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Experiences from Design Process of Renovation of Existing Apartment Building to nZEB

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Abstract

Toughening requirements for energy efficiency of buildings sets the new challenges to the building owners, designers and contractors. Although nZEB requirements will apply only to the new buildings, Tallinn University of Technology decided to renovate existing student hostel building to nZEB building. Building has same typical problems as many other existing buildings: high energy consumption, insufficient ventilation, overheating during winter, insufficient thermal comfort. Need for major renovation is evident but goal to renovate this building to nZEB building have raised many new challenges. Somewhat surprisingly chose challenges were not so much related to the specific technical problems but more to the overall understanding of the concept of nZEB and managing the design process in order to guarantee that the end result is nZEB building. In general, building owner is in favour of the nZEB, but nZEB renovation should not mean excessive investment costs. Therefore, designers have new challenge to devise nZEB renovation in such way that it is not significantly more expensive than standard major renovation. Our experience revealed that designers have not yet fully understood the whole concept of nZEB buildings and have some difficulties managing the design process in parallel with the energy calculations and cost optimality calculations. The solution which is often used that energy calculations just one solitary part of the design process is no longer suitable in concept of nZEB renovation. Energy calculations and cost optimality calculations must be used in parallel with designing the technical solutions already in the early stage of design.

Keywords – energy efficiency, design process, case study, nZEB, deep renovation.

1. Introduction

Energy Performance of Building Directive [1] states that European Member States shall ensure that new buildings are nZEBs by December 31, 2020. Estonia is one of the 14 European Member States that have defined the definition of nZEB and its subcategories [2]. The Energy Performance legislation [3][4] includes the definitions of nZEBs (nearly zero-energy) and net zero energy buildings. A nZEB is a building that is characterized by sound engineering solutions, considering the current best practices, on-site energy production by renewable energy sources (RES) (the share of energy by RES is not fixed) and meets the set primary energy performance requirements. Although nZEB requirements will apply only to the new buildings, Tallinn University of Technology decided to renovate existing student hostel building to the nZEB building. Goal to renovate buildings to meet nZEB energy efficiency requirements have raised many new challenges. Study conducted on Norway and Sweden [5] concluded that there is a lack of knowledge dissemination in nZEB renovations and contractors are very likely to pick the low hanging fruit as nZEB seems too ambitious and is viewed as difficult and unrealistic.

The environmental impact of new residential buildings is negligible compared to the impact of the existing residential building stock in the European Union [6] and the replacement rate of the existing stock is only 1-2% per year. Existing buildings will continue to represent most of the housing stock in coming decades in most western countries [7] Therefore, there is a need to speed up renovation process. In analysed renovation case, it was decided to use prefabricated retrofit modules. Earlier studies [8] have concluded that major advantages of those modules are reduce of the short installation time and prefabrication in factory can guarantee the quality of the solution.

Improving the energy efficiency and indoor climate conditions of exciting buildings has been priority in the resent years in Estonia. Several energy and cost efficiency analyses have been conducted in order to improve the indoor climate and to evaluate the energy efficiency and economic viability of buildings energy-renovation. Main attention has been on detached houses [9], apartment buildings [10][11] and historic buildings [12][13]. Conducted analyses have not thoroughly handled the renovation process and results of an nZEB renovation, as the idea of nZEB renovation is recent in Estonia and has been a possible option in very few renovation cases.

Renovation of exciting buildings is often seen as process with only one straight forward purpose – energy saving. Building design and construction process is based on a belief that experienced designers and contactors are able choose the best measures for the building. Actually the decision making process is more complex than just choosing the best technical solutions based on the numbers and calculations. Moezzi and Janda [14] claimed that social potential is as important as technical potential in an energy efficiency decision situation. It is important not to neglect important factors, such as knowledge and routines that are very important when choosing technological solutions during a renovation. Guy and Shove [15] highlighted the importance of understanding social aspects when energy efficiency decisions are made. It is important to understand how and why the choices were made during a renovation process.

Design process of one nZEB renovation project is described in this paper. Aim is to analyse how energy efficiency is taken into account in the design phase of the renovation process and how prepared are Estonian designers for the new nZEB requirements.

