A Belgian pilot project for zero energy office buildings

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Abstract

This paper describes the office building of V&R The Solarcompany in Heusden-Zolder (Belgium). The building has very low heating and cooling demands, due to a building fabric designed according to the Passive House standard, combined with well controlled strategies for night ventilation, a ground-air heat exchanger and solar shading as well as efficient heat recovery from ventilation air, when needed. The remaining energy demand is covered by extensive use of solar energy in combination with a ground-coupled heat pump. This combination makes the building an interesting example of a (near) Net-Zero Energy Solar Building (NZESB). Therefore it was chosen as one of the test-cases for Subtask B of the IEA SHC Task 40/ECBCS Annex 52 project “Towards Net Zero Energy Solar Buildings”. For these case studies monitoring data will be available, together with detailed simulation results and a description of the design process.

This paper focuses on the study of different parameters that are needed to create a calibrated energy model using EnergyPlus and continuous monitoring of all relevant data from the building, the HVAC system and the renewable energy production. Furthermore the documentation and further improvement of the design process by using the IDM method to establish process maps and exchange requirements is described.

1. Introduction

Net-zero energy solar buildings (NZESBs) are emerging as quantifiable design concept and a promising solution to minimizing the environmental impact of buildings. Extensive research is performed on this type of buildings, among them the IEA SHC Task 40/ECBCS Annex 52. Subtask B of this research addresses the issues of modeling, design and optimization of such buildings [1]. One of the goals is to create calibrated energy models of several case studies and compare them to their monitored performance.

The office building of V&R The Solarcompany was selected as a case study to identify the challenges for achieving NZESB status in Belgium. The main goal of this study is to create a calibrated energy model of the subject building, therefore studying all significant parameters and developing the necessary monitoring strategy.

Due to their complexity NZESBs cannot be designed based solely on the architects experience from earlier projects. We need to be able to guarantee that an expert simulation is called upon at the right time, and for the right design decision. This requires a dynamic view of all design activities, verification of their interrelatedness and anticipation of expected downstream impacts of alternative decisions [2].

Mapping the design process can serve as a base to investigate how reliable the results of simulations at different stages of the design process are. It also provides a more realistic picture of the capabilities and possible shortcomings of the software tools used for the different tasks described in the process maps.

2. Description of the building

The recently constructed office building of V&R The Solarcompany in Heusden-Zolder (Belgium) was designed and built to comply with the Passive House Standard (architect: AI-BS Bert Schellekens). The 3-storey building can be divided into four main volumes, a warehouse (330m²) on the ground floor, an atrium with a staircase providing access to the first and second floor, office spaces on the first and second floor (450m²) and an apartment (200m²) on the second floor (see Figure 1 and 2).

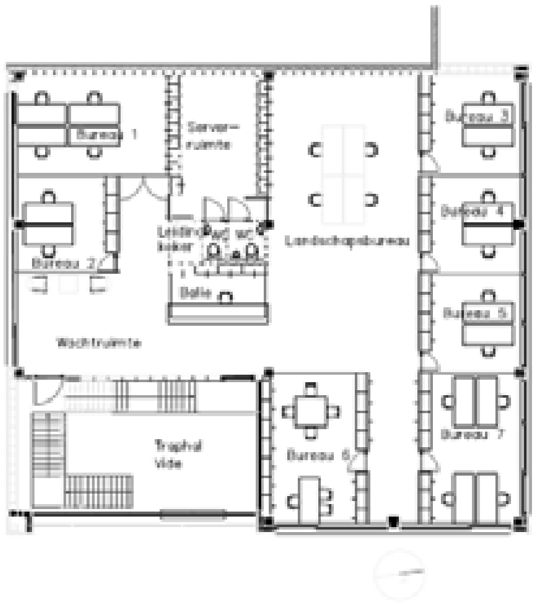

Fig. 1. Office spaces on the first floor.

