation of a monitoring system.

Figure 1 – 17 nZEBs financed by Piedmont Region (D.D. 25/7/2011 n. 160: http://www.bandopiemontequasizero.it/zeb_81_94.html).

IV. METHODOLOGY AND RESULTS

The monitoring data were provided monthly in Excel sheets by the buildings’ owners, as required by the D.D. 25/7/2011 n. 160 to access to the regional incentives. These monitored data, together with design data, were used in this work to describe the real energy performance of nZEBs.

In particular, the following monitored data were useful for defining the monthly energy consumptions (in Figure 2):

- Global energy consumption for space heating, cooling, hot water production and electric appliances: Q_{in}
- Energy consumption of the heat pump (HP): $Q_{G,in}$
- Energy consumption of electric appliances and artificial lighting (App): Q_{App}
- Energy provided by the heat pump (HP): Q_{HP}
- Energy produced by photovoltaic modules (PV): Q_{PV}
- Energy produced by solar thermal collectors (ST): Q_{ST}.

In Figure 2 the variables used in this analysis are represented: measured data in red, data obtained by the design report in blue and calculated data in green. Climate data were provided by the nearest weather station with similar altitude.

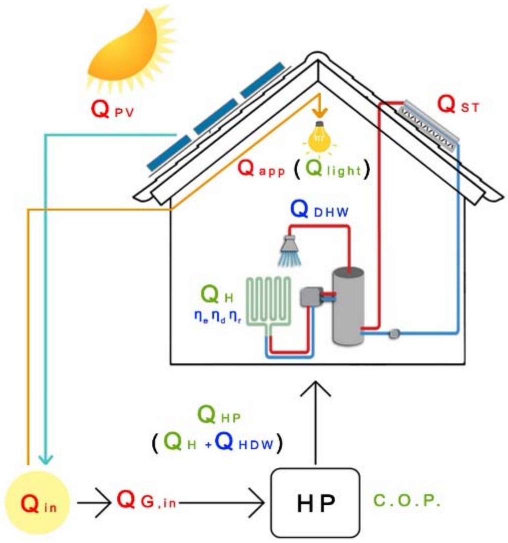

Figure 2 – nZEB house functional features scheme: measured parameters (red), design parameters (blue), calculated parameters (green).

TABLE I. DESIGN DATA OF THE NZEBS ANALYZED

nZEB	HDD		V [m³]	S/V [m⁻¹]	Uop [W/m²/K]	Uw [W/m²/K]	Emission system	Service	HP power [kW]	Type of HP	COP	PV power [kW]	ST area [m²]	Monitoring campaigns	
	DPR 412/93	UNI 10349:2016 at 20°C												years	HDD at 20°C
1	2613	2607	665.3	0.74	0.17	0.883	RF	H+DHW	6.84	A-W	3.35	4.4	4.2	2014	2283
2	2850	2772	1002.6	0.73	0.131	0.693	RF	H+DHW	12.30	A-W	3.40	3.4	5.8	2015-16	2981-3047
3	2650	2965	607.5	0.74	0.149	0.880	Split	H+DHW	10	A-A	3.60	4.0	4.7	2014-15	2843-3066
4	2536	2989	1028.7	0.81	0.175	0.952	RF	H+DHW	6	A-W	3.25	6.0	7.5	2014	2743
5	2802	2869	686.6	0.85	0.151	1.238	RF	H+DHW	6	A-W	3.40	4.5	7.8	2015-16	3176-3268
6	2862	2918	1104.8	0.72	0.150	0.633	RF	H+DHW	11.20	A-W	3.60	8.0	12.0	2015	3176
7	2589	2893	735.6	0.79	0.119	0.710	RF	H+DHW	6.31	A-W	3.50	5.0	7.5	2014-15	2283-2428
8	3467	3176	620.3	0.89	0.157	0.939	RF	H+DHW	6	A-W	3.20	3.5	15.0	2015-16	3190-3321
9	2741	2684	1027.8	0.73	0.156	0.832	Split	H	6.10	A-A	3.50	6.0	6.9	2014-16	2675-2916
10	2828	2754	986.9	0.74	0.152	0.938	Split	H	7.28	A-A	3.35	6.5	9.3	2015	2981
11	2728	2670	948.6	0.70	0.206	1.022	RF	H+DHW	16	A-W	3.55	3.0	5.0	2017	3262
12	2728	2670	1256.5	0.68	0.113	1.258	RF	H+DHW	8.3	A-W	3.55	6.24	7.5	2017	3262
13	2640	2735	944.4	0.74	0.164	1.162	RF	H+DHW	6	A-W	4.46	5.35	5.0	2016-17	3192-3221
14	2782	2718	1162.5	0.84	0.116	1.300	RF	H+DHW	16.70	A-W	3.94	4.2	25.0	2015-16-17	2981-3047-3041
15	2725	2801	664.6	0.70	0.147	0.980	RF	H+DHW	13.72	A-W	4.37	2.8	10.0	2016	2688
16	2647	2723	909.3	0.80	0.150	0.965	RF	H+DHW	11.60	A-W	3.30	6.4	12.5	2015-16-17	2981-3047-3041
17	3062	2919	672.2	0.70	0.149	1.107	RF	H+DHW	16.05	A-W	4.47	4.5	9.4	2016	3239

