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Appendix III
Requirements for project documentation for qualification as a Passive House Designer/Consultant

(see Section 3 of the Examination Regulations)

Project documentation can be submitted to an assessing body which has been accredited by the Passive House Institute (hereafter referred to as PHI). Project documentation may be compiled in the languages offered by the assessing body. A summary in English must be provided in addition to the project documentation (see Section 1 of the example documentation).

The assessing body reserves the right to make changes to the submitted project documentation or to demand additional information as proof of the suitability of the respective Passive House project as a basis for qualification of the applicant.

The entire project documentation in the form of a PDF file will be published on the Internet website *www.passivehouse-designer.org*. The PHI is entitled to use the documentation for its own publications on the Internet or in printed form, stating the name of the author.

1. Requirements for the documented building

The documented building must fulfil the following conditions:

- The building has been completed and is being used.
- The building is a Passive House building which has been certified by the PHI or by a PHI approved certification authority according to PHI criteria, or it is a certified EnerPHit retrofit or a certified PHI Low Energy Building.
- The building is listed in the Passive House database (*www.passivehouse-database.org*). The responsibility for entering the documented building in this database lies with the applicant.

2. Documents to be submitted

The following documents should be submitted:

- Application for the *Certified Passive House Designer/Consultant* qualification through project documentation (Appendix IIa). This application must be submitted in original with two signatures.
- A detailed description of the building in accordance with Appendix III as a PDF and Word document (alternatively as a RTF file).
- The PHPP calculation for the documented building, on which the certification is based, in digital form (unprotected Excel file).
- A copy of the building certificate, stating the certifying body.
- The project ID number under which the building is listed in the online Passive House database (www.passivehouse-database.org).
- If the applicant is not the same as the designer of the building, an informal written explanation by the designer should be submitted stating that the applicant was responsible for the parts of the planning that were relevant for the Passive House Standard (see Section 3 of the Examination Regulations).
- A copy of the educational qualifications if the applicant wishes to attain the *Certified Passive House Designer* title (see Section 7 of the Examination Regulations).

3. Requirements for project documentation

It is suggested that the structure of the example documentation in Section 4 of this Appendix should be used for the project documentation. The sequence and layout of the summary (Section 1) of this sample documentation should be adhered to. The sequence and layout can be changed from Section 2 onwards.

The documentation may not contain any advertisements and logos of companies or market participants. The names of products and their manufacturers may be mentioned in the documentation (once only). Except for the links to internet websites of the responsible project participants (see Section 1.3), the documentation may not contain any links to other internet websites.

The data given in the following checklist must be included in the project documentation; further data may be included if it is relevant for the Passive House.

Checklist for project documentation

1	Photographs of the front view of the building	
1.1	Building data	
1.2	Brief description of the construction task	
1.3	Responsible project participant, certification ID, Passive House Database ID, name and signature of the author of the project documentation	
2	Photographs of views from all accessible sides and example photograph of the inside	
3	Sectional drawing with description – dating from implementation planning	
4	Floor plans with description (in the case of large projects: typical floor plans are adequate)	
5.1	Description of the construction of the floor slab/basement ceiling including insulation (if necessary with connection points of exterior and interior walls)	
	... with at least one drawing or a photograph of executed work	
5.2	Description of the construction of the exterior walls including insulation) (if necessary with connection points with other walls)	
	... with at least one drawing or a photograph of executed work	
5.3	Description of the construction of the roof/top floor ceiling including insulation with connection points with exterior and interior walls	
	... with at least one drawing or a photograph of executed work	
5.4	Description of the window sections including installation drawing (recognisable scale) indicating the following:	
	- Window product (frame)/window type; frame U-value Uf	
	- Type of construction of the glazing (e.g. triple low-e glazing); glazing U-value Ug; g value	
	... with at least one drawing or a photograph of executed work	
6	Description of the airtight envelope (Information about the building components/layers which form the airtight layer near the roof, the exterior wall and the floor and how these are joined with one another)	
	Depiction of the pressure test result (if necessary stating the person/company who carried out the test)	
	... with at least one drawing or a photograph of executed work	

Table continued on next page...

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7.1	Description of the planning of the ventilation ductwork (by way of example) (fresh air intake near…; supply air in Rooms A,B and C; air transfer in Area Z; extract air from X and Y; is a geothermal heat exchanger present? …)	
	... with at least one drawing or a photograph of executed work	
7.2	Description of the planning for the central unit (of the ventilation system)/the ventilation device, indicating the following:	
	- ventilation system make	
	- effective heat recovery efficiency	
	- electrical efficiency (in Wh/m^3)	
	... with at least one drawing or a photograph of executed work	
8	Description of the heat supply system (by way of example)	
	... with at least one drawing or a photograph of executed work	
9	Brief documentation of important PHPP results (at least the information contained in the "Verification" worksheet) **Note**: The possibility of copying the relevant part of the "Verification" worksheet in the PHPP and inserting it at the corresponding place in the object/project documentation, is often made use of. If the author chooses this approach, then he/she is obliged to obtain the consent of the building owner for publication of information relating to the (personal) address (note: the object/project documentation will be published on the website www.passivehouse-designer.org under the heading "Model Passive House Project" under "Object/Project Documentation" immediately after completion of the certification or the renewal process). If the building owner wishes, information relating to his/her name and the street may be omitted (but the town/city must be stated!).	
10.1	Overall construction costs:..... €/m² living/useful area (Cost Category 300 to 400)	
10.2	Building costs	
11	*If available:* experiences (user assessment, actual consumption values)	
12	*If available:* reference to any existing studies/publications relating to this project	

4. Sample project documentation

Project Documentation
Gebäude-Dokumentation

Platzhalter für Siegel
"Zertifiziertes PH"
oder
"EnerPHit-Modern."
das Siegel erhalten Sie nach Antragstellung

1 Abstract / Zusammenfassung

Terraced housing with four units in Darmstadt Kranichstein, Germany

1.1 Data of building / Gebäudedaten

Year of construction/ Baujahr	1991	**Space heating / Heizwärmebedarf**	**14 kWh/(m²a)**
U-value external wall/ U-Wert Außenwand	0.138 W/(m²K)		
U-value basement ceiling/ U-Wert Kellerdecke	0.131 W/(m²K)	**Primary Energy Renewable (PER) / Erneuerbare Primärenergie (PER)**	30 kWh/(m²a)
U-value roof/ U-Wert Dach	0.108 W/(m²K)	**Generation of renewable energy / Erzeugung erneuerb. Energie**	135 kWh/(m²a)
U-value window/ U-Wert Fenster	0.78 W/(m²K)	**Non-renewable Primary Energy (PE) / Nicht erneuerbare Primärenergie (PE)**	54 kWh/(m²a)
Heat recovery/ Wärmerückgewinnung	80 %	Pressure test n_{50} / Drucktest n_{50}	0.2 h-1
Special features/ Besonderheiten	Solar collectors for hot water generation, heat recovery from wash water/grey water, rainwater utilisation		

1.2 Brief Description ...

Passive House Darmstadt Kranichstein

This terraced housing is the first Passive House building to be completed and used normally. The four terraced housing units each with a living area of 156m² and identical floor layouts was built in the development area K7 of the City of Darmstadt. The building is a precisely south facing solid construction with a full basement and large accommodation units, each of which extends over three storeys. These houses have been inhabited since 1991 by the same private clients who commissioned the architectural firm Bott/Ridder/Westermeyer with its planning in 1990 [Feist 1988].

50% of the additional construction costs for the project and its scientific evaluation were provided by the Hesse State Government. The objective of this research project was first and foremost to examine the extent to which energy consumption in residential buildings could be reduced through passive measures alone. After the evaluation of more than 16 years of monitoring, the building has met the expectations with regard to energy efficiency. Compared with average residential buildings in Germany, the measured heat consumption was reduced to approximately one-twentieth, and the total consumption of final energy for space heating, hot water and domestic electricity was reduced to roughly ten percent of the usual values.

