POLYURETHANE

The high-performance insulating material

Architecture and Energy

Design and construction using polyurethane rigid foam in accordance with the Energy Saving Regulation

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Foreword

This brochure is a concise, simple, but technically accurate source of information for architects, designers, builders and clients who not only wish to find out about the basic content of the Energy Saving Regulation (Energieeinsparverordnung, EnEV), but are also looking for directions on how to implement it.

To fulfill the German government's pledge to reduce fossil fuel consumption and CO_2 emissions by 30 % in the medium term, the Energy Saving Regulation dictates that new buildings must comply with the low-energy house standard.

High-performance polyurethane rigid foam is a material that is perfectly suited to meet the stringent demands that the new legislation makes on the insulation of building shells. With its outstanding insulating properties, polyurethane rigid foam permits much thinner roofs, walls and floors than other insulating materials. With the same external dimensions, the usable volume of the building is dramatically increased, as illustrated by the following example:

The thickness of the floor insulation required in a 100 m^3 ground-floor apartment is reduced from 13 to 8 cm if polyurethane rigid foam WLG 025 is used instead of WLG 040 insulating materials. This provides an extra 5 m^3 of usable space which, at €300 per m^3, saves €1500 in building costs. A very high-quality floor structure is achieved at the same time.

The Energy Saving Regulation also applies to the refurbishment of old properties, taking into account the enormous potential for energy saving and emission reduction that can be achieved by improving energy efficiency in existing buildings. Insulating measures generally pay for themselves within a few years as a result of the lower energy consumption.

However, the higher the standard of thermal insulation desired for a building, the greater the effect of any constructional weaknesses. Therefore, when old and new buildings are refurbished to improve their energy efficiency, it is important to evaluate aspects such as the avoidance of thermal bridges, air-tightness and wind-tightness, and not just the insulation of individual components. A wide range of polyurethane rigid foam insulating products is available to solve these problems.

Further information, publications and construction drawings are published by the Industrial Association for Polyurethane Rigid Foam (Industrieverband Polyurethan Hartschaum e.V., IVPU). You can find an up-to-date list of publications and a free computer program about the Energy Saving Regulation at <u>*www.ivpu.de*</u>.

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ARCHITECTURE AND ENERGY SAVING

1 Energy saving and building design

1.1 The history: Thermal insulation – from health and building protection to energy saving

One of the most important purposes of a building is to protect the occupants from the climate – humidity, water, cold or heat. As the architect and artist Friedensreich Hundertwasser said a few years back, architecture is "our third skin"; that is, the third layer after skin and clothing. This layer has been improved and optimized throughout the history of constructional engineering.

Although they did provide direct protection from cold and damp, houses had considerable shortcomings as regards healthy living, well into the 20^{th} century. In particular, the combination of poor ventilation and cold internal walls due to the high heat transfer coefficient of the building materials caused many illnesses. Medical experts noted serious health problems in the occupants of apartment blocks, due to poor thermal insulation.

In addition to health problems, however, the numerous problems associated with condensation also led to considerable structural damage.

For that reason, DIN 4108 "Thermal insulation in high-rise buildings" was introduced in 1952. This standard was based on the building materials commonly used at the time, and prescribed the minimum thermal insulation for various external components.

The oil crises and the resulting energy shortages led to the Thermal Insulation Regulations of 1977 and 1984 (Wärmeschutzverordnung, WSVO); these were the first measures taken to conserve energy.

