REPORT

(nearly) Zero Energy Hospital Buildings

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1 Introduction

The nearly Zero Energy Building (nZEB) for new buildings is one of the issues to be solved regarding sustainability in the built environment. Also hospitals have to comply. The nZEB (NL: BENG) targets set by the Dutch Government d.d. July 2015 now imply for new buildings a significant energy reduction of building in building services by 2020 compared to the current requirement.
Besides nZEB requirements for existing buildings which will be in place by 2050 on national level hospitals also have to reduce energy consumption by legislation. Furthermore hospitals also have to reduce the energy consumption in the existing Buildings by 2020. The Academic Hospitals have to realize together a reduction of energy consumption of 30% in 2020 compared to the energy consumption in 2005. In 2015 they achieved a reduction of 14% and consequently they are facing the challenge of reducing a further 16% in less than 5 years.

To meet the nZEB requirements will be for hospitals a greater challenge than for example offices. This because of the special focus on the sometimes live saving primary process, relatively low energy tariffs which negatively effects sound business cases for energy saving measures and consequently the way energy management is organized in hospitals. Although specific attention is given to energy reduction compared to other organizations the successful implementation of energy saving measures stayed behind in hospitals.

Hospitals consume circa 1 % of the primary energy in the Built Environment. Studies show that only 25% - 40% of the energy use by Academic Hospitals is for appliances and medical equipment. The rest is building and building services related to realize the required indoor conditions.

To achieve the energy reduction and nZEB goals hospitals are now focusing on the 3 pillars: organization, behavior (awareness) and technology. Wherein future scenarios of required building performances, functions/usage of the buildings, technological innovations and business case parameters, e.g. energy tariffs and rates, are part of the technology pillar.

Royal HaskoningDHV is executing the project “nZEB Hospital Buildings” in cooperation with the Eindhoven University of Technology. This project is supported and partly financed by TVVL and REHVA to give information and insight in nZEB developments that will occur in the near future and what the consequences of these developments are for hospital buildings and in particular for building services.

TEAM
The project is led by Wim Maassen. Different research projects have been executed in cooperation with Wim Zeiler. The project leader of TVVL and contact to REHVA is Hans Besselink. The execution of the project has been facilitated and authorized by Gerard Jansen.

W.H. (Wim) Maassen MSc PDEng, Leading Professional at Royal HaskoningDHV, TU/e Fellow at Eindhoven University of Technology

H. (Hans) Besselink BSc, Senior Consultant at Royal HaskoningDHV, REHVA Fellow, TVVL-Delegate

Prof. W. (Wim) Zeiler, Professor Building Services at Eindhoven University of Technology

G.A. (Gerard) Jansen BSc, Director Advisory Group Design & Engineering Healthcare at Royal HaskoningDHV

REHVA-TVVL Reference Group

The results of the project have been presented and discussed in a REHVA-TVVL Reference group during 2 meetings on 20th April 2016 and 15th November 2016. The members of the Reference Group are:

- Prof. Jarek Kurnitski, Professor, Ehitiste projekteerimise instituudi director, Tallinn University of Technology, Adjunct Professor, Aalto University, School of Engineering, Vice-president REHVA
- Sijtze de Boer – Director, Senior Consultant at Estee BV
- Johan de Feijter – Head of Technical Department at ZorgSaam Zeeuws-Vlaanderen
- Rob van Bergen - Director at ISSO – NL Knowledge Institute Building Services;
- Roel Braeken - RVE-Manager Real Estate at VieCuri Medical Centre
- Wobbe van den Kieboom - Senior consultant at KWA Bedrijfsadviseurs B.V.
- Hans Besselink (team)
- Wim Maassen (team)

(Sub)projects

The project consists of a set subprojects that have been executed together master students of the Eindhoven University of Technology. The topics of the subprojects are:

- Reduced ventilation for isolation rooms (ERASMUS - AMC Rotterdam)
- Renovation existing Policlinic (VUmc - AMC Amsterdam)
- Feasibility NL nZEB Hospital definitions
- Closing the Energy Performance Gap
- Transformation of multi- to one-patient rooms (AMC Utrecht, MC Meander)

The research project on the reduced ventilation for isolation was executed by the Eindhoven University in cooperation with Valstar Simonis and Royal HaskoningDHV was not directly involved. The other research projects were executed by Royal HaskoningDHV in cooperation with the Eindhoven University of Technology together with the involved hospitals.

2 Background

NL ENERGY PERFORMANCE REQUIREMENTS

Currently, the requirements presented below (EPC) apply to the energy performance of new buildings in the Netherlands. The requirements are applicable to the building-related part of the energy consumption (i.e., the energy consumption of devices such as computers and coffee machines are not taken into account) and is expressed in the Energy Performance Coefficient (EPC). The EPC is calculated on the basis of defined use, and is thus independent of the user.

