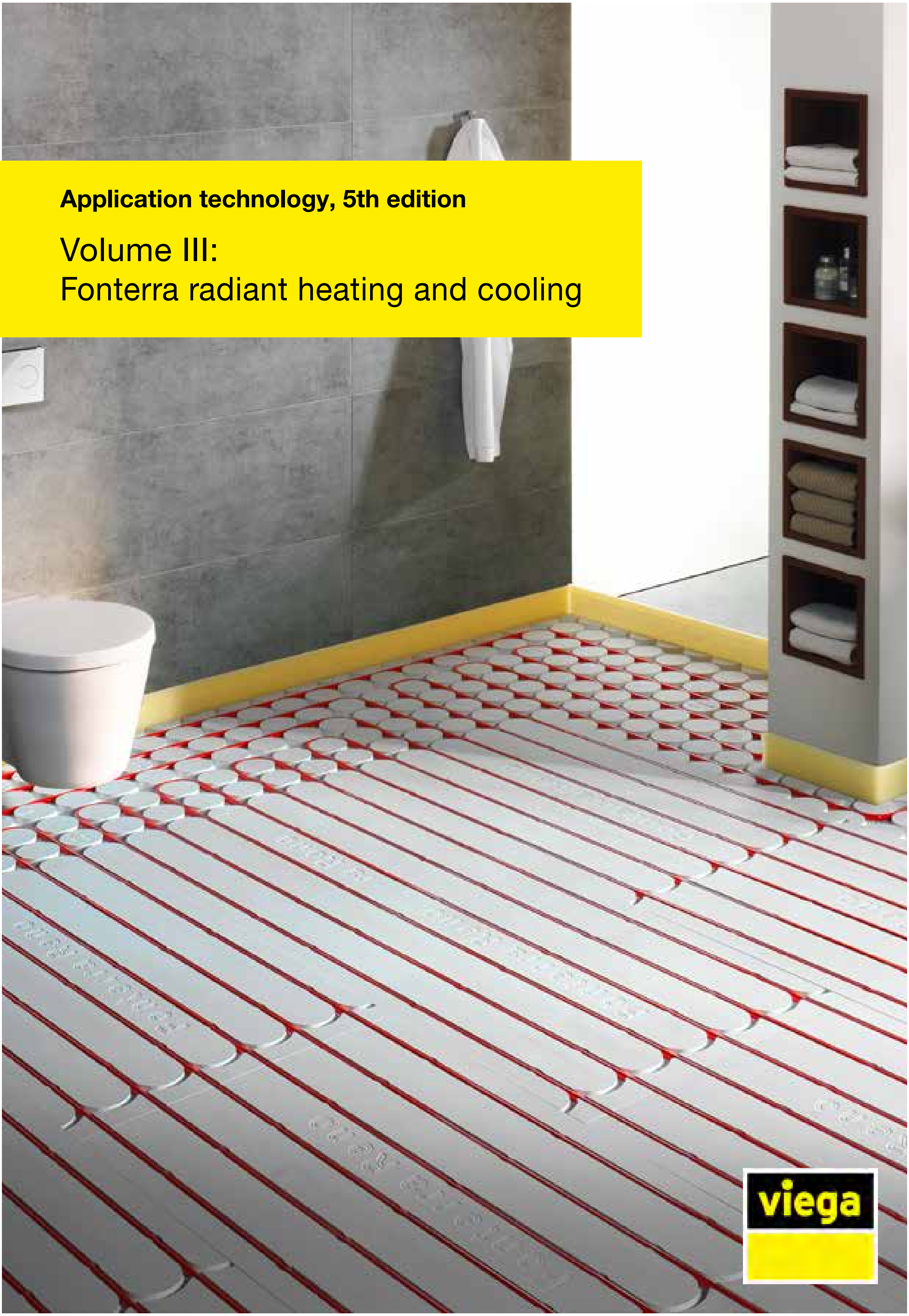
Application technology, 5th edition

Volume III:
Fonterra radiant heating and cooling



General

Basics

Since building owners wish for a comfortable and cosy heating system, radiant heating and cooling systems for room heating have become increasingly important. After all, an agreeable and healthy room climate is a major decision criterion.
In addition, many building owners seek to reduce the energy consumption of their building to a minimum.
The availability of fossil fuels is limited. The CO_2 released when burning fuels damages the world's climate. Accordingly, the heating energy requirements of modern buildings have been reduced continuously thanks to improvements in heat insulation and heating system technology.
Architectural measures such as south exposure of buildings for passive utilization of solar energy likewise reduce the energy consumption.