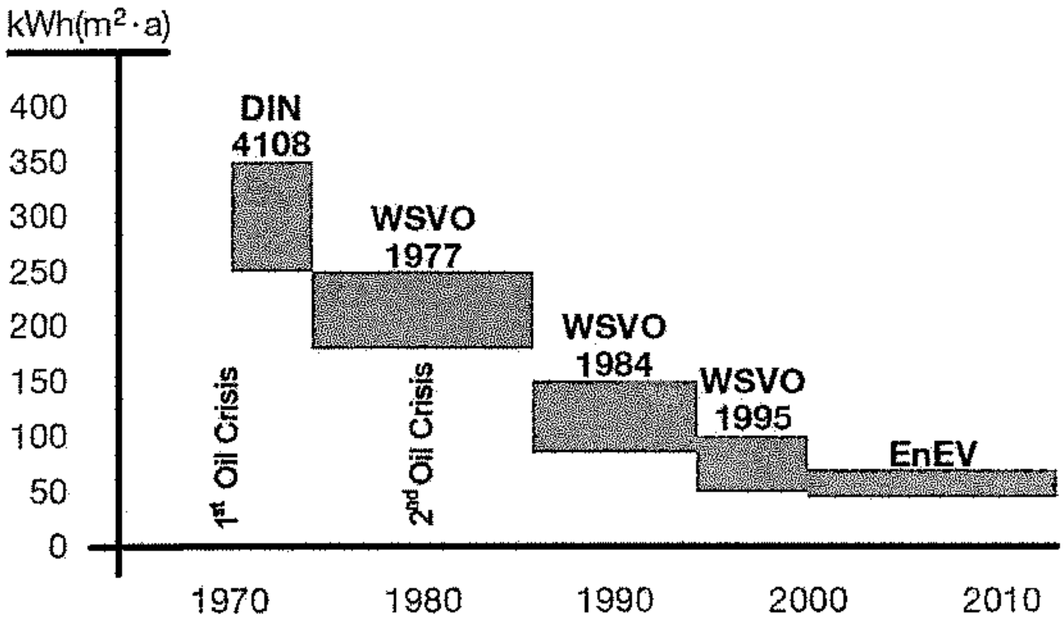

Fig. 1: Change in the maximum permissible heating requirements of buildings

Owing to the high energy prices, the huge amount of energy used for heating – approximately 200-300 liters of fuel oil per m^2 per year – was felt particularly keenly by the occupants of older buildings from the post-war period. It was imperative to reduce this energy requirement and save energy.

1.2 The politics – the construction industry as an instrument of energy and climate policy

The debate on energy consumption and the associated greenhouse gas emissions, which went on for many years after the oil crises, made one thing clear: room heating within the construction industry accounted for a large proportion of total energy consumption. In recent years, about one third of end-user energy has consistently been used for room heating.

End-user energy

End-user energy is the energy converted from primary energy into secondary energy as supplied to the consumer (cf. Fig. 11, page 24).

Based on the major consuming sectors, end-user energy consumption can be divided into roughly three parts: about 30 % of consumption is by private households, 26 % by industry and 30 % by transport. Business, commerce and services are only responsible for 16 % of end-user energy consumption.

