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FROM DESIGN TO OPERATION – LESSONS LEARNED FROM THE WORLD'S FIRST PASSIVE-HOUSE OFFICE TOWER

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Abstract

The RHW.2-tower in Vienna is the world's first office tower certified to the Passive-House-Standard. In operation since the end of 2012, the building was designed to fulfil the highest standards in terms of energy-efficiency and user satisfaction.

The building's design was based on two principles. The first was the consequent reduction of energy demand. This was reached through the use of energy-efficient equipment, a focus on reduction of standby-losses, a strictly demand-driven approach for the operation of all installations and a special attention in creating a superior building envelope with a low air-leakage rate. The second was to integrate several energy sources with a special attention to those given on-site. The system includes a biogas-fuelled CHP, geothermal probes within the buildings slurry trench walls, the use of the waste heat of a neighbouring data-centre and cooling with the water of the nearby Danube Canal. To be able to optimize the energy performance of the building during operation and to build a data foundation for further research and development, a comprehensive energy monitoring system was installed. The collected energy performance data of the first two years of operation prove the outstanding energy performance of the building. Nevertheless, the energy monitoring systems also enables the user and operator to identify areas for further optimization.

The paper shows the challenges and difficulties from the first steps of design to the actual operation of a highly energy efficient building like the RHW.2. In addition, the results of the first phase of the energy monitoring as well as the challenges faced in the first two years of operation shall be discussed.

Keywords:
large-scale Passive House; energy efficiency; energy monitoring

1 INTRODUCTION

In December 2012 construction of the world's first office high riser certified to the Passive-House-Standard was finished in Vienna, Austria. Located alongside the Danube Canal in the centre of the city, the goal of this building was from the very beginning to realize an energy-efficient model-building which fulfils the highest standards in terms of energy consumption as well as user satisfaction.

To meet these goals, it was necessary from the first steps of the design phase to include all disciplines in an integrated approach to find an energy optimized solution for the buildings construction and its installations. The building was designed to use the resources of the given location as efficiently as possible. An elaborate mix of different energy supply systems was also crucial within this concept, as the use of only one main energy source or technology to satisfy the special demands within buildings of this size is leading nowhere.

After overcoming all the challenges faced in the design and construction phase of complex large-scale buildings, the operational phase poses a huge amount of new difficulties on the way to energy efficient operation. In the end the energy consumption of the construction depends in large parts on the use of the building and the behaviour of the people working in there every day. Besides the user, it is especially the facility service provider (FSP) whose task it is, to keep an eye on the

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energy efficient operational mode of the building and fill the ideas of the design engineers with life.

In this paper in a first part, the building technological concept of the world's first high rise office building, which is certified to the passive-house standard, will be explained. A special focus lies on the discussion of the special challenges within the different stages of planning and construction an edifice with sharply increased standards in terms of energy demand and comfort. In a second part, the findings of the analysis of the energy consumption data of the building within the first two years of operation will be discussed against the background of high user demands with the need for energy efficiency at the same time. The energy consumption data is taken from the comprehensive energy monitoring system which was installed in the RHW.2 in order to be able to optimize the buildings installations during the operational phase.

2 DESIGN AND CONSTRUCTION

2.1 The technological concept

As already mentioned in the beginning, the design and construction phase of this building was characterised by an integrated approach in which all disciplines were involved and mutual interdependencies were taken into account in finding the ideal solution for the building's design. As an example, a design process, where architecture works independently from building technology and vice versa building technology works independently from architecture, leads inevitably to shortcomings in fulfilling the goal of designing an energy efficient model building. The construction has to be seen as one aggregate functional unit, which consists of several sub-units. The goals which are defined at the start of the planning process can only be achieved, when these sub-units are coordinated with each other and are able to form a functioning system in the end.