Protection of the environment

Fig. 12: Fonterra Reno – Comfort also for old buildings

To protect the environment, the energy required for heating a building must be provided with the best possible energy efficiency, or by using regenerative energy carriers. Time-proven systems for the supply of heating energy are available which fulfil the requirement for saving of energy and reduction of the CO_2 emissions.
Condensing boiler technology, heat pumps, and solar collectors or pellet heating systems are heat generators which guarantee efficient use of fossil energy carriers, or which use solar energy or environmental heat to supply the required heating energy.
For optimum functionality, however, these systems must be combined with a radiator with low supply temperatures, such as radiant heating and cooling systems.

Utilisation of the existing energy
All systems have one feature in common: The lower the necessary supply temperature of the heating water, the more efficient the utilisation of the existing energy. It follows that state-of-the-art economic heating systems should best be designed and operated as low-temperature heating systems to keep the energy consumption to a minimum. Low-temperature heatings can be implemented with large heating surfaces. Floor and wall heating systems are a perfect way of realising a low-temperature heating solution.

Saving energy
In respect of energy consumption, another strong point of surface heating systems becomes apparent: The cosy feeling and the perceived temperature are defined by the interaction of radiant heat and the warmth of the room air. Since the heat emission of floor and wall heating systems takes place with a relatively high ratio of radiant heat (approx. 60 to 75%), the room temperature can be set 1 to 2 K lower than with other heating systems – without compromising the occupants' ease and comfort. Setting the temperature to 20 °C for rooms with surface heating saves 10 to 12% heating costs per year compared to 22 °C with radiator heating.

Efficient single room regulation
The innovate single room regulation system Fonterra Smart Control ensures permanent automatic hydraulic calibration of the heat transfer. This not only saves 10 to 20% of energy but also allows the user to generate individual heating profiles via the WLAN-capable software. All these benefits are available without extra wiring because the system uses remote control, or because the components are pre-connected at the manifold, ready for plug-in.

Combined heating and cooling systems
With its optimised radiant heating and cooling systems, Viega has an extensive portfolio which meets various requirements, offering products for new as well as for old buildings, office buildings, industrial building, refrigerated warehouses and sports centres.
In addition to the wide range of the Fonterra program for underfloor heating system, Viega also provides systems for wall or ceiling heating or cooling. In many cases, it is a good idea to combine several radiant heating and cooling systems, for example wall and underfloor heating, to considerably increase the occupants' ease and comfort.
Refer to the section "System overviews" to find detailed information on the Fonterra systems or a "System table" indicating which Fonterra systems are suitable for the different applications.

Surface heating

To ensure ease and comfort in an apartment, a series of conditions must be met.

Temperature profiles

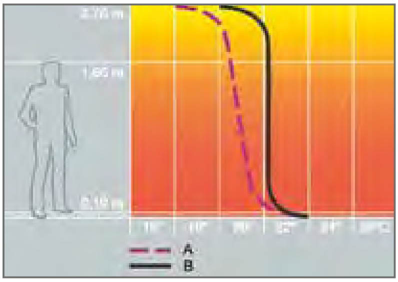


Fig. 13: Temperature profile underfloor heating

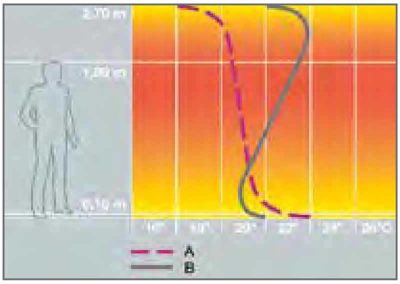


Fig. 14: Temperature profile radiator heating

Key
A - Ideal heating
B - Underfloor heating (left) or radiator heating (right)

A surface heating system designed as an underfloor or wall heating is an easy and efficient way of reaching this goal.
A near-perfect temperature profile prevents a raising temperature stratification in the room; furthermore, it allows for setting the room temperature somewhat lower than with radiators without compromising the occupants' ease and comfort.

Surface cooling

If equipped with a water chiller, radiant heating and cooling systems can be used for surface cooling in summer. Cooling can be effected via the floor, the walls, or - with best results - the ceiling surface.

A single system for heating and cooling

Fig. 15: Heating and cooling

Fig. 16: .... with a single system

Certain characteristics must be considered. Due to physical conditions, the cooling performance from an underfloor temperature regulation system is considerably less good than from a ceiling system; the results achieved from wall surfaces lie between these two values.

As another benefit, this type of cooling is free of noise and draughts and much less expensive than air conditioning systems.
This is also true for building part activation which has already been implemented in many projects, achieving premium results in terms of comfort and of economic efficiency.

