Stadt Leipzig

User Manual

for Passive House School Buildings

Using the example of the Wilhelm-Ostwald-Gymnasium in Leipzig

EEMTE
Energy Efficiency in Municipality - Training and Exchange of experience

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1. Preface

The efficient use of energy is one of the most effective ways to combat climate change. In particular the buildings sector reveals a huge energy saving potential in Germany since more than 40 % of the final energy consumption can be allocated to buildings. Therefore, the energy efficient refurbishment of buildings is considered as a crucial contribution to reduce the energy consumption in Europe. The German Federal Government has set itself ambitious goals to significantly reduce energy related CO_2-emissions and strives towards an almost carbon-neutral building stock until 2050.

The European Energy Efficiency Directive, released in 2012, calls upon the public sector to set a good example and to opt for high standards on energy efficiency when dealing with public procurement of products, services or buildings. At the same time, public authorities are requested to gradually reduce the energy consumption in their premises. Revised in 2011, the European Energy Performance of Buildings Directive (EPBD) commits public authorities to implementing nearly-zero energy standards for new buildings from 2019 onwards. Passive Houses have already met these requirements for many years.

In 2011, the city of Leipzig tightened its existing Energy Guideline in order to meet European legal requirements on the local level. Essential objectives are the reduction of energy consumption of municipal buildings by 45 % until 2020 and the reduction of accompanying CO_2-emissions by 50 %. Taking into account the achievable cost effectiveness on single building scale the precedence of renewable energies and combined heat and power generation as well as the implementation of the Board Decision on Passive Houses (released in 2008) are further requirements of the Energy Guideline.

Crucial in order to obtain maximum energy efficiency in Passive Houses are a consequent utilization of all energy gains within the building (generated by solar radiation, people and technical devices) and the minimization of heat losses by an insulated and airtight building envelope with optimized component connections and ventilation systems with a high heat recovery. Efficient electric devices support this process and an intelligent technique enables an efficient regulation of energy flows.

The aims of Passive Houses are to cut the energy consumption in the buildings as well as to improve the comfort of building occupants both in summer and in winter. However, it is often wrongly assumed that both aims are automatically achieved when starting the operation of a Passive House and in particular as soon as the installation of the technical devices is completed.

On this account the city of Leipzig started with the evaluation of all municipal Passive House school buildings in December 2012. Having started with the Wilhelm-Ostwald-Gymnasium as the first example for a refurbishment meeting Passive House standard, three other schools will follow which are currently in the planning and building phase. The evaluation considers both technical aspects and aspects of social communication.

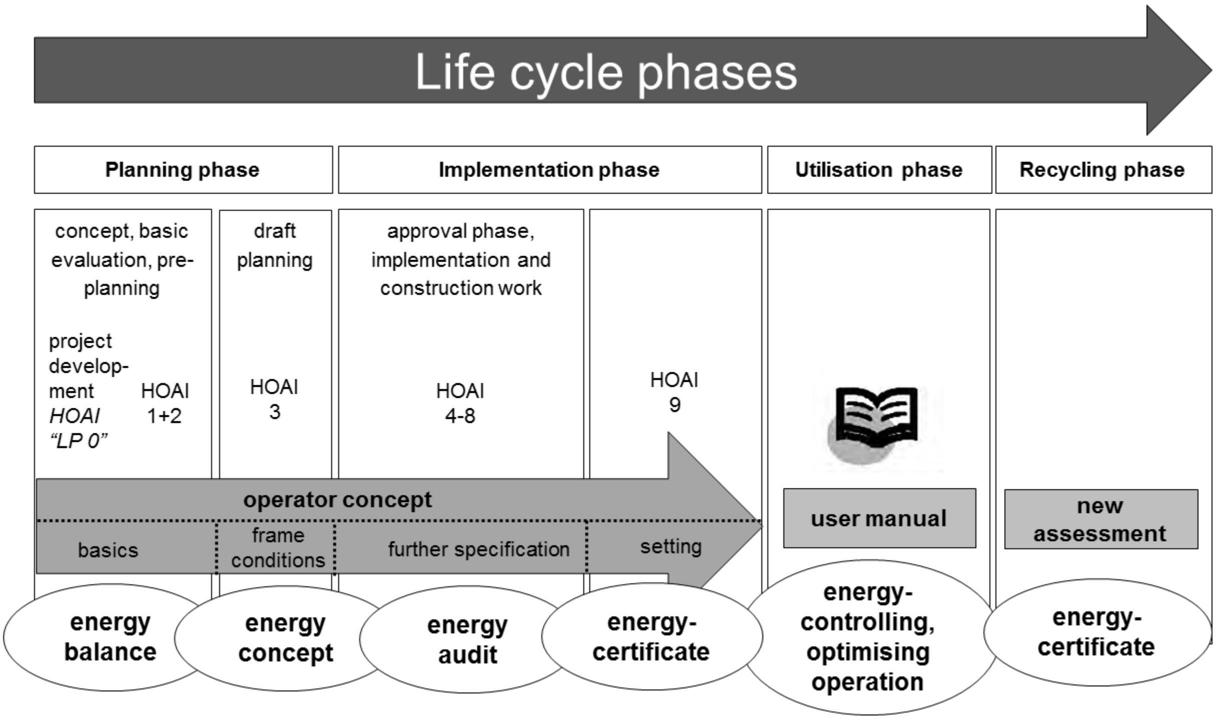
This user manual for Passive House school buildings using the example of the Wilhelm-Ostwald-Gymnasium constitutes a first and important milestone for the whole evaluation process. Not only concrete instructions for building occupants will be given (chapter 6). The manual should also provide staff of building authorities and building management units with profound knowledge on Passive Houses. Indeed, the construction of Passive Houses requires progress in existing approaches. But just as important for a long-term success is a smooth and appropriate starting and operation of these buildings by the operators and teaching staff as well as administrators in the responsible municipal departments.

2. Why a user manual is needed

2.1. Energy management of public buildings

An overview on main processes and required documents of all relevant life cycle phases of buildings together with further indications for energy management of public buildings is provided by the Working Group Mechanical and Electrical Engineering for State and Local Governments (AMEV)[1] in cooperation with the Federal Ministry of Transport, Building and Urban Development (BMVBS).[2] All life cycle phases presented below are already linked with the subsequent energy consumption during the building´s utilization phase. Hence, indications given in this manual are not strictly limited to building occupants as such (see chapter 6) but also address employees of building authorities and building management units who are dealing with the building´s life cycle phases.

Taking the right decisions towards minimizing energy consumption, greenhouse gas emissions and building`s operation costs will only be possible if technical staff tackled by Passive House building possesses the required basic knowledge. Implementing Energy Management mechanisms (including energy controlling and optimisation) enables the operator (municipality, usually the unit responsible for building management) pursuing the goals described above.



Source: AMEV, Energie 2010, Brochüre Nr. 104, Grfik 1: Lebenszyklusphasen (von BLB NRW / Herr Mengede)

Energy Management is an integrated approach to steer the efficient use of energy. Important aspects thereby are awareness raising and sensitisation of buildings occupants because the building's energy consumption depends only partly on its planning but also on the subsequent user behaviour (see AMEV, Energie 2010). AMEV states and recommends:

"Optimally planned and erected buildings may also reveal insufficient results during the utilisation phase if they are not appropriately operated. Therefore it is necessary to provide technical support by experts during the whole operation phase, to monitor consumption and costs and to counsel and train building users. …Energy Management should include user advisory service in order to fully consider

[1] Arbeitskreis Maschinen- und Elektrotechnik staatlicher und kommunaler Verwaltungen
[2] Bundesministerium für Verkehr, Bau und Stadtentwicklung

possible technical and building specific aspects. …The success of technical solutions finally depends to a great extent on the behaviour of building occupants. Thereby, not only technical aspects have to be taken into account. The process of convincing users has to be considered as predominant in order to overcome psychological barriers."

Thus, the need for a close communication with building users is not new with references to Passive Houses. However, specific advantage is gained by users and operators of such highly energy efficient buildings since there are new aspects to be taken into account which are unknown from conventional buildings and which require a new understanding.

A user manual is particularly suitable to provide an extended explanation of the building´s philosophy and respective reasonable user behaviour in an easy accessible form. Additionally, it strengthens the user´s motivation and therefore fosters the overall target to reduce the energy consumption while maintaining high user comfort.

The national standards for sustainable construction (BNB)[3] for office and administrative buildings of the Federal Ministry of Transport, Building and Urban Development (BMVBS) considers the development of a user manual as a pre-condition for an optimal building management. "Purpose of a user manual is to illustrate the technical background of building equipment and appliances as well as specifics of certain construction elements and components. The user should be enabled to manage all relevant building components in an appropriate manner. Furthermore, the user manual should provide indications for a sustainable utilisation of the building – among other things advice on how to reduce electricity consumption should be included."

2.2. A user manual as a monitoring-component

Integrative building monitoring is currently rather theory than common. Thus, this chapter will present findings and statements from important research sources. The present state of practice will be highlighted in chapter 9.

"While methods and data exist for ecologic and economic evaluation (e.g. monitoring of energy consumption, life cycle analysis, analysis of building utilisation costs) which have been widely implemented in the real estate industry, proofed approaches and accredited criteria to assess also the social dimension of sustainability are still missing. This includes the acceptance, the well-being and thus the performance of employees at their working place. Staff costs exceed all other costs for a building (including costs for building operation) by more than twofold. Therefore, appropriate working place conditions going beyond health aspects are of economic relevance (Brill & Weidemann, Bosti Associates, 2001). …

Involving the user´s perspective and therefore paying attention to the socio-cultural dimension would be in accordance with the intention to 'build houses for people' as formulated in the Guidelines for Sustainable Construction (BBR, 2001).

The implementation of a comprehensive certification system for office and administration buildings which considers sociocultural quality is still at its early stages. …Applied on construction policy and industry the involvement of user´s practical experiences with buildings would meet the idea of participation. In addition to the collection of technical data the benefit of such surveys is that detailed feedback on experience and behaviour of users are obtained which can serve as a basis for energetic improvements during the operation of the building. For instance experiences reveal that the energy

[3] Bewertungssystem Nachhaltiges Bauen

demand calculated during planning and the actual energy consumption differ remarkably due to various reasons."[4]

"During the planning phase office or administration buildings are often tagged as 'innovative', 'intelligent' or 'ecologic'. However, as soon as the construction is completed and the operation starts most reports and documentation stops although these tags given by the building planners remain – independently from the real success of the concept once developed. Diverse studies confirm that actual building´s performances often remain below targets set during the planning phase."[5]

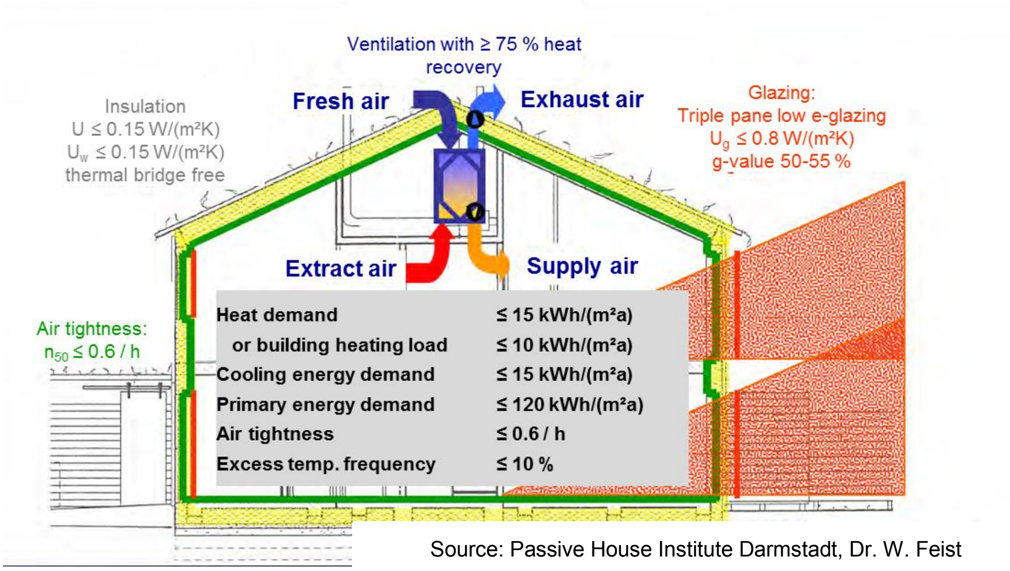
"In spite or because of sophisticated technology users play a decisive role since satisfied users are of utmost importance for buildings. There are many technical solutions to optimize individual comfort and to ensure high energy efficiency at the same time. However, a surfeit on technical facilities may overstrain users or may give them the impression to be patronized by pre-set technical regulations. Therefore users should be enabled to handle all these technical facilities - presupposed that they are familiar with the effects of their action. Otherwise the energy and comfort concept can be easily turned upside down."[6]

3. Passive Houses – principles of construction and functionality

3.1. Quality criteria for Passive Houses

The graphic below provides an overview on Passive House criteria (grey shaded).

There are defined maximum values for heat input and airtightness of the building envelope. Winterly heat input is provided by heating and primary energy consumption which includes domestic hot water and total electricity demand per usable area and year. Sommerly heat input considers the occurrence of indoor temperatures > 25 °C on 10 % of the days a building is in use (holidays are excluded for schools).