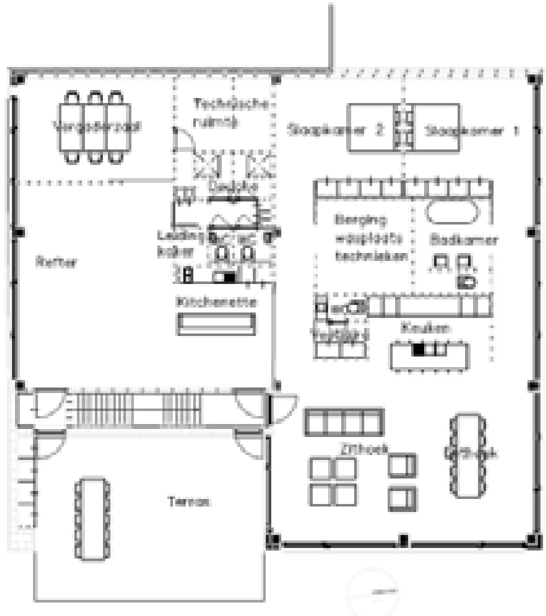

Fig. 2. Office spaces and apartment on the second floor.

The building is located at the former coal mine site at Heusden-Zolder adjacent to an existing building on the west-facing wall. An existing concrete structure was used as a basis for the construction of the new building. The outer walls and roof consist of timber-frame elements and were insulated with blown cellulose fibre insulation. In order to comply with the passive house standard U-values as listed in Table 1 were chosen and an air-tightness of n_{50} = 0,55 h^{-1} was achieved. The solar heat gain coefficient of the windows is 0,51. Automatically controlled window screens are installed on all south- and east-oriented windows.

Table 1. U-values of the building fabric

Building Element	U-value (W/m²K)
Outer wall	0,18
Inner wall staircase	0,18
Inner wall adjacent building	0,20
Roof	0,10
Floor	0,26
Glazing	0,60
Windows	0,74

For the supply of domestic hot water as well as space heating a storage tank of 1000 litres is used. This tank is heated by 8,25m² vacuum tube solar collectors and a ground source heat pump. Space heating is supplied through heating of the ventilation air and all offices are equipped with extra heating convectors to give the users more control over the required individual comfort temperatures. The ground source heat pump also incorporates an additional passive cooling function.

A mechanical ventilation system with a high efficiency heat recovery unit is used. On the first floor, fresh air is supplied to the office spaces continuously and extracted through the server room to evacuate and re-use heat from the computers. Ventilation rates on the second floor are controlled by a CO_2-sensor. Regarding summer comfort the ventilation system was equipped with a by-pass in combination with an earth-to-air heat exchanger which pre-heats or -cools the intake-air. In addition, an extractor fan was installed at the top of the technical shaft providing forced night ventilation during summer periods. The operable windows in the office rooms are controlled automatically based on measured indoor temperatures and outdoor conditions. In addition, a domotica system was installed to provide optimal control of the entire building based on the measured conditions and the occupancy of the different spaces.

To reduce as far as possible the amount of energy needed, energy-efficient lightning in combination with daylight control and presence detection is used. In order to optimize the visual comfort in the office rooms their internal partitions are fully glazed. For the purpose of energy production a photovoltaic array with 30kWp peak performance was installed on the roof and, in addition, a second photovoltaic array of 7,5kWp peak performance was integrated in the south facing facade.

3. Simulation results versus monitoring data

As mentioned before the office building of V&R The Solarcompany was selected as a case study for the research activities of Subtask B of the IEA SHC Task 40/ECBCS Annex 52 [1]. The aim of this study is to compare a calibrated energy model of the building with its measured comfort and energy performance.

However, to build an accurate simulation model of the considered building a lot of parameters have to be defined. Additional monitoring is therefore needed in order to verify the assumptions for some of these parameters. The first aim of this study is to identify all the required parameters that have to be included in the monitoring plan based on simulation results obtained from the energy model of the building. For modeling the building and its installations EnergyPlus [3] is used, in combination with DesignBuilder [4] as graphical interface.

3.1 Influence of weather data

The weather data used in a dynamic simulation influences almost every aspect of the heat balance of the building. A lot of standard weather files are available for different locations for the use during the design process . In this study the TMY2 weather data for Brussels is used, available from the U.S. Department of Energy EnergyPlus climate file database [5]. This simplification does not compromise the simulation accuracy [6]. However, in order to check simulation results against measured performance of the building some parameters have to be analyzed in detail. Therefore measured data is needed concerning outside temperature, wind speed and variation as well as global and direct solar radiation. The need for additional, locally measured weather data will be investigated during the first weeks of the monitoring.

