

Roadmap to nZEB Hospital – a Case Study: VUmc Polyclinic



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Hospitals need to substantially reduce energy consumptions and CO₂ emissions to fulfil requirements for the EU directive on nZEBs. This study assesses the great challenge of realizing energy reduction within a hospital, considering its far lower priority compared to the performance to be delivered for medical purposes.

Keywords: Hospital energy demands; Building energy efficiency; nZEB; Energy savings; User-Oriented; Control systems; Building energy simulation, Building Services.

Introduction

In the Energy Performance of Buildings Directive (EPBD) [1], the EU has set nZEB requirements to new buildings (2020) and all existing buildings (2050), which applies also to hospitals. Hereby, it is essential to guarantee appropriate functionality while saving energy. Therefore, achieving these requirements in hospitals is a greater challenge than, for example, in office buildings.

In the Netherlands, the healthcare sector consumes approximately 1.6% of the energy consumption, of which 64% is consumed by academic medical centers

(AMCs) [2,3]. The approaching EPBD requirements and the expected increase of energy costs have driven AMCs to review their energy policies resulting in the MJA3 energy covenant 2005-2020 (2% energy efficiency per year, compared to 2005) [3].

A case study was performed on VU Medisch Centrum (VUmc): an academic hospital located in Amsterdam, the Netherlands. The energy management (CCE) faces severe challenges to satisfy the MJA3 requirements both at campus, building and departmental level. Preliminary research has shown several lacks in: monitoring activity, building energy performance and user-oriented services. This study aims to indicate the potential of energy savings that can be achieved in the outpatient department of the VUmc Polyclinic. The existing Polyclinic building (**Figure 1a**), built in 1986 with a gross floor area of 80000 square meters, was chosen as case study according to a preliminary analysis and client issues. The building is extensively used and, although its lifetime has been extended (from 10 to 30 years, referred to 2014), any thorough re-commissioning has not been performed and maintenance is minimal. These circumstances occur in many AMCs and their campuses, which are in continuous transition to upgrade primary processes according to the latest developments.

Methods

The project objectives were obtained through a three-step methodology: first, in-depth analysis of case study; second, development of an nZEB-design approach and third, building energy simulations. The analysis of VUmc includes interviews with energy management staff, site visits and a literature study [4-11] on specific requirements for indoor environment and energy consumption in hospitals.

In-Depth Analysis of Case Study

In the in-depth analysis, the aim was to comprehend how VU, VUmc and Polyclinic are organized and how they operate. Then the major features related to energy demands, management and issues (e.g. **Figure 1b**) are examined. The investigation of the aforementioned points has been conducted through site visits, interviews to management staff and data analysis (e.g. MJA3 results, energy monitoring activity etc.).

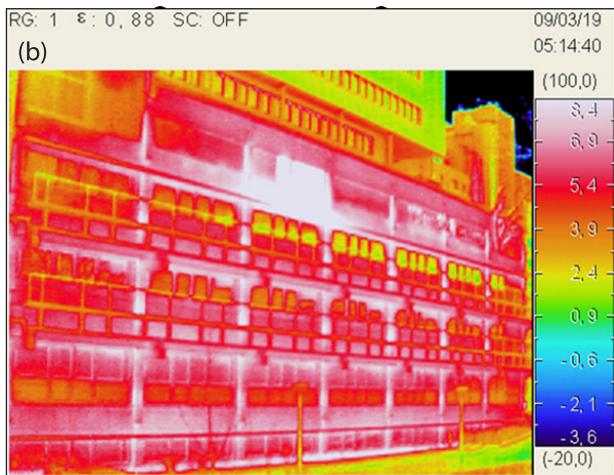


Figure 1. (a) VUmc Polyclinic building. (b) A thermal picture of polyclinic's façade highlighting, as bright patterns, the several thermal bridges within the envelope.

nZEB-Design Approach

In the Netherlands, a commonly used approach for an energy-efficient building design is the three-step strategy called 'Trias Energetica' [12]. At Royal HaskoningDHV, due to increasing concern and evolution of techniques, the approach has been upgraded to a 'Five-Step Method' [13] (**Figure 2**) with two additional steps:

- user demand and behaviour
- energy exchange and storage.