Ontwikkeling EPC-eisen per gebruiksfunctie

Getallen in **blauw en vet** geven een wijziging van de eis aan.

gebruiksfunctie	1995	1998	2000	2003	2006	2009	2011	2015*
woningen	1,4	**1,2**	**1,0**	1,0	**0,8**	0,8	**0,6**	**0,4**
logiesverblijf	1,4	1,4	1,4	1,4	1,4	1,4	1,4	**0,7**
bijeenkomst	3,4	3,4	**2,4**	**2,2**	2,2	**2,0**	2,0	**1,1**
cel	2,3	2,3	**2,2**	**1,9**	1,9	**1,8**	1,8	**1,0**
gezondheidszorg niet klinisch	2,0	2,0	**1,8**	**1,5**	1,5	**1,0**	1,0	**0,8**
gezondheidszorg met bedgebied	4,7	4,7	**3,8**	**3,6**	3,6	**2,6**	2,6	**1,8**
horeca	2,2	2,2	**1,9**	-	-	-	-	-
kantoor	1,9	1,9	**1,6**	**1,5**	1,5	**1,1**	1,1	**0,8**
logiesgebouw	2,4	2,4	**2,1**	**1,9**	1,9	**1,8**	1,8	**1,0**
onderwijs	1,5	1,5	1,5	**1,4**	1,4	**1,3**	1,3	**0,7**
sport	2,8	2,8	**2,2**	**1,8**	1,8	1,8	1,8	**0,9**
winkel	3,6	3,6	**3,5**	**3,4**	3,4	**2,6**	2,6	**1,7**
industrie	-	-	-	-	-	-	-	-

* tabel uit Aanscherpingsmethodiek, 50% van de EPC-eis voor van 2007 utiliteit

NL Minister Blok (Housing) presented on July 2, 2015 with a letter, the proposed requirements on the energy performance of new buildings to be applied from January 1, 2021, see table below. The energy items that are considered, are the same as the energy items in the EPC, i.e. devices are not considered and the calculation is independent of the user and is performed with a defined usage.

Building function	Energy demand [kWh/m².y]	Energy use [kWh/m².y]	Sustainable energy [%]
Dwellings	25	25	50
Offices	50	25	50
Schools	50	80	50
Health Care facilities	65	120	50

The nZEB definitions in the Netherlands are defined by three requirements:

- Maximum energy demand in kWh per m2 gebruik floor area per year
- Maximum primary fossil energy use in kWh per m2 gebruik floor area per year
- Minimum share of (local) renewable energy sources in %.

1) Energy demand

The energy demands consists of the demands for heating, cooling and lighting. Lighting is not included for dwellings. This energy demand can be provided by either using sustainable or fossil energy sources.

2) Primary fossil energy use

The primary energy use is the sum of the primary energy use for heating, cooling, domestic hot water, ventilation, lighting and humidification. Ligting and humidification is not included for dwellings. If

Photovoltaic solar panels are used, the energy provided by these panels is substracted form the total primary fossil energy use of the building.

Difference between energy demand and primary fossil energy use
Losses of energy in the system (e.g. distribution losses), transport energy (eg pumps) and the energy efficiency of generators (e.g. chillers, boilers) are taken into account within the primary fossil energy use. These are not taken into account within the energy demand.

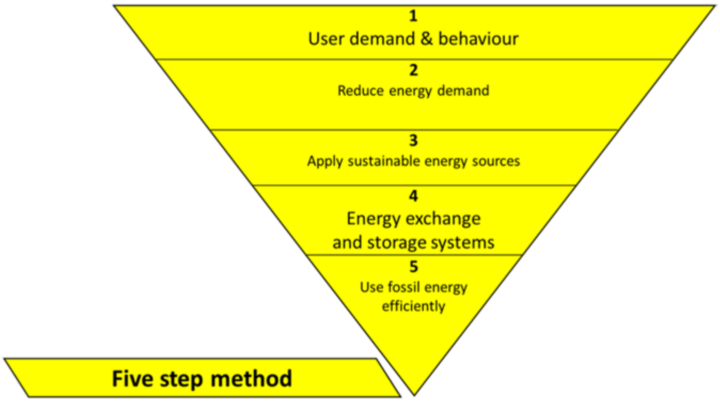
3) share of (local) renewable energy sources
The share of renewable energy is determined by dividing the total amount of renewable energy through the total amount of renewable energy and primary fossil energy.

METHOD: 5 STEPS
In order to comply with these requirements for nZEB) and beyond, a lot need to change in the short term. In my opinion there is great potential for achieving big energy reductions by designing more to user demand and user behaviour. It is no longer feasible to ventilate, heat, cool and light entire buildings – many of which are only in partial use. Buildings will have to be more ‘fit for purpose’ (tailored, appropriate to their specific use, now and in the future). This generates considerable energy savings and above all considerable benefits, such as a more comfortable building, higher productivity and lower absenteeism.

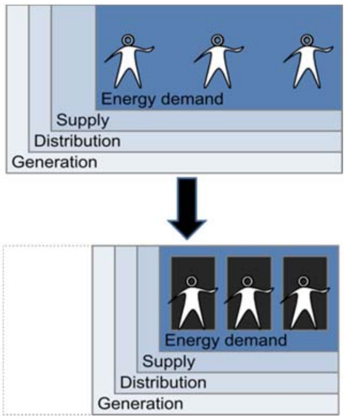
The recent publications by the US Green Building Council and the Dutch Green Building Council ‘Health, Wellbeing and Productivity in offices’ contain valuable information about how to tackle this issue in your organisation. Various possible techniques include:

- More zoning of areas in buildings (e.g. architectural partitions and fine-meshed easy to regulate installation systems).
- Individual climatisation (e.g. a climate system that controls the indoor climate with additional individual ventilation, heating, cooling and lighting. For example, workplace climatisation systems).
- Smarter occupancy-based control (e.g. better control based on planned occupancy and presence detection using infrared or other sensors, for example involving mobile phones).