1.2 Kurzbeschreibung der Bauaufgabe

Passivhaus Darmstadt Kranichstein

Dieses Reihenhaus ist das erste realisierte und normal bewohnte Passivhaus. Die vier Reihenhauseinheiten mit je 156 m² Wohnfläche und identischen Grundrissen wurden im Baugebiet K7 der Stadt Darmstadt als exakt südorientierter, voll unterkellerter Massivbau mit großen, über jeweils drei Geschosse gehenden Wohnungen realisiert. Die Häuser werden seit 1991 von den gleichen vier privaten Baufamilien bewohnt, die 1990 den Auftrag zur Planung an das Architekturbüro Bott/Ridder/Westermeyer erteilt haben. [Feist 1988]

Die baulichen Mehrkosten des Projektes und die wissenschaftliche Auswertung wurden zu 50% durch die hessische Landesregierung gefördert. Die Zielsetzung des Forschungsprojektes war es vor allem, zu überprüfen, wie weit der Energieverbrauch in Wohngebäuden durch ausschließlich passive Maßnahmen gesenkt werden kann. Nach der Auswertung von mehr als 16 Messjahren erfüllt das Haus die Erwartungen in Bezug auf die Energieeffizienz. Gegenüber dem Durchschnitt deutscher Wohngebäude ist der gemessene Heizenergieverbrauch auf ungefähr ein Zwanzigstel gesenkt, der gesamte Endenergieverbrauch für Heizung, Warmwasser und Haushaltsstrom auf ungefähr 10% der üblichen Werte.

1.3 Responsible project participants / Verantwortliche Projektbeteiligte

Architect/ Entwurfsverfasser	Prof. Dr. Bott, Ridder, Westermeyer http://www.uni-stuttgart.de/si/stb/
Implementation planning/ Ausführungsplanung	Prof. Dr. Bott, Ridder, Westermeyer http://www.uni-stuttgart.de/si/stb/
Building systems/ Haustechnik	Ingenieurbüro inPlan, Dipl.-Ing. Norbert Stärz http://www.inplan-pfungstadt.de/
Structural engineering/ Baustatik	
Building physics/ Bauphysik	Prof. Dr. Wolfgang Feist, Passive House Institute Darmstadt www.passiv.de
Passive House project planning/ Passivhaus-Projektierung	Prof. Dr. Wolfgang Feist, Passive House Institute Darmstadt www.passiv.de
Construction management/ Bauleitung	

Certifying body/ Zertifizierungsstelle	Passive House Institute Darmstadt www.passiv.de	
Certification ID/ Zertifizierungs ID	Project-ID (www.passivehouse-database.org) Projekt-ID (www.passivehouse-database .org)	0195

Author of project documentation / Verfasser der Gebäude-Dokumentation	Passive House Institute Darmstadt www.passiv.de
Date, Signature/ Datum, Unterschrift	

2 Views of the Passive House in Darmstadt Kranichstein

The south-facing side is shown in the cover page.

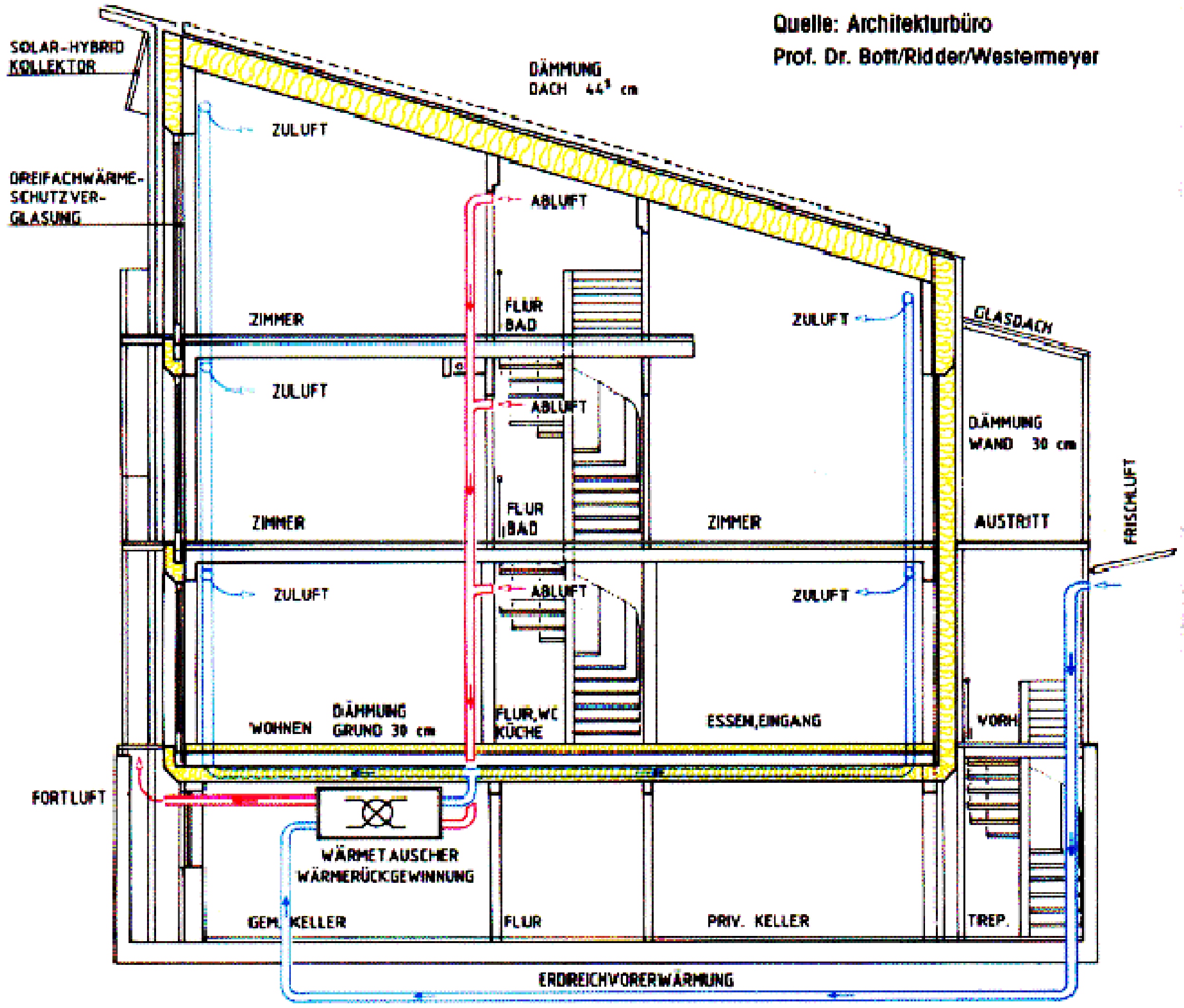
***West side* of the Passive House in Darmstadt Kranichstein with a small balcony and access ladder to the roof.** The weather station is clearly visible. (Photograph: Feist)

Picture of the Passive House in Darmstadt Kranichstein from the *northeast side*; the conservatory can be clearly seen, the air intake grilles of the four separate ventilation systems are visible at the ground floor ceiling level.

Passive House in Darmstadt Kranichstein, view from the *southeast*: In the gable wall facing the street, there is only a small east-facing window on the ground floor. The exhaust air outlet and the covered central entrance to the shared basement is clearly visible.

