Pareto analysis: a first step towards nZEB Hospitals

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The energy use of hospitals, especially University Medical Centres, is among the highest of all building types. It is important to reduce it without endangering the primary functions within hospitals. An energy management case study using the Pareto analysis method, in the isolation rooms of Erasmus Medical Center, revealed a large HVAC energy reduction potential.

Keywords: Energy reduction, Pareto analysis, nZEB Hospitals.

Introduction

The world's energy consumption raises concerns over supply difficulties, exhaustion of energy resources and heavy environmental impacts. Of this world's energy consumption, nearly 40% is used in the building sector of developed countries [1], with hospitals to be one of the largest consumers. In the Netherlands, the healthcare sector consumes 1,64% of the energy consumption, of which 64% is consumed by the 8 University Medical Centres (UMCs) [3]. HVAC systems consume approximately 50% of the total primary energy used in UMC buildings [4]. Operational optimization of these systems is not an easy task since many interrelated building parameters, building user characteristics and building services components influence the operation and performance of these large-scale HVAC systems. The main problems in the optimization process are the difficulties in detecting inefficiencies and intricate relations between the energy consumption and influencing parameters [5]. The majority of the research already performed on energy reduction in UMCs, was aimed on efficient generation of energy, compared to little research on the HVACs energy demand and supply (actual energy consumption), although its energy reduction potential. Awareness of user influences on HVAC systems is an important, but fairly unknown, parameter of the demand [6]. Additionally, research on energy reduction requires engineers to take patient safety, as far as it is provided by the building systems, as major priority [7]. However, preliminary research revealed that UMCs have high potential for energy through reduction in their heating, ventilation and air conditioning (HVAC) demands. To activate this potential, energy management, protocols and a framework are required to support energy reduction.

UMCs in general suffer from a lack of a consistent and homogeneous framework for energy reduction, due to complexity and diversity of their HVAC systems. Systematically approaching the energy reduction potential in UMCs requires a consistent framework. In this research, the ´Pareto analysis´ method is used as a guideline for the development of an energy reduction framework for UMCs. In order to define this framework as a step towards guided HVAC energy reduction in UMCs, the approach was applied in a test case UMC.

Methodology

The Pareto analysis, also known as the 80/20 rule, assumes that: the majority of problems (80%) can be identified by a few major causes (20%), or 80% of the problems can be solved with 20% of the effort. This analysis method is often used in decision-making issues, or in solving complex problems, for example, in the industrial engineering [8]. **Figure 1** illustrates this Pareto analysis, in which the required effort (causes) is plotted against the solutions (problems) [9]. The Pareto analysis identifies the few major causes that result in the majority of energy consumption problems. A Pareto analysis is a useful tool to direct to specific focus points and target the most important aspects that affect the energy consumption. The analysis identifies and rates the influencing parameters, resulting in the most important parameter to focus on first. “It is normally easier to reduce a tall bar by half than to reduce a short bar to zero. Significantly reduce one big problem, and then hop to the next”, as cited by [9].

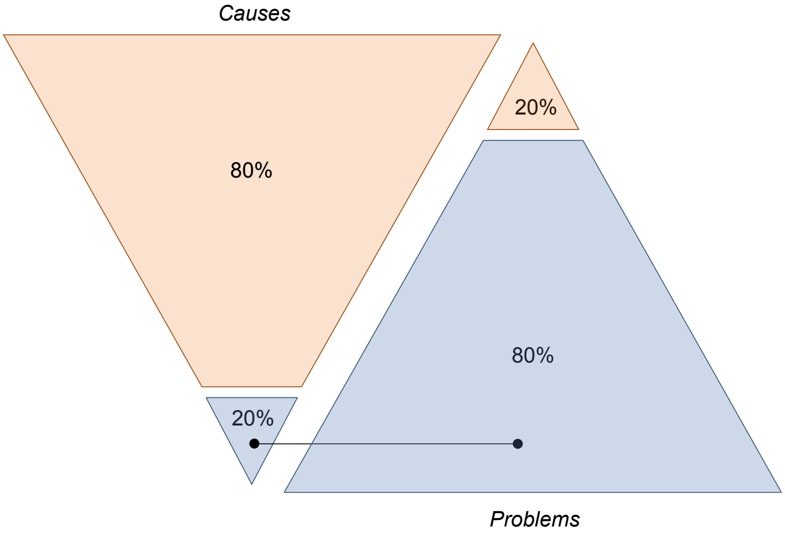

Figure 1. Methodology based on the Pareto-analysis. Majority of problems (80%) can be identified by a few major causes (20%). [9]

If the primary problems are solved, the same technique can be used in a new Pareto analysis, in which again new primary problems can be distinguished (continuous improvement). The Pareto analysis includes six basic steps, as illustrated in **Figure 2**.