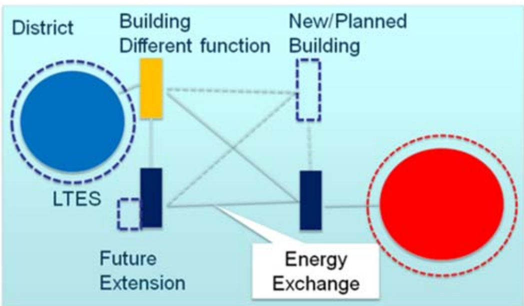
In order to meet the remaining energy needs, energy from sustainable energy sources will have to be used. However, these sustainable energy sources are not always available when you need them. It is therefore important to make optimal use of energy exchange (for example, using surplus heat in offices for homes) and energy storage (for example Long Term Energy Storage in the soil and also short term heat and cold storage). One or more of these techniques are already being applied in projects. Increasing urban density combined with the required higher energy performance offers opportunities and will also make it necessary to apply more of these techniques. The 5 steps method illustrates what I mean. In order to accelerate, I feel we must abandon the Trias Energetica and focus on this 5 steps method, especially steps 1 and 4.



STEP 1 – User demand & Behaviour



STEP 4 – Energy Exchange and Storage Systems



3 Results

In this chapter summaries of the executed (sub)projects are presented.

3.1 Reduced ventilation for isolation rooms (ERASMUS AMC Rotterdam)

The HVAC systems of hospitals, especially of University Medical Centres (UMCs), are large consumers of energy in the build environment were energy use becomes a real problem and raises concerns. If energy reduction in UMCs is considered, they encounter problems in defining reduction measures due to the complexity of their building systems. A consistent framework and good governance is recommended to provide guidance for energy reduction.

This research tested if the Pareto analysis method, as known in other fields, is a useful framework for defining energy reduction measures in UMCs. The Pareto analysis assumes that the majority of problems can be defined by a few major causes. For testing the hypothesis that the Pareto analysis is a useful method for energy reduction in UMCs, isolation rooms in Erasmus Medical Centre Rotterdam (EMC) were used as case study. This function was defined as the largest energy consuming function of EMC, based on energy intensity (GJ/m2) and total energy consumption (GJ based on the gross floor area of the function).

Considering the basic steps of the Pareto analysis, the Key Performance Indicators (KPIs) of the energy consumption in isolation rooms were defined: user influences, temperature and air changes per hour (ACH).

Users influence the energy consumption by their presence and occupancy, since rooms are conditioned for the users. Observations in EMC show that isolation rooms are often unoccupied or occupied by non-isolation patients, instead of isolation patients, for which the rooms are initially intended. Resulting in over conditioned rooms, if rooms are not occupied, or occupied by non-isolation patients. A lack of protocols for hospitalization of patients in isolation rooms is the root cause of this problem.

Relative large amounts of airflow influences the energy consumption of isolation rooms. And if ventilation is considered, the ACH in isolation rooms of EMC is larger than the by the ‘Werkgroep Infectie Preventie’ (WIP) recommended ACH. The root cause effect of this energy consuming aspect is defined as: the patient safety is replaced by insufficient founded HVAC operation, based on good practice, resulting in probably more energy consumption than needed for providing patients safety in isolation rooms. From data of the Building Management System and observations on user presence and occupancy, it was concluded that temperature setback (in case of non-occupied rooms) rarely occurs, due to the absence of protocols.

Based on these KPIs, corrective actions were defined, in which the fundamental causes are considered and adapted, resulting in minimization of the energy consumption. The action plan considered recommended ventilation amounts and temperature settings during different types of occupancy (not occupied, occupied by non-isolation patients or occupied by isolation patients).

Observations on the users activity and interviews on the functional use of isolation rooms concluded that the energy can be reduced by temperature setback, during times rooms are unoccupied or occupied by non-isolation patients. Additionally, energy reduction by setback in ACH can be implemented during times the level of activity is low, as activity (door opening/closure) increases the risk of transmission. From a room model and measurements on the potential of ACH setback during different type of occupancy, it was concluded that transmission of infectious particles through undefined cracks and gaps is the most critical situation of the infection transmission risk. These results revealed that at lower values of ACH, the contamination concentration in the isolation rooms is more uniform distributed and result in a more controllable situation.

In a simulation model, the energy reduction potential through alignment between ACH, temperature and occupancy and presence is considered. From these results it is concluded that the hypothesis that the Pareto analysis is a useful method for accessing the energy reduction potential in isolation rooms is accepted. The majority of the energy consumption can be reduced by accessing the KPIs.

3.2 Renovation existing Policlinic (VUmc AMC Amsterdam)

Hospitals need to achieve great reductions in energy consumptions and CO2 emissions for existing as well as new buildings to fulfill upcoming requirements for the European Union directive on nearly Zero Energy Buildings (nZEB). This is a great challenge because realizing energy reduction within a hospital compared to an office has a by far lower priority. Consequently, in hospitals, less data about energy consumption and building services operation is available. The case study VU Medical Center (VUmc) Amsterdam was analyzed and the energy saving potential (achievable in the outpatient departments of the Policlinic) identified. A three-step methodology was used: (1) in-depth analysis of case study, (2) development of a nZEB-design approach and (3) energy simulations. The analysis revealed that little attention is directed on energy performance and monitoring activity of buildings. Application of the proposed approach resulted in a top five of energy saving measures. According to VABI Elements© building energy simulations, significant (27%) energy savings can be achieved and indoor comfort can be improved by upgrading building envelope, HVAC system and applying occupancy-dependent controls.

