The high influence of ventilation on the energy efficiency in buildings containing large-volume spaces – Example-building: The German parliament building "Reichstag" in Berlin

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ABSTRACT

The influence of ventilation on the energy performance of a building is generally considered to be quite high. It rises clearly, when a building contains large-volume spaces. A famous example building for that is the Reichstag building in Berlin, housing the German parliament. The huge plenary hall in the building's centre, which occupies only 4% of the total net floor area but 20% of its net volume, is equipped with a powerful air-conditioning system. The remarkable effects of slightly different settings of this ventilation system on the building's energy performance are illustrated by example calculations based on the German standard "DIN V 18599: Energy efficiency of buildings". Extending the system's operating time significantly increase the zone's energy use by up to 205%, when running the system throughout the whole year, leading to a growth of the building's total delivered energy of 18%. A clear influence is also shown by the existence and quality of heat recovery, which is analyzed by stepwise improving the recovered heat coefficient from 0 to 45%, 60% and 75%. The latter reduces the zone's heating energy by half and that of the whole building by 6%. In conclusion, the analysis clearly demonstrates the high impact of ventilation in large-volume spaces. Consequently, especially for these areas, an energy efficient air-conditioning system should be installed and a reasonable ventilation strategy developed, as realized in the Reichstag building.

KEYWORDS

Energy efficiency, Large-volume spaces, Ventilation strategies, operating time, heat recovery

INTRODUCTION OF THE EXAMPLE-BUILDING

The German parliament building "Reichstag"

The Reichstag building, shown in figure 1, which is located in the government district of Berlin, was built during the years 1884 - 94 to house the *Reichstag*, the first parliament of the German Empire. It was planned by the architect Paul Wallot in the style of neo-renaissance. Due to a fire in 1933 and to consequences of the Second World War the building was severely damaged and not rebuilt until the reunification of Germany in 1990. After years of renovation and modernisation, following plans of the well-known architect Sir Norman Foster, the Reichstag building was reopened in 1999, again as meeting point for the German parliament.

Figure 1: The Reichstag building in Berlin

The point symmetric building with its four corner towers, two open atriums and the famous glass dome on top of the building consists of seven full storeys and two intermediate storeys covering parts of the building. Opposite the glass dome, there is a small restaurant located on the roof. In total the building's net floor area is approximately 46 000 m², 40 000 m² thereof are heated, taking in a net volume of about 232 000 m³.

The plenary chamber

Figure 2: The plenary chamber, view from the main entrance

The plenary chamber, located in the centre of the building occupies 1 700 m² net floor area and 47 000 m³ net volume. That's equivalent to only 4% of the total building's net floor area but 20% of the net volume. The plenary hall's floor level is on the first floor, where its main entrance is located as well as several small rooms for technical equipment, press and translators. In height it ranges over five floors up to the roof. There, on top of the hall, the glass dome is put, which includes the chambers ventilation shaft. The 700 seats are arranged in a circle. The speaker's desk is located on the Eastern side of the hall, below the huge Federal Eagle, which dominates the view from the main entrance, as shown in figure 2. Visitors can follow discussions open for public sitting on the visitor-tribunes, which can be entered from the first mezzanine floor, also called visitors' floor as it practically consists of a large-area gallery from which most of the spaces of the first floor, the main storey, can be seen.

Certainly, the plenary hall can be considered a large-volume space, which is additionally equipped with a powerful air-conditioning system fulfilling the tasks of heating, cooling and ventilating. The ventilation system is located underneath the plenary chamber and the air flow reaches the hall on numerous points beneath the seats, as shown in figure 3. Consequently, the high influence of ventilation therein on the energy performance of the whole building can be demonstrated using the Reichstag building as suitable example-building.