The 'user-oriented' concept, realizable through smart building designs and controls, aims to improve indoor climate and productivity while substantially decrease energy wastage.

The approach developed in this research focuses mainly on two principles:

1. Minimize the demand of energy,
2. User demand and behaviour.

In addition, the methodology must consider a few aspects strictly related to the case study at hand: those having relevant impact over design success. With respect to our case study building, the following aspects are also considered:

3. Case study analysis (issues, requirements and potential),
4. Building life expectancy and maintenance costs.

In light of these four aspects, a list of measures for upgrading performance and indoor comfort is determined and project steps were based upon their consideration.

Methods: Building Energy Simulations

A set of VABI Elements© building energy simulations is determined in order to validate the aforementioned measures and to provide insights about energy flows and controls over the case study. The plan of the polyclinic presents a variety of rooms modularly designed (see **Figure 3a**), thus the base module is adopted for the VABI model (see **Figure 3b**) and oriented to West in light of a set of sensitivity simulations.

Air-conditioning in the modelled space resembles the current system (see **Figure 3b**): conditioned air is supplied by the central system (central heating and cooling) and occupants can adjust temperature by a

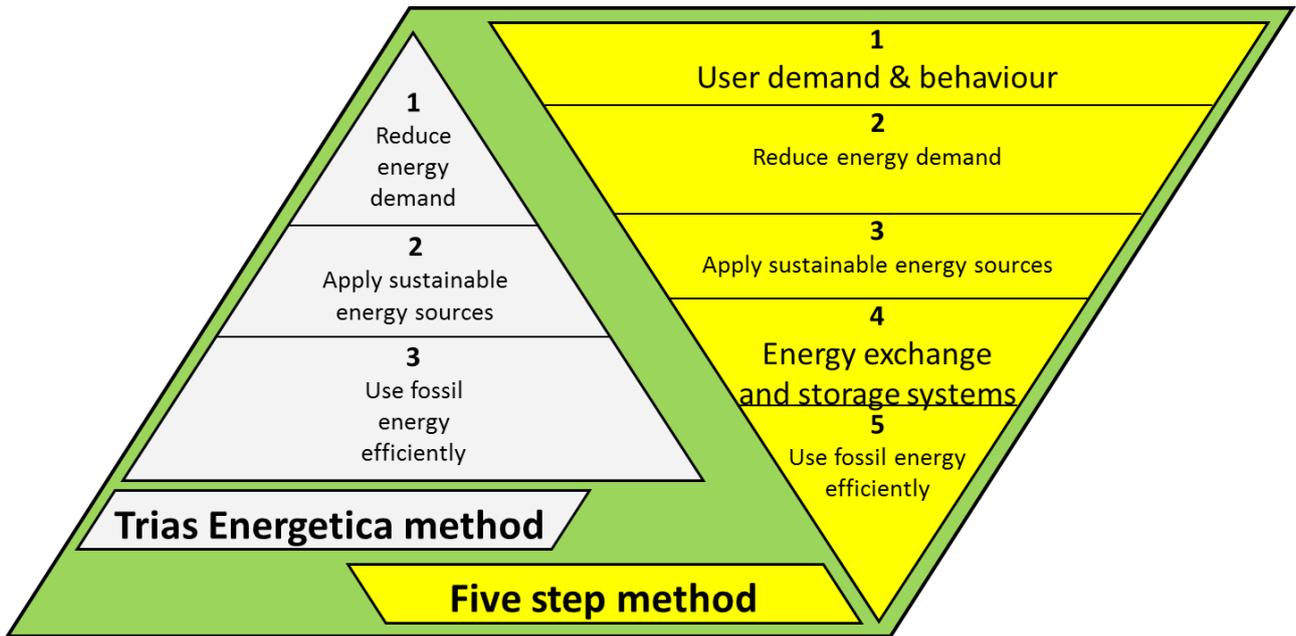


Figure 2. Building design approaches: 'Trias Energetica'[10] and the upgraded 'Five Step Method'[11].

