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Application of the EN directive for energy efficiency in buildings

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Application of the EU Directive for Energy Efficiency in Buildings

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***SUMMARY**:*

In order to promote energy-efficient buildings, declaration of energy efficiency and application of minimum requirements to energy performance of buildings, the European Parliament has adopted the directive on "Energy Performance of Buildings" (EPBD). The general framework for a methodology of calculation of the integrated energy performance of buildings defined in the directive includes the thermal characteristics of the building and its associated boundary conditions, the heating installation, hot water supply and ventilation as well as air conditioning installations and built-in lighting installations. In addition, the EU Member States are requested by the EPBD to set up minimum requirements on the energy performance of new buildings, based on the aforementioned methodology. Also for large existing buildings that are subject to major renovation, minimum requirements on their energy performance have to be established.

As a consequence for residential buildings, it becomes necessary to make up the balance on their heat use (transmission and ventilation losses, internal and solar gains), heat losses of the heating, and hot water preparation systems. This method has been used for calculations within the scope of the German energy conservation regulation ("Energieeinsparverordnung") for almost three years and has to be modified to cover not only new but also existing residential buildings. For non-residential buildings this energy balance has to be extended to include the amount of energy for ventilation, cooling, and lighting. The calculation method for the energy balance for non-residential buildings is formulated in the new German standard DIN 18599.

The paper describes the basics of the calculation procedure of the primary energy use for buildings and technical systems as well as the method of the German energy conservation regulation 2006. Furthermore examples of energy saving potentials of existing buildings in Germany are shown (Maas 2005).

1. Introduction

1.1 Requirements of the Directive on the Energy Performance of buildings

The European Parliament has drawn up the directive on "Energy Performance of Buildings" (EPBD) to harmonize requirements within the European Community and to frame them in a mandatory and holistic way.

The general framework for a methodology of calculation of the integrated energy performance of buildings, which is defined in the directive, includes the thermal characteristics of the building and its associated boundary conditions. This includes the heating installation, hot water supply and ventilation as well as air conditioning installations and built-in lighting installations, the last-mentioned (cooling and lighting) applying only for non-residential buildings, though.

The EU Member States are requested by the EPBD to set up minimum requirements on the energy performance of new buildings, based on the methodology under discussion. Also for large existing buildings that are subject to major renovation, minimum requirements on their energy performance have to be established.

Furthermore the Member States have to ensure that, when buildings are constructed, sold or rented out, an energy performance certificate (energy passport) is made available to the owner/buyer/tenant, depending on the case. In case of old buildings, recommendations for the cost-effective improvement of the energy performance are to be added to the certificate. In large public buildings the associated energy certificate, not older than 10 years, has to be placed in a prominent place clearly visible to the public to set a good example.

The EPBD was published in the Official Journal of the European Communities on January 4, 2003. Time for transposition of the directive into national standards is defined as 3 years.

1.2 EPBD-requirements already implemented in Germany

The German Energy Conservation Regulation “Energieeinsparverordnung” (EnEV, 2001), implemented in February 2002, refers to a calculation methodology for the energy performance of buildings which already covers most of the aspects mentioned in the general framework for a calculation procedure in the EPBD.

The main requirement value of the EnEV is the annual primary energy use of the building. This value comprises the amount of energy covering the heat use of the building (Q_h), i.e. transmission losses (H_T), ventilation losses (H_V), internal (Q_i) and solar (Q_s) gains, plus heat use for domestic hot water (Q_W), as well as the losses of the heating-, hot water preparation- and ventilation-system. Furthermore the primary energy use covers production, transformation and transport of the energy itself (Figure 1).

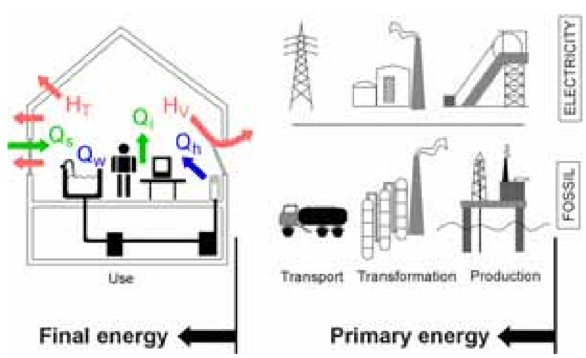

FIG. 1 : Primary energy use, the main requirement value of the EnEV, and its influencing variables (Maas, A. et al., 2002).

The calculated values have to under-run maximum requirement values defined in the EnEV, depending on building class (residential/non-residential) and shape (compactness).

What is not included in this approach to fulfil EPBD-conditions is the energy use for built-in lighting and air conditioning. Also the underlying boundary conditions, e.g. air change rates for natural ventilation, and the calculation algorithms for the building service system are suited for new buildings only.