2. nZEB renovation case

2.1. Case study building

The case study building is a typical 5-storey apartment building built in 1986 and is made of prefabricated concrete large panel elements. The building has simple, rectangular floor plan with two staircases and with 80 flats. Building is similar to many other mass production apartment buildings (series 111-121) from 1970-1990 in the former Soviet Union countries and in the Eastern Europe, see Fig.1. Building has same typical problems as many other older existing buildings: high energy consumption, insufficient ventilation, overheating during winter, insufficient thermal comfort.

Fig. 1 Photo of the pilot building (left) and the designed solution after the renovation (right) [16].

The building had a natural passive stack ventilation system that will be replaced with mechanical supply and exhaust ventilation with heat recovery. Building has on-pipe radiator heating system without thermostats and room temperature for the whole building is regulated in heat substations depending on outdoor temperatures. This causes uneven indoor temperatures and overheating during winter. The heating systems will be replaced with two-pipe system with hydronic radiators and thermostats. The net area of the building after the renovation is 4330 m^2 and living area 3120 m^2.

2.2. Evaluation of energy efficiency

Requirements for buildings energy performance and calculation methodology are given in Estonian legislation [3][4]. Requirement for the nZEB apartment building is primary energy use $\leq$100 kWh/(m^2a). The primary energy use is calculated for the building on according to its standardized use, and applied to the building as a whole: including energy needs for space heating, domestic hot water, cooling, lighting, ventilation, and electrical appliances. Data for standardized use includes a description of occupants, appliances and lighting usage profiles, operation times, as well as indoor climate requirements. The minimum energy performance value characterizes the primary energy use of the building; in other words, the delivered energy is multiplied by the primary energy factors of the energy carriers, and the exported energy multiplied by the same factors can be deducted.

3. Initial task

3.1. Objectives

Main objective was an optimal renovation design of the old apartment building according to the best construction practice with energy efficiency solutions and renewable energy technologies. Primary energy use after the renovation must be ≤ 100 kWh/(m^{2}a) and indoor climate category II, EN15251 [17]. In order to help the designer to choose solutions, following input were given:

- building envelope is additionally insulated according to the primary energy requirement, but not less than U_{roof} ≤0.10 W/(m^{2}K), $U_{external\ wall}$ ≤0.12 W/(m^{2}K), $U_{basement\ wall}$ ≤0.17 W/(m^{2}K), U_{window} (glass package with frame) U ≤0.80 W/(m^{2}K), $U_{basement\ ceiling}$ ≤0.26 W/(m^{2}K);
- additional insulation was planned to do by prefabricated multifunctional modular renovation elements;
- thermal bridges and air leakages should be minimised: temperature index of the inner surface must be f_{Rsi} <0.8, q_{50} <2 m^3/(m^{2}h);
- solar panels and collectors on the roof are used for the renewable energy production on site;
- heat recovery is intended from ventilation system and from sewerage's grey water (from showers kitchen, bath, and washing machine);
- summertime overheating must be avoided with passive solutions (screening), as no mechanical cooling system is not planned;
- building envelope should be designed so that moisture safety is guaranteed and moisture and mould damages or material degradation is avoided;
- the budgeted renovation cost should not exceed 460€/m^2.

3.2. Results and discussion

Calculation methodology used in Estonia [4] for calculating energy efficiency is mainly based on dynamic indoor climate and energy simulations, and therefore should help to see the building as one energy system. But in building design, the concentration was often more on the technical details of separate technical systems and not so much to the building as a uniform energy system where all components interact each other in terms of energy efficiency. The main base for decision making was the initial task where thermal transmittance of building envelope and renewable energy solutions were given in initial task. This information was given to help designer to start choose the solutions but designers planned to just follow those given numbers and solutions and no further analysis would not be necessary. One plan for achieving nZEB level was to add sufficient amount of PV-panels to the building envelope with thermal transmittance numbers given in initial task. In current case study, the detailed initial task was sort of barrier for the designers and mainly the question how we implement those give solutions was asked and not the question whether those solutions are reasonable and maybe there are better ones.