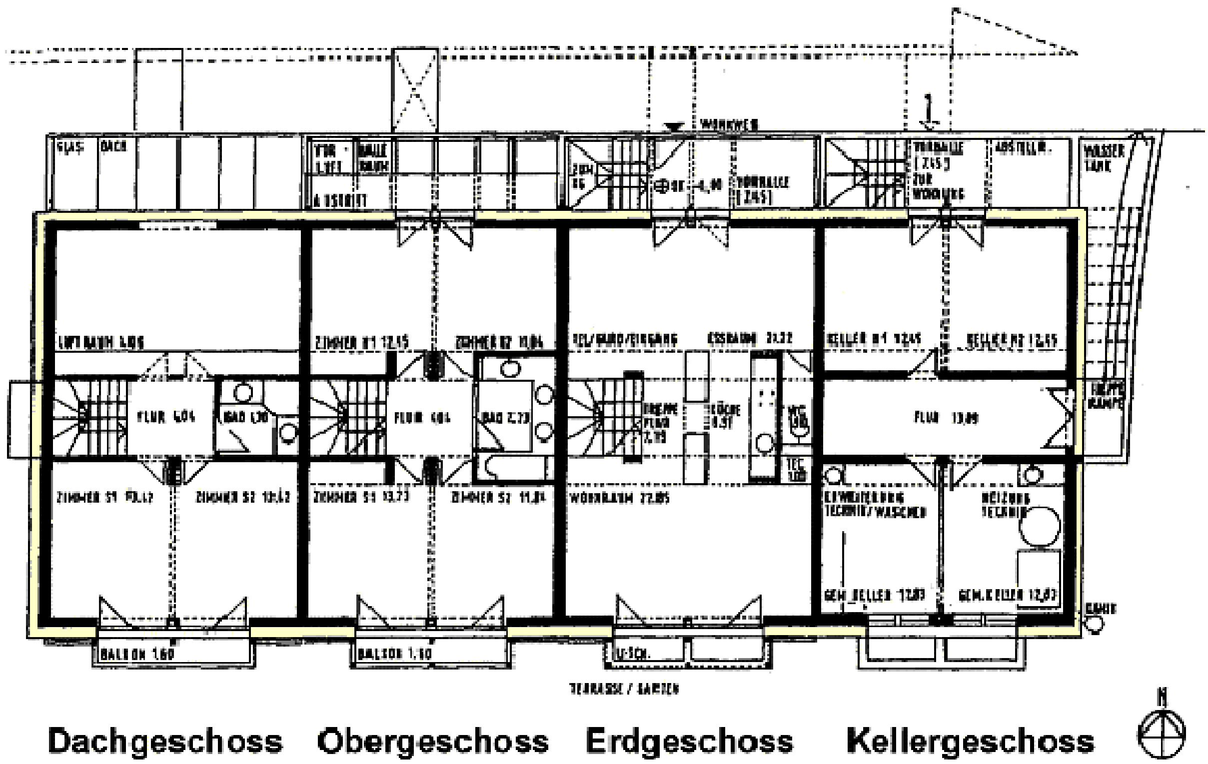
Interior view from the dining room towards the living room shows the open layout which seems to merge directly into the terrace through the amply-sized south-facing glazed area.

3 Sectional drawing of the Passive House in Darmstadt Kranichstein



Cross-section through the Passive House in Darmstadt Kranichstein. The thermal envelope with excellent uninterrupted insulation is clearly recognisable. Thermal separation of the basement floor and the separate access to the basement through the basement stairs in the north-facing glass porch can be clearly seen. The cross-section also shows the ductwork of the ventilation system: outside air is drawn in through a filter box in the glass porch and pre-heated inside the geothermal heat exchanger. After passing through the counter flow heat exchanger it is supplied to the living areas of the building on the northern and southern sides. Used air is extracted at the centre of the building from the bathrooms, WCs and kitchens and conducted towards the outside after heat recovery. The basement is thermally separated and cannot be heated; to the south of the central corridor which is accessed by a wide staircase from the west, there are rooms for shared use. The ground floor is a central installation zone (kitchen, WC and utility room), with the dining room on the north side and the living room on the south side. The central area on the upper floor is taken up by the staircase and the bathroom, with rooms on the north and south sides which can be optionally partitioned off (e.g. bedroom, child's room). On the top floor, only the southern part can be used; due to the pitched roof, an ample space opening towards the south results here, which may be partitioned if required.

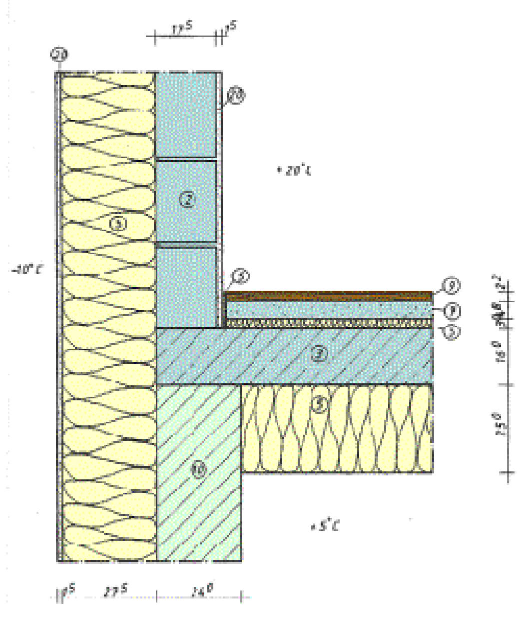
4 Floor plans of the Passive House in Darmstadt Kranichstein



Floor plans of the Passive House in Darmstadt Kranichstein. On the right is the basement floor which is sub-divided into a private part on the north side, which can also be accessed from each individual home via a steel staircase in the glass porch, and a common space with a central access area in the centre and common use rooms on the south side (utility room, laundry room, drying room, bicycle storeroom and joint workshop). The corridor has an additional shared access area over a ramp on the east side. The four separate ventilation systems are also located in the basement.

5 Construction details of the envelope and Passive House technology of the Passive House in Darmstadt Kranichstein

5.1 Construction including insulation of the floor slab or basement ceiling with connection points of exterior and interior walls

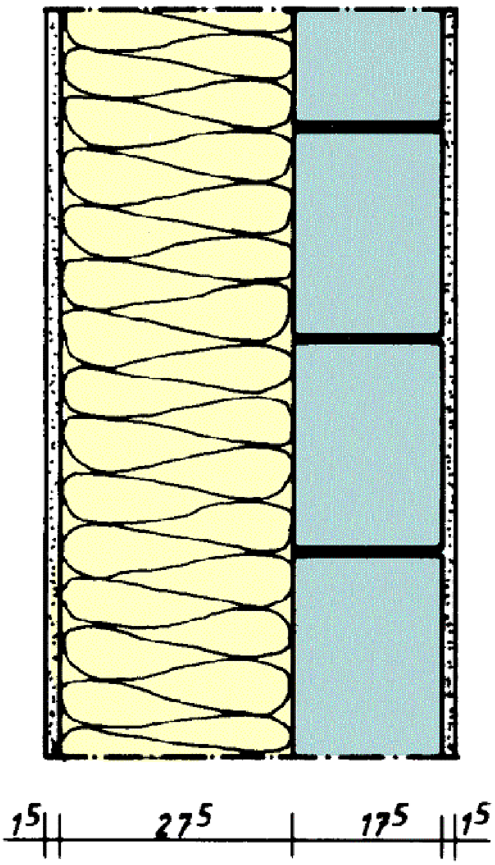



Avoidance of thermal bridges and basement ceiling build-up at the base point of the rising brick wall/ascending masonry. In order to keep the constructive thermal bridges small, the basement wall masonry ends in brick with excellent insulating properties (porous concrete brick, No. ⑩). The insulating brick layer is positioned so that gap-free connection of the basement ceiling insulation and the exterior wall insulation occurs. The interior walls of the basement also have a similar porous concrete brick layer. The photograph shows both top rows of bricks during the execution of the work.