3.3 Feasibility NL nZEB Hospital definitions

This report describes the possibilities and limitations in creating near zero-energy hospitals in the Netherlands. The main focus of this report is the proposed energy performance (EP) requirements that are proposed by minister Blok. These are proposed in a reaction to the EPBD, which states that all new buildings and buildings undergoing major renovations will have to be nZEB (near Zero-Energy Buildings) by 2021. The effectivity and feasibility of these EP requirements are analysed in this report. This is achieved by creating an overview of the energy flows in hospital buildings, the defining factors of hospital buildings, the trend in healthcare, the current and proposed EP requirements, and the measures that can be used to reach energy reductions to hospital buildings.

Hospital buildings are continuously changing. Hospitals have an exceptionally high renovation rate with 60% of hospital buildings being renovated between 2006 and 2011. Since the proposed nZEB requirements will go into effect in 2021, a very large share of existing hospitals will be affected by the proposed nZEB requirements. It is therefore of extreme importance for all hospitals in the Netherlands to thoroughly research how they can comply with these new EP requirements. Energy flows in hospitals are currently dominated by space heating, lighting and cooling, and about 12% of the energy demand in hospitals is related to electrical equipment. Due to trends in the healthcare sector, it is expected that energy in hospitals of the future will shift more towards non-building related energy demand.

With the introduction of the nZEB requirements, three new criteria are introduced, which apply to the entire healthcare building. For healthcare buildings, these requirements are: a maximum energy demand of 65 kWh/m2 per year, a maximum amount of primary energy use of 120 kWh/m2 per year, and a minimal percentage of renewable energy of 50%. These nZEB criteria are based on a study by DGMR, making use of a reference building to calculate energy flows in hospitals. It was concluded that the division of utility functions in the reference buildings is not representative of existing hospitals, which have an average division of 50% ‘healthcare other than bed-area’, 23% ‘office’ and only 25% ‘healthcare with bed-area'. It turns out that this division is a critical factor if the government wants to create EP requirements for the entire hospital, without separating the building functions. A new reference building is introduced to perform new calculations on.

The calculations that were performed by DGMR have been duplicated in this report, which shows that some errors have occurred, influencing the proposed nZEB requirements. Therefore, new EP requirements have to be determined. In order to do this, two sets of measures are applied to the new reference building. Thereto, an overview of possible energy reduction measures is included in this report, together with an analysis of their applicability and effectivity in hospital energy reduction. This analysis results in two lists of measures that can be applied to hospital buildings. These measures are subsequently applied to the new reference building, as well as the old reference building. The results are compared to the results of DGMR and to the nZEB requirements. Using these results, it can be concluded that the EP requirements should not be introduced to the hospital as a whole, but should rather be different for different building functions in a hospital.

Finally, new EP requirements per utility function are recommended. These EP requirements are expected to be effective and feasible for hospitals, when using the energy reduction measures proposed in this report. However if real energy reductions are to be achieved in hospitals, the criteria should be adjusted so as to include user-related energy demand as well. This is especially important, because the amount of non-building related energy in hospitals is expected to increase in the future. Proper use of electricity, like controlling the lights, ventilation, shutting-off of machines outside work-hours and including energy efficiency as a factor in buying medical equipment could attribute to a large energy reduction in hospitals. This energy reduction potential is currently ignored by the EP requirements, but should certainly be included in order to reach the maximum energy saving potential.

3.4 Closing the Energy Performance Gap

The building industry faces a significant mismatch between predicted- and measured energy consumption of buildings, known as the performance gap. This gap can have a large impact on the profitability of business-cases for energy performance contracting. A risk assessment is employed to determine the most important risks for energy performance contracting, including the risks on energy performance. A building performance evaluation on five office buildings is set up to quantify the current gap in the Dutch industry and the impact this has for a typical energy performance contracting business-case. The risk assessment shows that performance contracting includes a diversity of significant risks, of which the gap in energy performance is one. Results of the performance evaluation show that on average, the offices use 1.5 times more energy than predicted. For a typical performance contracting project, this decreases the profitability from 13 to 6% for the Energy Service Company. Better quantification of the uncertainty of energy predictions in current practice risk management is thus needed to ensure sound business-cases for all stakeholders.

Conclusions

It is shown that EPC-projects are characterized by widely distributed risk profile. This profile is composed of various types of risks, of which as well technical- as economical- and contractual risks are amongst the most important risks.

The building performance evaluation on 5 office buildings shows the thermal energy demand tends to be 1.5 times higher than predicted in their design. These findings are in line with other work on the performance gap. Results on the case study show the impact of uncertainty in the energy performance prediction can be significant for EPC-projects, decreasing the internal rate of return from 13 to 6% for a deviation of 50% in energy savings. Integrating the risk on energy performance into current practice risk management for EPC-projects is thus required to ensure sound business cases for all stakeholders.

Reducing the energy performance gap is a very important and major challenge for the building industry. Improving predictions is therefore essential, since the part of the gap due to poor assumptions in the design stage can generally not be redressed or reduced by building monitoring or –commissioning. Based on the findings of the mismatch in thermal energy demand, it can be concluded that energy performance predictions get accompanied by significant uncertainties. Despite these uncertainties, energy predictions are generally given as point-estimates, suggesting no uncertainty at all.
Quantifying uncertainties in standard practice energy predictions is needed to provide any valuable input for decision making.