Source: Passive House Institute Darmstadt, Dr. W. Feist

Energetic requirements needed to meet Passive House standards are displayed outside of the building in the graphic above.

[4] A. Wagner, K. Schakib-Ekbatan: Nutzerzufriedenheit als ein Indikator für die Beschreibung und Beurteilung der sozialen Dimension der Nachhaltigkeit. Forschungsbericht F 2758 der Forschungsinitiative Zukunft Bau des Bundesamtes für Bauwesen und Raumordnung, Karlsruhe 2010

[5] BMWi-Forschungsinitiative EnOB, Bereich Energieeffiziente Betriebsoptimierung

[6] bine-Themeninfo I/2010 „Gebäude energieeffizient betreiben"

Quality criteria for Passive Houses were summarized for residential buildings by IG Passivhaus. Some of these criteria cannot thoroughly be applied to Passive House schools. Respective passages were deleted (…), the term “resident“ was replaced by „user“ or comments by the author (C. G.) were added. Therefore, the subsequent description can be applied to all kinds of Passive Houses – residential as well as non-residential buildings.[7] Graphics provided by *proKlima - Der enercity-Fonds* were subsequently inserted for illustration reasons.

“Passive Houses are buildings where a comfort temperature can be achieved without an (C. G.: with supplemental) heating system in winter and without air condition in summer and which consume extremely low energy. Heating demand is limited to 15 kWh/(m²a) and primary energy demand including domestic hot water and total electricity demand to 120 kWh/(m²a). The components used in Passive Houses ensure an increased user comfort and protect the building fabric.

The construction of Passive Houses makes high demands on the components used.

- **Comfort and convenience**

A ventilation system combined with heat recovery provides constantly fresh air without the occurrence of draughts (indoor air inlet temperature above 17 °C) and without user´s having to actively care for fresh air. Ventilation systems should not be confused with air condition plants. Air moistening within the ventilation system should be prevented due to hygienic reasons.

Sound emissions of such ventilation systems should be restricted to 25 dBa by installing adequate air ducts and valves and inserting sound absorbers where necessary.

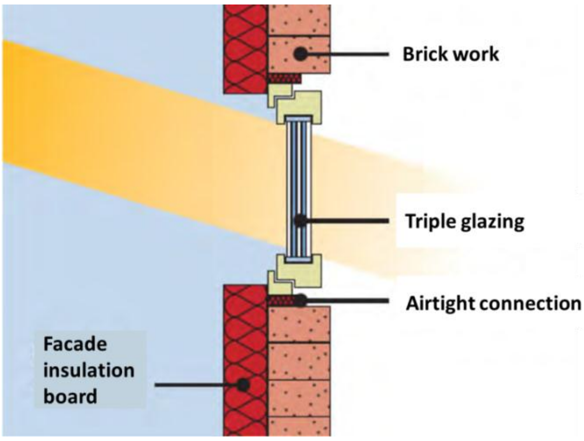
In summer sufficient cross-ventilation is assured by the possibility to open the windows. For summer operation the heat exchanger of the ventilation system should be equipped with a bypass. Additionally, an optional ground heat exchanger could provide cool air.

To avoid unnecessary heating-up of the building, larger windows aligned to the East or West should be amended with appropriate sun protection. For optimal climate reasons sun protection for south-facing windows is recommended as well.

Energy saving household appliances and lighting (C.G.: and IT equipment, see chapter 7.1.1) as well as the insulation of hot water storages and pipes reduce the indoor heat load and facilitate “passive cooling” in summer.

- **Quality standard for construction and technique**

A constantly running mechanic ventilation system and a thermal insulation that excludes any thermal bridges in external building elements are crucial to avoid building element moisture and mould formation.

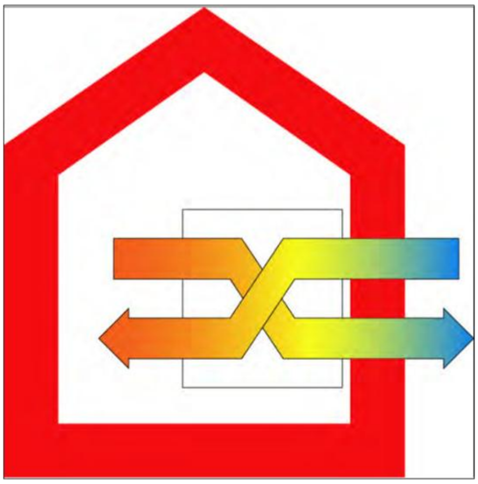


Special attention has to be paid to windows and doors since these components require insulated window profiles, triple glazing and thermally disconnected spacer at the glass edges (no aluminium!).

Source: proKlima, Der enercity-Fonds, Hannover

[7] Texts are only available in German: http://ig-passivhaus.de/index.php?page_id=150&level1_id=78

To guarantee the function of ventilation and heating and to prevent condensation caused construction damages the building must be perfectly airtight which can be verified by a pressure test. Air exchange during the test at 50 Pascal pressure difference should not exceed the 0.6 fold of the air volume per hour.



Clean fresh air supply requires the application of high-grade filters (F7 at air intake points) and condensate outlets at the ground heat exchanger (C.G.: if existing) and ventilation units.

Heat recovery from exhaust air has to take place without mixing with fresh air. For hygienic reasons there is no air moistening within the ventilation system (Passive Houses possess ventilation systems, no air conditioning!).

Source: proKlima Der enercity-Fonds, Hannover

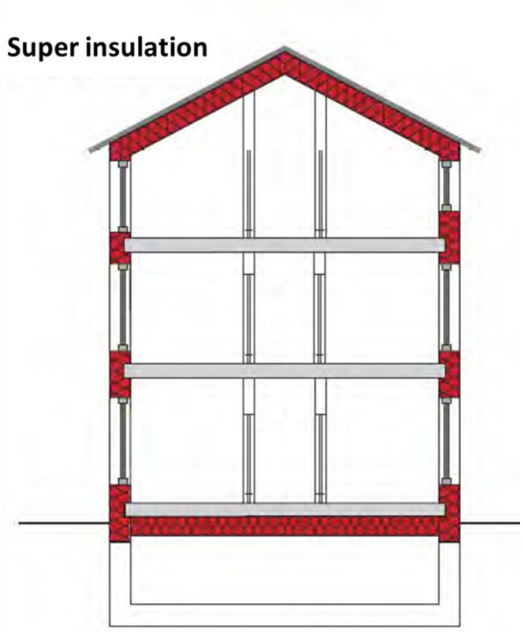
- **Energy efficiency**

Heat transition coefficients (U-values) of opaque building elements remain below 0.15 W/(m²K). …

The glazing should feature Ug-values below 0.80 W/(m²K) and a high total energy transmittance (g_3 50 %) to enable net heat gain during winter. …

Window systems require insulated frame profiles with multiple lip seals. The resulting heat transition coefficient of windows and doors has to be restricted. Uw (Ud) values should be lower than 0.80 W/(m²K) when taking into account frames (Uf), glazing (Ug) and spacer (ψ glas edge) and below 0.85 W/(m²K) when additionally considering the integration into insulated building elements (ψ installation).

The heat supply rate of the ventilation system (heat recovery rate resp.) should be above 75 %. Electricity consumption for ventilators and control technique should be limited to 0.45 Wh/m³ of exchanged air volume.

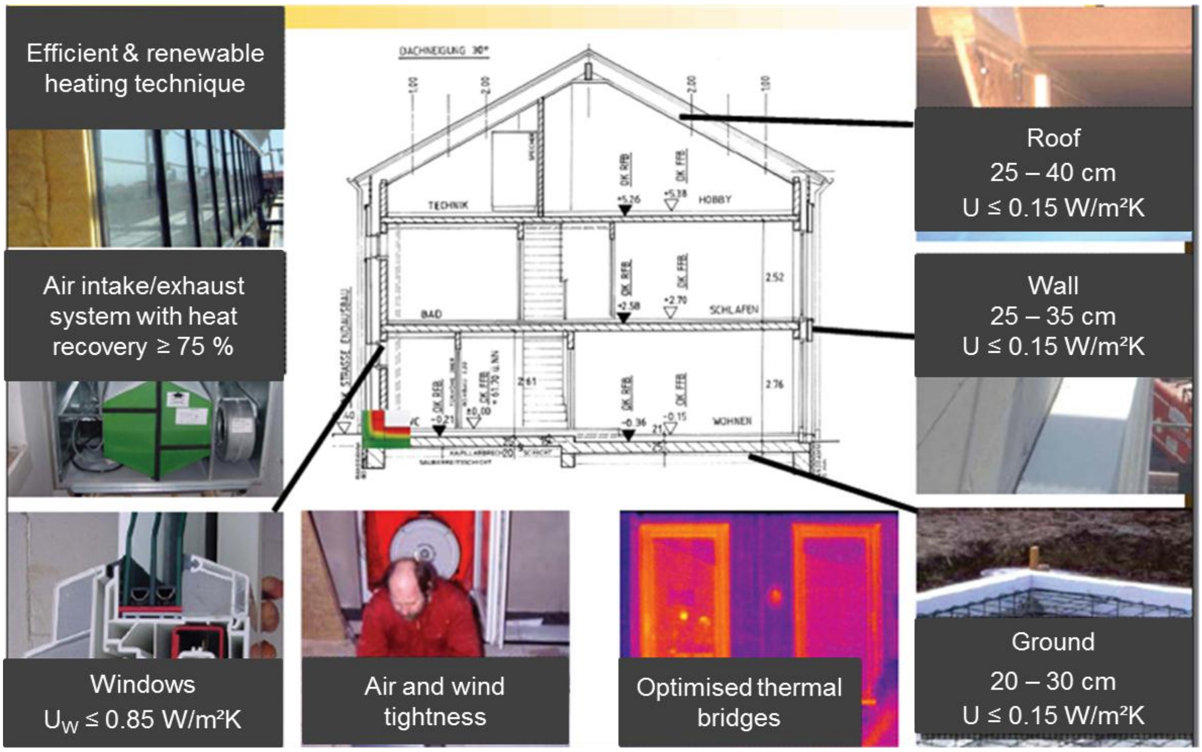


Source: proKlima Der enercity-Fonds, Hannover

Heat losses during domestic hot water preparation, storage and distribution have to be minimized by the complete insulation of all relevant components. In order to reduce electricity demand high efficient building technology (ventilators, pumps, control technique) as well as domestic appliances and lighting should be chosen.[8]

The following figure provides an overview on the minimum criteria for Passive Houses described before.

[8] IG Passivhaus http://ig-passivhaus.de/index.php?page_id=150&level1_id=78 (Status 29.08.2012), in German only



Source: Schulze Darup, Architekt, Nürnberg

3.2. Importance of indoor air quality

The recent study 'Child and Youth Survey' conducted by the Federal Environmental Agency[9] (2007) reveals that children aged three to fourteen years spent 90 % of the day indoor during the winter time and to a lesser extent also in summer. Indoor places are the home, school, kindergarten, theatre, cinema, library, sports hall, shopping centre, clubs and means of transport. Therefore it is of central significance for children´s well-being and health to consider indoor hygienic conditions by monitoring and ensuring a high air quality.[10]

This user manual would like to stress exemplary those air parameters that are directly linked to ventilation and technical installations: CO_2-saturation as an indicator for air quality and air moisture as well as air temperature which is in turn closely related to air moisture.

3.2.1. Air temperature

The Technical Rules for Working Premises[11] list the following minimum values:

predominant posture	work intensity		
	light	medium	hard
sitting	+ 20 °C	+ 19 °C	-
standing, walking	+ 19 °C	+ 17 °C	+ 12 °C

Derived from the predominant postures and work intensity in schools an indoor temperature of 20 °C can be recommended for classrooms. Further information on advised indoor temperatures depending

[9] Umweltbundesamt
[10] Umweltbundesamt (Hrsg.): Leitfaden für Innenraumhygiene in Schulgebäuden, Bonn 2008
[11] Arbeitsstätten-Richtlinie (ASR) A3.5 (June 2010)

on the kind of room use in municipal buildings can be found at the end of chapter 3.2.6 where an overview set up by the German Association of Cities[12] in July 2002 has been inserted. Since 1999[13], the following room temperatures are admissible for municipal school buildings of the city of Leipzig:

classrooms / lecture rooms	20 °C
sports hall	17 °C
changing room	22 °C
lavatories and showers	24 °C
gymnastics room	17 °C
medical examination rooms	24 °C
craft rooms	18 °C
school workshops	17 °C
(teaching) kitchen (at class starting time)	18 °C

As a general rule, an increase of the room temperature by 1 °C raises the energy demand for room heating by 6 %. However, since Passive Houses have a remarkably lower heat demand than conventional buildings, minor increases in indoor temperature (which is covered mainly by occupants and electric devices, see chapter 3.1) affects residual heat demand relatively to a much greater extent. An evaluation of the energy consumption of several municipal Passive Houses in Frankfurt am Main showed that the relative increase in energy demand accounted for 17,8 % when raising the indoor room temperature by 1 °C and by additionally 15,7 % when raising the temperature by another 1 °C.