One major outcome of this process was the special double-façade system which was designed and built for this building. In order to reduce cooling and heating load and therefor reduce the towers energy demand, the façade consists of two layers. The outer hull is made up of laminated safety glass-elements which define the contour of the building. The inner façade is being made up of massive concrete parapets with upgraded insulation and window strips with passive-house qualified window elements. The ventilation of the space between the two façade-layers is ensured by ventilation-fins located per floor around the whole length of the cladding. This fact is insofar important as it prevents the overheating of the interspace between the two layers in hot summer days. One benefit of this system is that it allows the use of outside shading devices, which are installed in the interspace between inner and outer layer. The outer layer works here as a wind shield and allows the screens to be used even in extremely windy conditions without any problems. Another benefit is the improvement in comfort for the office-workers, as the wind protection given through the outside layer, opening of the windows and thus natural ventilation of the rooms behind is possible.

Another cornerstone of the buildings technological concept is the integration of several energy sources in a complex system of energy generation and distribution (Fig. 1). The heart of this system is a biogas fuelled combined heating and power plant (CHP), which provides – based on the principle of trigeneration – heating energy for warming the building on cold winter days. When outside temperatures are rising and heating demand decreases, the excess heating energy is used – via an absorption cooling machine – to cover the cooling demand of the construction. The thermal output of the CHP is 450kW, while the

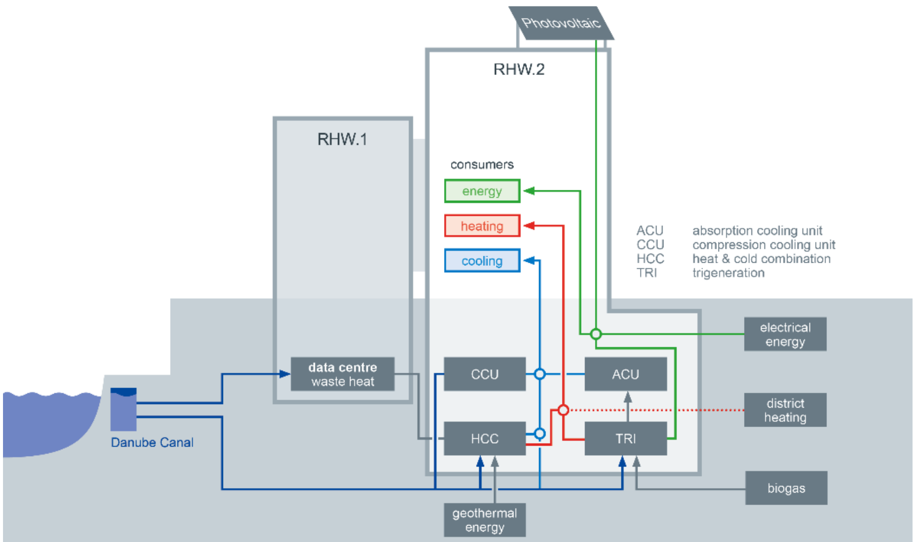

Fig. 1: Design concept of RHW.2.

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electrical output is 400kW. While the output of thermal energy is used to provide the necessary cooling and heating energy for the office tower, the generated electrical energy is – certified as green electricity – feeded directly into the public power grid.

Another energy source used is geothermal energy. For that geothermal probes have been included in the buildings deep reaching slurry trench walls. With a highly efficient compression chiller, which operates – in line with actual demand – as a cooling machine or a heat pump, additional thermal energy for the supply of the office building can be provided. To cover the peak demand on very hot summer days, a second energetic optimized compression chiller has been installed, which is recooled by the water of the nearby Danube-Canal. In times, when the water of the river is cold enough, it can be used for direct cooling too.

Another heat source incorporated in the supply system of the building is a data-centre, which is located in a nearby building. Normally the waste heat of the IT-equipment is lost. In this case it is ecologically worthwhile used for providing heat energy to the office building.

The whole system of energy generation and distribution is controlled through an integrated control system, which links all the different installations at a common point and processes all the data from the various appliances at a central location. Only with the existence of such a comprehensive and integrated system it is possible to operate complex buildings like the RHW.2 in an efficient way.

