Efficient systems and renewable energies

Technology and Energy Panel

BDH
Federation of
German Heating Industry

ISH

Federal Ministry
for Economic Affairs
and Energy

Welcome message from the patron:

An almost climate-neutral building stock by the year 2050 – this ambitious goal will only be achieved with new and improved heating and air-conditioning solutions.
They must fit both new and existing buildings. These solutions should be efficient and cost-effective as well as applicable to the mainstream market, addressing the needs of users. In future, digital and "smart" technologies are bound to enter our buildings. I am happy to lend my support for the Technology and Energy Panel at ISH Energy. Many stakeholders meet there to discuss core and future-oriented topics of the heating revolution. They cover a wide range of topics: The Panel will deal with "Digitalisation of heating technology", "Fuel cells", "Sector coupling" and "New, highly efficient technologies for heat generation".
The leading international trade fair ISH thus makes an important contribution to the dialogue on technically and economically feasible strategies for heat transition.
I wish the Technology and Energy Panel as well as ISH Energy the very best.

Yours sincerely,

Brigitte Zypries
Federal Minister for Economic Affairs and Energy

Foreword

Under the specialist leadership of the BDH, and together with 13 partner associations, the Frankfurt Trade Fair and the Federation of German Heating Industry (BDH) are organising the Technology and Energy Panel for the seventh time on the occasion of the ISH 2017 in Frankfurt. The event organisers are very happy about the renewed commitment of the most important associations in the energy industry as well as of the industry associations from the areas of energy-efficient system technology. This strong cooperation between the energy sector and industry serves as an impressive demonstration of the close systemic network between energy and technology suppliers for the provision of the largest energy consumption sector in Europe, the heating market. We and our partners are implementing the double strategy of efficiency and renewable energies and provide the technical solutions for reaching the aims of climate and natural resource protection in the EU and Germany.

No other event in the world stands for the technological trends and innovations in the field of higher efficiency and renewable energies like ISH Energy. The Technology and Energy Panel offers the specialist visitors from all over the world a complete, comprehensive and company neutral overview of the current state of the art, in particular also about innovations and market trends in the heating sector. The following key issues are at the focus:

- The protection of climate and natural resources requires affordable and progressive technical solutions. ISH Energy shows how ambitious aims can be attained. New here: Electricity and heat grow together.
- Hybrid systems, fuel cells and digitalisation of heating technology form three highlights of the Technology and Energy Panel.
- Trends and innovations in the energy industry, such as power-to-gas and power-to-liquid
- International, European and German political framework conditions for the sector
- Market development and market trends

We are very happy and honoured that the Federal Minister for Economic Affairs, Brigitte Zypries, is taking over the patronage of the Technology and Energy Panel. The Minister hereby acknowledges the commitment of the German heating industry to the protection of the climate and natural resources. The exhibitors of the ISH Energy are already showing today marketable system technology for the politically envisaged interconnection of the sectors of electricity and heat.

The ISH in Frankfurt is expecting around 200,000 specialist visitors. The largest part of the exhibition, the ISH Energy, is a unique event in that it offers a complete overview of the state of the art and of the future of modern system technology for the heating sector. Find the answers to all the major challenges in the international heating sector in Frankfurt.

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Table of contents

Frameworks in the heating market
Climate and resource protection with energy and technology 8

Energy label for heat generators and combination heaters
Energy label for heat generators and combination heaters 18

Energy sources in the heating market
Natural gas 22
Heating oil 24
Wood energy 26
Solar energy 28
Geothermal energy and environmental heat 29
Electricity in the heating market 30

Modern heating systems
Modern heating systems 34

Smart Heating
Smart Heating 40

Efficient technologies and hybrid systems
Gas condensing technology with solar thermal energy 44
Oil condensing technology and renewable energies 45
Principle of the heat pump and variants 46
Hybrid heat pump systems 48
System photovoltaics, heat pump and storage 50
Gas heat pump 52
Heat from wood 54
CHP: The power-generating heating system 58
Fuel cell heating 60
Solar thermal systems 62

Heat distribution, heat emission, system components
Heat distribution 68
Hydraulic balancing and high-efficiency pumps 70
Embedded surface heating and cooling system 72
Radiators 74
Residential ventilation systems with heat recovery 76
Storage technology 80
Flue gas systems 82
Tank systems 84

Examples of modernisation
Examples of modernisation – Variants with gas/oil condensing boilers 88
Examples of modernisation – Variants with heat pumps 90
Examples of modernisation – Variants with wood burning systems/CHP systems 92

Industrial heat generators/Standardisation
Large firing systems 96
From Smart Heating to the energy network 100
Standardisation in heating, ventilation and air-conditioning technology 102