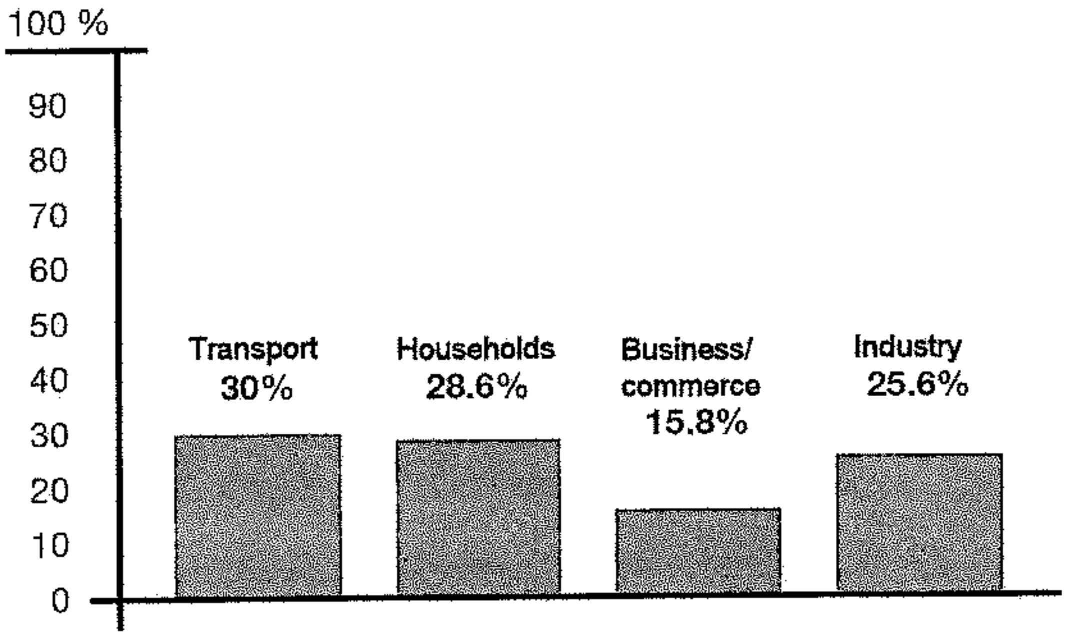

Fig. 2: End-user energy consumption by sector

Approx. 77 % of the end-user energy consumed by private households is for room heating, approx. 12.5 % for hot water, and the rest for lighting and domestic appliances. The strategy of taking measures to save energy in the construction industry – in particular in private households – is therefore appropriate and promising.

Energy consumption and energy supplies

The argument as to whether there are still sufficient energy supplies available has always been surrounded by controversy. However, there can be no doubt about the finite nature of fossil fuel supplies and the global increase in energy consumption. Just how long supplies will last is still a matter of dispute. The German Federal Institute for Geosciences and Natural Resources divides the supplies into reserves and resources.

Reserves of energy sources are clearly-identifiable supplies that can be extracted in a technically and economically viable manner under current conditions or under the conditions expected in the near future. These are therefore proven geological supplies.

Resources are supplies that go beyond reserves. They are proven or probable supplies that cannot currently be obtained for technical and/or economic reasons. Resources include deposits that are geologically feasible but have not as yet been proven. It is thus presumed that there are still enormous oil resources locked in oil sand and oil shale, but with current price structures exploiting them is not yet economical.

Source: Federal Ministry of Economics and Technology document No. 492, July 2000

In the meantime, virtually all experts agree that increasing energy efficiency, i.e. the saving and optimum usage of energy, is of vital importance in closing the gap between finite supplies and increasing demand. In Germany, considerable energy efficiency potential is seen in the construction industry in particular, since the majority of existing buildings were constructed before 1977, and thus before the first Thermal Insulation Regulation. Halving the consumption in existing buildings, predominantly by means of thermal insulation, would be technically simple and economically expedient, since thermal insulation measures pay for themselves through energy savings.

The Emission of greenhouse gases is closely linked to energy consumption. Discussion of this topic has intensified ever since the Rio de Janeiro Earth Summit in 1992, if not earlier. Again, the experts are in no doubt that the increase in the mean surface temperature of the earth is caused by the rapid increase in the combustion of fossil fuels, i.e. the resultant CO_2 emissions contribute to the greenhouse effect and thus to warming of the earth's atmosphere.

Sectors	Starting values		Predictions based on scenarios with further measures		
Year	1990	1995	2005	2010	2020
Industry	**199**	**142**	**119**	**112**	**97**
Small consumers	**97**	**68**	**62**	**57**	**46**
Households	**158**	**149**	**113**	**98**	**72**
Energy conversion	**145**	**166**	**180**	**167**	**139**
Total, excluding process emissions and international air traffic	**378** 977	**327** 852	**250** 724	**221** 655	**177** 531

Fig. 3: CO_2 emissions by sector
Heating the buildings used by private households and small consumers (businesses and public services) causes approx. 25 % of emissions.

As a consequence of the Rio summit, the German government resolved to reduce CO_2 emissions by 25 % based on 1990 levels. So far, emissions have been successfully reduced by 15.5 % between 1990 and 1999.

The measures are within the corridor of the national climate change target, but it will still take considerable work to reach the ultimate goal of a 25 % reduction. According to the German government's latest climate protection program, the construction industry will again play a major role, saving 13-20 million tonnes of CO_2 out of a total saving of 90-95 million tonnes [1][1]. The responsibility lies with building owners and architects in particular. Greater investment in optimum energy saving and in good architecture is needed.