Basement ceiling build-up:

Basement ceiling	Trowel-applied plaster on fibreglass mesh; 250 mm rigid polystyrene foam panels ⑤; 160 mm normal concrete; 40 mm impact sound insulation consisting of polystyrene; 50 mm cement screed; 8-15 mm strip parquet, bonded; solvent-free sealing coat.	U-value 0.13 W/(m²K)

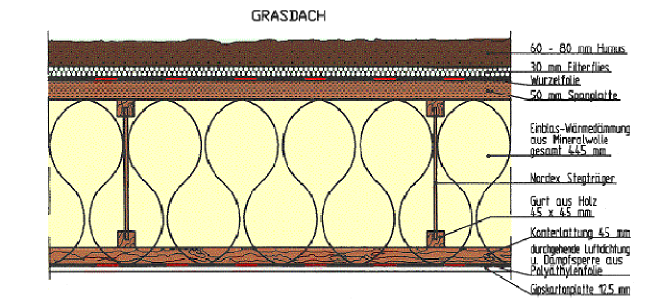
5.2 Construction including insulation of exterior walls

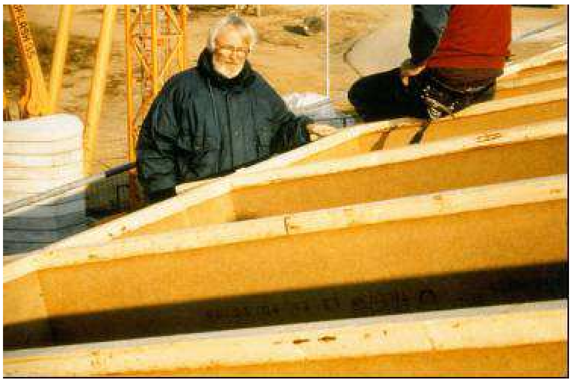


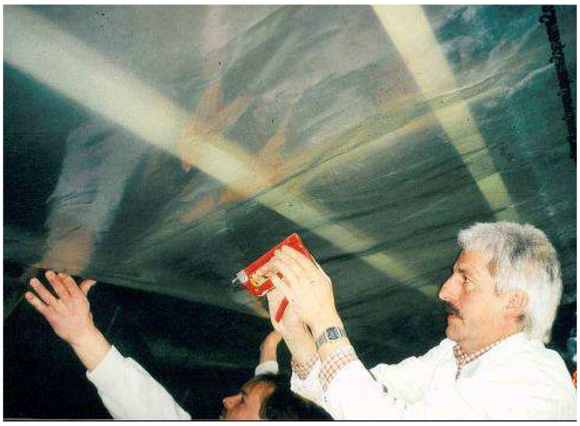
Exterior wall assembly. A lime-sandstone wall (17.5 cm thick as a rule) is applied with gypsum plaster on the inside. A double-layered exterior insulation and finish system with an insulation thickness of 275 mm and mineral plaster on the outside is applied on the outside. The k-value of this assembly is 0.138 W/(m²K). Top right: application of the insulation layer with 150 mm thick insulation panels of expanded polystyrene (EPS). The panels are applied directly to the masonry using cement-bonded adhesive; a bead of adhesive is applied all around the edge of each panel in order to prevent air flow behind the panels in the interconnected air spaces between the panels and the wall. Below right: application of the second layer of insulation panels with a thickness of 125 mm over the first layer. In 1991 there weren't any EIFS manufacturers that could supply insulation with this thickness.

Exterior wall	Mineral-based exterior plaster; 275 mm rigid polystyrene foam; 175 mm lime-sandstone masonry; 15 mm continuous interior gypsum plaster; woodchip wallpaper, dispersion paint coating	U-value 0.14 W/(m²K)

5.3 Construction including insulation of the roof



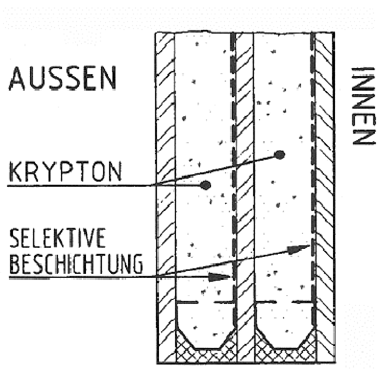


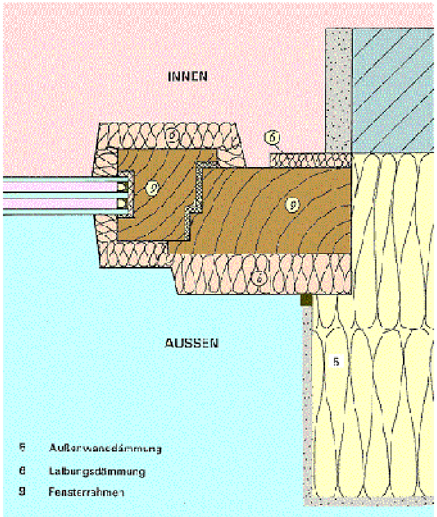


Roof build-up of the Passive House in Darmstadt Kranichstein. The use of green roofs was compulsory in this development area. Chipboard supported by I-beams bears the green roof build-up. The centre distance of the I-beams was relatively high with 1.08 m. Counter battens (45 mm), continuous airtight and vapour-tight sealing (polyethylene sheeting) and gypsum plasterboard were applied on the inside in that order. A roof U-value of less than 0.1 W/(m²K) results with an insulation thickness of 445 mm.

Roof	Green roof, filter fleece, root barrier, formaldehyde-free chipboard, wooden I-beam (web of hardboard), counter battens, **gap-free airtight sealing using polyethylene sheeting**, gypsum plasterboard, woodchip wallpaper, dispersion paint coating, entire hollow space (445 mm) filled in with **mineral wool**.	0.1 W/(m²K)

5.4 Window sections including installation drawing





Excellent glazing with three panes was used (left). One surface in each space between the panes reflects heat radiation; in the glazing available nowadays, the outer and the innermost panes have a low-e coating. The U_g value (in the centre of the glass) of this super-glazing is 0.7 W/(m²K). Glazing with $U_g \geq 0.49$ W/(m²K) or better are available today. The insulating shells of the frames made of CO2-foamed polyurethane were bonded to the inside of the window frames (centre illustration, photograph on the right) and screwed on inside. This measure resulted in frame U_f values of about 0.7 W/(m²K) and covering of the edge area of the glazing which exhibits a strong thermal bridge on account of the aluminium edge bond. In the building planning stage, these details were calculated using multi-dimensional heat flow software for the first time [Feist 1993].

The windows constitute passive solar "collectors" of the Passive House. However, in Germany, real solar heat gains can only be achieved with an extremely high quality of glazing: the U-values must be lower than 0.8 W/(m²K); this also ensures that the interior surface temperatures do not fall below ca. 17°C. This is important for a high level of thermal comfort inside the building without the need for compensating heating surfaces. For the first time in Germany, specially developed triple low-e glazing with a U_g value of 0.7 W/(m²K) in the centre of the pane was used in the Passive House in Darmstadt Kranichstein. When the sun shines during a cold winter, the interior surface of this window heats up to 35°C or more – a directly palpable feature of the Passive House principle for visitors.

Window data

Window	Triple low-e glazing filled with inert gas. Wooden window frames with insulated frame made of integrated polyurethane foam shells (CO2 foamed, CFC-free).	0.7 W/(m²K)

6 Description of the airtight envelope; documentation of the pressure test result

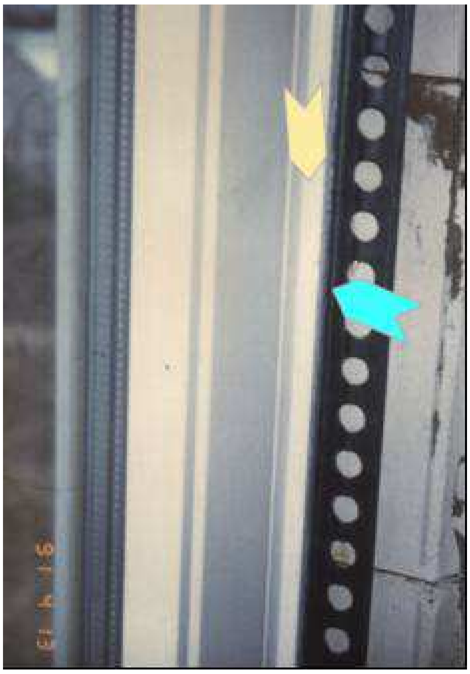
A very airtight building envelope is essential for a Passive House. Based on existing experience with airtight buildings, a target value of less than 0.6 h^{-1} for the 50 Pa pressure test air change rate was set in [Feist 1993]. The reason for this target value is given as follows:

- The low energy houses built in Germany to date have a pressure test air change rate between 1 and 4 h^{-1}, with a concentration around 3 h^{-1}. Very few buildings come close to 1 h^{-1}. In construction practice in Germany, there is very little experience with the construction of extremely airtight building envelopes.
- On the other hand, in Sweden pressure test air change rates of around 1 h^{-1} have regularly been achieved in new constructions for some years, usually with building envelopes consisting completely of timber frame constructions. Some pressure tests in Sweden even achieved values around 0.5 h^{-1}. This proves that such residual leakages are quite achievable based on the construction practice in Sweden.
- If e=0.04 is used for the infiltration formula, this results in an average annual infiltration rate of 0.024 h^{-1} for a target n_{50} value of 0.6 h^{-1}. This means infiltration heat losses of around 320 kWh/a for the entire building or 2 kWh/(m²a) in relation to the living area. This amount is already significant for a target energy demand of about 10 kWh/(m²a) for space heat.