The concept of an energy performance certificate stating primary energy use as main requirement value is already implemented in the EnEV as well but targets basically new buildings.

2. Regulations for residential buildings

2.1 New building sector

For new residential buildings with normal internal temperature the main value to verify is the annual primary energy use Q_P referring to the heated floor space A_N.

The fundamental calculation formula of the primary energy use can be stated as follows:

$$Q_P = (Q_h + Q_w)\, e_P \qquad (1)$$

Q_P = annual primary energy use; Q_h = heat requirement for heating; Q_w = domestic hot water heat requirement (fixed value); e_P = installation expenditure figure [-]

Maximum values for the annual primary energy use and the transmission heat losses are related to the ratio of the heat loss surface to the heated volume of the building, i.e. the A/V_e-ratio, which represents the compactness of the building shape. As for the combined system used for central heating and hot water supply in residential buildings, the calculation of the maximum primary energy use additionally takes the heated floor space, A_N, into account. The required value for residential buildings is shown in Figure 2 (Maas, A. et al., 2002).

For buildings with decreased internal temperature, the transmission heat losses referring to the heat loss surface A, i.e. H_T' are essential. This value also expresses the additional requirements for limiting the transmission heat losses for buildings with normal internal temperature. The H_T'-value of a building is similar, but not equal, to an average U-value of the building envelope.

For structural alteration of existing buildings, the requirements affect maximum U-values of the concerned building parts. Alternatively, the calculation of an energy balance similar to that of new buildings is possible.

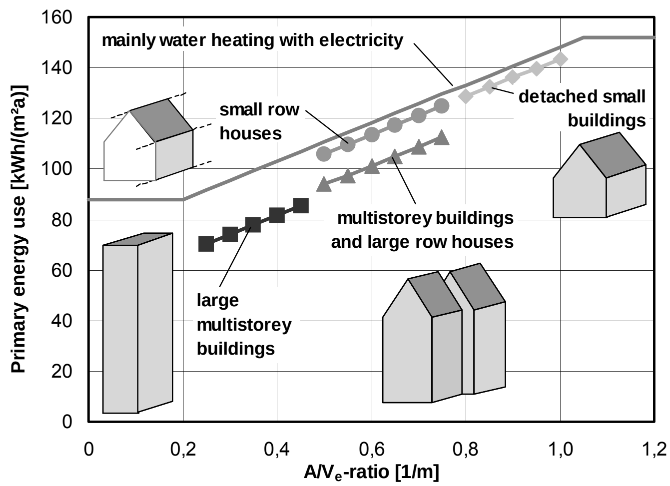

FIG 2. Requirement value Q_P (primary energy use) for residential buildings.

Additional requirements relate to:

- limitation of transmission losses to ensure the insulation quality of the building envelope,
- sufficient thermal comfort in summer,
- air tightness of the building envelope,
- minimum requirements for thermal insulation and thermal bridges,
- commissioning of boilers,
- distribution system of hot water supply

The described current regulations for new residential buildings will be taken into account for the energy conservation regulation 2006.

2.2 Existing buildings

2.2.1 Consideration of thermal bridges and air tightness for existing buildings

The heat requirement for heating (Q_h) is determined via a monthly balance calculation according to the European Standard (DIN EN 832, 1998) and the German Standard (DIN V 4108-6, Nov 2000), respectively, the latter comprising the same calculation procedure as DIN EN 832 but constitutes boundary conditions for an application in Germany.

Concerning the heat requirement for heating (Q_h) mainly two aspects had to be adapted to existing buildings: the handling of thermal bridges and air tightness of the building envelope, i.e. air change rates.

Thermal bridges are incorporated into transmission losses by enhancing the U-values of the building components to a certain degree:

$$H_T = \Sigma\, F_i U_i A_i + \Delta U_{WB}\, A \qquad (2)$$

H_T = transmission heat losses; F_i = temperature correction factor; U_i = thermal transmittance of the building component; A_i = area of the building component; ΔU_{WB} = correction factor for thermal brides; A = total heat loss surface.

Within the calculation procedure the thermal bridges are considered in one of the following ways, depending on the user's choice:

a) ΔU_{WB} = 0.15 W/(m²K); flat value to be used in case of building refurbishment by means of interior insulation.
b) ΔU_{WB} = 0.10 W/(m²K); flat value to be used in case of new or existing buildings except refurbishments described in a).
c) ΔU_{WB} = 0.05 W/(m²K); flat value to be used, if thermal bridges follow the design-examples described in the supplementary sheet nr. 2 of DIN 4108 (DIN 4108 Beiblatt 2, Jan 2004).
d) Detailed calculation by summation of the losses of every single thermal bridge within the building envelope (e.g. with the help of catalogues containing thermal transmittance values for different types of thermal bridges (Hauser G. et al, 1998), (Hauser G. and Stiegel H., 1996) or special software tools to calculate them.).