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[1] See list of literature in appendix

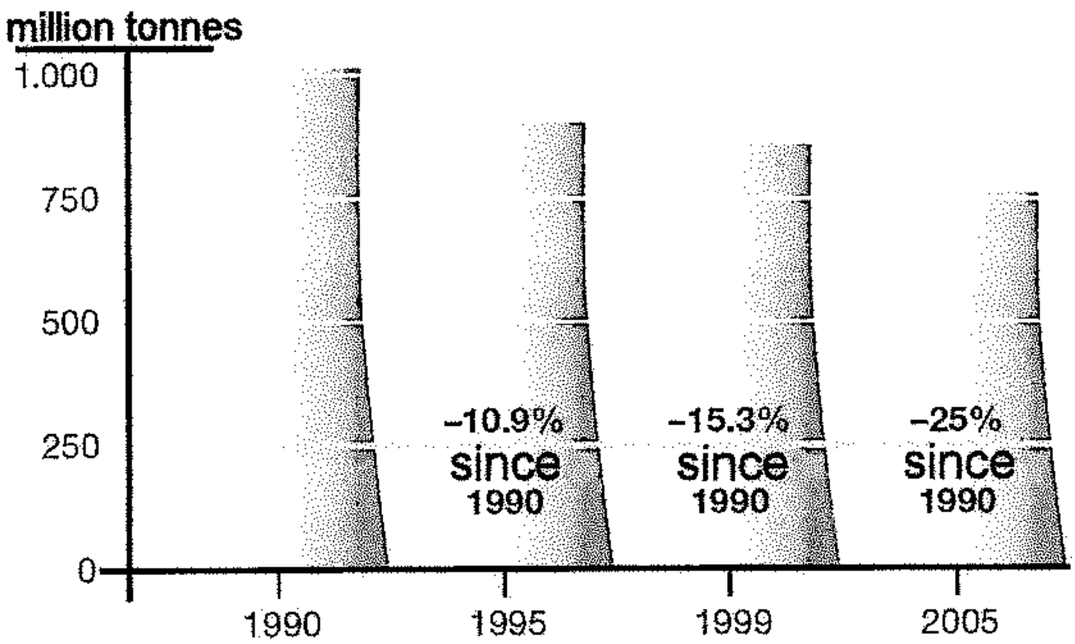

Fig. 4: CO_2 reduction target of -25 %
Energy-induced carbon dioxide emissions in Germany due to energy consumption and industrial processes that affect the climate.

1.3 The theory – the building as an energy system

Energy-saving architecture provides climate protection in two ways:

- protecting humans from the local climate, i.e. from damp, heat and cold.
- protecting the global climate by reducing CO_2 emissions.

Effective protection from the local climate primarily involves thermal insulation, i.e. preventing equalization of the internal and external temperatures. Effective protection of the global climate primarily involves reducing the heating requirement by means of effective thermal insulation, i.e. reducing the combustion of fossil energy carriers and thus decreasing CO_2 emissions.

A building may be considered as an energy system whose energy requirement can be determined in the manner of a balance. This is because a building only requires as much energy for providing heat as is lost in heat. To save energy, the heat losses through the building shell, i.e. through the roof, walls, floors, windows and doors and due to ventilation, must be reduced. These losses are basically compensated for by the heating, the energy required for this (heating requirement) being provided by external energy, but also by passive solar energy and internal sources of heat.