Step 1 and 2: Identify problems and root causes of problems (identify)

Main characteristics of energy consumption were indicated using data based on calculations, observations, interviews and reports. The cause-effect of these problems can be identified by a RCA, which defines the nature of the problems. The RCA includes defined basic steps:

1) Collect data: Systematically collect data and notify the problem. Determine for how long this problem has been occurring. Determine the frequency (quantify) and the impact (if the problem will not be solved) of the problem.
2) Define and classify possible causes: Identify how and under what conditions the problems arise, and identify what other problems arise if these identified problems are solved.
3) Define root causes: Define the causes that induce the problems and define their correlation.

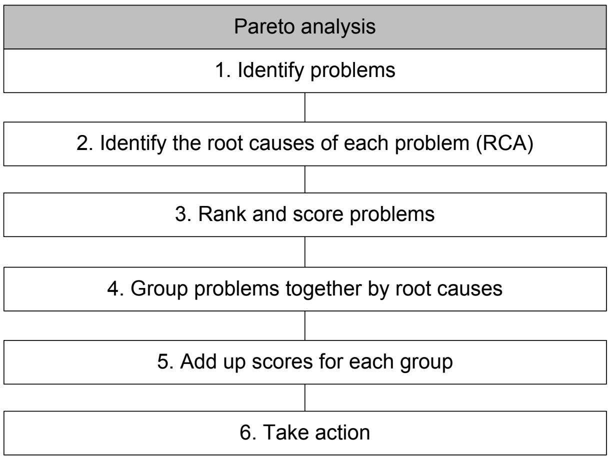

Figure 2. Basic steps of the Pareto analysis. Step 2 includes the Root Cause Analysis (RCA).

Step 3, 4 and 5: Rank, score and group problems (prioritization)

Identified problems are ranked to importance, scored and grouped together. An example of ranking in a financial approach, is the gravity of the problem concentrating on the organizational costs. If the main cause of the organizational costs is customer dissatisfaction (group), the focus is on the number of complains.

Step 6: Take action (corrective actions)

As the problems are identified, an action plan with improvement actions can be formulated in order to solve the problems.

Case study definition for testing the hypothesis (Pareto analysis)

The case study as used for testing the Pareto analysis was Erasmus MC Sophia (EMC). EMC is a compact UMC, includes all healthcare functions, provided in a good cooperation during preliminary research and already has knowledge and experience on this topic. The large scale and complexity of the HVAC systems in EMC was not a manageable situation and needed to be addressed on a smaller scale. The first step for accessing the energy reduction potential in EMC was through differentiation of energy consumption to different healthcare functions in EMC. The outcome of the preliminary research was the energy intensity and the total energy distribution per healthcare function. The energy consumption of EMC is differentiated to functions, see **Figure 3**. Two large energy consuming functions are marked as important functions to focus on: both surgery rooms(SR) and isolation rooms (Isol.r.) consume, overall (GJ) and per square meter (GJ/m²), significantly more energy than other healthcare functions.

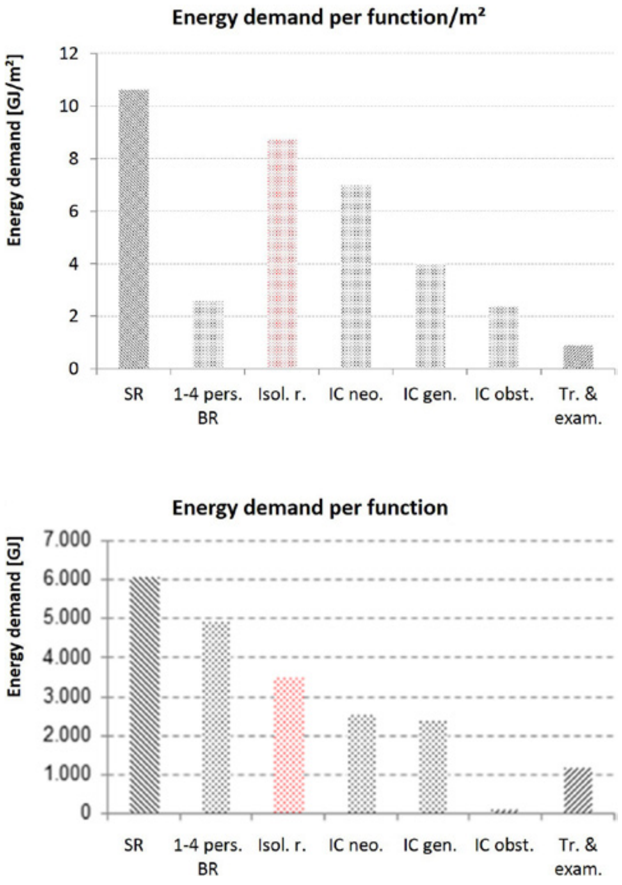

Figure 3. Local heating, cooling and fan energy demand per healthcare function/m² respectively total energy demand per healthcare function [GJ] in EMC. Surgery (SR), bedroom (BR), intensive care (IC), treatment and examination room (Tr. & exam.), assessed using Vabi Elements building simulation.