4. Selection of designer

4.1. Objectives

As the owner of the building was from public sector the, the public procurement process was needed. It has been common practice that the public sector selects partner based on the lowest price method. There have been many examples, that by selection with only the lowest price method, there has been difficulties in guaranteeing the quality of design process [18][19][20]. In current project the designer was selected with the most economically advantageous tender. Three selection criteria were used:

- professional experience and competence: max. 50%. Assessment was done based on occupational qualifications system (2 person level 8: 12 points, 1 level 8 + 1 level 7: 10 points; 1 level 8: 8 ponits, 2 person level 7: 6 points, etc.);
- previous experience in designing of nZEB: max. 10 points;
- price: max. 40 points

4.2. Results and discussion

Three tenders participated in the public procurement, see Table 1.

Table 1. Overview of tenders.

Topic	Overview of tender based on points in subdivision		
	Designer 1	Designer 2	Designer 3
Total	67	84	71
Experience and competence	29	41	41
Architect (max 12 p.)	5	6	6
Civil Engineer (max 12 p.)	5	12	12
Water engineer (max 4 p.)	4	4	4
HVAC engineer (max 9 p.)	9	9	9
Electricity engineer (max 6 p.)	0	3	3
Energy performance of buildings (max 7 p.)	6	7	7
Experience in designing of nZEB	5	3	5
Prize	33 (33% from lowest)	40 (the lowest prize)	25 (25% from lowest)

Previous experience in designing of nZEB was one selection criteria. Some of examples were aboard. In different countries the assessment of energy performance of buildings is different. Therefore in future procurement process, it should be determined more precisely, which assessment criteria should be used. When the example building is from aboard, additional calculation should be presented according to local assessment method. Only in this case all example buildings are comparable.

5. Design process

5.1. Objectives

Although the minimum energy performance requirements in Estonia were launched in 2007 and came into force in January 2008, the energy calculations are still not seen as a valuable input for the design decision process and more as a need for obtaining the building permit. Therefore in typical design process, calculation of energy efficiency is done only once, in the end of preliminary design before applying the building permit. To design energy efficient buildings, important decisions for energy efficiency are made in the early stages of design process. It allows testing the influence different energy performance measures and optimizing the final solution according to the initial target. Important aspects of building energy efficiency rely often only to the knowledge and experience of the architect because other designers seldom participate in early stage of design. It was marked in the initial task that energy efficiency calculations are repeated for all stages of the building design taken into account the specified energy efficiency solutions (properties of HVAC systems, thermal transmittance of building envelope, user profiles, etc). Expected design process is shown in Fig.2.

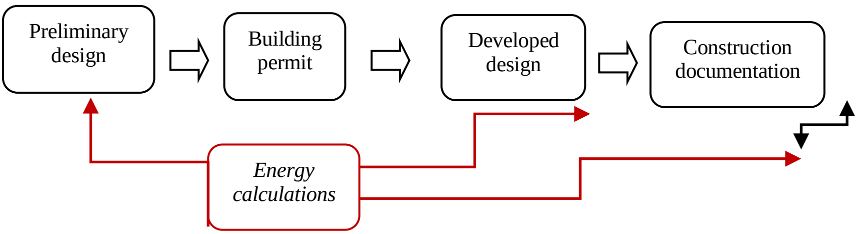

Fig. 2 Excpeted design process with energy efficiency calculations in every design phase.

5.2. Results and discussion

Toughening energy efficiency requirements sets new challenges for the designers and also for the design process. Our experience showed that somewhat surprisingly those challenges are not so much related with the specific technical solutions and technical problems but more to the overall understanding of the concept of nZEB and managing the design process in order to guarantee that the end result is nZEB building. Although energy efficiency was one of the main goals of this renovation and importance of energy efficiency was repeatedly emphasized in the initial task, in reality, the energy efficiency calculations were seen as a just one mandatory step in the design process and not as an input source for the design decisions, as those analyses should be. Tenders did not count the energy calculations as the part of every design phase and expected that energy calculations are made only once, as in previous typical design processes. Good example of underestimating the importance of energy calculations is that the head design company reduced the budget for energy efficiency consultations and calculations in the tender about five time. Reasons may lay in the everyday practice of planning and designing the buildings where energy calculations are often made only once when building design is almost finished. Earlier study conducted in Estonia [21] made similar conclusion that current design of energy efficient buildings is a linear and one-shot approach without iterations planned into the process. Project "Qualicheck" report [22] concluded that compliance frameworks are typically limited to verifications at building permit stage, therefore, not with "as-built" data. Most countries do not have control mechanisms at later stages, including design changes during construction, commissioning, final design/production information, and operation. Therefore, errors due to design modifications compared to the initial EPC submission seem common.