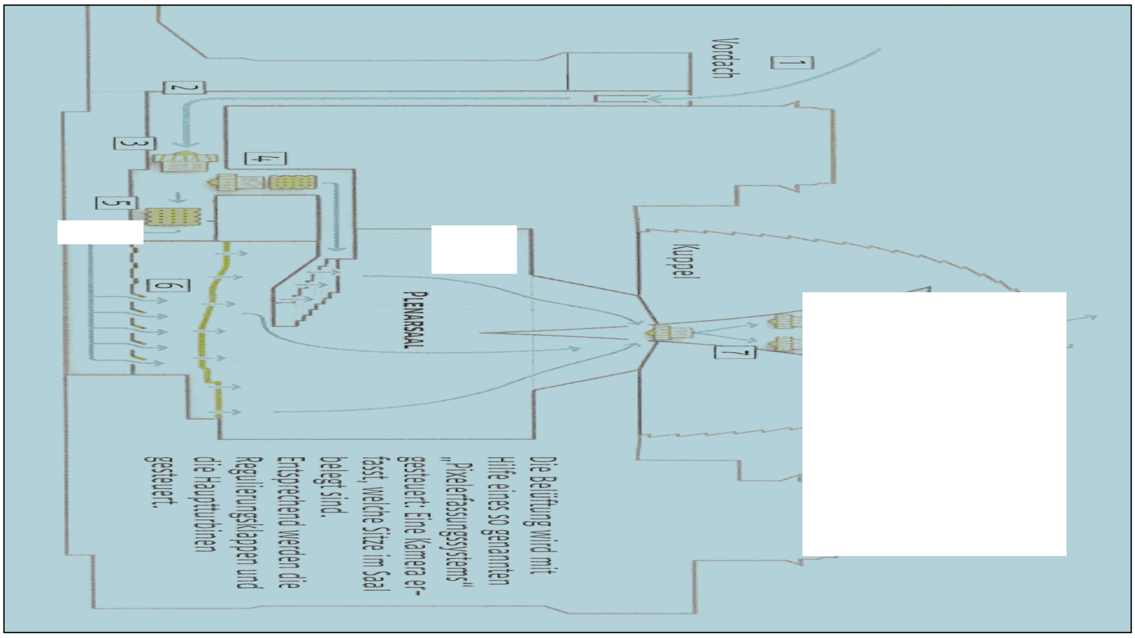

Figure 3: Sketch of the air flow in the plenary chamber ("Plenarsaal")

The energy performance of the Reichstag building

The energy performance of the Reichstag building is an exemplary manner for a highly energy efficient building as approved by its Energy Certificate, which is displayed in the building's main entrance. There, a primary energy value of 270,9 kWh/(m²a) is shown, depicted by the big arrow above the scaling, which clearly falls below the requirements, depicted by the two thin arrows, as shown in figure 4, an extract of the Energy Certificate. The left thin arrow shows the value required for a respective new building and the right one that for a building with major retrofits, both values follow the requirements of the German regulation for energy saving in buildings and building systems.

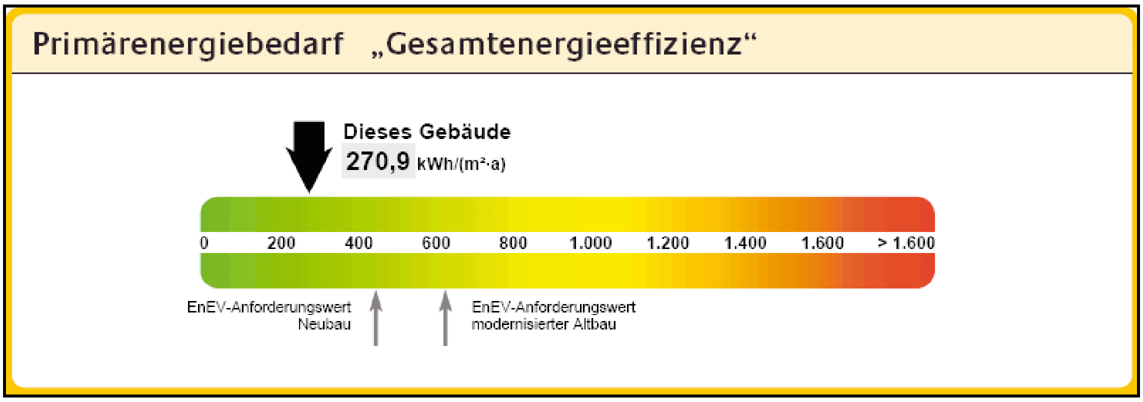

Figure 4: Detail of the Energy Certificate of the Reichstag building, showing the primary energy ranking

The energy use of the plenary chamber, which represents a single zone, accounts for 13% of the total delivered energy, even though it occupies only 4% of the building's net floor area. Recalling the big volume of the hall, which occupies 20% of the building's net and 17% of its gross volume, the double-digit number above is barely surprising. Instead it allows conjecturing the high influence of large-volume spaces. The zone's energy need consists to 43% of heating and to 36% of cooling energy, to 17% of energy for ventilation and to 4% of lighting energy. Especially the first three components, which cover 96% of the total energy, can be influenced by setting and regulation of the ventilation system.

EFFECTS OF DIFFERENT VENTILATION SETTINGS ON THE BUILDING'S ENERGY PERFORMANCE

In the following the results of several example calculations are presented, concerning slightly different ventilation settings, implemented only in the system of the plenary hall. These changes are not necessarily reasonable per se and partly presenting fictitious settings and situations, but they are suitable to demonstrate the effect of sometimes little changes. The calculations are based on the German standard "DIN V 18599: Energy efficiency of buildings", a holistic approach for the calculation of energy needs, delivered energy and primary energy for heating, cooling, ventilation, domestic hot water and lighting. For the application of the standard's methods, the building needs to be divided in different zones, presenting areas of the same use equipped by equal technical systems, such as heating, cooling or ventilation. In addition, as required for the preparation of energy certificates, standardized user profiles are applied, which were not adapted to the special needs for a parliament building.