The last three options were already known in the calculation-procedure of the EnEV, whereas a) had to be newly implemented to account for the fact that not all existing residential buildings can be provided with exterior insulation to improve their energy performance. There is also a number of buildings for which interior insulation is the only solution, e.g. if they are under monumental protection. Links of components in buildings with interior insulation, such as exterior wall / ceiling or exterior wall / interior wall, generally bring about higher heat losses due to thermal bridges than externally insulated buildings, even if they are designed and constructed very carefully (Hauser G. and Stiegel H., 1996).

Both air tightness of the building and applied air change rates influence the ventilation losses of the building:

$$H_V = \rho_L \, c_{pL} \, n \, V \qquad (3)$$

H_V = ventilation losses; ρ_L = density of air; c_{pL} = specific heat capacity of air; n = air change rate; V = air volume of the heated zone.

Within the calculation procedure the effective air change rate n (including infiltration) due to natural ventilation can be considered

a) $n = 1.0\ h^{-1}$ for natural ventilation, unsealed windows
b) $n = 0.7\ h^{-1}$ for natural ventilation, sealed windows
c) $n = 0.6\ h^{-1}$ for natural ventilation, building with proven air tightness

Options b) and c) could again be adopted from the EnEV. Choice a) takes account of the fact that many old buildings are equipped with unsealed windows, roofs etc. which have a major effect on the infiltration rate.

2.2.2 Consideration of existing heating and ventilation systems

The installation expenditure figure (e_P) (see equation (1)) incorporates the energy use for heating, domestic hot water and ventilation in terms of the losses for the primary energy process, generation, storage, distribution, control and emission of heat and auxiliary energy (electricity for pumps etc.) as shown for the heating system in Figure 3 (Maas, A. et al, 2002).

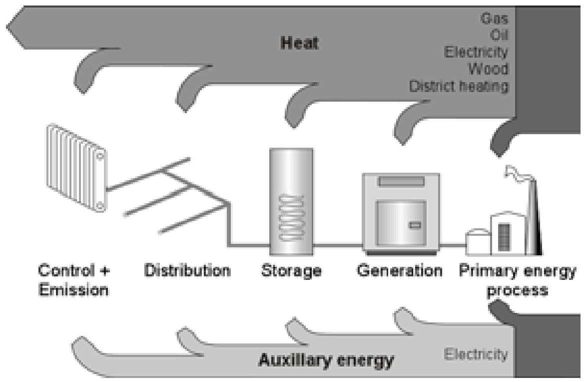

FIG. 3: Heat losses of the heating system included in the installation expenditure figure (e_P).

The specified fractions of e_P are calculated according to the German Standard (DIN V 4701-10, Feb 2001), which is also the calculation basis EnEV refers to in the case of new building installation components. For existing buildings and old installations, however, the boundary conditions and characteristic figures laid down in DIN 4701-10 are not suitable. Performance of technical equipment has noticeably improved within the last 30 years due to higher efficiencies and better insulation standards. Figure 4 and Figure 5 demonstrate this development considering boiler efficiency and heat-loss of a hot-water tank, respectively.

A standard (DIN V 4701-12, Feb 2004) (existing heat generators and hot-water tanks) together with a specification (PAS 1027, Feb 2004) (existing installations for control + emission, distribution and other components) provide appropriate calculation rules and characteristic figures for existing technical equipment in existing buildings.

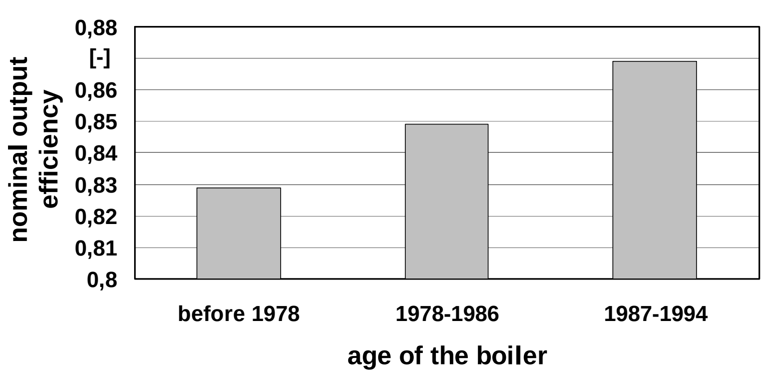

Figure 4: Nominal output efficiency of a forced-draught boiler (oil or gas) depending on its age.