The last point shows that in a Passive House, a substantially higher residual leakage rate may not have been tolerated without jeopardising the overall objectives. Then again, the first point shows that airtightness according to the objectives already implies very high demands in relation to common practice in Germany. The level of extremely good low energy houses had to be cleared and a much better level of airtightness had to be achieved.

Roof: Special lightweight construction I-beams were used for the roof which allow for extremely thick thermal insulation with a very small thermal bridge effect. Airtightness of this construction is achieved through continuous polyethylene sheeting lengths which were tacked under the counter battens. The planning foresaw that only a large piece of sheeting would be laid from gable wall to gable wall in each room of the top floor; due to this there was no need for adhesion between pieces of sheeting. (Incidentally, this kind of joining can be carried out using double-sided butyl adhesive tape in a permanently and reliably airtight manner; but time can be saved if this does not become necessary and the sheeting can be laid in one piece.)

In the roof (lightweight building component) the PE sheeting forms the airtight layer, while the continuous gypsum plaster forms the airtight layer of the solid wall. An absolutely airtight connection of these two layers was possible due to plastering: the sheeting was laid before applying the interior plaster; this has the further advantage that moisture cannot penetrate the lightweight construction during the plastering. The sheeting is allowed to extend 8 to 20 cm at the edges of solid building components and placed on the (unfinished) solid building component, on which an expanded metal plaster base is then fixed (using nails or staple fasteners). The fasteners may also pass through the sheeting, but there should be a distance of at least 5 cm from the edge of the building component. As a last step, the sheeting can now be completely plastered over with the standard application of the interior plaster. The connection thus created is easy to implement and absolutely airtight.



Exterior wall: For airtightness of exterior walls and partition walls of the Passive House building, gypsum interior plaster was applied all over the surface. It was specially ensured that all masonry areas were fully plastered, particularly the areas which are not visible at all after completion of the interior space. The plaster thus extends from the upper edge of the unfinished floor to the lower edge of the unfinished ceiling.

Windows: The window scantlings of wood are airtight. The glazing is sealed into this with silicone sealant all around. The plaster ends at the window about 10 mm from the frame with a plaster strip (blue arrow). The space between the strip and the window was filled to be airtight using acrylic (yellow arrow).

Basement ceiling: The in-situ concrete ceiling in itself is airtight. Any penetrations are filled in using liquid anhydrite which expands when it dries and thus seals even the small cracks.

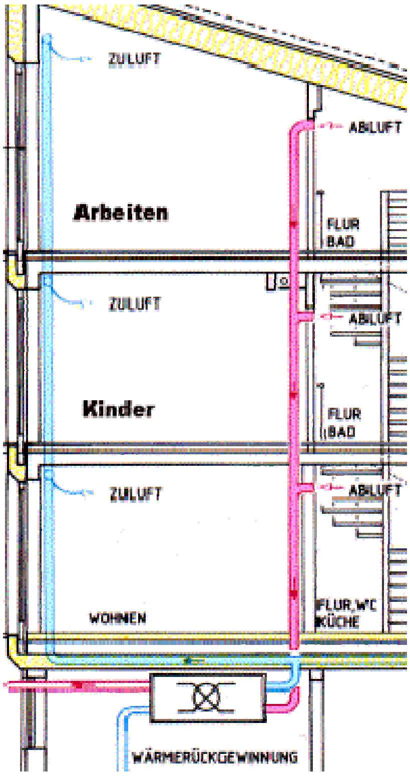
The first pressure test was carried out after completion of the airtight envelope on 24.5.1991 by the engineering consultants ebök.

Results of pressure test on 24/25.5.1991
in the Passive House in Darmstadt Kranichstein

Measurement	50 Pa pressure test air change rate n_{50} h^{-1}
House 1 normal	0.403
House 2 normal	0.276
House 3 normal	0.258
House 4 normal	0.240
House 1, front door sealed	0.253
House 3, one window on ground floor tilted open	12.886

7 Planning of ventilation ductwork (example)

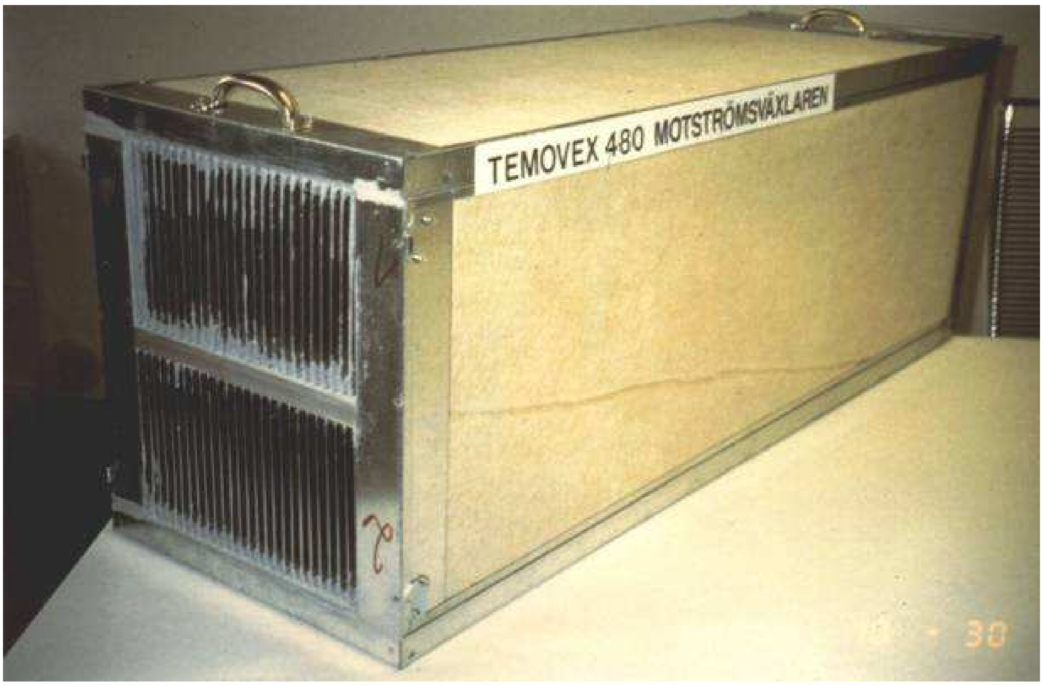
In order to greatly reduce the ventilation losses, a balanced supply air/extract system with a highly efficient counterflow air-to-air heat exchanger was used. A heat recovery rate of over 80 % was measured with operation of this device.