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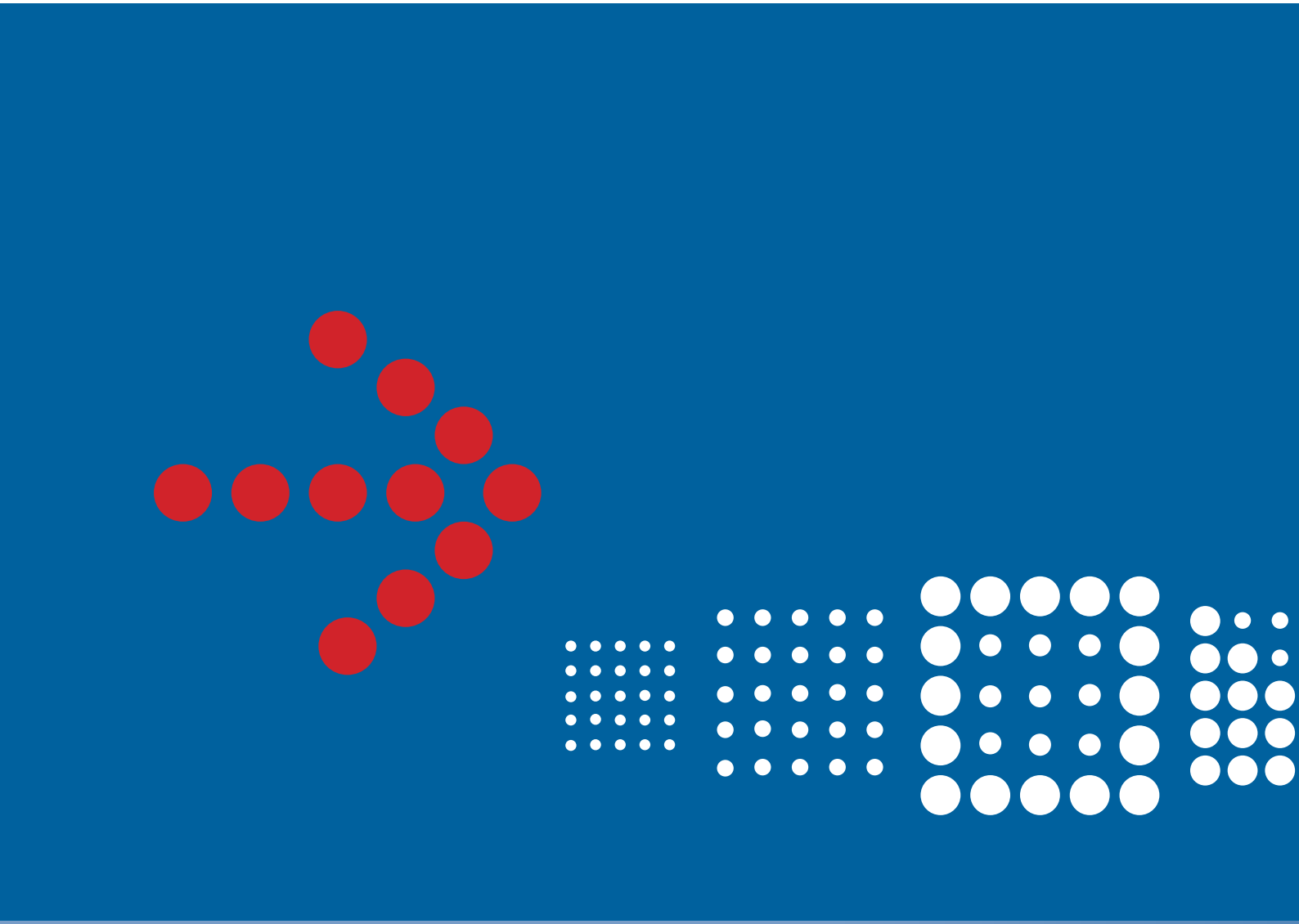


Frameworks in the heating market

- Climate and resource protection with energy and technology

Climate and resource protection with energy and technology

Ambitious resource and climate protection goals in Europe and Germany mark the energy and economic policy debate of the past few years. A key factor to achieving these goals is the commitment of the energy sector and the heating industry, because the maximum potential for energy-savings and CO_2 reduction lies with the largest of all energy consuming sectors of Europe and Germany, namely, the heating market.

The energy sector and the industry rely on the dual strategy of energy efficiency and renewable energies. Efficient technologies reduce the consumption of fossil fuels and at the same time allow an increasingly higher use of renewable energies to meet the needs in the heating market. The energy providers, on their part, rely on the strategy of significantly increasing the share of renewable energies in the energy mix of the future.