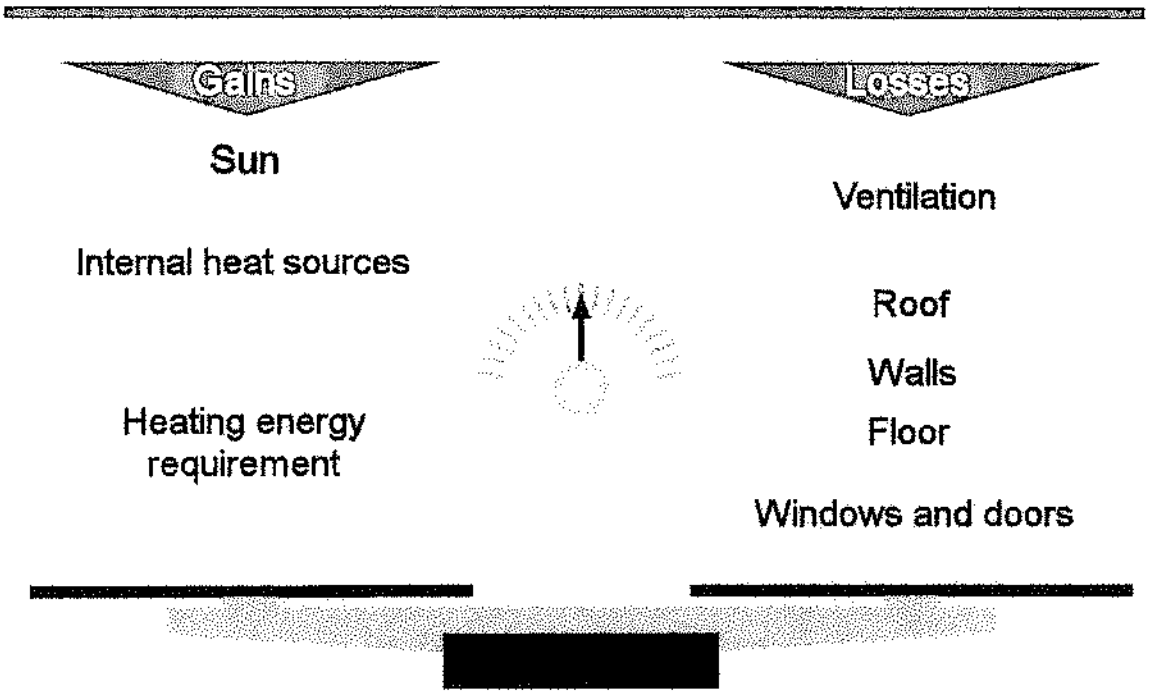

Fig. 5: Principle of balance between energy gains and energy losses in the Thermal Insulation Regulation 1995
The heat losses from the building shell are made up of heat that is lost through the roof, the external walls, the floor, the windows and doors and the foundations.

The heating requirement (expressed in kilowatt hours per square meter per year or $kWh/(m^2 \cdot a)$) is thus the amount of heat that must be supplied to the building to maintain the balance between the heat losses and the internal and external heat gains so as to produce a comfortable internal temperature. This concept of a balance was introduced with the Thermal Insulation Regulation 1995.