Source: Stadt Frankfurt a. M., Hochbauamt – Energiemanagement, Verbrauchsauswertung Heizenergie für Passivhaus-gebäude, (Status June 2012)

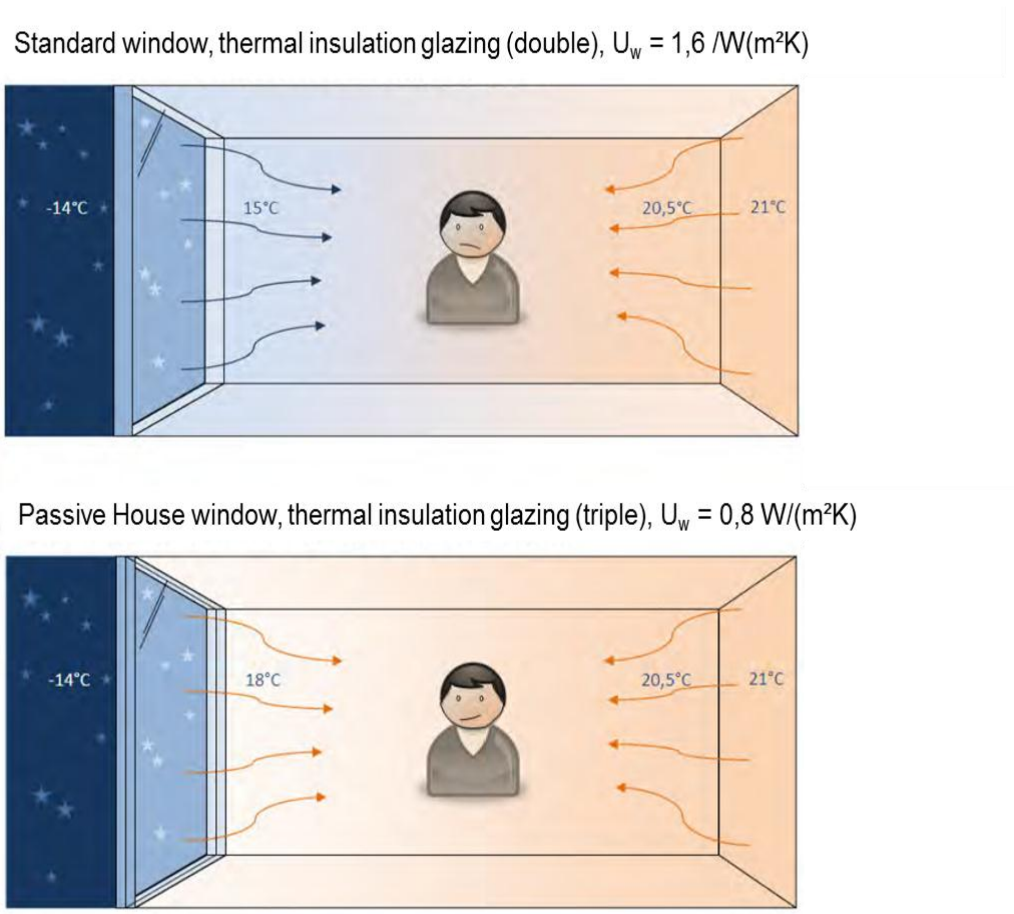
In all buildings the compliance with recommended room temperatures is of great importance, but in particular in Passive Houses. Otherwise the proportion of the remaining low additional heat demand raises significantly relative to the calculated one.

High indoor surface temperatures of all outer Passive House components (windows, doors and minimized leakages of the building envelope) increase convenience and comfort already at moderate indoor temperatures.

Beside the room temperature, the dissymmetry of radiation temperatures of enclosing surfaces (ceilings, windows, walls) has a great impact on the user´s comfort. If two room bounding building elements feature a different temperature the resulting different radiant flux will be perceived as discomforting by building´s occupants. According to a brief instruction for Passive House schools and kindergartens published by the city of Frankfurt am Main, the maximum radiation temperature difference should remain below 4 K to ensure the user´s comfort. Such a low radiation temperature difference can be achieved with windows featuring U-values below 0.85 W/(m²K) (see following figure).

The temperature received by the occupant of the room (named as operative room temperature) depends essentially on indoor air temperature (air moisture) and on the temperature of enclosing surfaces. This is because humans regulate their body temperature by heat exchange with the surrounding air and by heat radiation emitted by surrounding surfaces.

[12] Deutscher Städtetag
[13] Revised by departmental note 21/2011 from 04 October 2011



Source: Stadt Frankfurt a. M., Hochbauamt - Energiemanagement, Passivhausschulen und Kindergärten, Kurzanleitung für die Nutzer

The perceived or operative temperature in buildings revealing only minor differences between indoor air temperature and average radiation temperature of enclosing surfaces (as it is the case with Passive Houses) can be calculated using the following formula[14]:

$$T_O = \frac{T_A + T_R}{2}$$

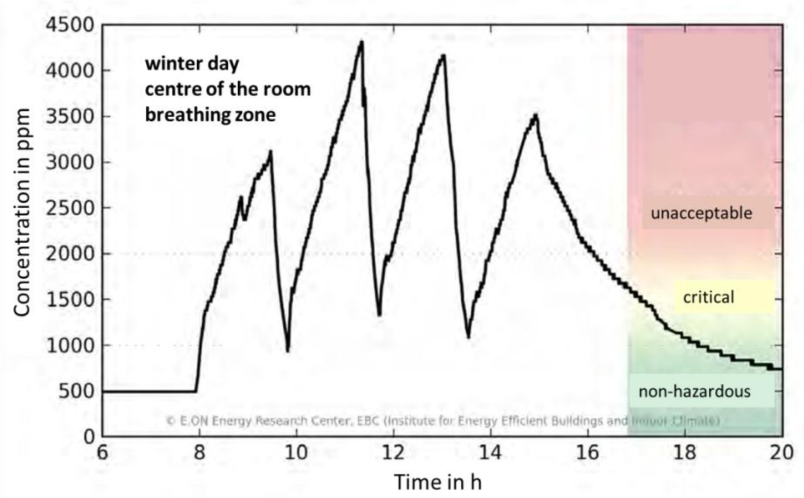
T_O - operative temperature / perceived temperature
T_A - indoor air temperature
T_R - average radiation temperature of enclosing surfaces

That means that real surface temperatures contribute to the same extent to operative room temperatures as the actual room air temperature does. Since enclosing surfaces reveal hardly lower temperatures than the air, Passive House occupants are not enticed to regulate the room temperature above recommended 20 °C to balance their discomfort. In other words, 20 °C are perceived by the Passive House users as exactly this temperature. As the recommended room temperature is strictly adhered, energy can be saved without cutting the occupant´s comfortableness.

[14] A. Greml, E. Blümel, A. Gössler, R. Kapferer, W. Leitzinger, J. Suschek-Berger, P. Tappler: Evaluierung von mechanischen Klassenzimmerlüftungen in Österreich und Erstellung eines Planungsleitfadens. Berichte aus Energie- und Umweltforschung 14/2008, Wien 2008

3.2.2. Air purity

The carbon dioxide (CO_2) concentration can serve as an adequate parameter for measuring air quality if humans are certainly the main causers of air pollution. CO_2 is a natural component of the air (normal atmospheric content 0.040 vol %, 400 ppm). When breathing, humans convert oxygen (O_2) into CO_2. The more people are situated in a room without sufficient aeration the faster the CO_2 concentration increases. The simultaneously decreasing O_2 concentration (normal at approx. 0.19 vol %) may gradually cause health impairment depending on individual responsiveness. The maximum CO_2 concentration at workplaces is limited to 0.500 vol %. The following figure shows the typical course of the CO_2 concentration in schools with conventional window ventilation.



Source: FGK-Fachkongress - Lüftung in Schulen - 27.03.2012, WTH Aachen University, EBC - Institute for Energy Efficient Buildings and Indoor Climate (speech Peter Matthes)

While the ventilation number for window ventilation with wide open windows accounts to 10-20 per hour, tilted windows allow only a fraction of this. Generally, phases of window ventilation (characterized by a significant decrease of CO_2 concentration in the graph above) are insufficient to guarantee the necessary air quality in the classrooms. This becomes true in particular during winter time when cold outside temperatures prevent frequent window ventilation in order to avoid constrains of comfort. Other causes for insufficient and infrequent window ventilation are noise from outside and safety regulations. Further, the ventilation rate during summer may be reduced due to low temperature differences between indoor and outdoor air.

"Measurements of CO_2 concentration in classrooms carried out by the health authority of the federal state of Niedersachsen[15] show that normal window ventilation is of such insufficiency that the threshold advised is often exceeded dramatically. Partly, CO_2 concentrations of 11,000 ppm have been measured. In view of such results it must be strongly recommended to install additional mechanic ventilation systems in schools to assure an adequate air quality. Concurrent installation of heat recovery plants for energy saving reasons is strongly recommended."[16]

In February 2012, the city of Frankfurt am Main as pioneer in municipal Passive Houses conducted comparative measurements of air quality in conventionally ventilated schools and Passive House schools with ventilation systems. It was stated that:

"Air quality measurements were carried out by the Energy Management in the period from January to February 2012. The aim of this investigation was to evaluate the indoor air quality by a quality check after the initial operation of a building. The CO_2 concentration serves as a measurable indicator to

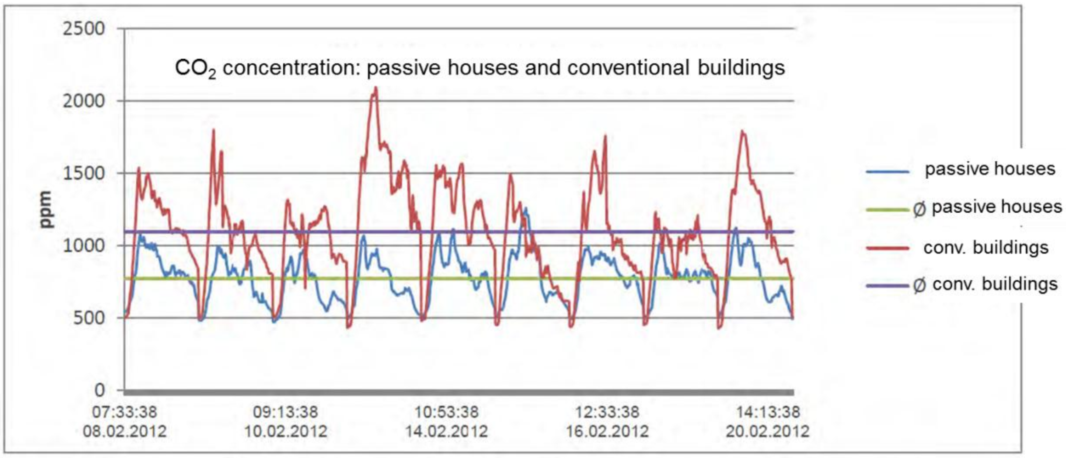
[15] Landesgesundheitsamt Niedersachsen
[16] FGK-Fachkongress - Lüftung in Schulen - 27.03.2012, speech of Ingenieurbüro Neuplan, Gießen

assess the air quality. The compliance with a minimum threshold value of 1,500 ppm (after IDA 4)[17] is generally considered as ensuring an adequate air quality.

CO_2 measurements were carried out in a total of 4 schools and 4 kindergartens in reference classrooms during teaching time over a period of one week. A direct comparison between existing buildings with “motivated window ventilation” and new Passive House buildings has been made. Reference room comparability was ensured by choosing the same type of use (depending on children/students´ age, number of students and size of the classroom). According to experience, window ventilation during the heating period is not carried out often enough to provide effectual air exchange.

The comparison between Passive Houses and existing buildings illustrates that measurements during the period of use are mostly “hygienically non-hazardous”. However, in existing buildings this appraisal could only be achieved by constant window ventilation. Tilted windows lead to high heat losses and thus to a significant increase in heat demand. Air quality is remarkably improved and heat losses reduced in mechanically ventilated Passive Houses with hygienically mandatory minimum air exchange and heat recovery.

Average CO_2 concentrations in new built Passive Houses during their period of use are approximately 300 ppm below measured values in existing buildings with constant ventilation with tilted windows (1,100 ppm).”[18]



Comparison of CO_2-concentrations of passive houses and conventional buildings during utilization time
Preciseness of measurement devices (Wöhler CDL 210): 50 ppm +/- 5 % of measured values (at 1500 ppm max. +/- 125 ppm)

Source: City of Frankfurt a. M., Hochbauamt - Energiemanagement, Evaluation Report from 07.05.2012

3.2.3. Air humidity

Many people are negatively affected by their nasal mucous drying out if the indoor air is too dry during winter time. Additionally, dust particles may irritate the nasal mucous under dry air conditions, since the capacity of binding dust decreases the dryer the air becomes and static charge increases which is found unpleasant to many people.