Room climate

Influencing factors

There is increasing demand for comfortable temperature control that ensures a pleasant environment throughout the entire year. Warm in winter, agreeably cool in summer: That is the goal modern heating systems must meet, while being environmentally compatible, economical, and ensuring design freedom for architect and building owner.
Most people prefer a room temperature between 20 and 22 °C. Other factors influencing the room climate are the air temperature, air speed, air exchange, radiant temperature, and humidity.

Factors influencing the room climate

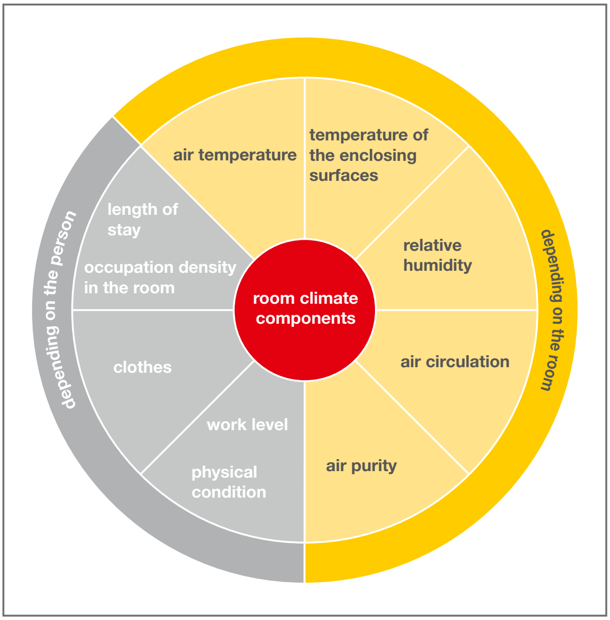


Fig. 17: Factors influencing the room climate

The first scientific experiments to find the parameters which define comfort date back to the middle of the 19th century. In many tests with changing framework conditions and various heating systems, taking the subjective perception of different groups of people into consideration, it was found that radiant heating and cooling systems are best suited for creating a room atmosphere perceived as agreeable. Thermal comfort is a quality criterion for heating or air conditioning systems. DIN EN ISO 7730 defines the respective specifications. Here, the "operative room temperature" and the "PPD" (Predicted Percentage of Dissatisfied) are decisive parameters.

Comfort

To generate a thermally comfortable room atmosphere, all conditions of the building, system, and control must be taken into consideration. As a rule, the following measures have a positive effect:

- radiant symmetry and avoidance of air draughts;
- keeping the residential zone free of cold air draughts from the outer walls by means of underfloor and/or wall heating systems;
- strong, optimised heat insulation.

We know from experience that a room is perceived as comfortable if the temperature differences in the room are small and do not exceed the following values:

Wall surface and room air	6K
Room temperature foot to head height	3K
Different wall surfaces (radiant symmetry)	5K

Room temperature

The room temperature is a key factor for residential comfort. However, the point when the temperature is perceived as comfortable depends on the occupants' clothing and activities and a series of other factors. Thus, it is for example important that the difference between the temperature of the room and the temperature of the enclosing surfaces (outer and inner walls, ceiling, floor, windows, furniture) is as small as possible. The temperature actually perceived by the occupants as room temperature is the mean value of the two temperatures.

Comfort in dependence on the temperature of the enclosing surfaces

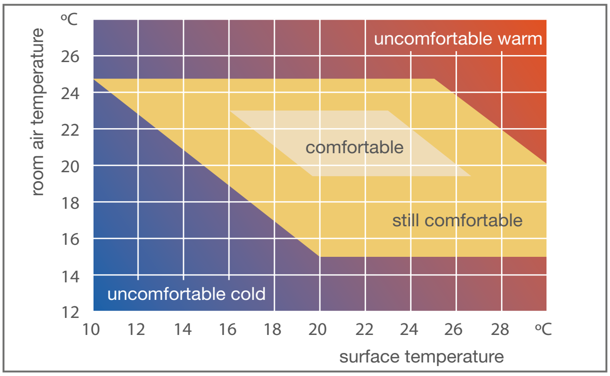


Fig. 18: Comfort in dependence on the temperature of the enclosing surfaces

If the temperature of the room air differs greatly from that of the enclosing surfaces, no thermal comfort can be achieved.
The significance of a healthy room climate has been evidenced by medical research. There is evidence for positive effects of a comfortable room climate on the human organism.