Future work
Further research is needed on quantifying the energy performance gap, preferably based on a larger set of buildings. Allocating the shares of the performance gap to the different stages in the building process is necessary to increase commitment of the industry in reducing the gap in energy performance.
It is shown that the mismatch in energy performance has a large influence on the profitability of energy conservation investments. Decision making for these investments is generally based on point estimations for energy consumption. Future work should include the development of a framework on defining accurate uncertainty profiles for input parameters and propagation of this uncertainty to the model's output. Next, the added value of propagating this uncertainty should be determined for decision making.

3.5 Transformation of multi- to one-patient rooms (AMC Utrecht, MC Meander)

Health care facilities need to become more energy efficient in order to reach upcoming nearly zero energy requirements (nZEB). However, for hospitals comfort and safety of the patients is paramount. In this research these two perspectives are combined. In situ measurements are compared with questionnaires involving 169 voluntary participating individual patients in two hospitals during summer and autumn. Energy demand is determined with dynamic building simulations and energy performance calculations. For most medium stay patients, indoor temperatures between 21°C and 23°C are experienced as comfortable. This is independent of hospital and season. Warmer indoor temperatures must be possible for patients needing this due to personal preference or health conditions. More influence on temperature and air quality is experienced by patients lying in a single patient room with the ability to open a window ($p<0.01$). The fraction of patients who find it necessary to control indoor temperature increases with the length of stay of the patient ($p=0.03$). Comfort models predict thermal comfort different than patients' perceive. For hospitals, upper and lower limit of the adaptive comfort limits may be shifted down for better agreement with orthopedic hospital patients. Broader temperature ranges and sustainable systems, e.g. heat pumps and ground storage, lower the energy consumption. However, it is concluded that renovation of the building façade with increased heat resistance has the biggest influence and is certainly needed to reach nZEB requirements.

3.6 Workshops - Realizing nZEB Hospital Buildings Together

Part of the project was an interactive workshop held at 12th REHVA World Congress CLIMA 2016, in Aalborg, Denmark on Monday, May 23, 10.30-12.00 (Meeting room: Columbinesalen). In this interactive Workshop different groups worked on making an Academic Medical Centre an energy neutral area. In the first part of the workshop the technical possibilities to realize a nZEB Hospital were explored on different scales. Then in the second part each group determined how to realize this goal together, from the perspective of the different stakeholders.

The result of the workshop are the answers on the 5 questions below.

How can Hospital Buildings achieve nZEB?

- Health and safety requirements make it difficult.
- Great energy reduction possible.
- Proposed methods useful.

What are the most promising technical solutions?

Step	Measures
1. User demand & Behaviour	Lower internal heat loads (more use of stand by mode), **smart zoning of the building**, smart positioning of building functions, **smart and individual control systems** (human in the loop, SR ventilation), low flow fume hoods, low energy consuming MRI, combining processes/equipment/test set ups, education of users
2. Reduce Energy Demand	Insulation, envelope airtightness, heat recovery ventilation/hot tapwater, use daylight, thermal mass, positioning of functions and integral design to make application of technologies possible e.g. natural/hybrid ventilation of wards, better Air Handling Units, larger ducts to reduce ventilation energy, variable air flow systems (**airflow management**), LED lighting, Less heating and cooling (change standards), energy efficient appliances, less or no humidification (clay products for dehumidification in ceilings), use **BMS and monitoring** to reduce energy consumption and to show and guarantee that systems perform as they should, less tap water stations with hot water supply.
3. Apply Sustainable & Energy Sources	Photovoltaic solar cells, biomass, wind energy, adiabatic cooling
4. Energy Exchange & Storage	Long term energy storage in the soil/acquifer (LTES), short term energy storage (buffers, Phase Change Materials), Concrete Core Activation (TABS), Exchange energy between internal/external functions
5. Efficient use of fossil energy	High efficient boilers, chillers, heat pumps, cogeneration of heat and power

What is necessary to implement these solutions in practice?

- Operate Hospitals not stand-alone with reliable energy supply
- Use energy exchange and storage on local and district scale
- Research results showing that health risks (risks to patient safety) will not increase when implementing energy-efficient solutions.
- Knowledge sharing and users' engagements

How can REHVA stimulate the above?

- Communicate with Hospital users (e.g. brochures, presentations, workshops, and guidebooks).
- Have meetings with stakeholders of medical centers in different countries (e.g. a first meeting in London was suggested), including ASHRAE Technical Committee 9.6 on healthcare facilities)
- Gather and produce evidence of best practices (e.g. research studies, project references and guidebooks).
- Develop a dedicated REHVA Guidebook (together with ASHRAE)

4 Conclusions

The main conclusions of the project are:

Reduced ventilation for isolation rooms (AMC Rotterdam)

- Significant energy reduction in hospitals can be achieved by selecting most effective measures using a Pareto analyses.
- Significant energy reduction can be achieved by challenging and optimising operation conditions of different rooms especially isolation rooms.