3.2 Influence of internal heat gains

In office buildings internal heat gains have a great effect on comfort and energy performance, especially on the cooling load prediction [7]. Therefore during shorter measuring periods additional data will be collected to better quantify the most important internal heat sources. In addition, presence detection is installed in all the office rooms to determine and document their occupancy.

3.3 Influence of night ventilation

During hot summer periods forced night ventilation is applied through the technical shaft on the first and second floor. Therefore an extractor fan was installed at the top of the shaft. The operable

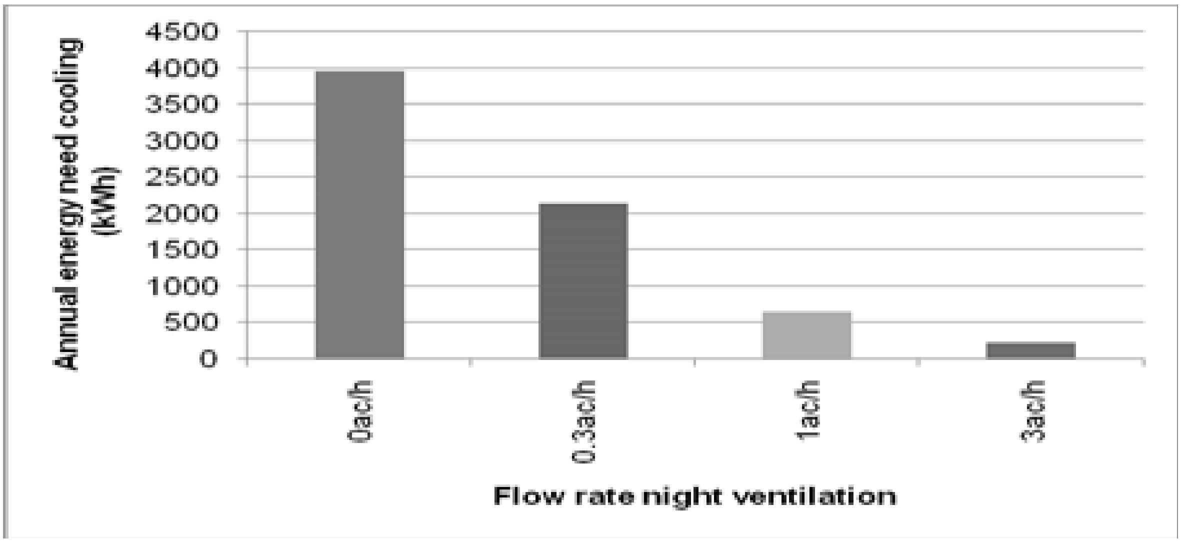

Fig. 3. Annual energy need for cooling of the first floor as a function of the night ventilation flow rate.

windows on these floors are controlled automatically by the domotica system, based on measured indoor temperatures and outdoor conditions.

Fig. 3 presents the simulated annual energy need for cooling of the first floor as a function of the night ventilation flow rate.