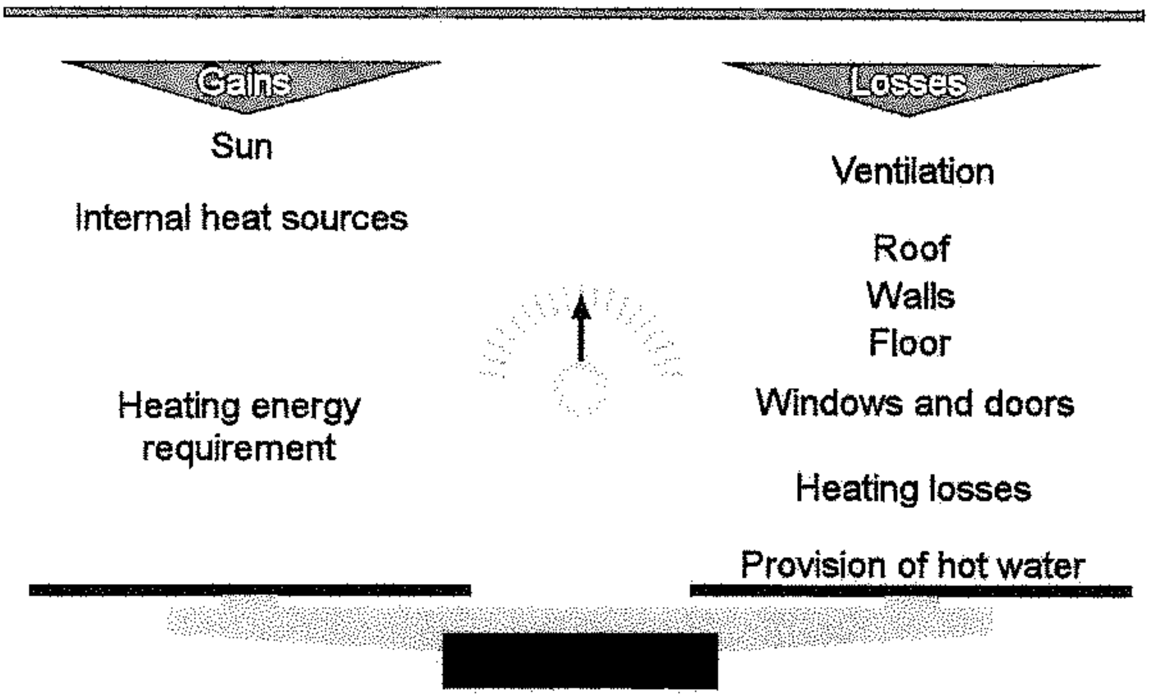

Fig. 6: Principle of balance between energy gains and energy losses in the Energy Saving Regulation The better the thermal insulation, the less energy required to cover the heating requirement. The simple concept of a balance based on the heating requirement can now be refined by also placing the losses from the heating system and the energy consumed in providing hot water on the loss side of the balance, and calling the resulting energy requirement the heating energy requirement. The Energy Saving Regulation is based on precisely this concept.

1.4 Energy efficiency – thermal insulation and insulating materials

Thermal insulation is highly effective in saving energy.

Energy efficiency thus involves:

- minimizing heat losses by insulating the building shell and decreasing the heat losses through ventilation
- improving the heating system
- using renewable energies (such as solar energy).

The heat transfer coefficient (U-value, formerly known as the k-value) determines the thermal quality of a component. The lower the U-value, the better the thermal insulation properties of the component. Insulating materials play a large part in minimizing heat losses through the building shell.

The insulating capacity of building materials, and in particular of insulating materials, is determined by their thermal conductivity λ. The same applies to thermal conductivity: the lower the λ-value, the better the insulating effect of the material.

The superior insulating capacity of polyurethane rigid foam is achieved by the use of blowing agents with a much lower thermal conductivity than air. Because of the exceptional closed-cell structure of the insulating material, the blowing agents remain in polyurethane rigid foam for a long time. In Germany, the hydrocarbon pentane and CO_2 are the principal blowing agents used nowadays.

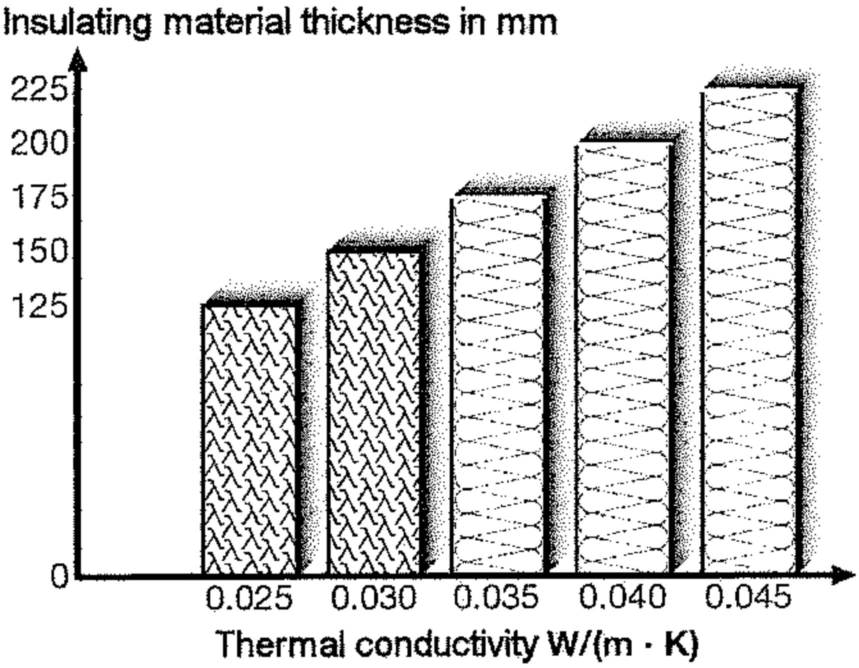

Fig. 7: Different insulating materials and their insulating effect

Required thickness of an insulating material to achieve the same insulating effect, or a U-value of 0.20 W/(m²·K). The high efficiency of polyurethane rigid foam insulating materials (WLG 025 and 030) is immediately apparent. Heat transfer resistance is ignored here.

Thermal conductivity group (WLG) 025 is achieved by using diffusion-tight metal facings; WLG 030 by using permeable facings.

Energy efficiency in architecture would be inconceivable without the use of insulating materials. Optimum energy efficiency can be achieved with high-performance insulating materials such as polyurethane rigid foam.