The Reichstag building was divided into 15 zones, covering the use for offices, conference rooms, plenary chamber, corridors and staircases, lavatories, engineering rooms, kitchens, refectories and the restaurant as well as different heating, cooling and ventilation systems. In the following example calculations, only little changes regarding the ventilation system of the plenary chamber are realized. In all other zones no changes at all are applied. Nevertheless the influence on the energy need of the zone "plenary chamber" as well as that of the complete building is clearly visible.

Effects of changes in operating time

A simple but influential way of changing the setting of the air conditioning system is to vary the operating time. In the following example calculations it is increased in two steps: First, the system's operating time is changed from 12 to 24 hours a day. Second, it is assumed that the system runs throughout the whole year, which means 24 hours a day on 365 days per year. Both cases are generally not suitable to fulfil the standardised user profile of 10 daily usage hours on 150 days of the year, as required for the energy performance certification. Nevertheless these settings may be used when the system is not properly adapted, or they might even be necessary or at least the easiest way to provide the comfort expected, when the room's time of use is inconsistent and impossible to predict.

TABLE 1: Percental increase of delivered energy due to extended operating time of the ventilation system in the zone "plenary chamber"

Basic Case **Period of Use: 10h/d, 150d/a** **Operating Time: 12h/d, 150d/a**	**Increase of Delivered Energy**							
	Heating		**Cooling**		**Ventilation**		**Total**	
	Zone	Building	Zone	Building	Zone	Building	Zone	Building
Operating Time: 24h/d, 150d/a	42%	4%	87%	10%	100%	10%	59%	5%
Operating Time: 24h/d, 365d/a	20%	10%	340%	39%	386%	38%	205%	18%

Table 1 shows how extending the operating time increases the energy need of the zone "plenary chamber" itself and that of the whole building. These notable effects on the building's energy need, caused only by the continuous operating time of one zone's air conditioning system illustrate the high influence of a large-volume space on the building's energy performance. These findings emphasize the importance of a suitable adjustment of ventilation systems, as badly adjusted systems may lead to enormous but unnecessary need of energy.

Effects of changes in heat recovery

Effective heat recovery systems are nowadays state-of-the-art. Nevertheless in older ventilation systems they are often not included and not always installed afterwards, despite their high impact on the heating energy. This impact is demonstrated in the following by running several calculations with varying only the heat coefficient factor of the plenary hall's air conditioning system, which is again especially influential due to the large volume of the plenary chamber.

TABLE 2: Percental decrease of delivered energy due to changes in the quality of heat recovery

Basic Case **No Heat Recovery**	**Decrease of Delivered Energy**			
	Heating		**Total**	
	Zone	Building	Zone	Building
Heat Recovery Coefficient 45%	- 33%	- 4%	- 22%	- 3%
Heat Recovery Coefficient 60%	- 42%	- 5%	- 28%	- 3%
Heat Recovery Coefficient 75%	- 48%	- 6%	- 32%	- 4%

Table 2 depicts the high influence of existing high-quality heat recovery systems, which practically halves the heating energy use of the zone “plenary chamber”. Even though the other energy consuming aspects cooling, ventilation and lighting are hardly affected and consequently not presented in the table, the total heating energy of the building can still be reduced by a third. Also the delivered energy of the complete building is noticeably affected, despite the small percentage of the zone on the net floor area. Again, that high impact can be explained by the large volume of the hall.

CONCLUSION

In buildings containing one or more large-volume spaces, which are ventilated and at least partly heated and cooled by air-conditioning systems, the influence of quality, settings and control of these systems on the energy performance of the whole building is very high. As the example calculations show, even small changes in controlling, like simply extending the system’s operating time, lead to crucial increases in energy use. As these extended times may easily occur as consequence of either lacking accurancy in controlling and management or due to inpredictable periods of use, the focus on careful and reliable controlling of the ventilation systems is essential, in particular in large-volume spaces.

Also the existence of a high-quality heat recovery system, especially when the ventilation system is completely responsible for heating the large-volume space, is crucial, as the heating energy use can be reduced by half. Heat recovery is not only state-of-the-art but obviously highly effective. Consequently, older systems with no heat recovery should be retrofitted, either by including a heat recovery system or by exchanging the central ventilation system. In addition, heat recovery systems of low quality are worth to be upgraded, as noticeable savings can be achieved. Again, those adaptions are especially effective for large-volume spaces.

The Reichstag building in Berlin with its plenary chamber presenting the large-volume space, occupying only 4% of the net floor area but 20% of the net volume, was not only a suitable example-building used as basis for calculating several variations. It also exemplifies how a building of such a size including a huge hall can be very energy efficient, as the energy certificate demonstrates.

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