The research revealed the healthcare function with most potential for energy reduction: isolation rooms.

Step 1 and 2: Identify problems and identify the root causes of each problem

The first step of the Pareto analysis identified the problems (energy consuming parameters) of the large energy consuming HVAC systems in isolation rooms. In this first step, hand calculations and simulations were used. The root causes of the problems were analysed using a Root Cause Analysis (RCA), a well-known method used in the second step of the Pareto analysis.

Figure 4 illustrates a Pareto diagram applied on the energy reduction problem of this research. On the x-axis the problems which causes the energy consumption and on the y-axis the energy consumption. The 80% value line illustrates 80% of the energy consumption, which is assumed to be caused by 20% of the problems. If primary problems are identified, the problems can be solved by defined corrective actions.

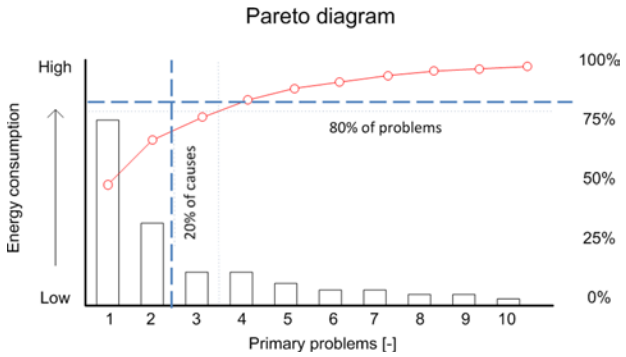

Figure 4. Pareto diagram projected on the energy problem. Primary problems are differentiated and are rated to their energy consumption. The dotted line indicates the 80/20 rule: 80% of the energy consumption can be solved with 20% of the influencing parameters.

Step 3, 4 and 5: Rank, score, group problems

The energy influencing parameters were grouped into five prospective (use influences, setpoints, building, system operation and external influences). The prospective including the parameters were scored and rated using a probability-impact analysis. A high probability and large impact means a high energy reduction potential. The outcome of this analysis were KPIs (user presence and occupancy, room temperature and air changes per hour (ACH)), which represented the focus of the research on corrective actions.

Corrective actions

The corrective actions are part of step 6 of the Pareto analysis. An action plan described improvement actions on the KPIs (user presence and occupancy, temperature and ACH) that were determined and formulated. Corrective actions resulted in a useful solution of energy reduction. Alignment of the actual system operation to the users' energy demand, potentially leads to energy reduction. In order to determine the magnitude of this energy reduction potential, a building simulation model was used. The quantified user influences and their related system operation as specified in the corrective actions of the previous step, were used as input for the building simulation model and defined the theoretical energy demand. The outcome of this simulation was compared to the energy consumption of the actual HVAC operation. Input of the actual HVAC operation was obtained from field measurements

Conclusions

The Pareto analysis is a useful systematic approach for determining energy reduction potential in UMCs. This hypothesis was tested using the case study as described. The rooms of the case study building were differentiated by functions which had the largest energy consumption (based on energy intensity and total area) and these were selected to be analysed. The Pareto analysis was found to be a useful approach for determining energy reduction potential in UMCs. ■

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References

[1] Colmenar-Santos A., de Lober L.N.T., Borge-Diez D., Castro-Gil M., (2012, October); Solutions to reduce energy consumption in the management of large buildings. Energy and Buildings, Volume 56 (2013), 66 – 77.

[2] Teke A., Timur O.,Assessing the energy efficiency improvement potentials of HVAC systems considering economic and environmental aspects at the hospitals, Renewable and Sustainable Energy Reviews, Volume 33, May 2014, Pages 224-235.

[3] Energy research Centre of the Netherlands, (2014, January); Waarom energie in de gebouwde omgeving?, Petten.

[4] Internal reports; Energy annual reports UMC St. Radboud, Erasmus MC, LUMC, AZM (2009-2013).

[5] Korolija I., Marjanovic-Halburd L., Zhang Y., Hanby V.I., (2011, January); Influence of building parameters and HVAC systems coupling on building energy performance. Energy and Buildings, Volume 43 (2011), 1247 – 1253.

[6] Pérez-Lombard L., Ortiz J., Pout C., (2007, January); A review on buildings energy consumption information. Energy and Buildings, Volume 40 (2008), 394 – 398.

[7] Kranenburg L., (2013, February); Verduurzaam de zorg mét gesloten portemonnee. BouwKennisBlog Marketingblos voor de bouwketen. Onderzoek van Royal HaskoningDHV.

[8] Ahmed M., Ahmed N., (2011); An application of Pareto analysis and Cause-and-Effect diagram (CED) for minimizing rejection of raw materials in lamp production process. CS Canada Management Science and Engineering, Volume 5 (2011), No 3, 87 – 95.

[9] Bonacorsi S., (2014, June); Step-by-step guide to using Pareto analysis. Process Excellence Tools process excellence network.

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