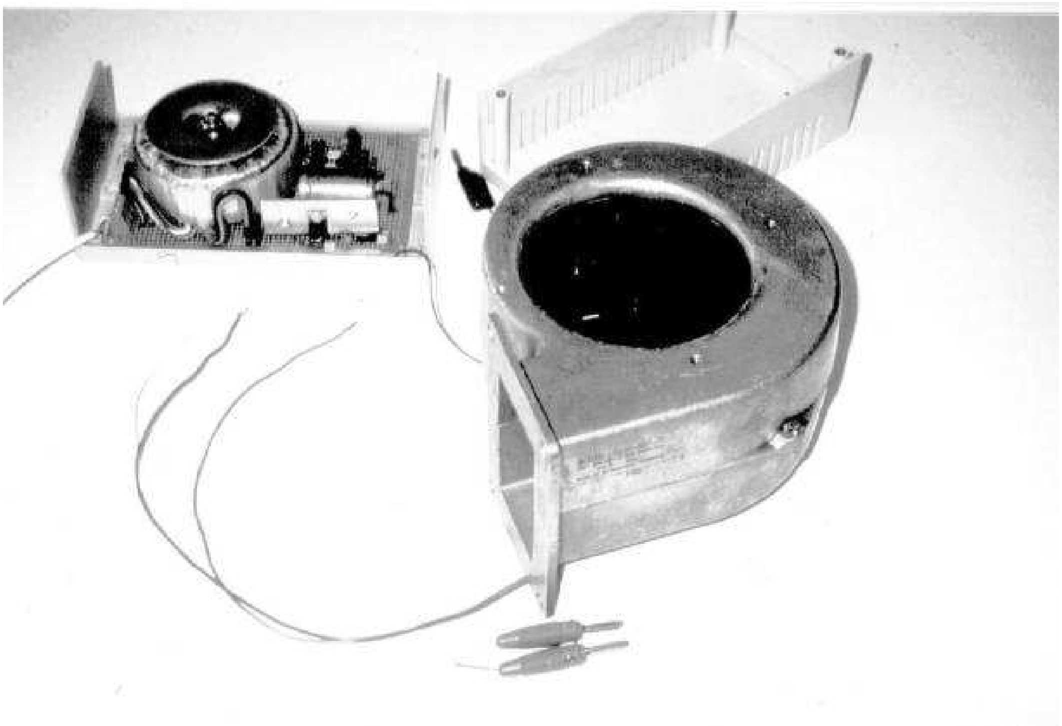
Supply air rooms include all main living areas (on the left in blue: supply air duct): study, children's room, bedroom, dining room and living room.

Extract air rooms include bathrooms, WCs and the kitchen.

Air transfer takes place through air transfer grilles in the internal doors in the corridor and the stairwell. From here, air travels through air transfer openings above the doors into the rooms with high humidity levels. From here, used air is returned to the heat exchanger via the extract air ductwork (shown in red on the left).



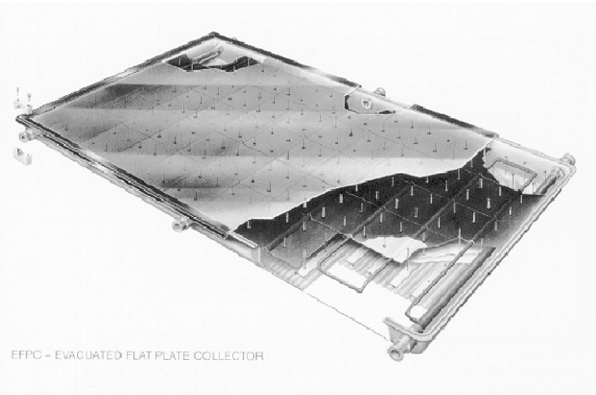
The counterflow air-to-air heat exchanger used for heat recovery. The picture shows a view of the plate pack from the extract air/supply air side. The fan housing with both fans is situated here.



Used for the first time in home ventilation systems in Darmstadt-Kranichstein: **the electronically commutated fan with high energy efficiency.** A matching control and regulation unit was developed (DC supply unit shown above in picture).

8 Heat supply

The solar coverage of the thermal flat plate collectors in the Passive House in Darmstadt Kranichstein is 66%. Because provision of hot water constitutes the biggest energy requirement of this building, an efficient domestic water system was of great importance here.




The thermal flat plate collector was mounted at an angle on the roof of the Passive House building. Flat plate collectors evacuated to about 50 mbar were used (convection in the gas filling (argon) is practically eliminated at this underpressure; only the heat loss due to heat conduction in the gas filling remains).

The rest of the hot water generation and space heating takes place through a central gas condensing boiler for all four housing units all together. This supplies a 1 m³ potable hot water tank which is also fed by the solar heating system. The condensing boiler is equipped with time control (winter operation at the beginning of December till the middle of March; during the rest of the year only post heating of hot water if this is necessary).

9 PHPP calculations

The Passive House Planning Package (PHPP) did not exist at the time of construction of the Passive House in Darmstadt Kranichstein. All analyses and calculations were carried out with a detailed dynamic simulation software program (DYNBIL). Only later on did it become evident from evaluating the measured results that calculation using specially adapted balance programs was still possible for buildings of this quality class – which led to development of the PHPP [AkkP 13].

Upon entering the data of the end-of-terrace Passive House in Darmstadt Kranichstein, the PHPP results (for the climate Frankfurt am Main) as documented below are obtained.

Passivhaus-Nachweis

Objekt:	Passivhaus-Endhaus Kranichstein			
Straße:				
PLZ/Ort:	64289	Darmstadt		
Provinz/Land:	Hessen	DE-Deutschland		
Objekt-Typ:	Reihenhaus			
Klimadatensatz:	DE-9999-PHPP-Standard			
Klimazone:	3: Kühl-gemäßigt		Standorthöhe:	-
Bauherrschaft:	Bauherrengemeinschaft Passivhaus			
Straße:				
PLZ/Ort:	64289	Darmstadt		
Provinz/Land:	Hessen	DE-Deutschland		

Architektur:	Prof. Bott/Ridder/Westermeyer		**Haustechnik:**	öeb Dipl.-Ing. Norbert Stärz		
Straße:	Jahnstr. 8		Straße:	Bahnhofstr. 49		
PLZ/Ort:	64285	Darmstadt	PLZ/Ort:	64319	Pfungstadt	
Provinz/Land:	Hessen	DE-Deutschland	Provinz/Land:	Hessen	DE-Deutschland	
Energieberatung:			**Zertfizierung:**	Passivhaus Institut		
Straße:			Straße:	Rheinstr. 44/46		
PLZ/Ort:			PLZ/Ort:	64289	Darmstadt	
Provinz/Land:			Provinz/Land:		DE-Deutschland	

Baujahr:	1991	Innentemperatur Winter [°C]:	20.0	Innentemp. Sommer [°C]:	25.0
Zahl WE:	1	Interne Wärmequellen (IWQ) Heizfall [W/m²]:	2.4	IWQ Kühlfall [W/m²]:	2.4
Personenzahl:	2.9	spez. Kapazität [Wh/K pro m² EBF]:	204	Mechanische Kühlung:	