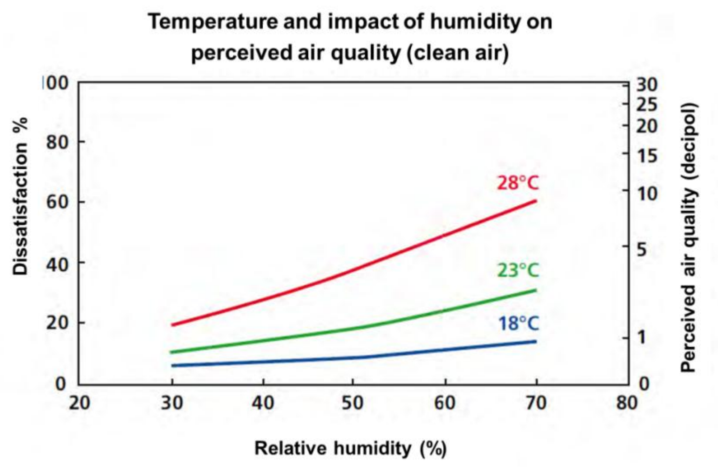
But also very humid air is perceived as suboptimal and can cause mould formation at surface temperatures below 12.6 °C. This is impossible in Passive Houses because even the window as the coldest outside building component exceeds by far this temperature in winter.

[17] Indoor Air Quality – based on European Standard EN 13779
[18] Stadt Frankfurt a. M., Hochbauamt - Energiemanagement, Evaluation Report from 07.05.2012

An optimal indoor climate is characterized by a relative air humidity between 25 and 60 %. Temporally going below this value at very cold outside temperatures is not to be considered as problematic because this is no specific issue in Passive Houses and would occur with window ventilation as well.

Climatic conditions in Leipzig feature predominantly low absolute air humidity at low outdoor temperatures. Nevertheless, high relative air humidity is given since the atmosphere is already saturated with moisture. During ventilation this moist air enters the building and is simultaneously heated up by the heat recovery plant. Thereby the inherent relative air moisture declines since the moisture absorption capacity of air raises at higher temperatures. Thus, mechanic ventilation coevally heats up temperature of indoor air which is perceived as very dry. This would not be the case if only window ventilation is carried out which is usually remarkably reduced in winter due to cold air entrance from outside.

Winterly indoor air dry out may be theoretically lessened by reducing air volume flow which would be however at the expense of air hygiene. Remoistening is technically feasible though an expensive solution (high increase in energy consumption) and again critical in terms of air hygiene. To some extent drying out can be reduced by not exceeding the recommended room temperature.



Source: H. Recknagel, E. Sprenger, E-R. Schramek: Taschenbuch für Heizung + Klimatechnik, Oldenburg Industrieverlag München, 2007/2008; Exhausto, teaching materials www.exhausto.de/learning

The graph (after Recknagel et al. 2007/2008) supports the statement above and also the following conclusion: "Recent studies show that the perceived air quality is significantly influenced by inhaled air temperature and humidity - even though the chemical properties remain the same and the body features a neutral thermal perception. The following figure reveals that people prefer rather dry and cool air that conveys the impression of cooling to them when breathing in (vgl. Recknagel et al. 2007/2008)."[19]

At this point, an erroneous assumption should be corrected: Couldn´t walls respire and thus contribute to moisture and air exchange? The answer is no. In this case respiration is mistaken with the ability of inside building elements as walls and furnishings to buffer moisture (and heat) to a minor degree. But air moisture only exhausts from the building by ventilation. Moisture diffusion through walls is a much slower seasonal process.

Beside present building occupants indoor plants are contributing to moistening of indoor air (please refer to http://www.reiter-rentzsch.de/downloads/Pflanzen_im_Passivhaus.pdf).

[19] A. Greml, E. Blümel, A. Gössler, R. Kapferer, W. Leitzinger, J. Suschek-Berger, P. Tappler: Evaluierung von mechanischen Klassenzimmerlüftungen in Österreich und Erstellung eines Planungsleitfadens. Berichte aus Energie- und Umweltforschung 14/2008, Wien 2008

3.2.4. Function and advantages of ventilation systems

"The main purpose of ventilation systems is to renew indoor air by removing gaseous and dusty pollutants as well as anthropogenic metabolites (odours, carbon dioxide, water vapour) and by supplying fresh air from outside. Thereby convenient room temperature and humidity are to be achieved and thermal loads to be balanced."[20]

The professional association Fachverband Gebäude-Klima e.V. (FGK) is the industry and trade association of the climate and ventilation industry in Germany and very active in raising awareness on this topic, e.g. by conducting public information events on a regular basis (quotations in chapter 3 are taken from some of these events).

"In summary, ventilation systems shall reduce or exclude odours, pollutants, mould, noise, exhaust gases, insects, pollen and dust. Ventilation is no primary energetic but hygienic problem. However, misapplied ventilation can have severe energetic and expensive effects."[21]

Further advantages of ventilation systems over conventional window ventilation were stated by Peter Matthes (RWTH Aachen University, EBC - Institute for Energy Efficient Buildings and Indoor Climate) at the FGK Ventilation Congress on 27 March 2013:

Constraints of window ventilation in summer:

- Possible overheating of classroom due to high heat loads
- Reduced fresh air inflow if temperature differences between in- and outside are low

Constraints of window ventilation in winter:

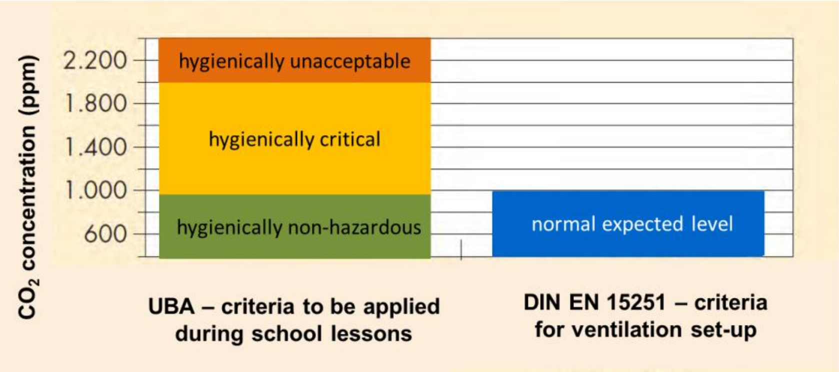
- Low outside temperatures and large opening areas may cause undercooling of indoor ground level
- Theoretically high temperature differences between in- and outside provide sufficient fresh air inflow but cold outside temperatures may prevent sufficient window ventilation and thus high CO_2 concentrations are not removed[22]

"The ventilation number is a measure for the renewal of indoor air by dividing the exchanged fresh air volume flow into the room by the room volume and is defined as non-dimensional parameter per time unit. A ventilation number of 1/h ("one per hour") means that a certain room air volume is completely exchanged within 1 hour (based on calculation). A distinction is drawn between natural air exchange caused by air pressure difference and thermal buoyancy and mechanic air exchange via ventilation."[23]

"There are diverse standards as well as publications recommending the appropriate dimensioning of ventilation systems. Different standards need to be applied to specialist rooms e.g. for chemistry or sports halls and school auditoriums. Since 2007, a detailed recommendation for the dimensioning is provided by DIN EN 15251… The fresh air flow rate for Passive House schools recommended by the Passive House Institute Darmstadt (PHI)[24] is consistent with fresh air flow rate standards set in the German Energy Saving Ordinance[25] (EnEV). This becomes possible since Passive Houses require higher standards for their heat recovery rate than the EnEV (60 % vs. 85 %).[26]

The following figure compares the appraisal of air quality made by the Federal Environmental Agency with DIN standardization:

[20] Umweltbundesamt (Hrsg.): Leitfaden für Innenraumhygiene in Schulgebäuden, Bonn 2008
[21] FGK-Fachkongress - Lüftung in Schulen - 27.03.2012, speaker Andreas Naumann
[22] Umweltbundesamt (Hrsg.): Leitfaden für Innenraumhygiene in Schulgebäuden, Bonn 2008
[23] Umweltbundesamt (Hrsg.): Leitfaden für Innenraumhygiene in Schulgebäuden, Bonn 2008
[24] Passive House Institute Darmstadt
[25] National legislation on implementing the European Energy Performance of Buildings Directive
[26] FGK-Fachkongress - Lüftung in Schulen - 27.03.2012, Speech of Ingenieurbüro Neuplan, Gießen



Source: Fraunhofer-Institute for Building Physics (IBP)

Regardless of the duly set-up of the ventilation system it may occur that acceptable indoor pollutant concentrations (determined as CO_2 concentrations) are exceeded when pollutant loads are high (e.g. caused by a higher number of present people). In this case, additional window ventilation will help to restore an appropriate air quality.

window ventilation	ventilation plan
	"ventilation signal lights"
	motor-driven window opening
exhaust systems	regulated exhaust systems
decentralized ventilation systems	single devices / undersill units
	facade ventilation devices
	wall devices
	ceiling devices
	floor-mounted devices
(semi)central ventilation systems	one ventilation device for several rooms
hybrid ventilation systems	These ventilation devices can be combined with window ventilation if appropriate outside climate conditions exist.

Interior fittings (inclusive furnishing or wall and ground panelling) may emit substances or odours and thus increase the necessity to exchange the air. Ventilation systems can be of great advantages in such a case. However, these particular problems should be treated separately from the regular operation of a Passive House as described in this user manual.

The table above lists existing ventilation systems which are extensively described and compared in the FGK-Status-Report No. 22 "Ventilation of schools" published by the Fachverband Gebäude-Klima e.V. (FGK).[27] For Passive Houses the first two ventilation systems (window ventilation and simple exhaust systems) are not sufficient (see chapter 3.1).

3.2.5. Ventilation during summer

Night ventilation during summer is indispensable in order to cool down the building and to avoid overheating. However, cooler outside temperatures are required for cooling down the building since heat exchange only occurs if heat differences between indoor and outdoor temperatures exist. Effectual storage mass serves as a buffer and helps to release heat accumulated during the day.

[27] R. T. Hellwig: Randbedingungen für die Lüftung in Schulen - Der FGK Status-Report 22. Fachkongress des Fachverbandes Gebäude-Klima e.V. „Lüftung in Schulen", Berlin 27. März 2012

Temperature controlled ventilation flaps may serve as a simple and effective addition of a ventilation system for night-time cooling. Such supplementary installations are applied as standard in municipal Passive Houses of the cities of Frankfurt am Main and Nürnberg.

Source: Stadt Frankfurt am Main, Hochbauamt - Energiemanagement, Passivhausschulen und Kindergärten, Kurzanleitung für die Nutzer

Further options to counteract overheating in summer exist for new buildings, e.g. the concept of thermal activation of building components which has been implemented in a Passive House school in Leipzig. If mechanic day-time ventilation should be used in summer, has to be decided in dependence on the general conditions. Some cities possessing Passive House schools or kindergartens as Frankfurt am Main and Nürnberg are giving the instruction to merely aerate by window ventilation during the non-heating period (May-October). Please refer to chapter 6 to find out how the Wilhelm-Ostwald-Gymnasium deals with this issue (active night-time cooling and ventilation system).

3.2.6. Lighting and indoor air temperature

What are the key factors for lighting apart from energy efficiency? Please refer also to chapter 7.1.2.

„Good lighting presupposes that the lighting system considers all relevant quality features and doesn´t focus on simply one criterion – e.g. the illumination value. Reading a book, assembling small parts or working on the computer: different activities at work or during leisure time imply different kinds of visual tasks the eyes have to carry out and thus determine the requirements on lighting quality. Brightness level and distribution, glare limitation, luminous colour and direction as well as colour reproduction belong to the technical quality criteria of lighting. The European Standard DIN EN 12464-1 "Lighting of indoor working places" extended the concept of quality. Now, classic quality criteria are amended by aspects of daylight use und energy efficient light generation.

The illumination level is horizontally and vertically measured and indicated in the unit lux. It presents the luminous flux which arrives from a source on a determined area. In case of sunlight an illumination level of about 100,000 lux is given, in the shadow of a tree about 10,000 lux, in a moonlit night 0.2 lux and less if there is only starlight. The indoor illumination level is restricted to 50 - 500 lux.