Comfort in dependence on the physical activity

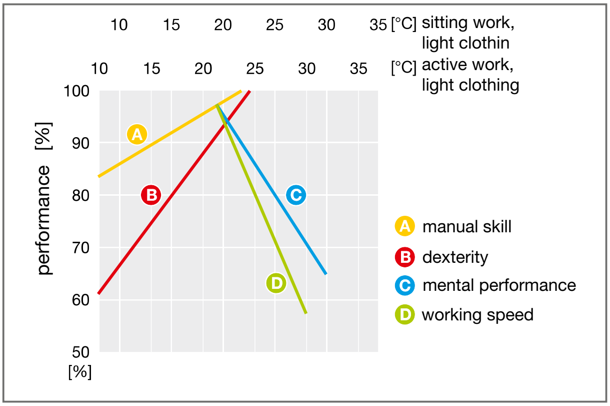


Fig. 19: Comfort in dependence on the physical activity

An uncomfortable room climate considerably reduces the occupants' productivity: Tests have shown a 30% reduction of productivity due to lack of concentration and fatigue at an operative room temperature of 28 °C. According to these tests, optimal productivity is achieved at an operative room temperature of approx. 22 °C.
Differently used residential zones require different temperatures. The following is recommended:

- Living rooms 20 to 22 °C
- Bedrooms 16 to 18 °C
- Bathrooms 24 to 26 °C

Hygiene

Surface heating systems with their low operating temperatures – they use almost exclusively radiant heat – are always relatively close to the room temperature. This automatically improves the hygiene conditions. The moderate temperatures of the surfaces do not cause much convection. Furthermore, there will be no humid corners on heated surfaces, and thus no mould.

Convection

When the air moves, dust and other particles can be carried along, potentially irritating the mucous membranes or triggering allergies. This may happen when radiators are run at high supply temperatures and the great difference in temperature causes formation of an air roll which conveys irritating particles. Surface heating systems with their low surface temperatures reliably keep convection to a minimum.

Convection of radiators and underfloor heating

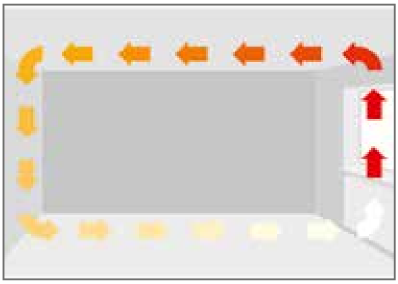


Fig. 20: Convection of radiators

Fig. 21: Convection of underfloor heating

The optimum room

The room climate is highly significant in rooms in which the occupants remain for many hours, e.g. office rooms, and is influenced by many factors.
The optimum room should have small radiant asymmetries only (e.g. room temperature compared to temperature of enclosing surfaces), admit no air draughts, have a medium humidity, and be perfectly hygienic. The Fonterra radiant heating and cooling systems have no problems fulfilling all these requirements. The best results are achieved by combining several systems.

Energy efficiency

Savings potentials

The basic principle of the energy efficiency of buildings is based on three levels. By means of an excellent insulation of the building envelope and optimum heat insulation glazing, the energy requirements of a building are reduced to a minimum. When selecting the heating system, high efficiency is ensured by using optimum technology for generation, storage, and above all distribution and transfer of the heat. Additionally, renewable energies should be integrated in the building concept to improve the total efficiency of the building and to reduce the primary energy consumption.

Energy efficiency as a basis for saving energy

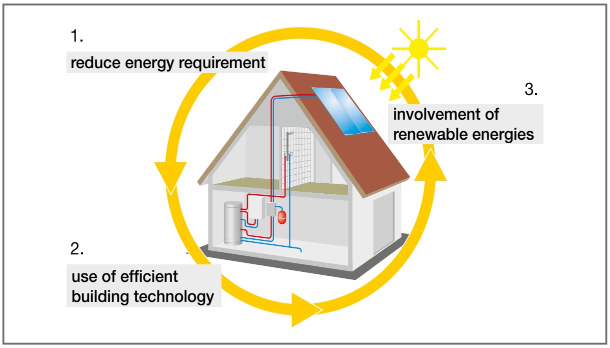


Fig. 22: Energy efficiency as a basis for saving energy

Heat pumps

To make effective use of the heat from the environment, heat pumps should be selected which use mature technology and have a high efficiency.

Functional principle of a heat pump

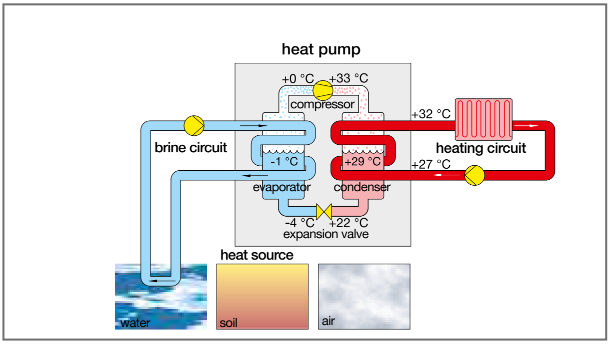


Fig. 23: Functional principle of a heat pump

A seasonal energy efficiency ratio of a heat pump of 4 means that 1 kWh of electricity must be used to generate 4 kWh of heating energy. It follows that ¾ of the heating energy is generated from the environment without any costs.