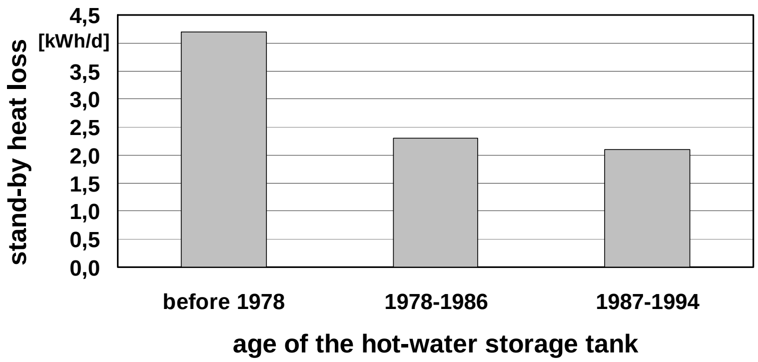

FIG 5: Stand-by heat loss of a domestic hot-water storage tank depending on its age.

3. New approaches for non-residential buildings

The maximum value for the annual primary energy use on a non-residential building has to be the one of a reference building with the same geometry and the same use. The partition (zoning) of the reference building and the building to be erected as well as the calculation procedure and the boundary conditions have to be in agreement.

The calculation of a conditioned part of the building (zone) has to be undertaken in cases of a certain use of the zone depending on the type of conditioning. E.g. heating has to be taken into account when the internal temperature is higher then 12 °C and the duration of use of the heating system is more than 3 months per year and 2 hours per day. The primary energy for lighting e.g. must be calculated when the illuminance is higher than 100 lx and the duration of use of lightning system is more than 3 months per year and 2 hours per day.

DIN V 18599 (not yet published) will provide the calculation procedure for heating, hot water preparation, ventilation, air conditioning, cooling and lighting as well as boundary conditions and conditions of use for different non residential types of buildings (for future energy saving regulations also residential buildings will refer to this standard).

A brief description shows the components of the building envelope and the technical equipment of the reference building (Maas, A 2005).

spec. transmission heat losses H_T' (Figure 6)

- buildings with internal temperatures > 19 °C and window/façade ratio < 30 %: $H_T' = 0.23 + 0.12/(A/V_e)$ W/(m²·K)
- buildings with internal temperatures > 19 °C and window/façade ratio > 30 %: $H_T' = 0.27 + 0.18/(A/V_e)$ W/(m²·K)

total solar energy transmittance and daylight transmission

- corresponding to a coated double pane glazing, a coated triple pane glazing or solar protection glazing, double (depending on the designated type of glazing)

specific heat capacity

- c = 50; 90; 130 Wh/(m²·K) for light; middle heavy; heavy construction respectively

air-tightness of building envelope

- natural ventilation n_{50} = 3,0 h^{-1}; mechanical ventilation n_{50} = 1,5 h^{-1};

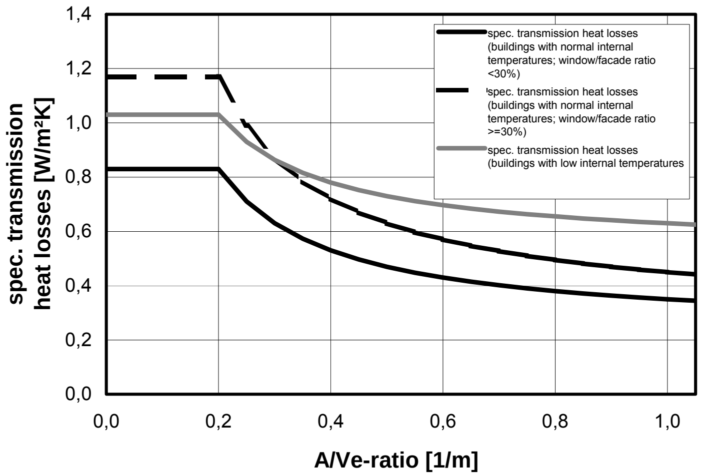

FIG. 6: Reference values of spec. transmission heat losses for different types and designs of non residential buildings.