Renovation existing Policlinic (AMC Amsterdam)

- Energy reduction in Hospital Buildings is not (yet) a real priority.
- Energy Simulation: shows 20% reduction potential of heating and cooling in treatment rooms
- To achieve significant energy reduction start with organization, base case performance, monitoring and setting ambitions

Feasibility NL nZEB Hospital definitions

- Set concept/draft NL nZEB requirements for Hospitals are not yet fit for purpose.
- nZEB requirements should differentiate more in functions. Especially for hopsitals with an variety of rooms, functions and processes.

Closing the Energy Performance Gap

- The inaccuracy of the calculated energy performance compared to the energy performance in practice has a major effect on the profitability of energy saving measures.
- The application of energy saving measures can be increased by improving the accuracy of the business case. The business case can be improved by using measured and optimized data of the performance of energy saving measures to provide reliable energy performance estimations in the design phase.

Transformation of multi- to one-patient rooms (AMC Utrecht)

- Transformation of multipatient rooms to single patient rooms canlead to a higher total energy consumption but doesnot automatically mean that nZEB requirements are more difficult to fulfil.
- Significant energy savings can be achieved by applying lower temperature setpoints and facilitating patients to adjust their thermal comfort by using extra blankets and/or opening the windows.

CLIMA2016 - REHVA Workshop (WS3) - Realizing nZEB Hospital Buildings Together

- The main conclusion of the REHVA workshop is the conclusion of the participants that realizing energy savings in hospitals is a real challenge and that more evidence of safe and effective measures to save energy should be presented. Evidence based on research and the performance of best practices will seduce hospital organizations to implement energy saving measures that are safe and in the meantime optimize the performance of their primary processes.

Don'ts:

- Only focus on CO_2 emission reduction
- Operate Hospitals (fully) stand alone
- Use gas
- Only focus on the energy plant

Do's:

- Apply and organise energy management
- Realise better fit to user behaviour for ''Safe, Fast and Comfortable Healing''
- Use energy exchange and storage
- Use energy of sustainable sources
- Present evidence for safe measures ➔ Guidebook nZEB Hospital Buildings

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Appendix I – REHVA Workshop (WS 3) Realizing nZEB Hospital Buildings Together, REHVA CLIMA 2016, d.d. November 2nd 2016

WS 3: Realizing (nearly) Zero Energy Hospital Buildings together

Workshop organizers

TVVL/REHVA and Royal HaskoningDHV, www.royalhaskoningdhv.com

Presenters

W.H. Maassen, Leading Professional - Royal HaskoningDHV, TU/e Fellow - Eindhoven University of Technology

H. Besselink, Senior Consultant - Royal HaskoningDHV, REHVA Fellow, TVVL-Delegate

T.J. Baas, Graduate Master Student Building Services - Eindhoven University of Technology

Introduction and Background

In the Energy Performance of Buildings Directive (EPBD), the EU requires all new buildings to be nearly Zero Energy Building (nZEB) by 31 December 2020 (2018 in case of public buildings) which also applies to hospitals. Within hospitals, it is essential to guarantee appropriate and sometimes live saving functionality while saving energy. Therefore, achieving these requirements in hospitals is even a greater challenge than, for example in office buildings. Worldwide, about 6% of the total energy consumption in the buildings sector is represented by energy usage in medical centres. In the Netherlands, the healthcare sector consumes approximately 1.6% of the energy consumption, of which 64% is consumed by academic medical centres (AMCs). The approaching EPBD requirements and the expected increase of energy costs have driven AMCs to review their energy policies. In light of these concerns, a multi-year energy-efficiency covenant 2005–2020 (MJA3), organized by the Dutch Enterprise Agency (RVO), was signed by each Dutch AMC. The most relevant commitment of MJA3 for each hospital is achieving 2% additional energy efficiency every year, resulting in a minimum of 30% energy savings in 2020 compared to the total energy consumption of the AMCs in 2005.

Summary of the Presentations

The workshop started with presentations with targets that covered the following four key issues:

1. **How can hospital buildings achieve nZEB?**
2. **What are the most promising technical solutions?**
3. **What is necessary to implement these solutions in practice?**
4. **How can REHVA stimulate the above?**

The target buildings were both new (thus involving optimization in the design phase) and existing hospitals (where energy saving potential and measures could be identified). After a short summary of some projects undertaken by Royal HaskoningDHV (e.g. project management, design and energy master planning of hospitals), the presenters illustrated, in detail, the definitions and approaches used for nZEB hospitals and considered how they differed from the Energy Performance Coefficient (EPC) currently established by the Dutch government (that will be amended prior to 2020).

Statistical data from hospitals in the Netherlands was also presented and reference energy targets and benchmarks were highlighted to the audience to provide examples of technically feasible nZEB solutions for hospital buildings. Energy demand of hospital buildings related to use (and also to number of rooms) was analysed, and the need to maintain a high quality indoor environment was emphasized. The presenters provided a detailed explanation of the methodology used in the projects that covers five steps: addressing user demand and behaviour; reducing energy demand of the building; applying sustainable energy sources; adopting energy exchange and storage systems and using fossil energy efficiently. The presenters proposed typical measures for this five tier approach and explained two innovative systems under development, "Human in the Loop" and Self-Regulating (SR) ventilation systems for hospitals. The presentation session ended with a description of a case study of the VU University Medical Centre in Amsterdam.

Discussion and main results

The participants worked together in groups to consider the case study. With the feedback from the groups four key questions were answered as follows.