75% environmental energy
+ 25% electrical energy
100% heating energy

The seasonal energy efficient ratio β covers the operation of the heat pump during an entire year; thus, it is the major factor in respect of the efficiency of heat pump systems because it also considers the performance of the circulation pumps. It can accordingly be understood to define the degree of utilisation of the system.

Benefits of heat pumps
- Full-scale heat generation system (heating plus hot water)
- Independent of oil and gas
- Optional cooling of the building with brine via depth drilling or well
- High efficiency (also without state subsidies)
- Energy can be generated from water, air, or soil
- Mature technology (COP values of heat pumps > 4) [1)]
- High CO_2 saving potential

[1)] Coefficient of Performance (COP) is the ratio of the heat output (kW) dissipated to the heating network to the electrical power required. Measured according to DIN EN 255.

Solar installations

As a result of further developments in solar technology, particularly in the fields of solar panels and heat accumulators, combination boilers for domestic water heating by means of solar energy and accumulators supporting room heating systems are available which can be profitably combined with radiant heating and cooling systems.

Design and function of solar installations

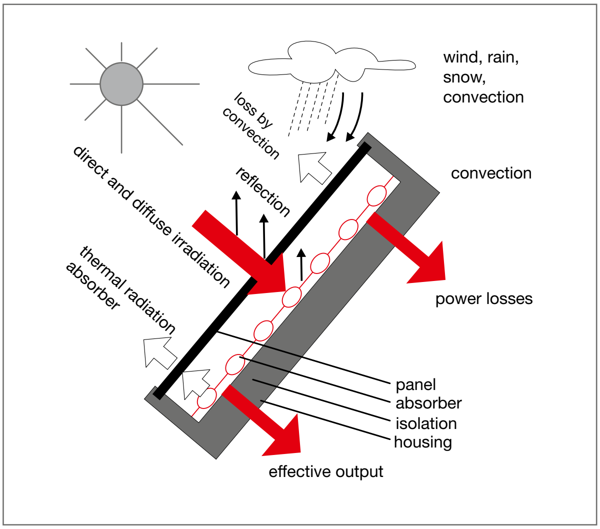


Fig. 24: Design and function of solar installations

Calorific value method

A test carried out by the German test institute "Stiftung Warentest" showed that solar panels on an area as small as 10 to 15 m², combined with a modern combination boiler for domestic water warming and heating support, cover up to 24% of the energy requirement for heating and hot water of a

low-energy house.
In calorific value boilers, vapour can condense at a heat exchanger in the exhaust gas flow, dissipating its energy to the return flow of the heating system. This effect can only be used efficiently if the return temperature is just slightly higher than the room temperature.

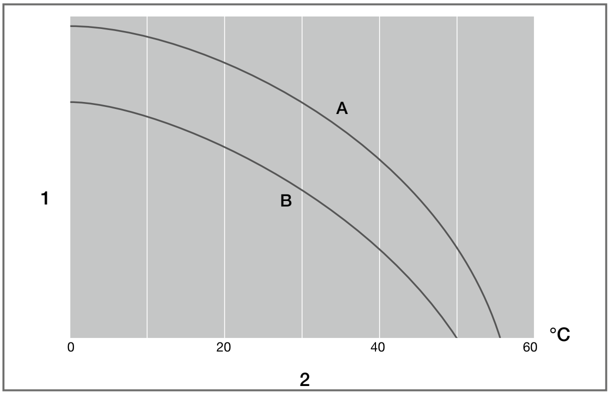


Fig. 25: Calorific value effect – in dependence on the condensation temperature

Key
A - natural gas H
B - fuel oil EL
① Energy saving
② Return temperature [°C]

The Figure shows the benefit from using the calorific value effect in dependence on the condensation temperature which is roughly equivalent to the return temperature of the system. It is evident that with a return temperature of under 30 °C, or even lower than that in the case of mean annual temperatures of underfloor and wall heating systems in new buildings, a part of the heating of a building can be provided by calorific value technology. Here, savings of up to 15% compared to conventional boilers can be achieved.

Biomass
Using wood as an energy carrier, a biomass heating system can supply heat with the greatest possible extent of CO_2 neutrality. Regarding the burning of the fuel wood, one assumes that only that amount of CO_2 is released that was bound during the growth of the tree. Since wood is a renewable resource which, if used sustainably, will never cease to exist, wood firing is a major component of environmentally compatible energy supply. Nowadays, wood pellet heating systems are an established technology for residential buildings. Suitable filter systems reduce the contamination from combustion to a minimum. Combined with a radiant heating and cooling system, a highly efficient heating concept is provided which ideally connects state-of-the-art environmental technology with economic benefits.