During the past years much attention was given by experts to lighting in school buildings. By now it is considered as a main contributor to health, well-being and learning success."[28]

The following table gives an additional overview on nominal illumination levels (and indoor temperatures) as recommended by the German Association of Cities subjected to room utilization:

[28] bine-Projektinfo 09/201216

Target values for indoor temperature during operation & nominal illumination levels (examples)

Type of room / function	room temperature	nominal illumination level
General premises		
Recreation rooms	20 °C	200 lux
Changing rooms	22-24 °C	100 lux
Lavatories, showers	22-24 °C	100 lux
Toilets	15 °C [1)]	100 lux
First-aid rooms	21 °C	500 lux
Offices and office-like rooms		
Offices with daylight working place directly at the window	20 °C [2)]	300 lux
Other offices	20 °C [2)]	500 lux
Open-plan offices with high reflexion	20 °C [2)]	750 lux
Open-plan offices with medium reflexion	20 °C [2)]	1000 lux
Conference rooms	20 °C [2)]	300 lux
Rooms open to the public	20 °C [2)]	200 lux
School workshops		
Repair facilities		
Mainly hard work intensity	12 °C	500 lux [6)]
Mainly non-sitting activities	17 °C	500 lux [6)]
Mainly sitting activities	20 °C	500 lux [6)]
Vehicle halls	5 °C [5)]	30-100 lux
Common rooms		
Halls, stair areas	12-15 °C [1)]	100 lux
Auditoriums	20 °C [3)]	100 lux
Reading rooms	20 °C [2)]	500 lux
Libraries	15 °C	200 lux
General classrooms		
Preschool classrooms	20 °C [2)]	300 lux [4)]
Classrooms	20 °C [3)]	300 lux [4)]
Classrooms with a daylight quotient D<1% at the most unfavourable working place, for evening occupation and for adult´s education	20 °C [3)]	500 lux [4)]
Specialist classrooms		
Teaching kitchens	18 °C	500 lux [4)]
Craft rooms	18 °C	500 lux [4)]
Physics, chemistry, biology	20 °C	500 lux [4)]
Lecture halls		
Lecture halls with windows	20 °C [3)]	500 lux [4)]
Lecture halls without windows	20 °C [3)]	750 lux [4)]
Indoor sport facilities		
Local and international competitions	15 °C [5)]	300 lux [7)]
Training for regional competitions	15 °C [5)]	200 lux [7)]
School sports and local competitions	15-17 °C [5)]	200 lux [7)]

[1)] Heating becomes necessary only if room temp. falls below the indicated one above since room temperature usually remain stable due to heat gains from adjacent rooms; stair areas and halls with temporally stays: 15 °C
[2)] During occupation (19 °C at the beginning)
[3)] During occupation (17-19 °C at the beginning, depending on dimensioning)
[4)] Additional lighting for black board and demonstration desk (DIN 5035/T4)
[5)] Higher values in special cases
[6)] Values are valid for repairing machines and devices, depending on activity carried out 200 – 300 lux are sufficient (DIN 5035/T2)
[7] Horizontal illumination level min. requirement, depending on sports higher values may be necessary (EN 12193

Source: Deutscher Städtetag: Hinweise zum kommunalen Energiemanagement, Raumtemperaturen und Innenraumbeleuchtung im Gebäudebestand, July 2002 http://www.staedtetag.de/fachinformationen/energie/061541/index.html

4. Specifics for educational buildings

This chapter is based on the information given in the "Guidance for energy efficient educational buildings" published 2010 by the Hessian Ministry for Environment, Energy, Agriculture and Consumer Protection[29] and made possible by the European EFRE-Fond. Therein specific aspects applying on schools, sport halls and kindergarten that are constructed as energy efficient buildings were investigated and analysed in detail for the first time. The following statements taken from this guidance are most important for Passive House school buildings and link the essential principles of a Passive House as indicated in chapter 3 with the specific kind of use as a school.

Schools and kindergartens are very suited to be built in Passive House standard since children may contribute a remarkable amount to the heat demand of their classroom by their own heat radiation.

The most important issue for educational buildings is the indoor air quality. Many scientific analyses prove an extremely bad air quality in schools where a ventilation system is missing. Sufficient aeration by window ventilation cannot easily be achieved due to the high number of people in classrooms and draughts may occur when large amounts of air have to be exchanged. Children are very sensitive to poor indoor air quality and are verifiably less capable to concentrate under such circumstances.

In comparison to conventional school buildings and due to the emphasis put on air quality Passive House schools have an advantage that is most beneficial for its users: Together with the air refreshment guaranteed by the mechanic ventilation system the particulate air pollution is reduced in the classroom as well.

Another advantage is the high insulation of the building which improves the comfort and well-being of the occupants. Further, building fabrics are protected and mould formation inhibited which increases the building´s value.

The low energy demand provides more independency from prospectively increasing energy prices to the building´s operators and thus raises the planning reliability with regards to operation costs. From all municipal buildings schools are often the ones with the highest energy consumption (C. G.: in Leipzig, the current heat consumption of schools accounts to two-thirds of the overall heat consumption in municipal buildings and the electricity consumption to half of it). Thus, in particular for schools the realisation of the Passive House concept would be of great benefit.

Educational buildings should set shining examples. Here, children should learn how energy efficient construction works and how one behaves in an energy saving manner. They further realize that Passive Houses offer perfect studying conditions.

Increased insulation thickness and triple glazed windows are cost-effective even without additional financial support. Investment costs for controlled ventilation systems are often still seen as additional costs. But they also show cost-effectiveness in the building`s overall concept and will stay within reasonable limits when soundly planned. In general, additional investments of 6-8 % of construction costs can be refunded by operation cost savings.

Classrooms need a proper daylight illumination by large window areas. In summer, movable exterior solar shading is required. Since outside air provides sufficient cooling potential most of the time during summer, window ventilation should be conducted whenever possible. Thus, a sufficient number of windows is essential for natural ventilation during summer and also wanted by building´s occupants. The size of the windows should be dimensioned with a minimum of 0.1 m² per user if the building is cross ventilated and 0.3 m² per user without cross ventilation. As the numbers reveal, window ventilation is not only wanted but absolutely required in summer. Burglar-proof window aeration during the night should be possible too. In order to reduce indoor peak temperatures in summer a high

[29] Hessisches Ministerium für Umwelt, Energie, Landwirtschaft und Verbraucherschutz (HMUELV)

thermal storage capacity is necessary. Massive construction components as ceilings and walls that are not covered by sound insulation or wall cupboards are effectively storing heat.

Heat losses due to frequent main entrance use are small and raise the energy consumption of the whole school building by only 0.5 kWh/m²a. However, a porch with cleaning zone should be integrated into the main entrance area.

To prevent vandalism on the façade insulation measures such as back-ventilated façades, carbon-containing insulation systems and protective plates at the base of the building have proven a success.

Central ventilation systems ensure a cost effective operation of the system. Halls and stair areas, ancillary rooms and sanitary facilities have to be involved. The operation of the ventilation system has to be adapted to the occupation times of the school and emphasis should be put on filter ventilation. Classroom ventilation should start one hour before lessons begin in the morning to clear the air from contaminants possibly accumulated during the shutdown period over the night. It should be possible to uncomplicatedly switch on the ventilation system in case of special events or parents´ evenings.

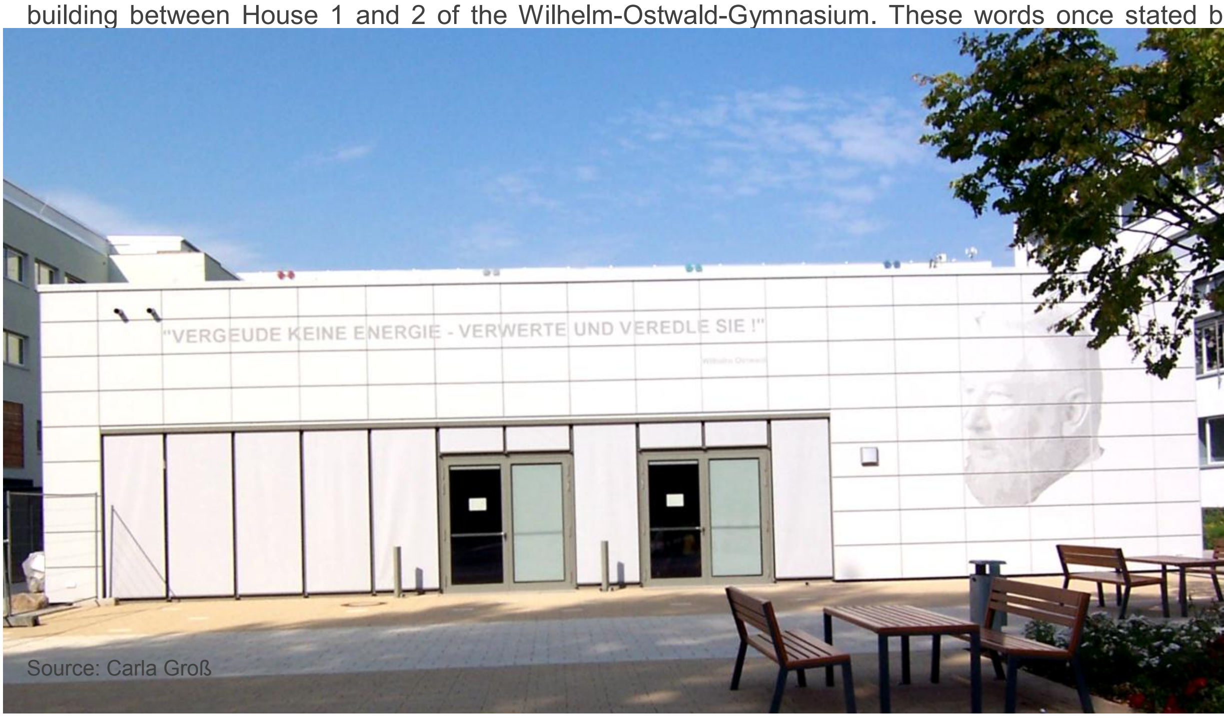
To avoid unnecessary construction and maintenance costs the ventilation system should be conformed to the fire protection concept and pipes should be orientated on fire compartments.

Passive Houses require only one heating system and common small cost-saving heating devices may be chosen. It is recommended to opt for a heating system with automatic temperature drop option. After temperature reduction (during night or weekends) the indoor air should be reheated, e.g. with heating devices.

With the implementation of the all-day school concept more and more schools have own school canteens ranging from catering kitchens to fully equipped kitchens which generally require separate ventilation systems in order to dissipate higher heat and moisture loads.[30]

5. Example Wilhelm-Ostwald-Gymnasium Leipzig

“Do not waste energy – utilize and refine it!” – this sentence is written on the newly erected connecting building between House 1 and 2 of the Wilhelm-Ostwald-Gymnasium. These words once stated by



Source: Carla Groß

[30] W. Feist: Leitfaden für energieeffiziente Bildungsgebäude, Passivhaus Institut Darmstadt, Darmstadt 2010

The whole building complex connects 2 almost identical slab-buildings. The photo below shows the view from House 1 to House 2 - which is currently still under construction – and the central connecting building.

Source: Carla Groß

The entrance and corridor area in the connecting building:

Source: Carla Groß

House 1 and 2 were refurbished in accordance with the Passive House standard while the connecting building is in compliance with requirements set in the German Energy Saving Ordinance (EnEV 2007, valid version during the planning phase of the refurbishment).

Further information:

- Completion of refurbishment: October 2011
- Primary energy demand for House 1 and 2 (Passive House standard): 59.26 kWh/m²a*
- Primary energy demand for connecting building (EnEV 2007 standard): 213.92 kWh/m²a*
- Net floor area (incl. connecting building): 7,296.54 m²

*specifications made during planning

Refurbishments of slab-buildings in Passive House standard are much more challenging than new constructions. Furthermore the supplementary installation of a ventilation system is not necessarily cost effective.

But it is the ventilation system that has a great beneficial effect to the occupants of educational buildings as schools and kindergartens (see chapter 3.2.2). Nevertheless it is also responsible for a considerable amount of the additional costs of buildings constructed in Passive House standard in comparison to EnEV standards and it becomes even worse if the building is refurbished and not newly built.

The following improvements were undertaken during the refurbishment of the Wilhelm-Ostwald-Gymnasium to Passive House standard:

- **Building envelope**

Thermal insulation of external walls: 25 cm (thermal conductivity class 035)

Areas touching the ground: perimeter insulation 25 cm (thermal conductivity class 040)

Roof insulation: 33 cm - 58 cm tapered insulation (thermal conductivity class 035)

Ground floor insulation: ground floor plate (concrete subbase) on 14 cm perimeter insulation (thermal conductivity class 040) + 8 cm thermal insulation (thermal conductivity class 040) in cellar ground floor

Windows: exchange of all windows by plastic windows with Uw=0.8 W/Km²

- **Supplementary heating**

The additional heating is based on the existing district heating system which has been used before the refurbishment already.

Nominal heat output of the new transfer station (for all 3 building parts): 291 KW, inlet / outlet flow 70 °C / 45 °C

Current primary energy factor of energy supplier Stadtwerke Leipzig: 0.31

- **Hot water**

There are single decentral tapping points in specialist rooms which are assessable only by key locks.

- **Ventilation system**

A central ventilation system has been installed with 2 circular ventilation systems per building for classrooms, administration rooms, side and specialist rooms and 2 circular ventilation systems for hallways and toilets. Presence detectors steer the ventilation flaps responsible for the air volume flows). The maximum volume flow in classrooms is configured to 450 m³/h and the basic ventilation to 150 m³/h (school auditorium: 6000 m³/h). This configuration is based on an assumed room occupation of 25 people and a maximum CO_2 concentration of 1.500 ppm (after DIN 1946).

Ventilation devices have a maximum heat recovery rate of 90 %.

During winter a high comfort in classrooms and administration facilities is ensured by a regenerative heat exchanger with moisture transition. Specific requirements were respected for the school kitchen.

A technical cooling (split-unit) provides cooling to server rooms in both buildings by heat dissipation and is not to be mistaken for air conditioning.

Fresh air input into the ventilation system takes place without additional cooling.

- **Lighting**

The energy saving lighting has been set up according to the recommended values provided by the Technical Rules for Working Premises[31] (see chapter 3.2.6). In classrooms, steering of lighting is carried out by presence detectors (see photo below). Corridors, stair areas, windowless recreation rooms, specialist and technical rooms are accessorily equipped with emergency lighting which will take over the general lighting in case of failure. A central battery installation steers the emergency lighting system.