Using the energy and indoor climate study results data from earlier measurements conducted in the building and energy audit as the input source for the energy calculations and design solutions, seemed to be also new approach for the designers. In Estonia, energy audits are often made in the apartment buildings but in the same time energy audits are not often used as a valuable input source for the building design to calibrate the indoor climate and energy simulation model. Same kind of observation is also made in other countries. Study conducted in Sweden [23] concluded that surprisingly, energy calculations attracted little interest and had little impact on the process and empirical experience were valued much more than figures and statistics concerning the buildings to be renovated.

Indoor and energy simulations itself were correct in general. Still there were some minor deficits in initial data (thermal transmittance of building envelope and windows, efficiency of service systems, making the building model, taking into account thermal bridges, etc.) Therefore in future projects it is appropriate if owner has consultant that communicate directly with energy performance specialist. From building physical calculations, thermal transmittance of building envelope was accomplishable for the designer. Drying out of constructional moisture, criticality of thermal bridges, long term hygrothermal performance of building envelope were questions that did not get answers in the design process. Therefore in future projects these questions should be highlighted already in the early stages of design process.

nZEB renovation should not mean excessive investment costs. Therefore, designers have challenge to devise nZEB renovation in such way that it is not significantly more expensive than standard major renovation. In scientific papers, cost-optimal calculations are often based on the cost optimal method introduced by the European Commission Delegated Regulation [24]. Case study showed that designers and energy efficiency consultants are not familiar with this methodology to identify the cost optimal solutions, Fig.3. When building owner asked the cost optimal calculations and comparison of the different energy efficiency measures, then it turned out that this kind of analysis caused major problems for the design company. This means that the methodology and the results that have been published for the different building types in different countries have not reached designers and energy consultants who are actually working with energy efficiency renovations in everyday bases.

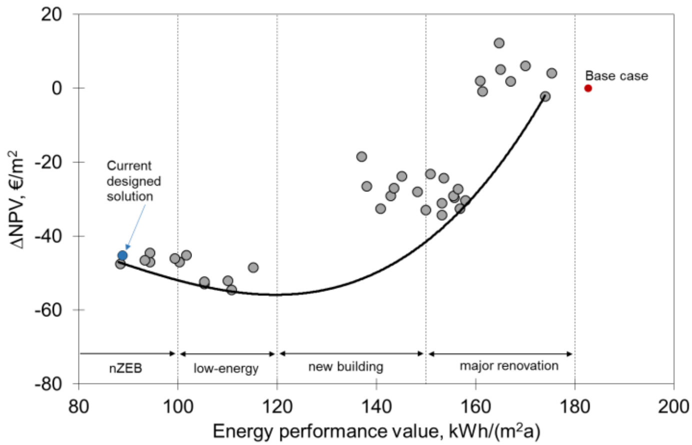

Fig. 3 Identification of the designed solution cost-optimality in case study renovation

One of the problems was also the general quality of the building design. Expert examination about the preliminary design and developed design concluded several mismatches, remarks and comments. This means that more attention should be paid to train architects and engineers to respond nowadays requirements on building design and energy efficiency and also to the future requirements of nZEB buildings.

6. Conclusions

Design process of one nZEB renovation project was analysed in this paper. Our experience revealed that although the overall result came out as expected, there were some problems with overall quality of the design. The designers have not yet fully understood the whole concept of nZEB buildings and have difficulties managing the design process in parallel with the energy calculations and cost optimality calculations. The solution which is often used that energy calculation is just one part of the design process and energy calculation are mainly seen only as a mandatory step for the building permit, is no longer suitable in concept of the nZEB renovation. Energy calculations and cost optimality calculations must be used in parallel with designing the technical solutions in order to guarantee that the end result meets the nZEB requirements and construction costs are economically feasible for the building owner.

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