For each building, due to a lack of the monitored data, it was possible to verify only two of the three requirements defined by the regional tender: the energy need for space heating ($Q_{H,nd}/S \leq 15$ kWh/m²/year) and energy production from renewable sources ($EP_{res}/EP_{tot} \geq 50\%$); no building has provided consumption data for space cooling.

Climate and morphological components of the Piedmont Region can strongly influence and characterize the energy performance of buildings, reason why energy consumptions were normalized with respect to the local weather conditions. The normalization considers the heating degree days at 20°C (HDD) provided by DPR 412/93 and the HDD registered by the weather stations.

In this analysis the semi stationary evaluation (monthly based) was used to measure the energy performance of nZEB comparing also the estimates made in the design phase.

A. *Verification of the first requirement: low energy consumption for heating service $Q_{H,nd}/S \leq 15$ kWh/m²/y*

The calculation related to the space heating need was carried out starting from the analysis of the monitoring data, related to the external temperatures and envelope characteristics, like the dispersing surface of the nZEB. This allowed studying the possible causes behind the inconsistencies found with respect to the design data.

The space heating need $Q_{H,nd}$ was calculated from the energy provided by the heat pump Q_{HP} for space heating and domestic hot water services. The Q_{DHW} was calculated from the design variables knowing the useful heated area S_u of residential buildings with the Italian Standard UNI/TS 11300-2:2019 "Energy performance of buildings – Part 2". The same standard was used also to estimate di efficiencies (η) of the space heating and domestic hot water systems [6].

The consumption data were acquired monthly and represented using the energy signatures of each building represented in Figure 3; in detail, the specific daily energy consumption was reported as a function of the average monthly outdoor temperatures. It is possible to make some observations on the matter to the slope of the energy signatures that depend by heat dispersions and systems losses; a slight slope represents an adequate level of thermal insulation of the building envelope and a good efficiency of the heating system.

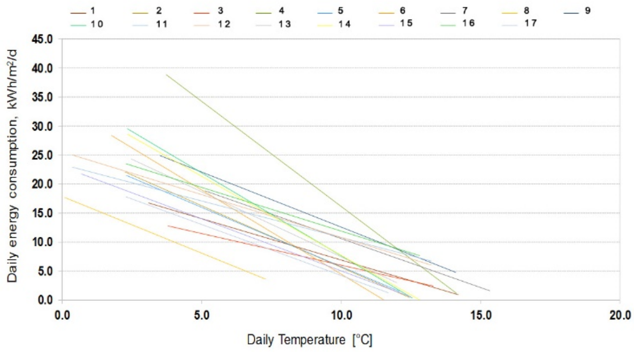

Figure 3 – Representation of the energy signatures of the 17 nZEBs.

Furthermore, as shown in Table III, it's possible to observe a correlation between the nZEBs that result not comply with the requirement for space heating $Q_{H,nd}/S_u \leq 15$ kWh/m²/y and the average thermal transmittance (U) of opaque and transparent surfaces, as well as to geometric characteristics of the building, in particular the surface to volume ratio S/V, and the HDD registered in the monitored heating season.