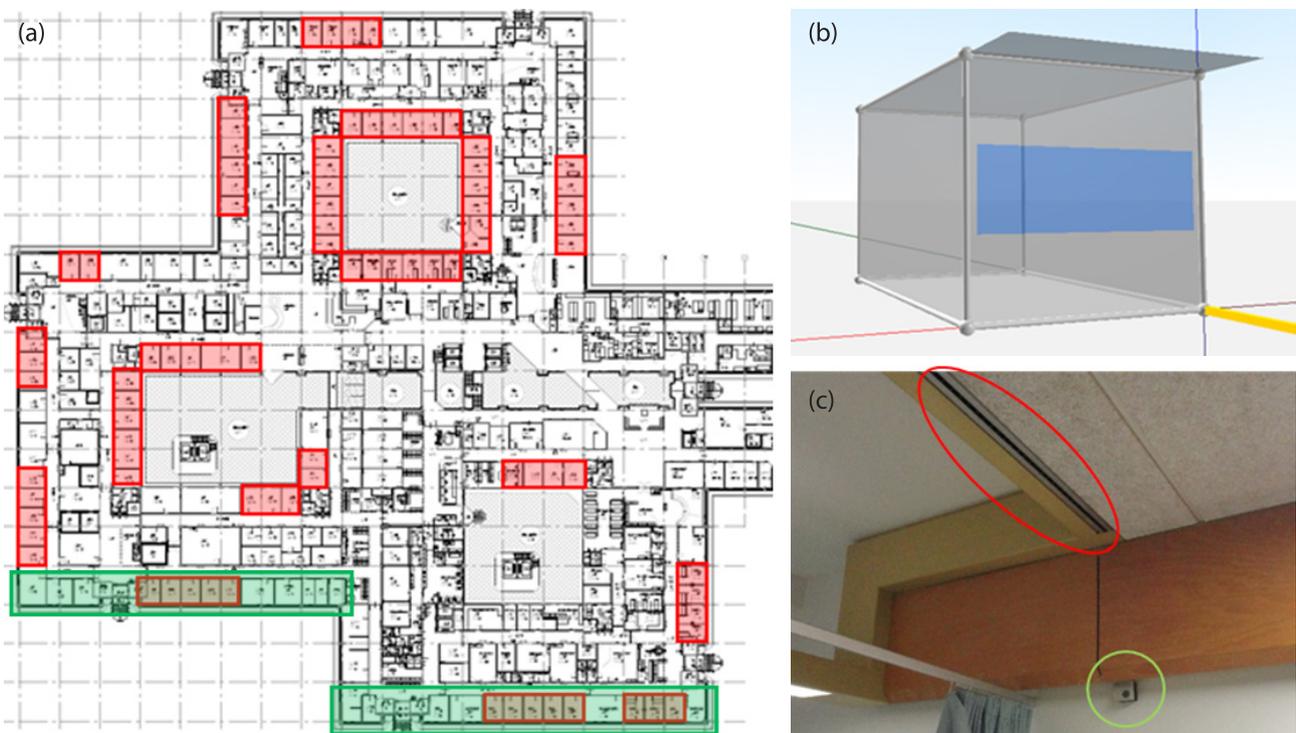


Figure 3. (a) Plan of policlinic building with highlighting of modelled space (red) and western façades (green). (b) VABI Elements© model. (c) Local re-heating system: air inlet (red) and temperature set-point control (green).

local re-heater (local heating). The external conditions are modelled with the climate file for year 1964-1965 at De Bilt, the Netherlands. Building simulations are performed for an entire year period and the focus is oriented on energy consumptions and indoor thermal comfort.

The set of simulations is composed by eight scenarios involving the variation of three major groups, which are modelled as currently operating and, then, in an improved configurations. The groups are:

1. HVAC: The existing system is a Constant Air Volume (CAV) and the improved is a Variable Air Volume (VAV) system. The CAV has only an ‘On-Off’ modality with a constant airflow rate. Differently, the VAV has a high-low ventilation rate controlled by CO₂ set-points.
2. Occupancy profile: Currently the systems consider a constant occupancy opposed to a more realistic random occupancy. The average number of people per hour in a week is equal between the two profiles. The profiles are based on building opening schedule and controlling the internal heat loads of equipment (non- medical) and lighting.
3. Building envelope: The current envelope is defined by lump-sum values for R_c (opaque) and U (transparent) related to Dutch standards at the time of construction while the improved is designed to satisfy current standards.