heating system

- radiators with thermostat valves 2 K; maximum flow/return temperatures 70 °C/55 °C, horizontal distribution outside the thermal skin, vertical trains inside, regulated pump; low-temperature boiler outside the thermal skin

hot water preparation

- central system: indirectly heated tank outside the thermal skin; horizontal distribution outside the thermal skin, with circulation; low-temperature boiler
- local system: electric continuous-flow heater

lighting

- direct / indirect lighting system: low loss ballast; linear fluorescent lamp
- direct lighting system: low loss ballast; compact fluorescent lamp
- building control system: manual; daytime lightning control in the room: manual

ventilation / air conditioning system

- extract ventilation system: specific power consumption of fan P_{SFP} = 1,25 kW/(m³/s)
- supply/extract ventilation systems <u>without heating and cooling</u>: specific power consumption of supply-air fan P_{SFP} = 1,6 kW/(m³/s); specific power consumption of exhaust-air fan P_{SFP} = 1,25 kW/(m³/s); recovery temperature ratio η_t = 0,45
- supply/extract ventilation systems <u>with air conditioning</u>: specific power consumption of supply-air fan P_{SFP} = 2,0 kW/(m³/s); specific power consumption of exhaust-air fan P_{SFP} = 1,25 kW/(m³/s); recovery temperature ratio η_t=0,45; supply air temperature: 18 °C

room / space cooling

- cooling system: fan-coil 14/18 °C cold water temperature
- cold water circuit: specific power consumption for distribution $P_{d,spez}$ = 35 $W_{el}/kW_{Kälte}$

cooling refrigeration (up to 500 kW per system)

- refrigerator: inside thermal skin, piston and scroll compressor, R134a, air-cooled, cold water temperature 6/12 °C
- cold water circuit: overflow ratio 30%; specific power consumption for distribution $P_{d,spez}$ = 25 $W_{el}/kW_{Kälte}$

cooling refrigeration (more than 500 kW per system)

- refrigerator: inside thermal skin, screw compressor, R134a, water-cooled, cold water temperature 6/12 °C
- cold water circuit: overflow ratio 30%; specific power consumption for distribution $P_{d,spez}$ = 25 $W_{el}/kW_{Kälte}$
- recooling system: evaporation recooler, open circuit, without additional silencer, cooling water temperature 27/33 °C
- recooling circuit: overflow ratio 50%; specific power consumption for distribution $P_{d,spez}$ = 20 $W_{el}/kW_{Kälte}$

4. Energy Certificate

According to meet the requirements of the EPBD (see chapter 1.1) Member States of the EU shall ensure that, when buildings are

- constructed
- sold or
- rented out,

an energy performance certificate is made available to the owner or by the owner to the prospective buyer or tenant, as the case might be. The validity of the certificate shall not exceed 10 years.

Certification for apartments or units designed for separate use in blocks may be based:

- on a common certification of the whole building for blocks with a common heating system, or
- on the assessment of another representative apartment in the same block.

The energy performance certificate for buildings shall include reference values such as current legal standards and benchmarks in order to make it possible for consumers to compare and assess the energy performance of the building. The certificate shall be accompanied by recommendations for the cost-effective improvement of the energy performance. The objective of the certificates shall be limited to the provision of information and any effects of these certificates in terms of legal proceedings or otherwise shall be decided in accordance with national rules.

Member States shall take measures to ensure that for buildings with a total useful floor area over 1 000 m² occupied by public authorities and by institutions providing public services to a large number of persons and therefore frequently visited by these persons an energy certificate, not older than 10 years, is placed in a prominent place clearly visible to the public. The range of recommended and current indoor temperatures and, when appropriate, other relevant climatic factors may also be clearly displayed.

Examples of the certification of public buildings are the town hall of Kassel (Germany) and the headquarter of the EU-Commission in Brussels (Belgium) shown in Figure 7 and 8.