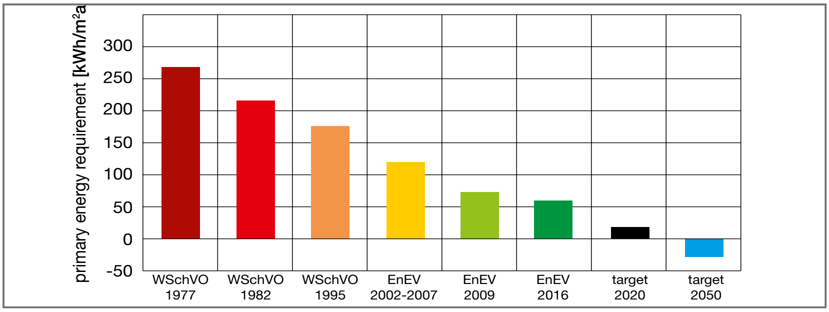
Standards / regulations

Reducing the requirement in primary energy

The German Federal Government follows certain strategies for increasing the energy efficiency of buildings. Energy-saving construction is subject to statutory requirements specified in 2002 in the German Energy Saving Ordinance (EnEV), and is also subsidised by various funds.
With the introduction of the EnEV, the energetic assessment of buildings combined the aspect of the structural thermal insulation standard with that of the heating system technology. Accordingly, the measures for reducing the annual primary energy requirement pursue the following goals:

- increasing the thermal insulation standard
- using innovative heating technology to improve the efficiency
- using passive or regenerative energy
- optimising heat distribution
- selecting an energetically appropriate operating system

Closely following this development, Viega designed its state-of-the-art radiant heating and cooling systems to ensure that they support these tendencies while being in compliance with the latest standards and guidelines.
One example is the Fonterra Smart Control area heating control which not only increases the energy efficiency but also the users' comfort, thanks to its intuitive operation.



Development of the annual primary energy requirement in Germany

Fig. 26: Development of the annual primary energy requirement in Germany

DIN EN 12831

Today's calculation standard for the heating load is based on DIN 4701.
DIN EN 12831, version 2003, was approved by the CEN on 6 July 2002. In the "German version EN 12831 (2003)", it specifies the process used today to calculate the standard heating load. By means of a "national appendix", this standard was adapted to the geographical situations and utilisation requirements. Supplementary Sheet 2 on "Simplified process for determination of the building heating load and heat generator performance" has been in force since May 2012. Supplementary Sheet 3, "Simplified process for determination of the room heating load", was updated in December 2016.

Creation of the EnEV

The Energy Saving Ordinance EnEV replaced and summarized the Heat Insulation Ordinance and the Heating Systems Ordinance.

- 2002 First version of the EnEV came into force on 01.02.
- 2004 Second version was issued
- 2007 New version introduced on 01.10.
- 2009 The Regulation of 29.04. modified and strengthened the requirements as of 01.10.2009.
- 2013 The amendment of the EnEV was pronounced on 21.11. and the majority of the modifications came into force on 01.05.2014.

Since some of the modifications were applicable only from 01.01.2016, the regulation is sometimes called 'EnEV 2016'. However, all three names describe the same version of the Ordinance.
Its aim is to ensure that all buildings will be nearly climate-neutral by 2050.

EnEV 2009

On 1.10.2009, the modifications to the Energy Saving Ordinance came into force. In addition to the tightening of the energetic requirements by approx 30%, new calculation methods and approaches were introduced, as well as a new standard for assessment of residential buildings, the DIN 18599. Here, the most important change was the definition of limit values by means of the so-called reference building method.
In terms of geometry and alignment, the reference building corresponds to the planned building, but is equipped with a specified heat insulation and uniform system engineering.

EnEV 2013/2014

At the time of the introduction of the EnEV 2009, the German Federal Government announced that the requirements regarding primary energy will be tightened by another 30% with the next amendment of the EnEV, scheduled for 2012. Accordingly, the German Federal Government reduced the permissible requirement level for residential buildings almost by half within three years only. This comes quite close to meeting the aim specified by the EU that by 2021 at the latest, all new building projects must be "almost-zero-energy buildings".