1. How can hospital buildings achieve nZEB? It is a difficult task because of all the specific health and safety requirements. However great improvements in energy consumption can be achieved. The proposed methods form this workshop were considered as being very useful in creating nZEB conceptual design variants for hospital buildings.

2. What are the most promising technical solutions? The five-step nZEB approach used in the projects was discussed and the attendees provided additional inputs to the proposed measures:

- User demand and behaviour.
  Lower internal heat loads (more use of standby mode), smart zoning of the building, smart positioning of building functions, smart and individual control systems (human in the loop, SR ventilation), low flow fume hoods, low energy consumption Magnetic Resonance Imaging (MRI) systems, education of users and combining process, equipment and test set-ups;

- Reduce energy demand.
  Insulation, envelope airtightness, heat recovery systems for ventilation and hot water services, use of daylight, thermal mass, integrating design with occupant functions to make the application of technologies possible (e.g. natural or hybrid ventilation of wards), better

air handling units, larger ducts to lower pressure resistance and consequently reduce the energy consumption for ventilation, variable air volume systems (air flow management), LED lighting, reduced heating and cooling (application of different standards), energy efficient appliances, passive solutions for dehumidification (e.g. clay-based products for dehumidification in ceilings), building management systems (to guarantee and evidence system performances), reduction of tap water outlets with a hot water supply;

- Apply sustainable and renewable energy sources
  For example, photovoltaic solar cells, biomass, wind energy, adiabatic coolers;

- Energy exchange and storage.
  Long Term Energy Storage (LTES) (e.g. aquifer storage or ground storage), Short-Term Energy Storage (e.g. thermal buffers or Phase Change Materials);
  Thermo-active building systems (e.g. concrete core activation), Exchange energy between internal and external functions;

- Efficient use of fossil energy.
  High efficiency boilers, chillers, heat pumps and combined heat and power.

Step		Measures
1.	User Demand & Behaviour	Lower internal heat loads (more use of standby mode), smart zoning of the building, smart positioning of building functions, smart and individual control systems (human in the loop, SR ventilation), low flow fume hoods, low energy consuming MRI, combining processes/equipment/test set ups, education of users
2.	Reduce Energy Demand	Insulation, envelope airtightness, heat recovery ventilation/hot water services, use daylight, thermal mass, positioning of functions and integral design to make application of technologies possible, e.g. natural/hybrid ventilation of wards, better air handling units, larger ducts to reduce ventilation energy, variable air flow systems (airflow management), LED lighting, Less heating and cooling (change standards), energy efficient appliances, less or no humidification (clay products for dehumidification in ceilings), use BMS and monitoring to reduce energy consumption and to show and guarantee that systems perform as they should, less tap water stations with hot water supply.
3.	Apply Sustainable Energy Sources	Photovoltaic solar cells, biomass, wind energy, adiabatic cooling.
4.	Energy Exchange & Storage	Long term energy storage in the soil/aquifer (LTES), short term energy storage (buffers, Phase Change Materials), Concrete core activation (TABS), Exchange energy between internal/external functions.
5.	Efficient use of fossil energy	High efficiency boilers, chillers, heat pumps, combined heat and power.

3. What is necessary to implement these solutions in practice? While the reliability of energy supply should be guaranteed in hospitals, it should not be designed and operated as a stand-alone system. Energy and CO_2 emission reduction should be realized on a local (or district) scale with a holistic approach using energy exchange and energy storage. Research shows that health risks (risks to patient safety) will not increase when implementing energy-efficient solutions. Different standard-based design solutions may provide the required level of safety and comfort, and it is important to gather and produce evidence from best practices. Knowledge sharing and user engagement (e.g. meeting with stakeholders) may also make the difference since medical staff are used to reading and relying on research studies and evidence.

4. How can REHVA stimulate the above? Speakers suggested that REHVA could assist in the following activities:

- Organizing communication activities targeting hospital users (e.g. brochures, presentations, workshops and guidebooks);
- Organizing and attending meetings with stakeholders in medical centres in diffrent countries (e.g. a first meeting in London was suggested), including ASHRAE Technical Committee 9.6 on healthcare facilities;
- Gathering and producing evidence of best practice (e.g. research studies, project case studies and guidebooks);
- Developing a dedicated REHVA Guidebook (together with ASHRAE).

Conclusion and future work directions in the field

Hospitals are conservative systems with hierarchical decision-making (with medical staff having ultimate responsibility). The suggested solutions have to be reliable and based on documented research and testing to gain users' trust. The development of guidebooks by REHVA and ASHRAE would stimulate the realization of nZEB hospitals. Participants from Switzerland, UK and Morocco expressed their will to join the REHVA project on nZEB hospital buildings.

Acknowledgement

This workshop is part of the project "nZEB Hospital Buildings" that Royal HaskoningDHV is executing in cooperation with the Eindhoven University of Technology. This project is supported by TVVL and REHVA.