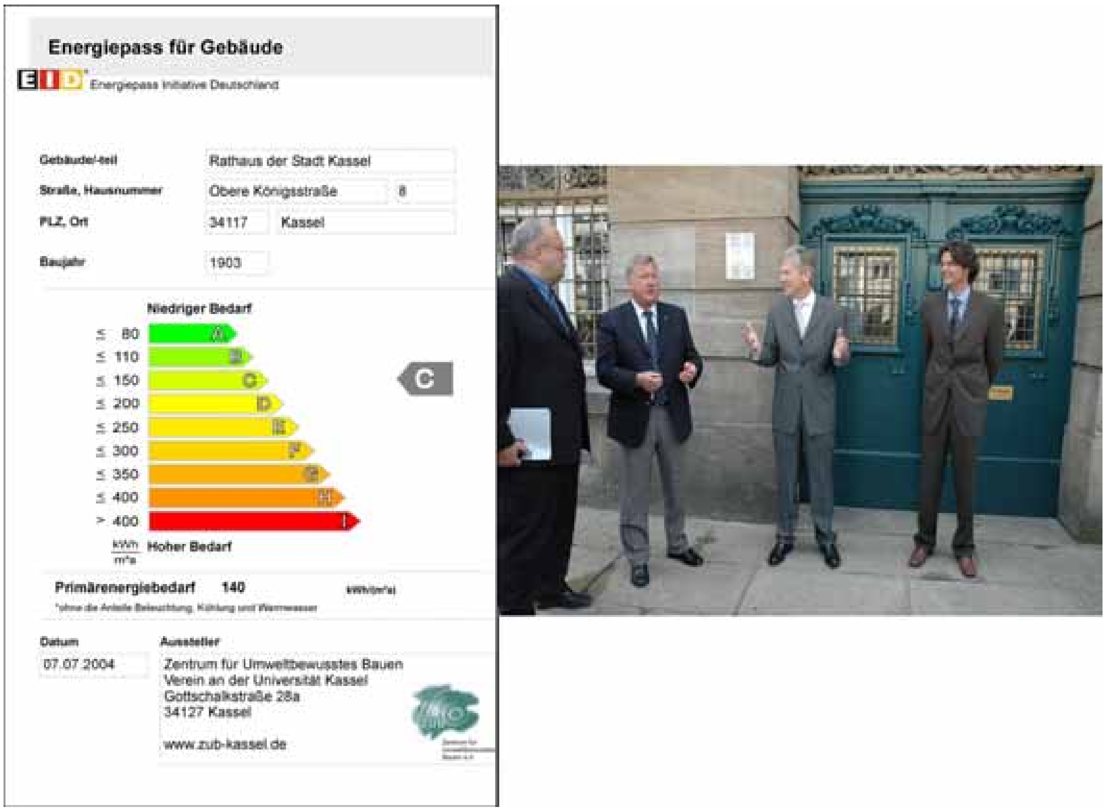

FIG. 7: Energy Certification of the town hall of Kassel (Bbl, 2004).

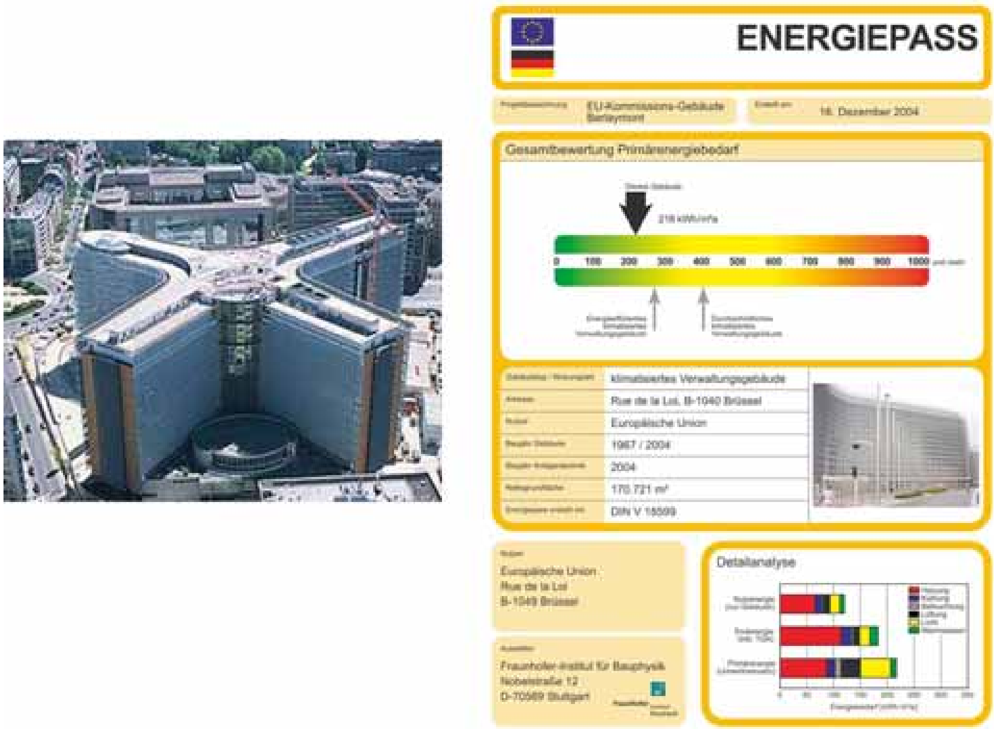

FIG. 8: Energy Certification of the EU-Commission headquarter "Berlaymont Building" in Brussels (Enper, 2005).

5. Energy saving potentials for existing buildings in Germany

Already in April 2000 the "Energiepass-Initiative Deutschland" - EID (initiative on energy passport in Germany) – a cooperation of 3 intersectoral contracting associations - was founded to enforce the implementation of unified energy certificates for new and existing buildings throughout Germany. This aim was put into practice for new buildings with the official implementation of the "Energieeinsparverordnung" (EnEV) in 2002. The importance to realize it for existing buildings as well was emphasised with the publishing of the EPBD in the beginning of 2003. At that time a group of experts assigned by EID had already developed appropriate calculation formulas and boundary conditions and was close to release a software tool to calculate the primary energy use for existing residential buildings called "EID-Bestandsenergiepass" (EID-Bestandsenergiepass, 2003).