TABLE III. CORRELATIONS BETWEEN ENVELOPE'S CHARACTERISTICS AND YEARLY $Q_{H,ND}$ (FOR 1 AND 2 HEATING SEASONS) OF THE NZEBS

nZEB	$Q_{H,nd}$ m1 kWh/m²/y (HDD at 20°C)	$Q_{H,nd}$ m2 kWh/m²/y (HDD at 20°C)	$Q_{H,nd}$ m3 kWh/m²/y (HDD at 20°C)	S/V m²/m³	Uw W/m²/K	Uop W/m²/K
1	14.89 (2283)			0.74	0.883	0.17
2	11.80 (2981)	11.14 (3047)		0.73	0.693	0.131
3	13.77 (2843)	12.60 (3066)		0.74	0.880	0.149
4	17.72 (2743)			0.81	0.952	0.175
5	14.42 (3176)	16.70 (3268)		0.85	1.238	0.151
6	14.24 (3176)			0.72	0.633	0.150
7	15.17 (2283)	14.76 (2428)		0.79	0.710	0.119
8	15.26 (3190)	16.79 (3321)		0.89	0.939	0.157
9	16.07 (2675)	18.00 (2916)		0.73	0.832	0.156
10	13.02 (2981)			0.74	0.938	0.152
11	11.40 (3262)			0.70	1.022	0.206
12	11.43 (3321)			0.68	1.258	0.113
13	12.79 (3262)	12.35 (3221)		0.74	1.162	0.164
14	10.83 (2981)	10.73 (3047)	14.0 (3041)	0.84	1.300	0.116
15	14.66 (2688)			0.70	0.980	0.147
16	16.61 (2981)	18.30 (3047)	18.94 (3041)	0.80	0.965	0.150
17	14.84 (3239)			0.70	1.107	0.149
Average				0.76	0.97	0.15

For the nZEBs 4, 5, 8, 9 and 16 with a $Q_{H,nd}/S_u$ upper than the limit, higher values of thermal transmittance and surface to volume ratio were reported. A high surface/volume ratio implies a higher quota of dispersing surface and therefore a consequent unfavorable geometric shape.

The results of space heating requirement are summarized in the Table IV. It regards the 17 buildings for which it was possible to analyze, punctually, the monitoring data. It is possible to observe that the percentage error is around an average percentage value of 20%. And only for 3 nZEBs the monitored energy is minor than the design value. Moreover, for nZEBs 4, 9 and 16, in which the requirement $Q_{H,nd}/S$ was not respected, higher errors can be observed.

TABLE IV. COMPARISON BETWEEN DESIGN "D" AND MONITORED "M" DATA OF HEATING ENERGY DEMAND

nZEB	$(Q_{H,nd}/S_u)_d$ [kWh/m2/y]	$(Q_{H,nd}/S_u)_{m1}$ [kWh/m2/y]	$(Q_{H,nd}/S_u)_{m2}$ [kWh/m2/y]	$(Q_{H,nd}/S_u)_{m3}$ [kWh/m2/y]	Relative error [%]
1	13.34	14.89			12%
2	12.74	11.80	11.14		-(8-13)%
3	11.61	13.77	12.60		9-19%
4	9.84	17.72			80%
5	14.04	14.42	16.70		3-19%
6	10.80	14.24			32%
7	13.18	15.17	14.76		12-15%
8	13.37	15.26	16.79		12%
9	10.51	16.07	18.00		53-71%
10	12.02	13.02			8%
11	12.20	11.40			-11%
12	12.86	11.43			-11%
13	12.25	12.79	12.35		1-4%
14	13.40	10.83	10.73	14.00	±(4-20)%
15	14.15	14.66			4%
16	14.40	16.61	18.30	18.94	15-32%
17	9.79	14.84			52%

In Figure 4 the comparison between the design and measured data of $Q_{H,nd}$, show a similar trend, but measured data are relatively higher than the design ones. It is also important to consider that with such small energy requirements, errors of 52% as for the nZEB n.17, correspond to differences of just 5 kW/m^2/y; also the different climatic conditions should be taken into account.

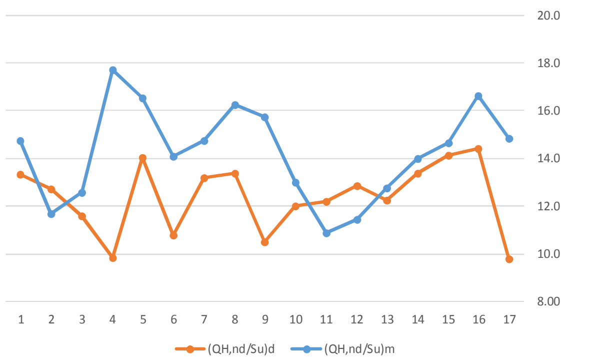

Figure 4 – Comparison between $Q_{H,nd}/S_u$ design "d" and monitored "m".