To decrease the energy demand of the building significantly – which was required to fulfil the Passive-House requirements – it was necessary to optimise all the installations and processes already in the design phase. Due to the limit of space in this paper only two examples shall be discussed here.

The first is the ventilation system, which are in general among the main energy consumers in large-scale buildings [1]. To optimize working hours, the ventilation was divided in an outer (office spaces) and an inner zone (sanitary facilities, secondary rooms, corridors). On days with moderate temperatures building occupants can use their operable windows for natural ventilation, while the mechanical ventilation system is reduced as much as possible. The amount of inlet air is adjusted as a function of indoor air quality. Beyond office hours (night, weekend) the ventilation plant is put out of operation or the air flow limited as far as possible.

Besides the optimization of large-scale installations like the ventilation system a lot of effort in the design phase was put into the reduction of the standby-power-consumption of the construction. Standby-consumption is the amount of energy which is consumed outside the operating hours of the construction and in most buildings makes up for a large part of the overall energy consumption [2].

To reduce this amount of 'grey energy' in RHW.2 a special focus was put into small scale consumers which can be found in huge numbers in large buildings (like electronic ballasts, thermoelectric drives, bus modules etc.). Although – seen individually – this small-scale equipment's power consumption is very low (normally several Watts), in sum they compose a large amount of the buildings standby-power-losses, solely because of their amount. The electronic ballast of standard office luminaire for example, consumes 1W even when switched off. In the example of the passive office building in Vienna, about 6.000 light fixtures have been installed, which means that only the ballasts add up to a standby-loss of 6kW. To reduce the energy consumption of these devices simple switching mechanisms have been included in the electrical design, which automatically shut off power supply for these devices outside office hours.

To sum it up, in RHW.2 a technological concept which was based on the conditions on the given site, the consequent use of highly energy efficient technologies, a focus on demand driven design of the installations and an integrated control system led to a building design which should lead to significant reduction in energy consumption compared to conventional office buildings.

2.2 The construction phase

The construction of a highly energy efficient large-scale building raises several special challenges, which may be not that important in raising conventional buildings, but are crucial for the success of complex, energy-efficient projects.

One of these challenges is to raise awareness for the special character of the building and to link all the different disciplines and companies engaged in the construction process, so they take care of interdependencies and understand that the goals of the project can only be met when all subsystems work together seamless. Just as it was necessary in the design phase for architects, building physics and building engineers to work together and take into account interdependencies between the different fields, this mutual approach is an essential prerequisite too, when it comes to building an energy efficient model office tower. Furthermore, the comprehension to use new technologies and designs instead of old and maybe well-tried concepts is normally not very distinct among the people and companies involved in the construction process. In the case discussed in this article, increasing this understanding was a main and often troublesome task at the very beginning of construction.

Another challenge is the supervision of a high-quality execution of construction work. Large-

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scale buildings, which are intended to fulfil the passive-house standard, e.g. the impermeableness of the building hull is a crucial factor. Therefor it is necessary to monitor the diligent execution of previously specified implementation details in every phase of the construction process (e.g. leakproof building of façade junctions) very thoroughly. Besides quality control of the construction work, it is moreover necessary to check the selection of the installed products. Energy efficient devices are usually more expensive than conventional devices, what provides economically oriented construction companies an incentive to use conventional instead of efficient technology.

3 RESULTS

3.1 Key figures from the energy monitoring system

The RHW.2 was equipped with a comprehensive energy monitoring system, which allows a detailed analysis of the buildings energy flows and provides a rich database for the analysis of the function of the different energy efficiency measures included in this construction. For that over 650 meters for electrical energy, heating/cooling energy and water have been installed on the basis of a detailed metering concept. All in all, over 1,000 data points were defined and are being processed within this system.

After more than two years of full operation the first findings from the performance analysis of the building can be presented. The data is taken from the first full year of operation in 2014. To make comparisons with other buildings possible, the performance figures were referenced to the gross floor area (GFA) of the building.