The organisers and partners of the Technology and Energy Panel establish a direct connection between the heating market's energy sources and the systems developed for their utilisation. Hence, an alliance was formed eight years ago to link efficiency and renewable energies:

BDH Federation of German Heating Industry
for efficiency and renewable energies

Energieeffiziente Gebäude BDI initiativ
for energy efficiency in buildings

BSW German Solar Association
for the solar industry

bwp German Heat Pump Association
for heat pumps

DEPV Deutscher Energieholz- und Pellet-Verband e.V.
for wood and pellets, as well as the corresponding plant technology

DIN NHRS
for standardisation

DVGW
for the gas industry and the standardisation body

INITIATIVE EEBUS
for digitalisation

Fachverband Gebäude-Klima e. V.
for air-conditioning technology and ventilation systems

geea Die Allianz für Gebäude-Energie-Effizienz
for building energy efficiency

HEA Fachgemeinschaft für effiziente Energieanwendung e. V.
for the electricity industry

HKI
for efficient single room furnaces

iwo Institut für Wärme und Oeltechnik
for the heating oil industry

Zukunft ERDGAS e.V.
for the natural gas economy

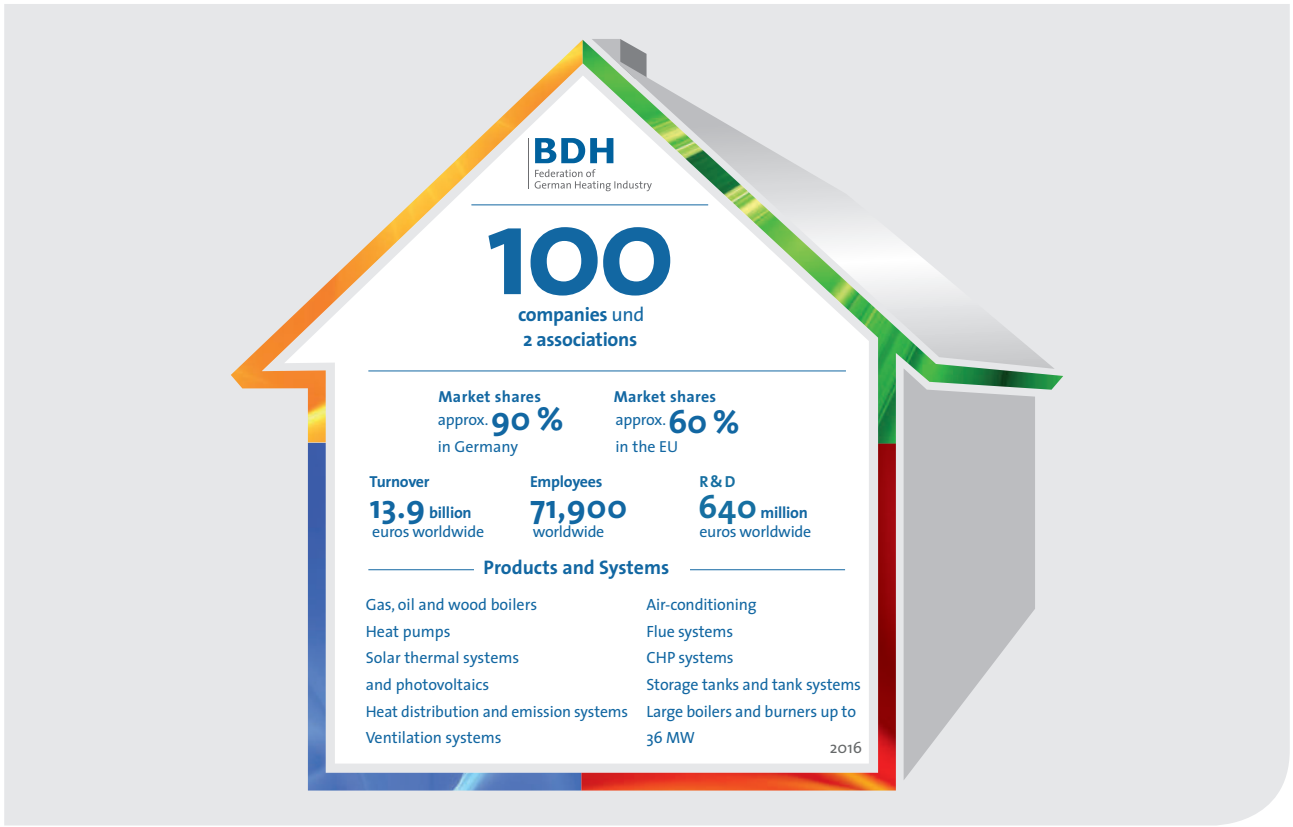


Fig. 1: The BDH stands for the dual strategy of energy efficiency and renewable energies