The set of simulations is presented in **Table 1**.

Table 1. Simulation set scheme.

SIMULATION NUMBER	HVAC		OCCUPANCY		ENVELOPE	
	Type	Type	Type	Type	Type	Type
	I – CAV	II – VAV	0 – Constant	1 – Random	0 – Current	1 – Improved
I.0.0	I		0		0	
I.1.0	I		1		0	
I.0.1	I		0		1	
I.1.1	I		1		1	
II.0.0	II		0		0	
II.1.0	II		1		0	
II.0.1	II		0		1	
II.1.1	II		1		1	

Results

In-Depth Analyses of Case Study

In typical hospital buildings energy consumers, flows and wasting components are often unknown or disregarded, resulting in uncertain parameters for investments in sustainable energy reduction and higher operation costs.

The research on VUmc and policlinic showed that little attention is directed on inefficient processes and part of the buildings present obsolete building systems and services. Current systems are coarsely monitored and not user-oriented with little focus directed toward occupant’s requirements (e.g. indoor comfort) and occupancy.

In the policlinic, the current energy management method is not fulfilling MJA3 requirements for both short and long term; therefore, requiring additional measures to address the requests of lower energy demands and better indoor comfort. The extended life of policlinic highlights the necessity to upgrade both components and services (severe issues in building envelope, HVACs and ducting design) in the building considering the constantly increase of energy costs and demands of new and more specialized healthcare treatments.

nZEB-Design Approach

The application of the approach resulted in list of energy saving measures, suitable to both typical hospital and to the policlinic case, in consideration of:

- Current energy demands per type: total amount, total cost and cost per unit.
- Positive outcomes for indoor environment: improvement of comfort and healing conditions.
- Current condition and performance of systems and components.

A selection of five high-potential solutions was based on these criteria and supported by a literature review on related previous research [4-11]. It was found that the ventilation load in hospitals, due to the processing of outdoor air in the AHUs, is the greatest demand. In conclusion, the top five solutions for hospital buildings are:

1. Upgrade of the HVAC system (from CAV to VAV system);
2. Application of occupancy-based controls to HVAC;
3. Upgrade of the building envelope;
4. Upgrade of the lighting;
5. Application of occupancy-based controls to lighting and devices.

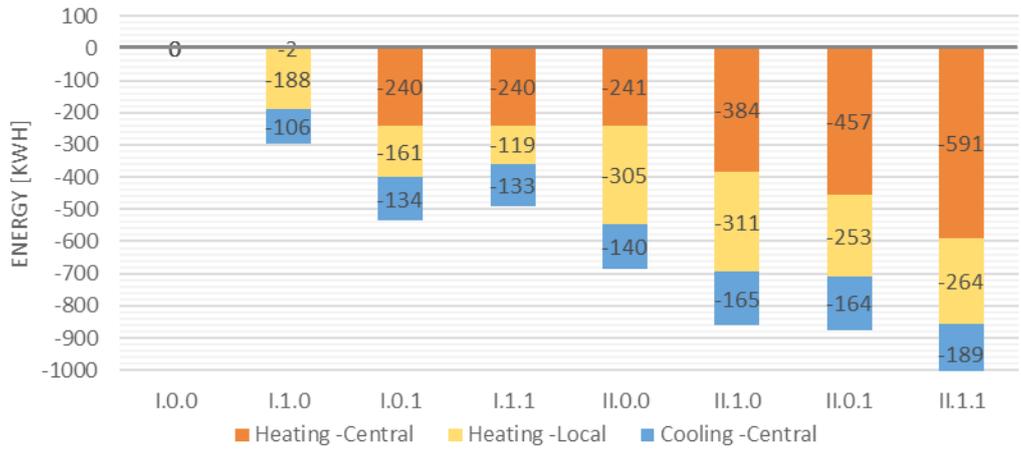


Figure 4. Yearly energy reductions of energy demands (central heating, central cooling and local heating).