The analyzes conducted on the nZEBs included also the evaluation of the monthly coefficient of performance COP and the relative seasonal performance factor (SPF) got from the monitoring data; COP was calculated by the ratio between the thermal energy supplied and the electricity absorbed by the heat pump. The results obtained (in Table V) show that the seasonal performance factors (SPFs) of the COP are slightly lower than the minimum value of 2.875 (considering a transformation efficiency from primary energy to electrical energy of 0.4, from the Directive 2018/2001/EU on renewable energy sources). Comparing these results with the design values reported in Table 1, some inefficiencies of the heat pump with low values of SPF can be noticed (especially in localities at higher altitudes). These results are more evident on a monthly period with low COP with low outdoor air temperatures, high relative humidity and the presence of frost in the outside unit. This result can be observed also in Fig. 5.

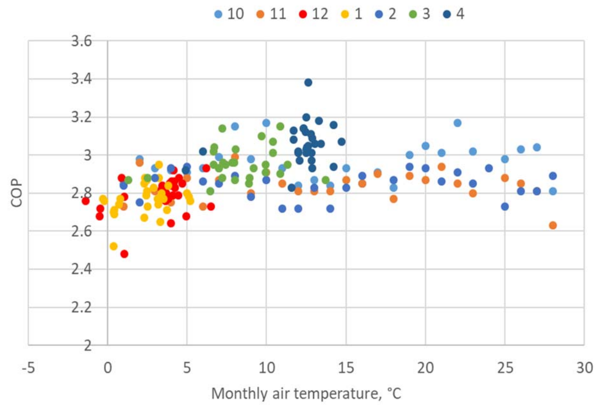

Figure 5 – Monthly COP values calculated from $Q_{G,in}$ and Q_{HP} data.

B. *Primary energy production by renewables sources: $EP_{tot,ren}/EP_{tot} \geq 50\%$.*

Among the requests made in the call, there was the obligation to use energy produced from renewable sources to meet at least 50% of the primary energy for space heating, domestic hot water and artificial lighting. To calculate the primary energy the conversion factor for electric energy $f_{p,el}$ was applied to the energy supplied ($f_{p,el}$ =2.18 in 2011 and 2.42 today with 0.47 of renewable). The primary energy for artificial lighting was deduced by the energy consumed by the electrical appliances as its 10% [7, 8].

For all the nZEBs solar thermal collectors and photovoltaic modules were installed to support the heat pump. Table V shows the electric and thermal capacity in relation to the annual solar irradiance registered by the weather stations. With the exception of the nZEB n.8, the solar irradiance increase with the altitude, where the heating demand is also higher. For each month, only the used quota of the energy produced by PV and ST was considered; on average the 30-50% of energy produced by PV modules and almost all (85-100%) by ST collectors.

TABLE V. FEATURES OF PV, ST AND HP SYSTEMS OF THE 17 NZEB

nZEB	Solar irradiance [kWh/m^2/y]	Altitude [m a. s.l.]	PV power [kW]	Q_{PV} [kWh/y]	ST area [m^2]	Q_{ST} [kWh/y]	(SPF) COP
1	1407	237	4.4	10394	4.2	1554	2.86
2	1412	431	3.4	6529-5613	5.8	1180-1300	2.89
3	1397	266	4.0	5646-6143	4.6	1295-1850	2.89
4	1390	289	6.0	10606	7.5	2912	2.85
5	1436	520	4.5	7619	7.8	3138	2.89
6	1445	**574**	8.0	5702	12.0	4145	2.84
7	1388	420	5.0	5582-4353	7.5	2160-1974	2.90
8	1356	**742**	3.5	3654-4115	15.0	2104-3489	2.85
9	1402	345	6.0	5028-5906	6.9	3351-3732	2.86
10	1405	414	6.5	5028	9.3	4146	2.91
11	1362	247	3.0	6644	5.0	3533	2.92
12	1362	247	6.24	6687	7.5	1801	2.76
13	1407	395	5.35	7992-8284	5.0	2535-2397	2.94
14	1407	378	4.2	12549-13163-10768	25.0	4582-3380-5192	2.92
15	1408	289	2.88	5613	10.0	2956	2.96
16	1407	383	6.4	-	12.5	2440-2641-2346	2.94
17	1396	**575**	16.5	6220	3.4	2111	2.87

The verification on energy supply (QP) to the nZEBs refers to the sum of the renewable and non-renewable quota:

$QP_{tot} = QP_{res} + QP_{tot,\,nres}$.