Macro data, which means gross energy efficiency figures, confirm that the design concept is working and led to a significant lower energy consumption. The electrical energy consumption in 2014 was 69.2 kWh/m², the heating demand 30.1 kWh/m² and the cooling consumption 39.5 kWh/m² (see Fig. 2). In this figures all energy consumers in the building (office, kitchen, restaurant, conference, general areas) are included. In relation with the figures of other office towers which were analysed in different reports, these numbers are significantly lower. [3] (see Fig. 3)

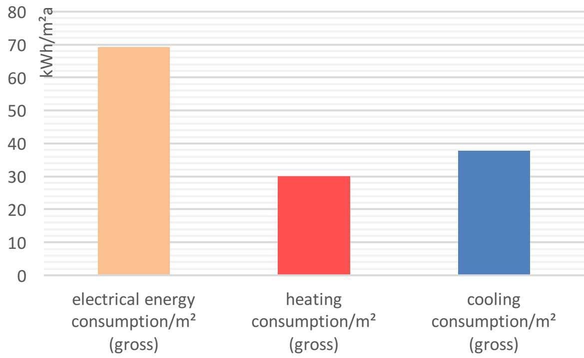

Fig. 2: Overall energy consumption RHW.2.

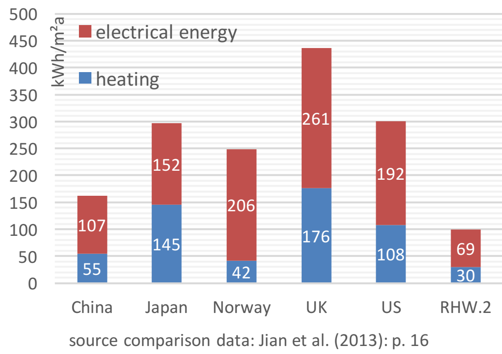

Fig. 3: Comparison energy demand office buildings.

When analysing the energy consumption figures of the RHW.2 building it has to be taken into account, that the building is used as the headquarter of a bank and therefor the user has very high standards and expectations for indoor air temperatures and humidity, which means that the air-condition and ventilation plants have to be operated within very narrow setpoint value windows. Lesser strict standards for indoor air quality would lead to a significant reduction in energy consumption.

Though the RHW.2 building was designed and constructed as a Passive House, the air-conditioning system was able to provide comfortable indoor climate conditions for the user on extremely hot summer days as well as on cold winter days. That shows that energy efficient buildings can be as comfortable as other buildings and the fear of a lot of people that energy efficiency means less occupant comfort can be disproved. On the contrary the example of the RHW.2 shows, that the user highly appreciates the benefits of the energy efficient design like operable windows or the fanless cooling system via concrete core activation.

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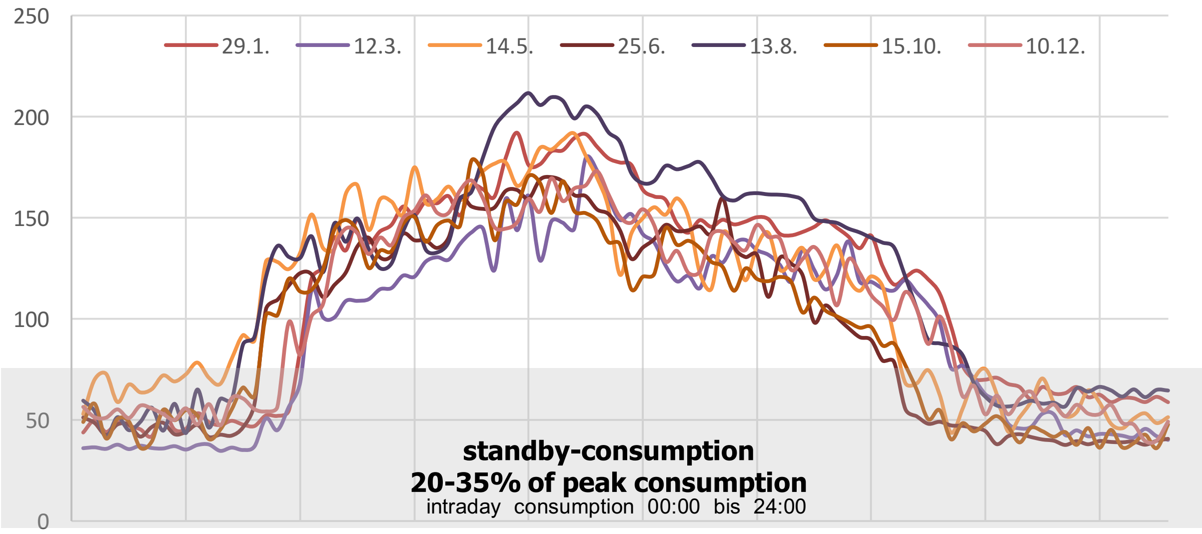