To achieve fast results during an "On-site" energy consultation, e.g. to approximately quantify the influence of different types of building or installation refurbishment, the software is equipped with a typology database of typical existing German residential buildings assorted by age (starting before 1918) and size of the buildings (Figure 9). The implemented typology results from an empirical survey in 1995 on the energy saving potential in new and existing buildings in Germany (Born et al, 1995).

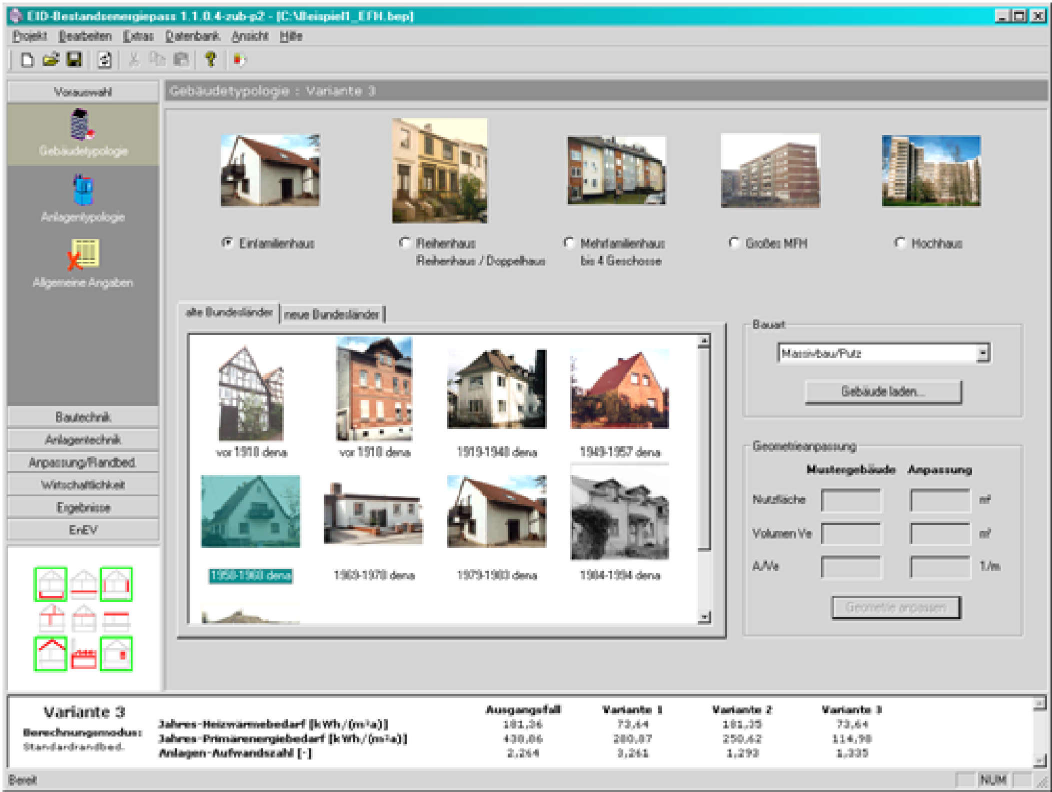

FIG. 9: Typology database of 47 typical German residential buildings as part of the software tool.

To give an impression of the magnitude of primary energy that can be saved by modernising old buildings and installation systems, four buildings of the building typology database are evaluated with EID-Bestandsenergiepass.

The four buildings pictured in Figure 11 - a detached two-family house, a one-family row-house, a small and a large multifamily residence - are typical representatives of their category in Germany (Born et al, 1995).

The calculation is at first carried out for the original "old" building and installation system and then for a variant with thermal improvement of the heat loss surface (i.e. exterior walls, windows, roof / upper ceiling, basement ceiling) and modern installation components (Figure 11).

The U-values of the original building components (U_{old}) are based on typical constructions of the particular type of building as described in (Born et al, 1995). The U-values of the corresponding renovated variant (U_{new}) result, if insulation material (λ = 0,04 W/(mK)) with a thickness of 8 to 12 cm is applied to the old component. The thickness is chosen so that the "new" constructions just fulfil EnEV-requirements on U-values in case of alteration of components in existing buildings, e.g. 0,35 W/(m²K) for insulating exterior walls.

The "old" installation systems chosen can actually be found in the accordant building type but must not necessarily come along with it. The example-buildings could as well be equipped with other types of installations and the chosen combination of building and installation system is just one out of many possible combinations.