Source: Carla Groß

6. Instructions for school building users

Users of school buildings are students, teachers, school board members and secretarial staff. For them a comfortable indoor climate is most important, both, in winter and in summer. Thereto much attention has to be paid to winterly and summerly heat protection and indoor air hygiene. Depending on their behaviour, users themselves can strongly influence these aspects.

Passive Houses are of good nature and forgive all mistakes made by the users. In general, one can behave in the same way as in conventional buildings without causing severe trouble. However, advantages of Passive Houses (in particular a low energy consumption) will only come into effect if users behave according to the building philosophy. That is not complicated if the background is clear. Therefore, basic aspects of Passive Houses will be subsequently explained using the example of the Wilhelm-Ostwald-Gymnasium in Leipzig. Deviations may exist for other Passive House schools since there are various technical options and concepts for such constructions. In order to separate general information from specific conditions of the Wilhelm-Ostwald-Gymnasium, the latter information will be presented italicised.

[31] Arbeitsstätten-Richtlinie (ASR) A3.5 from June 2010

Source: Carla Groß

Winterly heat insulation ensures comfortable indoor temperatures even if outside temperatures are very low. An additional heating system is required to heat up single rooms if necessary. As described in the Preface (chapter 1) Passive Houses cover their heat demand mainly by heat emitted by electric devices, lighting, their occupants and by solar heat gains of the windows. Due to high **heat recovery** rates only little heat losses caused by the ventilation systems occur. However, in schools a supplementary conventional heating is needed to ensure the minimum required indoor temperature at the beginning of lessons (when the expected number of people is not yet present) (see chapter 3.2.1) which would be impossible after weekends or holidays during winter. Due to heat insulation of the building envelope the heating period is much shorter than in conventional buildings and normally only minor cooling – even after such an exceptional case as the winter holidays - occurs. Heat transfer of the additional heating system takes place by conventional heating devices. In the case of the Wilhelm-Ostwald-Gymnasium, district heating serves as the heat source.

- **Basic conditions for the operation of the supplementary additional heating**

According to an internal instruction which is based on recommendations of the German Association of Cities (see chapters 3.2.1 and 3.2.6) a target temperature of 20 °C is set for classrooms and of 15 °C for hallways and toilets in the Wilhelm-Ostwald-Gymnasium.

Room temperature sensors are placed at a height of 1.80 – 2 m and should not be manipulated since otherwise the regulation system could be disordered and the sensor even destroyed.

Indoor temperatures are regulated according to the class schedules which are fed into the steering of the heating system. Moreover people being present for more than 5 minutes will stimulate additional heating.

Room temperature is checked before the projected start of utilization.

Basic settings foresee a heating up to 8 hours in advance of utilization start. The duration of the preheating period can be modified.

Additional heating is stopped (decrease mode) when rooms are not occupied according to the class schedules, after 30 min with no presence of people in the room (even if foreseen according to the schedule) and after 5 pm at schooldays (and before weekends and holidays).

Room temperatures must not fall below 14 °C. However, due to good insulation of the building envelope such a low temperature is rarely to be achieved.

Temperature is decreased to a minimum of 17 °C in offices and secretariats (in House 2) during a utilization period between 7 am to 5 pm. Additional heating can be steered by an operator control panel in each room. In case of modifications the temperature regulation is reset to the automatic mode after 8 pm.

- **Basic conditions for the shut-down of sun protection during winter**

Sun protection facilities installed at the southern side of the building are of relevance for the building´s energy balance even during the heating period. In contrast to summer, it should be assured that solar heat gains by the windows are sufficiently used. Therefore sun protection in winter only serves as glare protection.

If the room is occupied and the sun intensity > 64,000 lux (strong solar radiation), jalousies should be half-closed.

- **Basic conditions for the shut-down of sun protection during summer**

Summerly heat protection should keep the room temperature within the range of 20 °C to maximum of 26 °C even during heating conditions caused by solar radiation (that is actually only appreciated during the heating period) and high outside temperatures.

Shading in order to reduce solar radiation is not only required for the southern side of the building but also important for western and eastern sides.

Case I (heat protection at minimum light incidence)

If the room is occupied and the sun intensity > 15,000 lux (overcast sky), jalousies should be half-closed.

Case II (heat and glare protection)

If the room is occupied and the sun intensity > 64,000 lux (strong solar radiation), jalousies should be closed completely.

Case III (maximum sun protection)

Jalousies will remain completely closed except during night, during stormy or rainy weather conditions (steered by a wind sensor), when the room temperature is below 22 °C and if manually controlled.

Manual opening or closing of jalousies is always possible (by a key switch). Generally, automatic regulation of sun protection is carried out during the breaks. Manual regulation of jalousies can be conducted centrally for the whole building too. Switching between summer and winter time has to be carried out manually.

Due to the excellent insulation of the building envelope a Passive House offers both, protection against cold in winter and against heat in summer which means that it will heat up much slower than a conventional building. The risk of overheating is limited already during the planning phase (see chapter 3.1). However, during the day, heat is stored in massive building parts (walls, ceilings, floors) which can be released when outside temperatures are cooled down, e.g. during the night. The effect of night-time cooling depends on the existing amount of storage mass and temperature difference and may be weak when conditions are inappropriate (see chapter 3.2.5). Large scale acoustic panels on walls and ceilings may improve this effect.

- **Basic conditions for active night-time cooling**

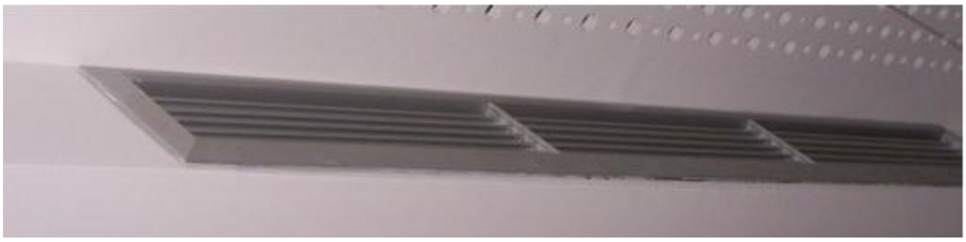
Night-time cooling is carried out once during the summer period (May – September) between 10 pm and 6 am if the outside temperature > 10 °C, the difference between outside and indoor temperature is between 4 and 6 K and at least one room holds a temperature of > 24 °C.

Flow volume controllers are completely opened during the night-time cooling mode and heating devices and pumps of the ventilation system turned off (heat recovery is out of action).

The ventilation system ensures the indoor air quality (see chapter 3.2).

Fresh air is delivered only to an extent that is necessary to ensure users comfort and health. Heat recovery from exhaust air offers the advantage of pre-heating the supply air. The air entering the room is no circulation air but air that is untreated and contains no pollutants and pollen thanks to effective filtering of outside air. Therefore a high degree of air hygiene is reached in Passive Houses. Chapter 3.2.2 provides information on recommended maximum values and on interdependency with other parameters. To reduce unavoidable drying out of indoor air caused by the ventilation system (especially at low outside temperatures and high air exchange rates, see chapter 3.2.3) heat exchange devices with partly moisture recovery were chosen and installed in the Wilhelm-Ostwald-Gymnasium.

Each classroom has at least one supply air (lower photo) and one exhaust air opening (top photo). The orientation of ventilation flow can be manually adjusted at the exhaust air opening.



Source: Carla Groß

(supply air opening above the black board at the ceiling, behind the lighting)

Source: Carla Groß

Supply air and one exhaust air opening must always be open.

- **Basic conditions for the operation of the ventilation system**

The ventilation system is switched on only during the time of use by the school, generally that is on school days from 6 am to 5 pm (toilets and hallways from 7 am, auditorium from 8 am). The ventilation starts as early as 6 am to remove possible air contaminants and thus ensure a good air quality at the beginning of lessons already. Accompanying, the supply air can be pre-heated and indoor temperatures be raised if necessary.

With respect to experiences made and specifications given by other municipalities as Frankfurt a.M. and Nürnberg concerning their municipal Passive Houses, the ventilation system is turned off from April to October except for active night-time cooling (see above).

There are 3 ventilation levels:

a) Maximum air volume if room is occupied (measured by presence sensor)

b) Minimum air volume if room is not occupied (nobody is present for 30 minutes)

c) Complete shutdown of the ventilation system (e.g. during the day from April to October, during holidays)

The target supply air temperature is consistent with target room temperatures (see chapter 3.2.1).

Due to safety regulations for specialist rooms advanced ventilation requirements have to be implemented regardless of the procedure described above. E.g. exhaust air is continuously removed from facilities where chemicals are stored or worked with.

In school workshops an illuminated push-button enables to manually activate or deactivate the ventilation for a certain period of time. The system is reset into the automatic mode at 10 pm.

The ventilation system is automatically operating in the connecting building throughout the year during lunch time (serving of school meals) and when the auditorium is occupied (according to school schedule). Here, an operator control panel enables the manual two-stage regulation of the ventilation. At midnight the system is reset into the automatic mode. The ventilation system of the auditorium is connected with the exhaust air system for the toilets there and can therefore be jointly handled. Aeration of the school kitchen is manually steered by an operator control panel and runs for 2 hours after activation.

It should be kept in mind that ventilation devices always hold a post-run time after being switched off to prevent them from moisture damage and bacterial and fungal infestation.

Of course, additional window ventilation is allowed when air quality is poor (e.g. when more than 25 people are present in the room). Opening the door towards the hallways is another option to improve the air exchange but is only a temporary solution.

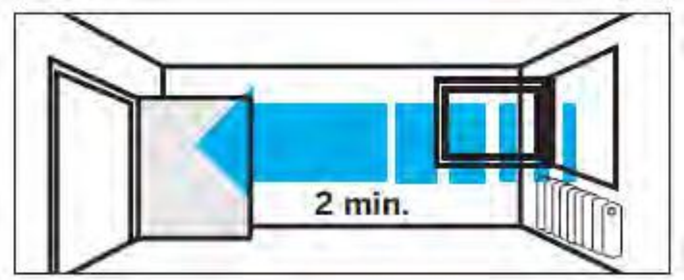
In general, window ventilation is not necessary but also not forbidden! Short but intensive airing with wide open windows can be conducted if necessary during the cold season.

Concerning window ventilation some basic rules have to be respected. To cool down indoor temperatures in summer windows facing north (no direct sun) should be chosen. In case the outside temperature is higher than the indoor one window ventilation can easily lead to an unwanted heating up of the room.

During winter the following indications are of relevance:

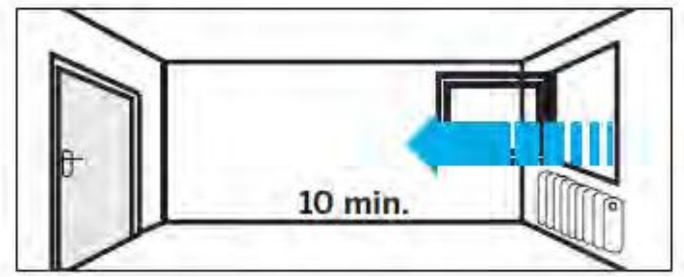
- Those windows should be preferably opened where no heating devices are installed below (because heating losses during aeration would be higher if the heating device causes higher temperature differences between indoor and outside).
- Ventilation should be conducted only by short but intensive aeration with wide open windows until air exchange has sufficiently taken place and not longer than 15 minutes (no tilted windows!)
- Cross-ventilation supports and accelerates air exchange rates.

The graphic below schematically demonstrates the average duration of air exchange depending on the kind of ventilation in an exemplary room.



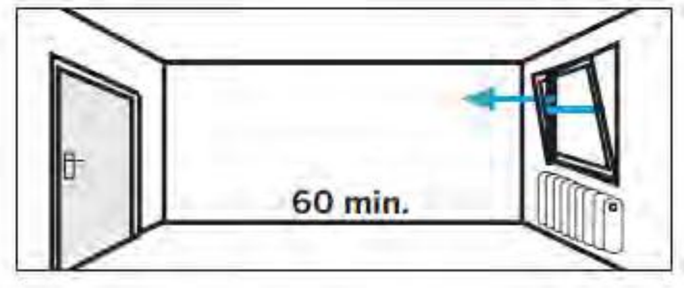
Cross-ventilation (two-sided, short but intensive aeration with wide open window and door)

(In spite of this picture: if possible no windows where heating devices are installed below)



One-sided short but intensive aeration with wide open window

(In spite of this picture: if possible no windows should be used for aeration where heating devices are installed below)



Aeration with tilted window

(Permitted only outside of heating period)

Window ventilation allows no heat recovery. Thus, even the short but intensive aeration as described above should not be carried out too often when outside temperatures are below 20 °C since it may cause an indoor temperature decrease which is perceived as uncomfortable. Further, subsequent re-warming of the room will take some time. Therefore, during the cold season attention should be paid to closed windows especially subsequent to the daily occupation of the room!

Items fixed to the glass are forbidden (e.g. pictures) since they might cause heat accumulation. Resulting enhanced tensions may cause breakage of the window pane!