Gebäudekennwerte mit Bezug auf Energiebezugsfläche und Jahr

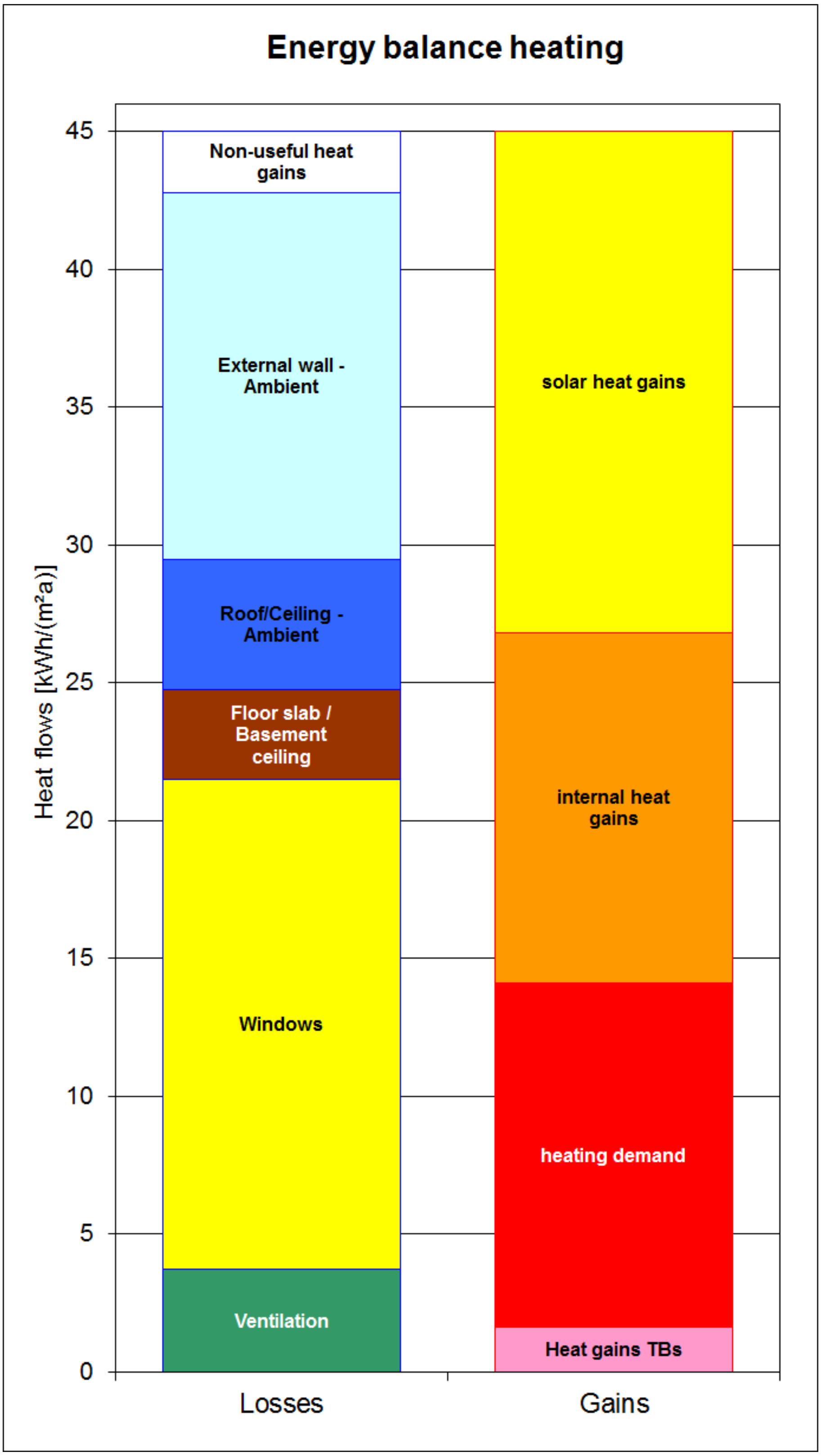
				Kriterien	alternative Kriterien	Erfüllt?[2]
	Energiebezugsfläche m²	156.0				
Heizen	Heizwärmebedarf kWh/(m²a)	13	≤	15	-	ja
	Heizlast W/m²	10	≤	-	10	
Kühlen	Kühl- + Entfeuchtungsbedarf kWh/(m²a)	-	≤	-	-	-
	Kühllast W/m²	-	≤	-	-	
	Übertemperaturhäufigkeit (> 25 °C) %	1	≤	10		ja
	Häufigkeit überhöhter Feuchte (> 12 g/kg) %	0	≤	20		ja
Luftdichtheit	Drucktest-Luftwechsel n_{50} 1/h	0.2	≤	0.6		ja
Nicht erneuerbare Primärenergie (PE)	PE-Bedarf kWh/(m²a)	54	≤	-		-
Erneuerbare Primärenergie (PER)	PER-Bedarf kWh/(m²a)	30	≤	60	60	ja
	Erzeugung erneuerb. Energie (Bezug auf überbaute Fläche) kWh/(m²a)	135	≥	-	-	

[2] leeres Feld: Daten fehlen; '-': keine Anforderung

Ich bestätige, dass die hier angegebenen Werte nach dem Verfahren PHPP auf Basis der Kennwerte des Gebäudes ermittelt wurden. Die Berechnungen mit dem PHPP liegen diesem Nachweis bei.

Passivhaus Classic? ja

PHPP document for the end-of-terrace Passive House in Darmstadt Kranichstein. The designers involved are also mentioned here. With otherwise identical data, a heating demand of 8.2 kWh/(m²a) results for the mid-terrace house (without a gable wall). q_H = 9.4 kWh/(m²a) results for the whole terraced housing row.



The heating demand balance of the end-of-terrace Passive House in Darmstadt Kranichstein, calculated using the PHPP.

The windows account for almost half of the heat losses, and the exterior walls account for a quarter of these.

Almost half of the losses are compensated again by the solar gains through the windows (right).

Internal heat gains account for about a fourth, while the heating only accounts for the remaining fourth of just over 10 kWh/(m²a).

10 Construction costs

The Passive House in Darmstadt Kranichstein was built during the construction boom following the German reunification in 1991. Interest rates were very high at the time and the construction cost index was unusually high.

Comprehensive cost documentation exists for the construction of this building [Militzer/Feist 1999]. According to this, the costs for construction alone (Cost Category 300 to 400) were 1825 Euros/m².

This is a relatively high value – particularly the full basement, the large north-facing glass porch and the south-facing balcony installations must be taken into account in order to put these costs into context. According to the above-mentioned study, for the Passive House in Darmstadt Kranichstein the additional costs for energy efficiency amounted to 292 Euros/m², or about 16% of the construction costs. These high extra costs were mainly due to the innovative building components, the majority of which had to be manufactured individually. In the last 15 years this extra investment could be reduced to less than 8 % of the usual construction costs as a result of further development of the methods and products, larger quantities and simplifications for terraced housing. 50% of the additional investment were provided by the Hesse State Government. The building owners thus financed 146 Euros/m².

11 Measured results of the inhabited Passive House in Darmstadt Kranichstein

1.1 Measurement data acquisition

The engineering firm ebök (offering energy consultancy and ecological concepts) carried out comprehensive **measurement data acquisition continually** in the Passive House building. Over 200 measured parameters were constantly recorded including:

- Climate (external air temperature and humidity, wind velocity and direction, solar radiation)
- Indoor air temperatures (in all houses, all rooms)
- Indoor air humidity levels (House IV, all rooms)
- Temperatures of radiators (House IV, all rooms)
- Temperature of wall cross-section, heat flow measurement of wall
- Temperature of roof cross-section, heat flow measurement of roof

- Surface temperatures of windows
- Status of insulated sliding shutters
- Air volume flows of the ventilation system (as well as temperature and humidity)
- Volume flows for cold water, rainwater and hot water, and temperatures
- Heat meter for heating, hot water, circulation and solar collectors

Beyond these, the following were ascertained in short-term measurement activities:

- With thermographic imaging: any inhomogeneities of the thermal insulation
- With pressure tests: airtightness of the envelope
- With tracer gas measurements: air changes, efficiency of the ventilation system

After evaluation of sixteen measurement years (measured data from October 1991 to September 2007, see table), the building meets expectations with reference to energy efficiency [AkkP 5] [Feist/Werner 1994]. Compared to average residential buildings in Germany, the measured heat consumption was reduced to approximately **one twentieth**.