References

Workshop presentations are available at
http://www.rehva.eu/events/clima2016/clima-2016-workshops.html

Appendix II – Presentation TVVL Techniekdag d.d. November 2nd 2016

Appendix III – Project description REHVA Guidebook nZEB Hospital Buildings

Towards nZEB Hospital Buildings

powered by TVVL/Rehva and Royal HaskoningDHV in co-operation with Eindhoven University of Technology

Introduction

EU legislation (Energy Performance Directive for Buildings) demands all EU member states to set maximum energy usage requirements for new buildings by 2020. Also hospitals have to comply. The so-called nearly Zero Energy Building (nZEB) requirements set by the Dutch Government d.d. July 2015 now imply for new buildings a significant energy reduction of building en building services related energy by 2020 compared to the current requirement. These NL nZEB requirements were set preliminary and are still under consideration.

nZEB Requirements for existing buildings will follow in 2050. Furthermore besides nZEB requirements for new buildings hospitals also have to reduce the energy consumption in the existing Buildings by 2020. The Academic Hospitals have to realize together a reduction of energy consumption of 30% in 2020 compared to the energy consumption in 2005. In 2015 they achieved a reduction of 14% and consequently they are facing the challenge of reducing a further 16% in less than 5 years. To achieve their target they have to reduce instead of 1.4% energy reduction per year in the last 10 years now > 3% energy reduction per year each year from 2015 to 2020.

For hospitals this will be a greater challenge than for example offices. This because of the special focus on the primary process, relatively low energy tariffs which negatively effect sound business cases for energy saving measures and consequently the way energy management is organized in hospitals. Although specific attention is given to energy reduction compared to other organizations the successful implementation of energy saving measures stayed behind.

Hospitals consume circa 1 % of the primary energy in the Built Environment. Studies show that only 25% -40% of the energy use by Academic Hospitals is for appliances and medical equipment. The rest is building and building services related to realize the required indoor conditions.

To achieve the energy reduction and nZEB goals hospitals are now focusing on the 3 pillars: organization, behavior (awareness) and technology. Wherein future scenarios of required building performances, functions/usage of the buildings, technological innovations and business case parameters, e.g. energy tariffs and rates, are part of the technology pillar.

TVVL/ Rehva and RHDHV-TU/e want to:

- Give information and insight in nZEB developments that will occur in the near future and what the consequences of these developments are for Hospital Buildings and in particular for Building Services.
- Contribute to the road to nZEB for Hospital Buildings and help our society to make the right choices.

To this end in 2016 the project nZEB Hospital Buildings has been executed. Results of the project have been presented and discussed during REHVA and TVVL workshops and led to the following conclusions and directions for future work:
''Hospitals are conservative systems with a high hierarchy in decision-making (medical staff take responsibility of crucial decisions). The suggested solutions have to be reliable and based on documented research and testing to gain users' trust. The development of guidebooks by REHVA and ASHRAE would stimulate the realisation of nZEB Hospital Buildings. Participants from Switzerland, United Kingdom, Turkey and Morocco expressed their will to join the REHVA project on nZEB Hospital Buildings.''

REHVA Guidebooks are realized by the REHVA Technology and Research Committee, see http://www.rehva.eu/committees/technology-and-research.html. Available REHVA Guidebooks can be found here: http://www.rehva.eu/fileadmin/Promotional_material/Brochures/REHVA_guidebooks.pdf

Scope
Hospital Buildings and HVAC systems within the scope of the EU nZEB definition.

Target Group
Hospital Building Designers, especially HVAC consultants, hospital owners, developers and users. To communicate, inspire, seduce/convince (evidence based) and enable them to search for, find, select, apply, use and maintain/optimize safe evidence based nZEB Hospital Building design solution .

Main Content
- Overview of future Hospital Building requirements
- Method how to fulfill these requirements
- Overview design solutions
- Overview future innovations
- Best practice case providing evidence of safe and effective solutions
- Indication of financial feasibility of nZEB Hospital Building solutions using LCC (EU cost optimality method) and LCPD (EU method including benefits and scenario's) calculations.

Inivited Authors
- Prof. Jarek Kurnitski Professor Tallinn University of Technology
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- Marco Waldhauser - CEO / Owner Waldhauser+Hermann AG
- Prof. Dr. Birol Kilkis, Fellow ASHRAE - Baskent University and Chair of Energy Engineering Graduate Program
- Wim Maassen – Royal HaskoningDHV, TU/e
- …..

Approach
This REHVA Guidebook will be realized following the steps:
1. Define outline Guidebook
2. Invite authors

3. Set structure and content
4. Define Workpackages
5. Deliver concept chapters
6. Optimize
7. Deliver final chapters
8. Edit final version
9. Review by authors
10. Review by REHVA

Meetings will be held in combination with REHVA meetings and using skype.
The Guidebook will also be discussed with ASHRAE TC 9.6.

The REHVA Journal in November 2017 will be about nZEB Hospital Buildings and present ca. 15 articles on this topic. Preparations for this Journal are ongoing. It is the intention to let the authors of these article participate in the nZEB Hospital Guidebook.

Time Schedule
The project will be executed in a period of 2 years.
Preferably starting January 2017 and ending February 2019.
This includes review by REHVA (max 3 months) and making some adjustments (2 months) based on possible comments for revision.

Reference group
The study will be conducted under the supervision of a reference group, the members are:

- Jarek Kurnitski Professor Tallinn University of Technology
- Hans Besselink Consultant RHDHV, TVVL –Impuls
- Rob van Bergen, Managing Director ISSO, Scientific Institute of Dutch Building Services Organizations
- Sytze de Boer, Managing Director Estee bv
- Johan de Feijter, Stichting Zorgsaam
- Roel Braeken, VieCuri
- Wobbe van den Kieboom, KWA

Results:
This results in a REHVA Guidebook Design of nZEB Hospital Buildings (ca. 50 pages)

Planning:
(intended) start date: January 2017
end date: February 2019