The overview below summarizes all behavioural instructions for Passive House users independent of the current status of the automatic / technical steering:[32]

Summer:

- Timely regulation of sun protection devices in the morning (closing of jalousies to avoid overheating)
- Avoiding frequent opening of doors and windows on hot summer days
- Opening of windows only for the purpose of fresh air provision if the ventilation system is switched off
- Short but intensive aeration with wide open windows during cool time of the day (morning, evening)
- Constant night-time cooling by tilted windows (if no active night-time cooling is conducted)
- Controlling of room temperatures (maximum 25 °C) (single peak temperatures may occur in summer)

[32] SAENA - Sächsische Energieagentur, Hinweise zum Nutzerverhalten bei neu errichteten Grundschulen und Kinderbetreu-ungseinrichtungen in Passivhausbauweise

- Economic usage of lighting and technical devices (decrease of energy consumption and heat radiation)

Autumn and spring:

- Avoiding opening of windows on warm days
- Opening of windows is not necessary if the ventilation system is running
- Opening of windows to provide fresh air is possible when the ventilation system is switched off
- Exchange of air filters (by janitors, other instructed staff)
- Window ventilation is allowed in order to cool down room temperature (as in summer)
- Solar radiation entrance should be regulated by sun protection devices
- Economic usage of lighting and technical devices

Winter:

- Windows and doors should be kept closed to avoid heat losses
- Control of room temperatures (minimum 19 °C during heating period)
- No regulation of solar radiation entrance (avoid shading)
- Economic usage of lighting and technical devices (decrease of total energy consumption)

Further instructions: http://www.saena.de

7. Instructions for operators and administrative staff

Users of a building are here defined as the administrative department in the municipality and the department that is operating the building as well as technicians and janitors. All these actors should be informed about the functionality of a Passive House (see chapter 3) and also know the instructions for its users. Maintenance and repair works require utmost care to not impair the operational mechanisms of the Passive House (e.g. the airtight building envelope). The unrestricted functioning of all constructional and technical facilities has to be ensured, partly by own staff, partly by service contracts (in particular for technical facilities).

In the city of Leipzig these tasks have to be carried out by the Agency for Building Management / Department Technical Building Management and here by the units "Operation Management and Technique" and "Maintenance of Values". The unit "Energy" is responsible for the commercial and technical energy management. The tasks within the Department Technical Building Management are set forth in an agreement between the Agency for Building Management and the School Administration Agency (dated to 2005). This document also defines test and control cycles for janitors.

A fraction of the buildings is steered and controlled by a control system. Generally this is the case with new constructions and extensive refurbishments as in the Wilhelm-Ostwald-Gymnasium so that deviations from normal operation parameters can be easily detected.

Legal inspection requirements indicate test and maintenance cycles:

The following service contracts are in force for the technical facilities described in chapter 5 (and other) in the Wilhelm-Ostwald-Gymnasium (examples!):

- *Heat supply (heating plant)*
- *Ventilation system (room air technique and fire protection flaps)*
- *Smoke and heat exhaust ventilation system*
- *Sun protection system*
- *Building automation*

- *Safety lighting*

Due to the complex technical nature the Passive House is more challenging to operators and janitors than a conventional building. Therefore the technical staff must be able, to immediately detect technical errors – by local displays, the control system or deviations from the normal operation that is defined by parameters as air quality and temperature. It has to be assured that the required maintenance cycles for technical plants are kept (recommended maintenance cycle for ventilation systems: biannual, filter change inclusive) and additionally components of the building envelope involved. The high airtightness of the building requires periodical inspection of potential weak points as windows and adjustments if needed. For this purpose it may be useful to repeat the BlowerDoor-Test which was conducted for the final acceptance of construction work and which tests the airtightness of the building envelope. Subsequent testing via Infrared Thermography during the operation phase of the building might be appropriate as well.

The janitor is often seen as a key figure in municipal energy management. … Out of his experiences he generally obtains an excellent knowledge about the building such as strengths and deficits. Even though he is often responsible for the monitoring of the installation engineering his knowledge about this topic is often less extended. Since maintenance is often carried out by external contractors janitors will only act if there is a malfunction of the technical systems. Regarding operation costs, consumption of media and possible energy saving potentials - in most municipalities janitors have no responsibilities for these aspects so their knowledge on the building and its technical system is of no benefit to generate positive effects. … Research and experiences demonstrate that motivated and committed janitors can reduce the energy consumption of “their” building by up to 20 %, in some cases even up to 50 %. It would be wise to make use of this potential.

Further information: http://www.een-sachsen.de/content/view/30/127/

7.1. Instructions for electric devices and lighting

Energy efficiency criteria should be an issue already when buying electric devices. Basic instructions shall be given in the following passages. Further information can be obtained in the guidelines presented below and on the website:

www.keds-online.de/keds-Themen/Energieeffiziente-Kommune/Beschaffung/Leitfaeden

- **Procurement guidelines of the German Energy Agency**[33]

In the framework of the “Initiative EnergieEffizienz” the German Energy Agency GmbH set up the procurement guideline “Professional procurement of energy efficient office equipment”[34]. Therein it is demonstrated step by step how to integrate energy efficiency criteria into the procurement process using the example of purchasing office equipment.

The guideline combines technical information with representative examples. Its structure follows the steps to be taken during the procurement procedure: from setting up of performance criteria over evaluating the tenders to identifying the most cost-effective one. Sample templates provide practical formulations for the call for tenders.

The guideline can be downloaded here: www.stromeffizienz.de/dienstleister-oeffentliche-hand/green-it/beschaffung.html

[33] Deutsche Energieagentur dena
[34] “Energieeffiziente Bürogeräte professionell beschaffen“

- **Procurement guideline of the Energy Agency of Berlin**

The Energy Agency of Berlin has set up several procurement guidelines dedicated to "Procurement and Climate Protection". A general part informs about the basic conditions with respect to the competition law and to procurement regulations. Furthermore, assistance with procurement is provided for the following product groups: office equipment / IT technique, domestic appliances, lighting, green electricity and vehicles. The guidelines provide technical background, present specific criteria for each product group and describe the procurement procedure. Additionally the guidelines contain performance sheets with criteria relevant to the environment. These sheets can be downloaded as word-files and thus be directly used for a call for tender.

- **Guideline of the European Commission**

The European Commission offers, together with other information on the European environmental label, a handbook on environmental public procurement.[35] The handbook deals with the issue of environmental friendly procurement in six chapters ranging from general strategies over organisational issues in public procurement to specific topics directly linked to practical application. Practical examples from European countries illustrate each key aspect.

The guideline is available for download here:

http://ec.europa.eu/environment/gpp/pdf/buying_green_handbook_en.pdf

7.1.1. IT and communication equipment

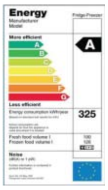
The Federal Ministry of the Environment awards the environmental label "Blauer Engel" with the amendment "protects the climate" now. Producers of computers, notebooks and monitors can apply for awarding their energy efficient and environmental friendly products with this label if the related criteria are fulfilled. The energy consumption of Desktop PCs that are awarded with the "Blauer Engel" is 50 to 75 % less than other computer customary in the market. Efficient computer monitors require about 40 % less energy. Even though the energy efficiency is constantly improving, modern IT- and communication equipment is still responsible for about 10 % of the total electricity demand in Germany with an increasing tendency.

7.1.2. Electric devices and lighting

In order to provide information on energy efficiency to the consumer, electric devices have to be obligatory labelled with the respective energy-performance label. The paragraph below provides an overview on the state of the art of these labels using a presentation from the Ökoinstitut e.V. that participated in the EU-project "come-on-labels" in the Intelligent Energy Europe Programme (IEE). Further information: www.come-on-labels.eu.

[35] "Buying green! A handbook on environmental public procurement"

Overview on Energy Labels:



- Products with **„old“ labels:**
  Electric baking oven, air conditioner, dryer, lighting

- Products with **“new” labels:**
  Cooling devices (incl. wine storage units), washing machines, dish washer, TV

- New labels are foreseen for:
  Room air conditioner (from January 2013)
  Lighting (from September 2013)

- Products with “new” labels in preparation*:
  Water heater, boiler and dryer

*status March 2012

Which energy efficiency grades exist on the market?
Impact of the Eco-Design Directive
Class A sets the minimum requirements for:

- Refrigerators and freezers as well as combined devices (from July 2012 only A+)
- Washing machines (from December 2013 only A+)
- Dish washer (60 cm models, from Dec. 2013 only A+)

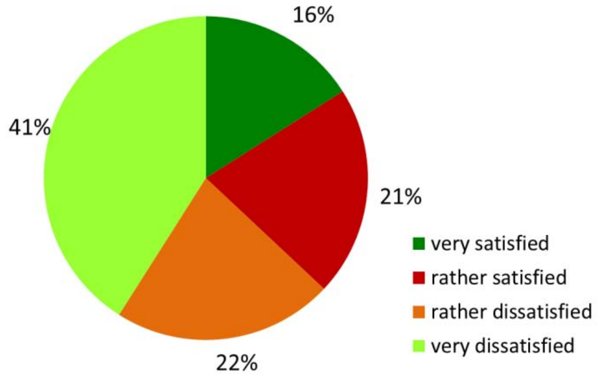
What does the “+” stand for?

- **Refrigerators**: The A +++- product is 60 % more energy efficient than a product of grade A.
- **Washing machines:** The A +++- product is 32 % more energy efficient than a product of grade A.
- **Dish washer:** The A +++- product is 30 % more energy efficient than a product of grade A.

Further information:
ISBN 978-3-8462-0086-5
(in German)

8. Specifics during initial operation phase and monitoring

New technologies often face problems in terms of acceptance that have to be expected when introducing the product to the consumer. In the scope of an evaluation of mechanic classroom aeration in Austria an enquiry among teachers regarding their satisfaction with ventilation systems or devices was conducted and finally provided the following result:



Source: Hellwig 2012[36]

The following statement and advice given by Prof. Dr.-Ing. Runa T. Hellwig can be transferred to Passive Houses without restrictions:

- Need of an intensive communication strategy with teaching staff and students in order to avoid misunderstandings and inappropriate expectations
- Lack of information and communication cause acceptance problems which leads finally to incorrect user behaviour and further to unsatisfied users, in particular if the system is malfunctioning in the very beginning of the building´s operation

Only a user manual would be insufficient to ensure a good communication but it can be a part of it and help to solve problems of acceptance.

However, there are problems caused by different aspects that should be distinguished from general problems with the acceptance of the Passive House. The incomplete line-up of the technical system at the beginning of the operation often courts user´s resentment since it takes some time until all components run optimally. Another problem occurs if deficiencies have to be detected during the guarantee period. Both problems will definitely arise during the start-up phase of the building which often lasts up to 3 years, depending on the technical equipment. Thereby different aspects have to be considered for each season and the line-up has to be adjusted respectively. The city of Nürnberg realized that controlling and revising the technical settings for the first 3 years of building`s operation is not only helpful but even required and made a 3-years monitoring obligatory for its municipal Passive Houses.[37]

Monitoring is of great benefit in terms of detecting defects in the normal operation of a Passive House which enables the operator to quickly remedy them. It is very important to have satisfied users and to motivate them to contribute to the building´s monitoring and to behave in an expedient manner. Involving the occupants in the monitoring process by ensuring a close communication after the initial operation of the newly erected or refurbished building contributes significantly to reaching the target

[36] R. T. Hellwig: Randbedingungen für die Lüftung in Schulen - Der FGK Status-Report 22. Fachkongress des Fachverbandes Gebäude-Klima e.V. „Lüftung in Schulen“, Berlin 27. März 2012. Based on data from: A. Greml, E. Blümel, A. Gössler, W. Kapferer, W. Leitzinger, J. Suschekberger, P. Tappler: Evaluierung von mechanischen Klassenzimmerlüftungen in Österreich und Erstellung eines Planungsleitfadens. Bundesministerium für Verkehr, Innovation und Technologie (Hrsg.) Berichte aus Energie- und Umweltforschung 14/2008. Wien 2008

[37] Personal communication during a study visit to the 1st municipal Passive House on 21 November 2011

energy savings. A contact person should be appointed that deals with all enquiries, complaints and remarks of the users.

Parameters requiring a line-up are for instance the room temperature at the beginning of school lessons and draughts (displeasing perceived).

9. Practical experience from Germany

A comprehensive variety of pilot projects and reports based on experiences were collected by the research project "Energy Efficient Schools" (EnEff:Schule) that was carried out in the scope of the concept "Research for energy optimized construction" and founded by the Federal Ministry for Economics and Technology[38] (in German).

The goal of the project was to research and present all activities within the field of energy efficient refurbishment of schools. Another key aspect was the scientific monitoring of demonstration projects carried out within the project EnEff:Schule (http://www.eneff-schule.de).

Pilot school buildings:

Plus energy schools are awarded as flagship projects by the research project EnEff:Schule. Calculated over a whole year they generate more primary energy as needed by themselves for heating, ventilation, domestic hot water production and lighting. To reach this ambitious goal heat losses caused by transmission and ventilation have to be drastically reduced in the first place. This can be achieved by high thermal insulation of the building envelope, extensive elimination of thermal bridges and efficient ventilation. In a second step the remaining energy demand has to be generated (with as low energy losses as possible) and preferably by using renewable energy sources. A building under refurbishment can be turned into a plus energy house if the residual energy demand is e.g. covered by photovoltaic modules. Optionally, the electricity generated can be fed into the general grid. The energetic evaluation of the schools is carried out in accordance with the calculation method provided in DIN V 18599.