To have the primary energy, these two components were multiplied by the energy conversion factor of primary electric energy $f_{p,el}$: 2.18 in 2011 (the coefficient used in this work) and 2.42 today (with a quota of 0.47 from renewable).

Table VI shows the results of the renewable energy share and the comparison between measured value and the design ones. It can be said that this requirement is not satisfied only for buildings 2, 3 and 15; the energy requirement from renewable sources it has been almost reached. The problem is the relative difference between the monitored and design data which is clearly high, equal in average at 25%. Indeed, the renewable energy share was overestimated in the design phase, according to the characteristics of the installed systems. The measurements showed a lower energy production by RES through the energy recovered from the external unit of the heat pump ($Q_{G,in}$ - Q_{HP}) and the energy produced by the PV modules and the ST collectors, in relation also to the exposition of the building's roof area. In Figure 5 it is possible to observe the COP values registered from measured monthly data ($Q_{HP}/Q_{G,in}$); lower values of COP were registered in the coldest months with temperatures under 5 °C, resulting also in little energy recovered from the HP external unit.

TABLE VI. SECOND REQUIREMENT FOR ENERGY COVERAGE OF 50% FROM RENEWABLE ENERGY SOURCES MET BY 17 MONITORED NZEB.

nZEB	$EP_{res}/EP_{tot}\|_d$	$EP_{res}/EP_{tot}\|_m$	Relative error
1	75.19%	53.8%	28%
2	71.95%	51.8% - 49.34%	31%
3	77.81%	48.50% - 50.0%	37%
4	55.63%	50.89%	8.5%
5	70.30%	53.85% - 52.77%	25%
6	55.91%	50.0%	10%
7	72.74%	53.04% - 54.51%	27%
8	56.55%	52.0% - 50.24%	11%
9	59.13%	53.2% - 50.2%	13%
10	62.69%	52.24%	17%
11	64.85%	58.92%	9%
12	73.40%	51.59%	29%
13	70.30%	53.7% - 56.07%	21%
14	69%	56.48% - 55.31% - 50.93%	21%
15	69.43%	48.69%	30%
16	75.20%	-	-
17	70%	51.40%	26%

V. DISCUSSION

A. nZEB in Italy can be done (from a technical/economic feasibility point of view) and work well

Due to the crisis of the residential buildings market, a very little number of new buildings were constructed between 2013 and 2018, from 20,000 in 2008 to 6,000. The reduced market demand forced the few building companies that survived the crisis to improve the standards before the regulation deadline.

In Italy, at approximately the same construction cost a wise building company can offer a more interesting nZEB (energy class A4) high performance building which buyer can compare with a barely legal A1 building. Lower consumption, high comfort levels, domotics and innovative thermal and service plants are strong selling points for a new generation of buildings. Sustainability, comfort and low running costs are the key values of the market proposal.

This study on Italian nZEBs, is an analysis of the current operating conditions and system efficiencies, but besides some critical factors were identified. The requirements imposed by the Piedmont Region were almost achieved by all nZEBs and this shows that low consumption buildings can be built and work well. Furthermore, the technologies used have been on the market for a long time and therefore work quite well and at reasonable costs. The choice of casing the envelope technologies and the technological systems are a choice that must be studied case by case even depending on the context in which a building is inserted and the climate characteristics of the area.

Only single-family buildings participated at the regional incentive call and these are the easiest to design both for the simplest management and for the large availability of space for the installation of solar thermal collectors and photovoltaic modules. The solutions on nearly zero energy condominiums will be the future challenges especially in urban space and also the advanced retrofit measures on existing condominiums. In this context, some measures at low costs could also be considered such as the real-time monitoring of energy consumptions and contractual arrangements on the energy management and maintenance stimulating energy savings and energy efficiency measures with cost-effective investment solutions.

B. With which methodology it is better to evaluate the energy performance of nZEBs?

In this work, the combined use of different technological systems (heat pump, solar collectors and photovoltaic modules) was evaluated with a semi-stationary monthly-based energy balance. The heat pump efficiency can vary depending on climate conditions and on the required thermal load; especially in the cold and humid months this solution may hold some surprises with low COP and high electricity consumption, when even solar technologies work little. Also during the hours of the days, these phenomena could be observed.