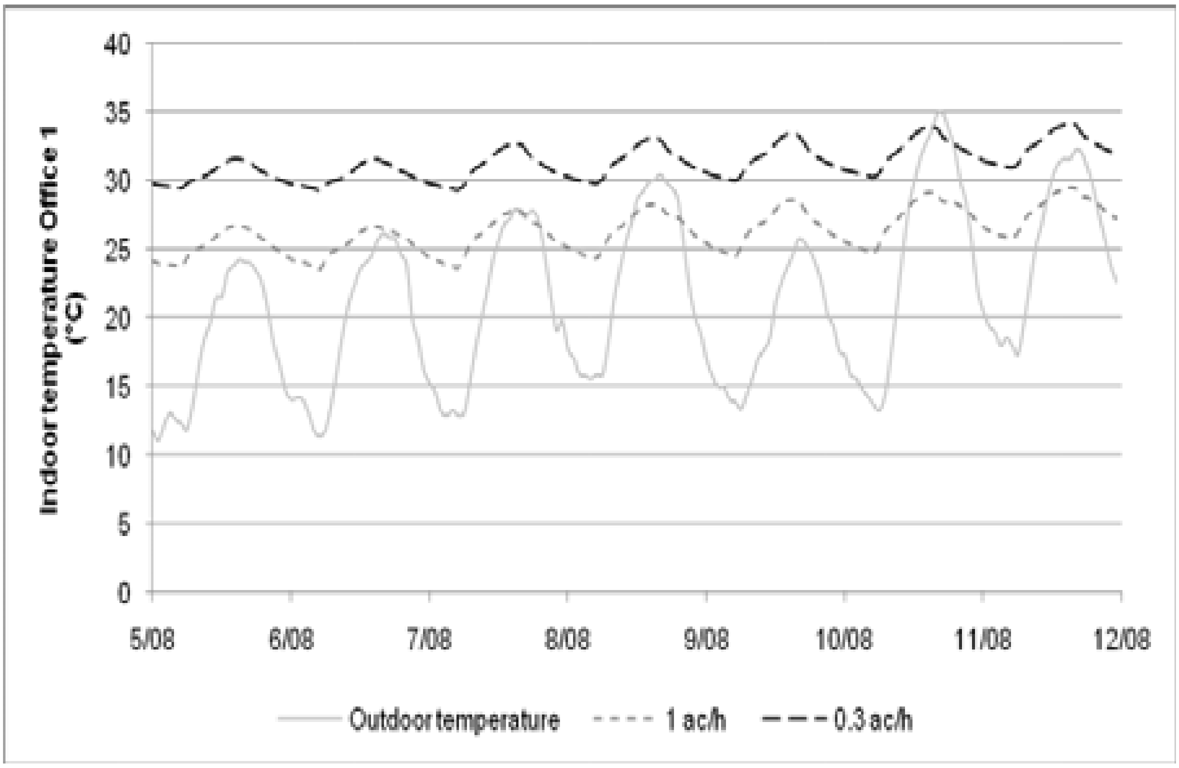

Fig. 4. Temperature curve for an office room during a summer week as a function of the night ventilation flow rate.

Fig. 4 shows the simulated temperature curve for a south-oriented office room as a function of the night ventilation flow rate. A continuous flow rate is assumed through all the rooms. In reality however, flow rates will depend on indoor as well as outdoor conditions like wind speed and variation, the internal lay-out of the building, the operation of windows etc. It is clear that a realistic estimation of these night ventilation flow rates for each room is necessary in order to create an accurate energy model. Further investigation will be performed in order to compare available values in literature and measured data from the considered building. Other parameters that affect the heat balance of the building model, like the usage of window screens or the application of an earth-to-air heat exchanger, will also be investigated.

An additional objective of this study is the optimization of the applied control strategy for the HVAC system in order to minimize energy consumption as well as improving comfort conditions within the building. Therefore different control strategies will be tested and compared with the simulation model. Finally re-design studies will be performed achieving, e.g. net-zero energy for a lower cost, lower end use energy consumption, and/or greater thermal comfort.

4. Analyzing the design process

To analyze and optimize the design process, the methodology of the Information Delivery Manual (IDM) can be used [8]. In this method, a “Process Map” (PM) gives a graphical representation of activities, their sequence and the performing actors or disciplines. It answers the questions: ”who“, ”what” and “when”; thereby providing an overall view on the course of the design process. For this research project, the Business Process Modeling Notation (BPMN) is used.

The information exchange between consecutive activities or sub-processes is documented in “Exchange Requirements” (ER). The ER defines the required information at a given point of the design process, distinguishing between “required” and “optional” data. Thus, it provides the foundation for the development and possible certification of building information models (BIM) and interfaces for data-exchange between a model server and simulation software based on an open standard.

Existing process maps developed by BuildingSMART Norway [9] were used as a starting point. These maps describe the design process of more traditional buildings with less ambitious energy performance targets. Through interviews with various domain experts involved in the design of Passive Houses or NZESBs substantial changes in the design process where discovered, regarding performed tasks as well as required information. During the design process of their building the participating experts kept track of the relevant tasks they performed and described the required input and output information. Based on this information, a new PM and a set of ER’s were established.

The overall design process can be divided in 4 sub-processes, defining two key parts: the conceptual and the detailed part of cyclical design process (Fig. 5). Each depicted sub-process frame links to a detailed sub-process map.