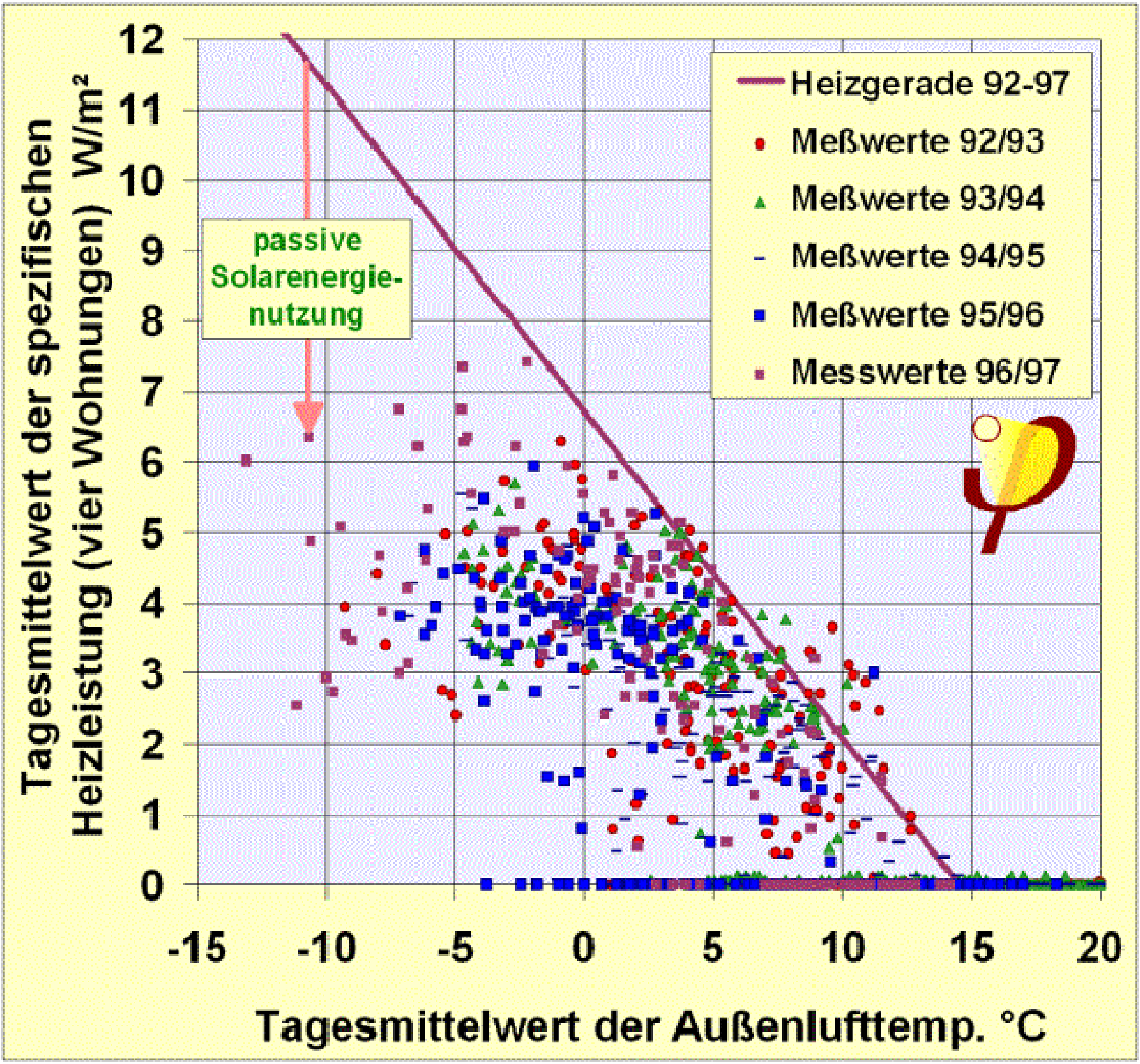
1.2 Measured energy consumption values

In total, the measured total energy demand (domestic electricity, shared electricity, cooking gas, ventilation, hot water and space heating) in the Passive House building is less than 33 kWh/(m^2a) in the second to the fourth year of the measurement cycle [Ebel/Feist 1997]. The target value of 30 kWh/(m^2a) was thus exceeded only slightly. As envisaged in the objectives, the total energy consumption in this Passive House building is **lower** than the domestic electricity consumption in average buildings alone in Germany (based on the living area). The total energy demand of the Passive House building (including all terraced units) is thus almost 90% lower than in comparable existing single-family houses.

The following figure shows the measured daily average heating loads of the four housing units based on the living area. From the second year onwards, the heating demand decreased further due to frame insulation; in the third to fifth measurement years, the measured maximum heating load always remained below 7.2 Watt/m^2. These are extremely low heating outputs; for example, this gives a peak output of around 150 watts for the living room with a floor area of 22 m^2. Thus this room could easily be "heated" using two ordinary incandescent bulbs.

1.3 User satisfaction, user behaviour

An independent social science study was carried out for the Passive House in Darmstadt Kranichstein, for which the residents were asked about their assessment of the indoor climate in summer and winter, and the results were compared with the statistics from low energy houses [Rohrmann 1994]. On average the results were better than those of the comparison group – but these were not significant on account of the small aggregate. Nevertheless, this result was enough to consider as meaningful, more comprehensive, demonstration projects.

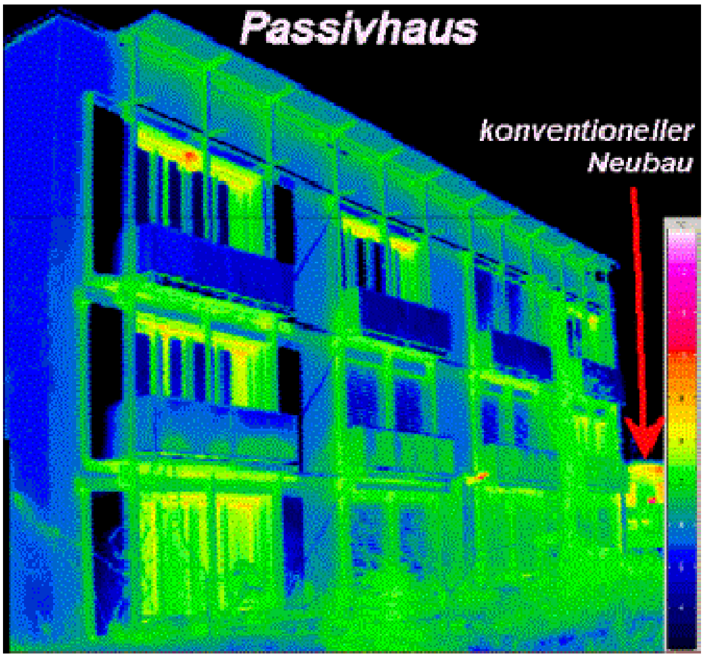


Daily specific heat output, measured in the Passive House (average value over all four housing units, each with a living area of 156 m²) over two heating periods (from [Feist 2005]).

Table: Measurement results: Specific energy demand in the Passive House in Darmstadt Kranichstein, Years 1 to 4

Specific energy value (final energy) kWh/(m^2a) (living area)	Energy source	Passive House Measurement 91/92	Passive House Measurement 92/93	Passive House Measurement 93/94	Passive House Measurement 94/95
Domestic electricity		6.27	6.17	7.11	7.48
Ventilation (electricity)	ELECTRICITY	2.65	2.93	2.93	2.93
Shared electricity		2.85	2.10	1.87	1.82
Cooking gas		2.43	2.60	2.89	2.85
Hot water	NATURAL GAS	8.28	6.12	7.52	7.45
Heating		20.81	11.91	11.45	7.42
Total		**43.29**	**31.83**	**33.77**	**29.95**

Measured values for the annual heat consumption as an average value for all four housing units in the period between 1991 and 2006. The average value of the measurements is slightly less than the value of 9.4 kWh/(m²a) calculated with the PHPP. These measurements were taken at the gas meter and allocated to the space heating and hot water circuits according to heat meter readings. The consumption value has remained stable for 15 years (apart from fluctuations due to weather).



The picture on the left shows a **thermographic image of the Passive House building**. The intensity of heat radiation indicates the surface temperatures: the highest temperatures appear white, while the lowest temperatures appear black. It is evident that the exterior wall consistently has extremely low surface temperatures; the excellent insulation of the window frame is obviously effective. The super-glazing also has very low heat losses. The higher surface temperatures of the conventional new building in the background are particularly conspicuous.

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