BDH and Messe Frankfurt: Organisers of Technology and Energy Panel of the ISH

The Technology and Energy Panel of the ISH is jointly organised by the BDH and Messe Frankfurt since 2005. About the organisers:

- 100 manufacturers of heating systems and components, as well as 2 associations belong to the BDH. The industry organised in the BDH manufactures systems with a capacity between 6 kW and 36 MW. At the international level, the German heating industry assumes a leading position, in terms of both technology and market importance. In 2016, the industry organised in the BDH achieved sales worth 13.9 billion euros and had 71,900 employees.
- Messe Frankfurt occupies the top position among the organisers worldwide having their own exhibition centres. In the year 2015, sales of the Group amounted to 648 million euros. Thus, it is pursuing its business strategy as planned, with a steady expansion of its brands at its home venue and worldwide. One of the most important events in Frankfurt is the ISH with its two pillars "ISH Energy" and "ISH Water".

ISH Energy: Efficiency and renewable energies in the spotlight

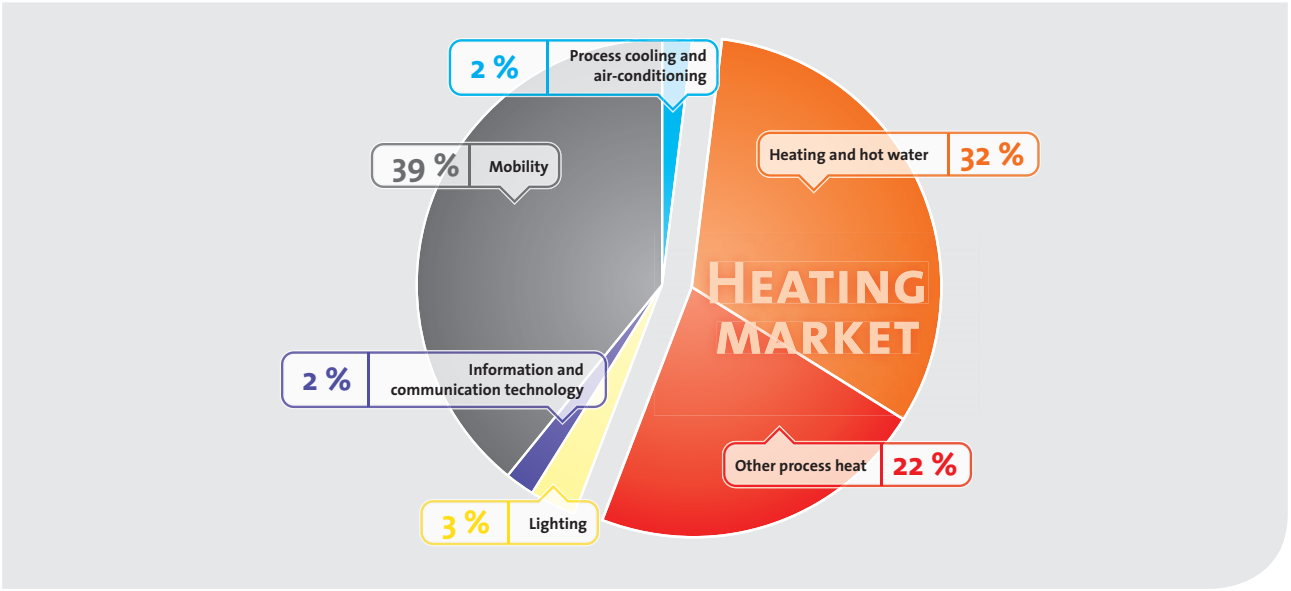
The ISH Energy takes place at a time when the European and German energy policy prepares ambitious schedules for climate and resource protection. Efficiency First and the direct use of renewable energies constitute the duopoly of the European and German strategy to lower resource consumption and thus to support ambitious climate protection goals. With a share of over 50 %, the largest energy consuming sector of Europe and Germany, namely the heating market, plays a key role in the implementation of this strategy, by having high energy-saving and CO_2 reduction potentials.