The "new" installation systems also comply with EnEV requirements on installation retrofitting. Boilers which have been installed before 1978 have to be replaced by low-temperature-boilers at the least. Requirements on insulation of heating- and domestic hot-water pipes are also accounted for.

Figure 10 shows the calculation results in terms of primary energy use per m² floor space. If all the measures listed in figure 10 are accomplished, more than 60 % of the primary energy use can be saved for each of the examples.

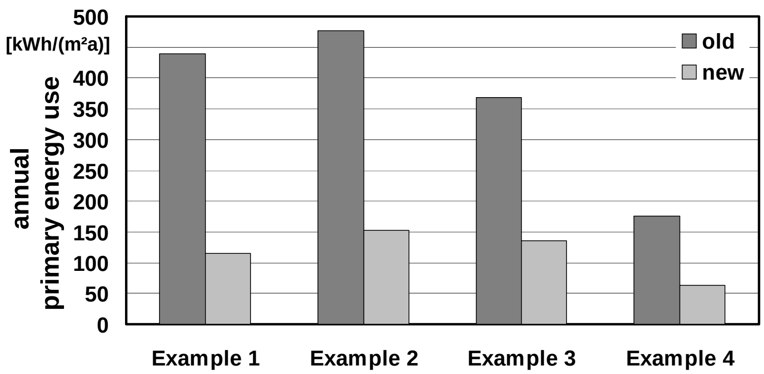

FIG. 10: Primary energy use per m² floor space before and after modernisation of buildings and installation systems.

Example 1:		
Detached two-familiy house		
Age group: 1958-1968		
Floor space: 299 m²		
Building components:	U_{old} [W/(m²K)]	U_{new} [W/(m²K)]
Exterior walls	1,44	0,31
Windows	2,9	1,5
Roof	0,92	0,27
Basement ceiling	0,97	0,33
Old installation system:	Standard oil-fired boiler (central), combined domestic hot water heating, indirectly heated tank, radiators.	
New installation system:	Low-temperature oil-fired boiler, solar installation for domestic hot water preparation, new tank, improved pipe insulation.	

Example 2:		
One-familiy row-house		
Age group: 1969-1978		
Floor space: 107 m²		
Building components:	U_{old} [W/(m²K)]	U_{new} [W/(m²K)]
Exterior walls	0,8	0,31
Windows	1,7	1,5
Upper ceiling	0,52	0,26
Basement ceiling	0,97	0,33
Old installation system:	Standard gas-fired boiler (central), combined domestic hot water heating, indirectly heated tank, radiators.	
New installation system:	Basically same system but replacement of old devices, i.e. low-temperature gas-fired boiler, new tank, improved pipe insulation.	

Example 3:		
Group of small multifamily residences		
Age group: 1958-1968		
Floor space: 3327 m²		
Building components:	U_{old} [W/(m²K)]	U_{new} [W/(m²K)]
Exterior walls	1,21	0,3
Windows	2,6	1,5
Upper ceiling	2,27	0,29
Basement ceiling	0,97	0,33
Old installation system:	Standard gas-fired boiler (central), radiators, electric through-flow heaters for domestic hot water preparation (roomwise).	
New installation system:	Basically same system but replacement of old devices, i.e. low-temperature gas-fired boiler, new electric heaters, improved pipe insulation.	

Example 4:		
Large multifamily residence		
Age group: 1969-1978		
Floor space: 3138 m²		
Building components:	U_{old} [W/(m²K)]	U_{new} [W/(m²K)]
Exterior walls	1,46	0,31
Windows	2,6	1,5
Upper ceiling	0,82	0,27
Basement ceiling	0,97	0,33
Old installation system:	District heating from co-generation (fossil fuels) for heating and domestic hot-water preparation.	
New installation system:	Basically same system, improvement of pipe insulation.	

FIG. 11: Examples for calculation of improvement of energy performance (Maas, A. and Kammer, A.., 2004).

6. Conclusions

The new German energy conservation regulation for 2006, fulfilling the requirements of the directive on “Energy Performance of Buildings”, is based on a methodology of calculation of the integrated energy performance of buildings. For new residential buildings the procedure of the German Energy Conservation Regulation “Energieeinsparverordnung” from 2002 will be kept for the next years. Some modifications to this approach (heat bridges, air tightness, old installation systems) are introduced to cover boundary conditions for existing residential buildings.

A new method to describe the requirements on energy conservation and also a new calculation method for non-residential buildings were found by means of the method employing a “reference building” and make up the energy balance based on the holistic approach of DIN V 18599.

With the software tool presented in this paper the primary energy use for new and existing residential buildings can be calculated. The results of the example-calculations carried out for typical German residential buildings demonstrate dimensions of how much energy and emissions can be saved if existing buildings and installation systems are modernised up to today's (German) standards.

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