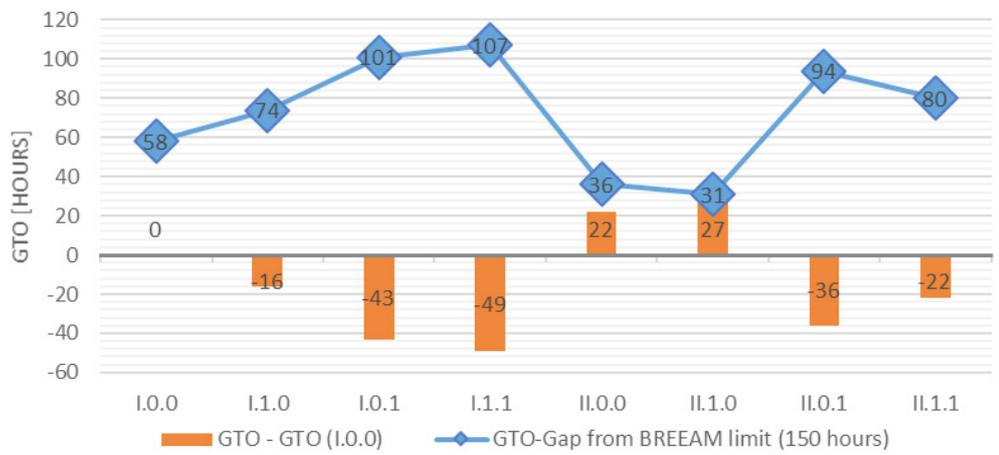


Figure 5. GTO index amount for one-year simulation compared to simulated current conditions for a single room and to BREEAM temperature comfort requirement.

The first three measures are chosen to be implemented in the building simulation models to evaluate their effect on energy consumption and indoor comfort.

Building Energy Simulations

The building simulations are performed over a period of one year, resulting in energy consumptions and GTO (Weighted Overheating Hours) index values, which are presented for both aspects in comparison to the simulated current situation (I.0.0).

Figure 4 presents the yearly reduction of energy demands and showing that the greater savings are obtained from the central heating. Significant reduction (up to 535 kWh, 14%) can be achieved without upgrading the HVAC system. However, savings double for set II in scenarios with VAV system reaching 1044 kWh in scenario II.1.1, 27% lower compared to current conditions. Scenarios II.1.1 and II.0.1 are the

most expensive, therefore, the most convenient option seems the implementation of the VAV with occupancy controls.

GTO is a performance index representing the yearly number of hours resulting in an unpleasant indoor climate. The whole set of simulations is performed to meet the BREEAM temperature comfort requirement of 150 overheating hours, see Figure 5. Scenarios II.1.0 and II.1.0 shows the highest reduction of GTO hours compared to I.0.0 confirming as best solution the VAV with occupancy controls.

Discussion and Conclusions

This research is about obtaining effective reductions in energy consumption and while improving comfort of hospital buildings. The case study, VUmc Polyclinic, has shown that despite the great efforts to fulfil energy requirements, the current performances are still inad-

equate. Moreover, realizing effective reductions are quite a challenge due to strict budgets, life expectation of buildings and their influence on hospital's incomes. Expertise in hospital building processes, life-cycle and maintenance are essential to increase energy performance when the primary process, healing, is extraordinarily leading more than in any other markets and buildings.

A three-step methodology was used to identify possibilities to reach towards nZEB requirements for hospitals. This approach consisted of three steps: (1) in-depth analysis of case study, (2) development of an

nZEB-design approach and (3) energy simulations. The in-depth analysis revealed that little attention is directed on energy performance and monitoring activity of buildings.

Application of the proposed nZEB-design method resulted in a top five of energy saving measures. The case study VU Medical Center (VUmc) Amsterdam was analysed and the energy saving potential of the Policlinic quantified. In conclusion, the approach was found to be adequate and showed important potential for energy reduction in hospitals. ■

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