Plus Energy School in Stuttgart-Rot, "Uhlandschule"

http://www.eneff-schule.de/index.php/Demonstrationsobjekte/Plusenergieschulen/plusenergieschule-in-stuttgart-rot.html

"Low-Tech" and "Low-Cost" Plus Energy – Grundschule Hohen Neuendorf:

http://www.eneff-schule.de/index.php/Demonstrationsobjekte/Plusenergieschulen/low-tech-und-low-cost-plusenergie-grundschule-hohen-neuendor.html

Plus Energy School Reutershagen, Rostock:

http://www.eneff-schule.de/index.php/Demonstrationsobjekte/Plusenergieschulen/plusenergieschule-reutershagen-rostock.html

Three-Liter-House-Schools are denoted as "beacons" by the research project EnEff:Schule. Their primary energy demand for heating and ventilation and related auxiliary energy accounts to only 34 kWh/m²a which corresponds to 3 liter mineral oil or 3 m³ natural gas. The energetic evaluation of the schools is carried out in accordance with the calculation method provided in DIN V 18599.

[38] Bundesministerium für Wirtschaft und Technologie (BMWi)

Energy Saving School Max-Steenbeck-Gymnasium Cottbus:

http://www.eneff-schule.de/index.php/Demonstrationsobjekte/3-Liter-Haus-Schulen/energie-spar-schule-max-steenbeck-gymnasium-cottbus.html

Three-Liter-House-School in Olbersdorf:

http://www.eneff-schule.de/index.php/Demonstrationsobjekte/3-Liter-Haus-Schulen/3-liter-haus-schule-in-olbersdorf-landkreis-loebauzittau.html

Science College Overbach in Jülich-Barmen:

http://www.eneff-schule.de/index.php/Demonstrationsobjekte/3-Liter-Haus-Schulen/science-college-overbach-in-juelich-barmen.html

Gymnasium Marktoberdorf:

http://www.eneff-schule.de/index.php/Demonstrationsobjekte/3-Liter-Haus-Schulen/nachhaltige-heizungssanierung-durch-erfolgscontracting-naerco-am-gymnasium-marktoberdorf.html

Further Best Practice Examples

During the recent years more and more schools were successfully refurbished in an energy efficient manner. Such projects were partly financed by the Federal Ministry for Economics and Technology and partly by other institutions and seen as “Best Practice Examples” since they reveal a right balance between energy efficiency and cost-effectiveness. The energetic evaluation of the schools was carried out in accordance with the calculation method valid before DIN V 18599 came into force.

Passive House School - Berufliche Oberschule Erding:

http://www.eneff-schule.de/index.php/Demonstrationsobjekte/Best-Practice-Beispiele/nachhaltiges-passivhauskonzept-in-niedrigenergiebauweise-berufliche-oberschule-erding.html

Passive House School - Musikhauptschule und Polytechnische Schule in Schwanenstadt, Austria:

http://www.eneff-schule.de/index.php/Demonstrationsobjekte/Best-Practice-Beispiele/sanierung-zum-passivhaus-standard-mit-vorgefertigten-holzwandelementen-musikhauptschule-und-polytechnische-schule-in-schwanenstadt.html

Passive House School - Grundschule Riedberg, Frankfurt am Main:

http://www.eneff-schule.de/index.php/Demonstrationsobjekte/Best-Practice-Beispiele/passivhausschule-grundschule-riedberg-frankfurt-am-main.html

Recommended links to further projects or institutions connected to the EnEff:Schule project:

Federal Ministry for Economics and Technology (www.bmwi.de)

Project Management Jülich (www.ptj.de)

Fraunhofer-Institute for Building Physics / Heat Technology (http://www.ibp.fraunhofer.de)

Fraunhofer-Institute for System and Innovation research (www.isi.fraunhofer.de)

University of Applied Sciences Munich (www.fh-muenchen.de)

IREES Institute for Resource Efficiency and Energy Strategies (www.irees.de)

Energy – optimised construction (www.enob.info)

Energetic Refurbishment of Building Components (www.archiv.ensan.de) (only in German)

IEA ECBCS Annex 36 – Retrofitting of Educational Buildings (www.annex36.com)

EU - BUILD UP – School of the Future (www.buildup.eu/communities/schoolfuture)

Saxony´s first refurbishment of a school in Passive House standard (**Waldschule Grimma**) was completed in 2007 after a construction period of one year. As the Wilhelm-Ostwald-Gymnasium it is a prefabricated concrete slab construction and was built in 1988.

The Waldschule Grimma is a school for mentally handicapped children and run by the district of Leipzig. The refurbishment was funded by the State of Saxony (All-day School Concept and Passive House Programme). Further information (in German only):

http://kettner-haus.de/static/kettner-haus.de/indexcd1a.html?id=161 as well as http://www.ib-hofmann.de/00_download/passivhausschule-grimma.pdf

Another interesting EU-project puts its emphasis on Passive Houses, in particular with recommendations for the implementation in the public sector: http://www.passreg.eu/

This link leads to a platform where the region of Hannover presents Passive Houses and refurbishments with Passive House components in the region (in German only). Public and office buildings are presented with construction details, building technique and energy performance indicators: http://www.passivhaus-plattform.de/

Further recommended links

Efficient consumption of energy in buildings is achieved on the one hand by constructional measures and on the other hand by user´s behaviour. Projects dealing with energy offer students a great opportunity, to practically learn more about the topic in their daily life and thus achieve new knowledge while having fun at the same time.

Many Best Practice Examples exist for energy related pedagogic projects in schools. Further information is provided here (only in German):

http://www.eneff-schule.de/index.php/Demonstrationsobjekte/Best-Practice-LINKS/paedagogische-projekte.html

10. At a glance – how to use a Passive House

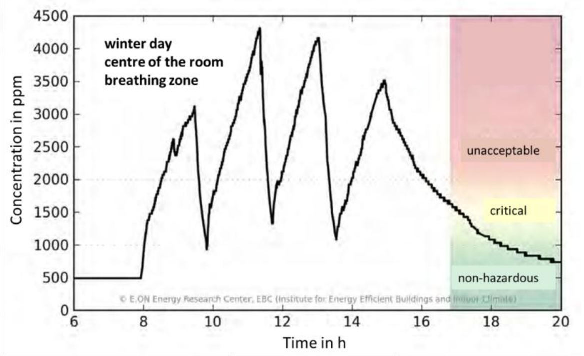
A short instruction for the use of the Wilhelm-Ostwald-Gymnasium was created in form of a flyer (see following page).

The flyer compiles basic and general knowledge on Passive Houses, some information about the Wilhelm-Ostwald-Gymnasium and instructions for users on how to deal with their Passive House.

What are the benefits of ventilation systems?

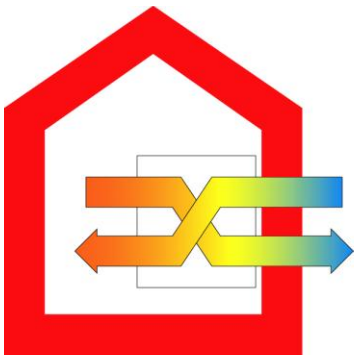
An appropriate air quality (measured as CO_2-concentration) is often hard to achieve in schools without a ventilation system as the graph below shows for a school with sole window ventilation.

Decreasing peaks mark the aeration phases.



Source: FGK-Fachkongress - Lüftung in Schulen - 27.03.2012, WTH Aachen University, EBC - Institute for Energy Efficient Buildings and Indoor Climate

An automatic ventilation system ensures constantly fresh air input during the whole teaching time in winter so that the CO_2-concentration usually does not exceed 1,500 ppm without opening windows. High heat recovery rates (up to 90 %) limit heat losses that would normally occur during window ventilation.



Source: proKlima Der enercity-Fonds, Hannover

What are the benefits of Passive Houses?

The efficient use of energy in buildings is crucial to effectively contribute to climate protection. With the "Energy Guideline", tightened in 2011, the city of Leipzig meets the legal requirements set forth in the German regulations Energy Saving Ordinance (EnEV) and Renewable Energies Heat Act (EEWärmeG). Essential objectives are the reduction of energy consumption of municipal buildings by 45 % until 2020 and the reduction of accompanying CO_2-emissions by 50 %. The Board Decision on Passive Houses released in 2008 specifies requirements of the Energy Guideline.

Specifics of the School Building

Both school buildings were erected in 1972 and 1976 as concrete slab constructions and refurbished in Passive House standard in 2009-2011.

Passive Houses ensure a high comfort without active heating and air conditioning. Passive heating is realized by consequent utilization of all internal energy gains in the building (sun radiation, heat radiation of occupants and electric devices). Heat losses are minimized by an efficient thermal insulation of the building envelope and a ventilation system with a high degree of heat recovery.

Further information is provided in the User Manual: www.leipzig.de/stadtentwicklung

Contact: carla.gross@leipzig.de, Dep. for Urban Development & Construction, Energy Management

Editorial deadline: 15.04.2013

Developed 2013 in EU-Project EnercitEE/EEMTE

INTERREG IVC

EnercitEE

LANDESAMT FÜR UMWELT, LANDWIRTSCHAFT UND GEOLOGIE

Freistaat SACHSEN

European Union
European Regional Development Fund

Stadt Leipzig

How to use a Passive House?

- Brief instruction -

Wilhelm-Ostwald-Gymnasium

EEMTE

Energy Efficiency in Municipality - Training and Exchange of experience

Department for Urban Development and Construction

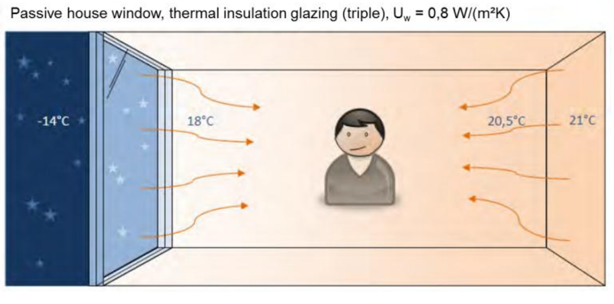
Why are building occupants important?

The concept of Passive Houses foresees a remarkable reduction of building´s energy consumption with concurrent increase of comfort both in winter and in summer. However, improvements are not automatically implemented as soon as the technical conditions are prepared for the operation mode. Beside monitoring and line-up of technical systems an advisory service for users is crucial to enable them to deal with technical and constructional specifics of the building in an optimal manner since the success of a Passive House depends remarkably on user´s behaviour. The better they know about it the better the success.

What are the advantages of a thick thermal insulation?

The exterior construction parts reveal very low heat transition coefficients and cause not only low heat losses but also higher indoor wall temperatures. Resulting low differences between temperatures of enclosing surfaces and the room itself lead to a pleasant temperature perception. Due to the airtightness of the building draughts are excluded.

The following picture shows the reduced radiance asymmetry:



Source: Stadt Frankfurt a. M., Hochbauamt - Energiemanagement, Passivhausschulen und Kindergärten, Kurzanleitung für die Nutzer

Instructions for the heating period

In winter switching on the heating system is restricted to achieving a minimum temperature already at the beginning of the utilization.

Window ventilation is unnecessary but not forbidden!

If needed a short but intensive aeration with wide open windows achieves a fast air exchange. Tilted windows are not allowed during the heating period.

Exterior doors should be closed whenever possible.

Solar heat gains should not be prevented (and shading avoided).

An internal instruction for room temperatures of Leipzig sets the maximum temperature for class rooms at 20 °C during the heating period.

Temperature restrictions are very important for all heated buildings, but in particular for Passive Houses! If exceeded the remaining heat demand increases significantly relative to the calculated demand.

Instructions for autumn and spring

Opening of windows while the ventilation system is out of action is possible but unnecessary when the ventilation is running.

Exchange of air filters is carried out by janitors or other instructed staff.

Window ventilation (as in summer) is possible if room temperatures are too high but should be avoided if outside temperatures increased as well.

High room temperatures should be avoided by timely shutting sun protection devices in all rooms (automatic mode). If daylight is needed, jalousies should remain at least half-closed.

Instructions for summer

Timely (e.g. in the morning) shutting of sun protection devices prevents over-heating.

Frequent opening of windows and exterior doors during hot days should be avoided

Short but intensive aeration with wide open windows during cooler times of the day (morning, evening) is effective against overheating as well.

Windows are opened for the purpose of fresh air provision if the ventilation system is switched off.

The ventilation system is switched on for active night-time cooling between 22 pm and 6 am when room temperatures exceed 24 °C and the difference to outside temperatures is high enough. Aiming at cooling down remarkably all rooms may be difficult to achieve when only little interior storage mass exists and temperature differences between indoor and outdoor are too low.

Measures to minimize overheating in summer should be considered already during the planning phase of the Passive House.

General instructions

Economical use of light and technical devices (also avoidance of no-load losses) helps to cut the total energy consumption in the building. Further, undesired heat gains during the non-heating period are reduced.

Openings for fresh and exhaust air of the ventilation system must not be shut. Light, presence and room temperature sensors must not be manipulated.

Items placed on window glass (e.g. pictures) are forbidden since they may cause heat accumulation and resulting enhanced tensions may cause breakage of the window pane.

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