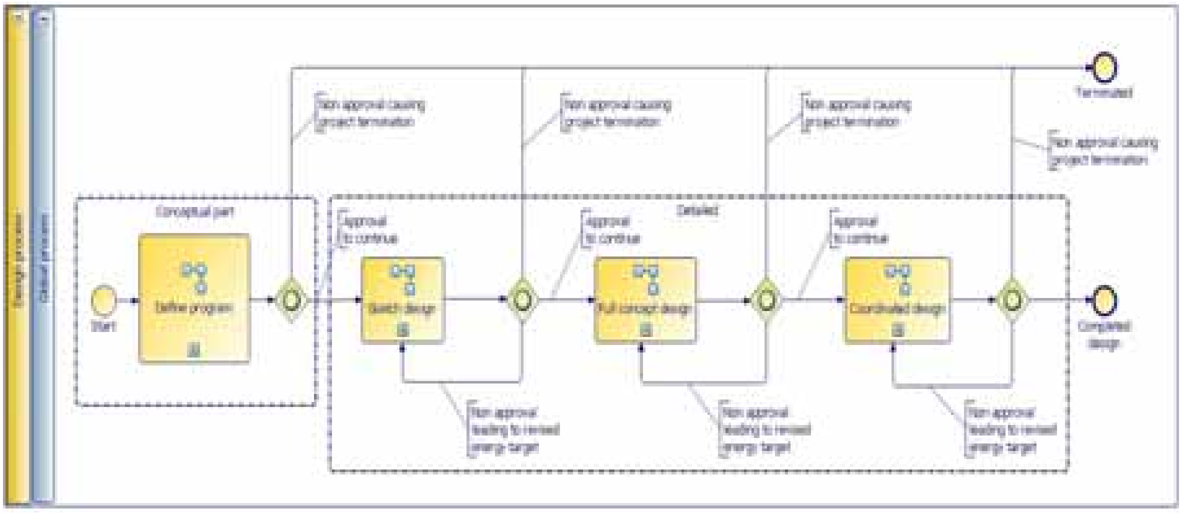

Fig. 5. Global design process of a Net Zero Energy Solar Building

The “Net Zero” target strongly influences the entire design process. To meet the energy target, a tight interaction between various disciplines is needed already from the very early stages of the conceptual design. Mapping this interaction provides a clear view on the design process to the extent that future design teams could use it as a manual and as a base for the definition of an integrated commissioning process to achieve the designed performance during the operation of the building.

The presence of a PM completed with a clear description of the information exchange (ER) can be useful to detect the sub-processes that are affected by the changes, the actors of the building team to be informed about the changes and the documents that need to be updated.

A complete and detailed description of the design process of Net Zero Energy Buildings also helps to select appropriate calculation and simulation methods and tools for a certain stage of the design process. A global process map with high abstraction level does not suffice. Each underlying sub-process gives a more detailed description of exchanged information (input – output). Mapping processes at the highest possible detail level (parameter level) makes it possible to define a calculation/simulation method based on the available information (input parameters) and the required output parameters.

The first maps have been established for dwellings in the Flemish context [10]. To extend this approach to other building typologies and contexts further research is conducted in the framework of STB, with the aim of mutual improvement by learning from similarities and differences. While defining and extending the process maps to the STB NZESBs, a list of requirements and priority targets will be developed for each stage of the process. Recommendations on how to meet these targets will be given and adapted software tools and calculation methods for each stage will be selected.

5. Conclusion

As part of the STB of the IEA SCH Task 40/ECBCS Annex 52 the measured comfort parameters and the energy performance of the considered building have to be compared with simulation results from a calibrated energy model. In order to create this calibrated energy model of the building additional monitoring is needed to define some of the necessary parameters. Climate conditions for example should definitely be included in the monitoring plan due to their impact on every aspect of the buildings energy balance. In addition, every parameter influencing this energy balance has to be examined carefully to determine the sensitivity of the results to a change of this parameter.

Mapping the design process of a Net Zero Energy Solar Building and comparing it to the design process of buildings with less ambitious energy performance targets, indicates a substantial change of tasks, actors as well as required information. The "Net Zero" target strongly influences the entire design process. To meet the energy target a tight interaction between various disciplines is needed already from the very early stages of the conceptual design. Mapping this interaction provides a clear view on the design process to the extent that future design teams could use it as a manual and as a base for the definition of an integrated commissioning process to achieve the designed performance during the operation of the building.

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