Fig. 4: Power consumption on selected days.

3.2 Potentials for optimisation

Although the gross energy efficiency figures of the given building are very good compared to average buildings, an in-depth analysis of the energy data reveals that there is still a lot of potential for further optimisation and reduction of energy consumption.

Especially in the area of standby-consumption further optimisations are needed to reduce the share of 'grey-energy'. As Fig. 4 shows, although several measures have been taken to reduce the loads outside office hours, the share of standby-power was still 20-35% of the peak-power of the building.

A closer look on the data from the energy monitoring shows, that standby-consumption was mainly caused by an inefficient operational mode of the cooling system in the first phase of operation. Due to the complexity of the system in this initial period the integration of the different energy generators and the demand driven operational mode were still not working as efficient as they could do.

This analysis does not only show the potential for further optimisation, it also shows the importance of comprehensive energy monitoring systems for energetic optimization of large-scale buildings. An in-depth examination of energy flows can only be done if there is enough detailed data available to analyse all systems and their sub-systems separately. Gross figures are definitely not enough for this task.

The example of the RHW.2 also shows that the investment needed for energy monitoring systems can pay back in a very short time, because of the value of this system for optimisation of energy consumption and reducing energy bills for the owner. Especially in the first months of operation the meter data was a valuable source for finding problems in the buildings installations, which probably would have never been found without these data available.

4 SUMMARY

With this brief presentation of the main challenges and findings of designing and operation a highly energy efficient building like the RHW.2, it was shown that the consequent implementation of an energy efficient design can reduce the energy demand of office building significantly.

The given example also shows that the complexity of the realisation of new concepts for energy efficient building design shouldn't be underestimated. Complex buildings call for a higher degree of supervision not only in the conception- and construction-phase but also during the first years of operation.

For a successful transition from construction to operation it is necessary, that the persons involved in the building's design are also included in the first operational period. The facility service providers often lack the detailed technical knowledge needed for dealing with the challenges that arise in the first operational months and years in complex buildings. An involvement of the building engineers, responsible for the idea of the buildings concept, can lead to better results and a smoother transition from construction to operation.

For building owners it is very important to understand that the energy consumption of the building largely depends on the way how the building is used. The best building design can lead to disproportional energy consumption figures if installations are operated in modes they are not designed for or failures in the systems (e.g. because of wrong setpoints) are not noticed or neglected.

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5 REFERENCES

1. Bundesamt für Energie BFE, Energieverbrauch von Bürogebäuden und Großverteilern, Erhebung des Strom- und Wärmeverbrauchs, der Verbrauchsanteile, der Entwicklung in den letzten 10 Jahren und Identifizierung der Optimierungspotentiale. 2010, Bern.

2. Hong, Tianzhen et al. (2013): Building Energy Monitoring and Analysis. Lawrence Berkeley National Laboratory. June 2013.

3. Jiang, Yi et al. (2013): Volume III – Case Study Buildings. In: Institute for Building Environment and Energy Conservation (Hg.): Total Energy Use in Buildings. Analysis and Evaluation Methods. Tokyo. 2013

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