New residential buildings

The execution of the reference building for the construction of new residential buildings is described in Appendix 1, Table 1 of the EnEV. The primary energy parameter calculated with these technical preconditions is the standard for the building to be constructed.
The main condition of the EnEV is that the specified primary energy requirement is met; additionally, the requirements regarding minimum structural thermal insulation must be fulfilled. Appendix 1, Table 2 determines a fixed value of this specific transmission heat loss (H'_T value) to be implemented for certain building types. In the calculation of the annual primary energy requi-

rement according to the method defined in Appendix 1 no. 2 for heating, hot water generation, ventilation and cooling, not only the design of the building envelope but also other components such as the installation engineering are considered. This is why the building planners must check the entire building before making decisions regarding internal structural components, e.g. floor installation.

Thermal transmission coefficients of the reference building for new residential buildings

Building envelope of the reference building	
Floor panel / basement ceiling	0.35 W / (m²·K)
External wall	0.28 W / (m²·K)
Entrance door	1.8 W / (m²·K)
Window	1.3 W / (m²·K)
Roof area window	1.4 W / (m²·K)
Roof	0.20 W / (m²·K)

Tab. 1: Thermal transmission coefficients of the reference building for new residential buildings (excerpt from EnEV Appendix 1, Table 1)

From 01.01.2016, the [...] annual primary energy requirement of the reference building [...] must be multiplied by 0.75. (Excerpt from EnEV Appendix 1, Table 1, Line 1.0)

Maximum transmission heat losses for new residential buildings

Line	Building type		Maximum value of the specific transmission heat loss
1	Free-standing residential building	$A_N \leq 350\,m^2$	$H'_T = 0.40$ W/(m²K)
		$A_N \geq 350 m^2$	$H'_T = 0.50$ W/(m²K)
2	Semi-detached residential building		$H'_T = 0.45$ W/(m²K)
3	All other residential buildings		$H'_T = 0.65$ W/(m²K)
4	Refurbishment and extensions of residential buildings according to § 9 paragraph 5		$H'_T = 0.65$ W/(m²K)

Tab. 2: Excerpt from the EnEV Appendix 1, Table 2

Since 01.01.2016, the specific transmission heat loss in relation to the heat-transmitting enclosing walls of a newly built residential building must not exceed the corresponding value of the respective reference building multiplied by the factor of 1.0. The respective maximum values must not be exceeded, see Appendix 1, Table 2 [EnEV 2013].

Refurbishment of residential buildings

For refurbishment, i.e. "Modification, extension and renovation of buildings" according to EnEV §9, the thermal transmission coefficients of the respective external building parts specified in Appendix 3, Table 1 must not be exceeded.

If the thickness of the insulation layer provided according to these measures in external walls, ceilings, roofs, pitched roof areas, walls and ceilings adjoining unheated rooms, soil, and exposed to outside air from below is restricted for technical reasons, the requirement is considered met if the insulation layer is installed with the greatest possible thickness achievable according to the recognized state of practice (with a calculation value of the thermal conductivity of Lambda = 0.035 W/mK).

The requirements are considered met if the specific transmission heat loss in respect of the heat-transmitting enclosing walls according to EnEV Appendix 1, Table 2 and the Qp value calculated according to § 3 of EnEV are not exceeded by more than 40 per cent.

For refurbishment, i.e. "Modification, extension and renovation of buildings", the following requirements must be met according to EnEV §9:

Thermal transmission coefficient of the reference building in case of refurbishment of residential buildings

Building part	Refurbishment of residential buildings with IT > 19 °C
Outer walls	0.24 W/(m²·K)
Ceilings, roofs and pitched roof areas	0.24 W/(m²·K)
Ceilings and wall bordering on unheated rooms or soil	0.30 W/(m²K)
Ceilings exposed to outside air from below	0.24 W/(m²·K)
Floor installations	0.50 W/(m²·K)

Tab. 3: Excerpt from the EnEV Appendix 3, Table 1

The specified maximum values of the thermal transmission coefficient for the building parts concerned must not be exceeded.

The requirements do not apply if less than 10% of the outer parts of the building are modified ("de minimis limit").

Construction of new non-residential buildings

§ 4 specifies that, comparable to the regulation for residential buildings, the annual primary energy requirement must be calculated using the method defined in Appendix 2, no. 2 or 3 also for non-residential buildings (buildings which are not primarily used as a residence according to §2) for a reference building according to Appendix 2, Table 1. The maximum values of the mean thermal transmission coefficients must not exceed the values specified in Appendix 2, Table 1.