The differences between design and measured energy performances could be significant and this is typical of technologies that exploit renewable sources that have limited availability over time and then a discontinuity in generation. In the design of these low-consumption buildings, however, it is not advisable to oversize the systems either due to cost problems or due to technical problems with energy over-production in some months or seasons.

In these years, energy software tools are evolving from semi-stationary evaluation (monthly based) to dynamic hourly evaluation [9], this introduces new landscapes in the design of nZEBs with more accurate but long calculation times. A future development of this research could go towards dynamic evaluations.

C. In Italy, high insulation = low consumption?

Less energy demand means, generally speaking, less consumption. Italy's climate however doesn't fit very well with a simple approach that foresee for the equation: high insulation = low consumption. Aiming for a low thermal dispersion in winter is not the only key to look at. In the Po valley with its typical continental climate, winter is cold and summers are hot. The average air temperatures range between -3°C (January) to 28°C (July) with peaks that spread from -20°C to +38°C. A very wide range that requires flexible and integrated building design features. The high insulation used in the nZEBs, to reduce consumptions during the heating season, can become a disadvantage in the summer season when air temperatures and solar radiation grow to uncomfortable values. Then in an ZEB a cooling system becomes mandatory to ensure comfortable living conditions; so lowering the winter consumption introduces a new summer consumption of primary energy. Construction mass can play an important role, some architects and designers prefer the multi-layer technology with light to medium wall mass (wood or bricks) and external insulation, others choose a single layer wall with high thickness aerate concrete blocks without further insulation.

Shading and cool roofs are other strategic elements of the envelope that must be better integrated in the design of the buildings. A smart shading device can solve a lot of problems with overheating in the summer season but it is rarely implemented.

D. What kind of heating/cooling system is required to build a nZEB?

A brand new field of scenarios originates from the question: "what kind of heating/cooling system is required to build a nZEB?". First of all, we must consider that the new generation of plants will be strongly based on renewable sources. The most interesting configuration seems to be based on the hydronic circuit (e.g. radiant floor) powered by heat pumps. This entails a new consideration, such plants bear a considerably higher cost and this would have to be compared with the relatively low energy saving they will address moves the "break even point" further. Complex plants lead to high maintenance costs that can have significant impact on the running cost.

Lower energy demand shifts the importance of the old design based on the raw power, new buildings need a more efficient and predictive regulation system to maximize the solar gains and avoid the overheating. This requires new trained technicians and IT technologies to be implemented.

E. Limits and constrains on energy production in Italy

A last mention on the Italian regulations on photovoltaic energy production. The Italian grid regulation allows to buy and sell energy with a lot of constrains and limitations, the self- produced electric energy from renewable sources has to be self-consumed and PV plants over 20 kWp are discouraged by the complexity of the technical regulation.

The transition from consumer to prosumer strongly supported by the clean energy union strategy, is far to be a reality. The Italian government introduced the prosumer and the renewable energy community in the National Integrated Energy and Climate Plan ("Piano Nazionale Integrato Energia e Clima", in Italian, December 2018, available at: https://www.mise.gov.it/images/stories/documenti/Proposta_di_Piano_Nazionale_Integrato_per_Energia_e_il_Clima_Italiano.pdf) but there will be some time to change the grid market rules and allow producers to sell energy without economical loss.

At this moment, a multi-family nZEB building must have a PV plant over it, but the energy produced can't be utilized directly by the family. It has to be utilized only in common services (pumps, lighting of common areas, elevators etc.) or has to be conveyed to the public grid and after that bought back to the families (with some royalties).

VI. CONCLUSIONS

The results of this work show that nZEBs, energy efficiency measures and renewable technologies are now part of the present thanks to efficient envelope and system technologies at competitive costs. Territorial planning can contribute on citizens' awareness and guide policy makers and public and private investments for the energy transition process [10]. The energy transition can be guided by the promotion of energy savings and low environmental impacts, through various initiatives on a territorial scale (like the energy communities): research, experimentation, incentive for innovative projects and use of local natural resources.

In this framework of rethinking urban practices and starting from the exemplary strategies adopted at national level, there would be a possible perspective that sees the implementation of additional virtuous models and planning initiatives; an innovative built heritage management will be required, through evaluation tools and cooperation actions between public and private, supported by the presence of new incentive formulas.

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