Thermal transmission coefficients of the residential building for non-residential buildings

Building part	room temperature > 19 °C	Room temperature 12-19 °C
External wall	U = 0.28 W/(m²K)	U = 0.35 W/(m²K)
Floor panel	U = 0.35 W/(m²K)	U = 0.35 W/(m²K)
Roofs	U = 0.20 W/(m²K)	U = 0.35 W/(m²K)

Tab. 4: Thermal transmission coefficients (excerpt from EnEV Appendix 2, Table 1)

> From 01.01.2016, the [...] annual primary energy requirement of the reference building [...] must be multiplied by 0.75.
> (Excerpt from the EnEV Appendix 2, Table 1, line 1.0)

Refurbishment of non-residential buildings

§ 9 specifies that in case of refurbishment of non-residential buildings, the annual primary energy requirement of the reference building according to § 4 and the maximum values of the mean thermal transmission coefficient according to Appendix 2, Table 2 must not exceed 40 per cent.

Heat insulation of pipelines and fittings

§ 10 specifies that formerly non-insulated accessible heat distribution and hot water pipelines and fittings located in heated rooms must be insulated according to Appendix 5 to restrict the heat dissipation. According to § 14, this also applies to the first installation and replacement of such lines and fittings.

Heat insulation of pipelines and fittings

Line	Type of pipelines/fittings	Minimum thickness of the insulation layer in respect to a heat conductivity of 0.035 W/(mK)
1	Inner diameter max. 22 mm	20 mm
2	Inner diameter > 22 mm to 35 mm	30 mm
5	Pipelines and fittings according to lines 1-4 in wall and floor breakthroughs, in the crossover areas of pipelines etc.	50% of the requirements of the lines 1-4
6	Heat distribution lines according to lines 1-4 installed after 31.01.2002 in building parts between heated rooms of different users.	50% of the requirements of the lines 1-4
7	Pipes in accordance with line 6 in the floor construction	6 mm
8	Cold distribution and cold water pipes as well as fittings of room air and air cooling systems	6 mm

Tab. 5: Excerpt from the EnEV Appendix 5, Table 1

- Heat distribution and hot water pipes exposed to outside air must be insulated with double the minimum thickness according to the above table.
- The above table does not apply if the pipes of central heatings according to lines 1 to 4 are located in heated rooms or building parts between heated rooms of one user and when the heat dissipated by such pipes can be controlled by accessible shut-off systems. This exception also covers hot water pipes with a maximum water volume of 3 litres which are neither integrated in the circulation nor equipped with an electrical temperature retaining strap and which are located in heated rooms.
- For materials with thermal conductivities other than 0.035 W/mK, the minimum thicknesses of the insulation layer must be converted according to the recognized technical rules.

Definition of insulation layers according to DIN EN 13163 and DIN EN 13164

Definition of insulation layers according to DIN EN 13163 and DIN EN 13164

EPS	Expanded polystyrene
XPS	Extruded polystyrene hard foam
DEO	Top-side inner insulation of the ceiling/floor panel under screed without noise insulation requirement
DES	Top-side inner insulation of the ceiling/floor panel under screed with noise insulation requirement
sm	Footfall sound insulation mean compressibility ≤ 3 mm
sg	Footfall sound insulation low compressibility ≤ 2 mm

Tab. 6: Definition of insulation layers according to DIN EN 13163 and DIN EN 13164

Heat insulation to be installed is defined in the EnEV, DIN 4108 and DIN EN 1264. It must be coordinated with the Service Center in Attendorn in keeping with the requirements, the available total height, and the desired floor coverings.

If additional insulation layers are required, they must be laid staggered and closely abutting under the on-site base layer.
They must comply with the general considerations of DIN 13162 - 13171, must be tested and marked.

Major changes to the EnEV after 2016

- 25% reduction of the annual primary energy requirement for residential and non-residential buildings
- Compliance with the heat insulation of the reference building is mandatory.
- Primary energy factor electricity mix falls once again to now 1.8
- Implementation of the EnEV-easy (Model building process) according to EnEV §3, paragraph 5 since 08.11.2016

Subsidy options
Compliance with the EnEV gives the building owner access to various subsidy options.
The KfW-Bank for example subsidizes the construction of residential buildings with a low annual energy consumption (efficiency houses 55, 40, and 40plus) in the frame of Program 153 "Energieeffizient Bauen". The programs 151/152 and 430 offer loans or an investment subsidy to support energy-efficient refurbishment. Individual measures such as the optimisation of the heating installation can likewise qualify for subsidies.

Furthermore, BAFA subsidies are available for refurbishment and optimisation of the heating installation; they cover 30% of the investment costs to a maximum of 25,000 €.

As a precondition for both types of subsidy for heating optimisation, evidence of hydraulic compensation of the entire heating installation must be provided (VdZ form).

Installation of the innovative single room regulation Fonterra Smart Control ensures the permanent and fully automated hydraulic compensation of the floor heating circuits. This not only provides evidence of hydraulic compensation for the underfloor heating but also for comfortable energy saving.

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