The ISH Energy has been following the dual strategy of efficiency and renewable energies (now adopted in the political arena) for six years now. Thus it is the most important international platform for the professional, but also political dialogue on technical/commercial approaches to achieving the goals. The ISH Energy 2017 deals with marketable technologies for the required coupling of the heating, transport and industry sectors through

Climate and resource protection with energy and technology

Fig. 2: The leading world trade fair ISH Energy shows the status quo and future of the heating market

the existing power supply (sector coupling). In addition to proven system technology, which efficiently converts fuels into heat, and at the same time, integrates renewable energies, the ISH Energy and thus, also the Technology and Energy Panel show hybrid system technology, for example, the combination of heat pumps and backup heat generators using condensing technolgy, as well as the digitalisation of the heating technology. But also the use of excess electricity for the conversion to synthetic gas or oil (power-to-gas, power-to-liquid) by electrolysis is part of the sector coupling demanded by the policy.



Source: Working Group Energy Footprints (AGEB)
German Association of Energy and Water Management (BDEW), 2015

Fig. 3: The heating market is one of the largest sectors of energy consumption

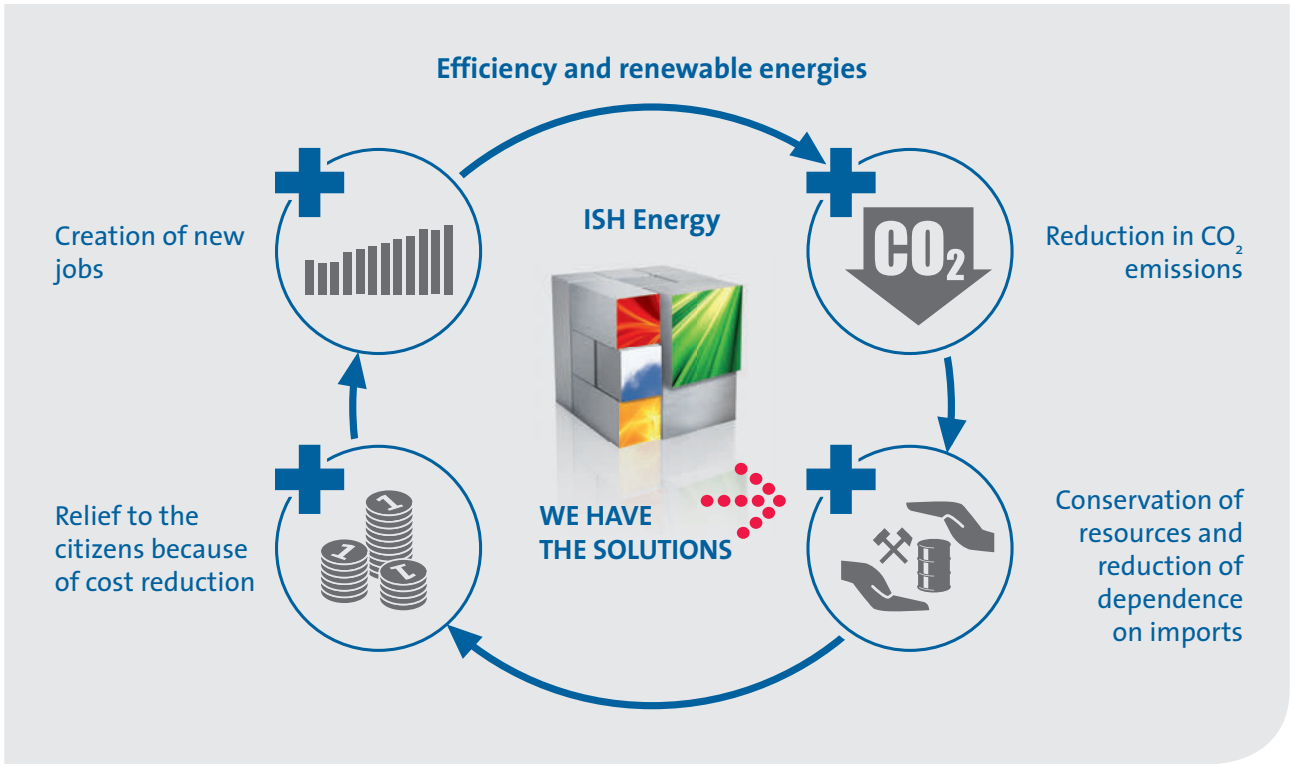


Fig. 4: Win-win situation through accelerated modernisation of old heating systems

Heating market – a sleeping giant

In almost equal amounts, the heating market accounts for over 50 % of final energy consumption in Europe and Germany. As regards Germany, room heating and domestic hot water heating in the building sector alone account for exactly one third of Germany's energy consumption. In the building sector, the energy demand is met almost 50 % by natural gas and approx. 25 % by heating oil. The renewable energies still take a backseat with just over 10 %.

With the Heating and Cooling Strategy published in 2016, the European Commission addressed the importance of the heating market for a sustainable energy policy for the first time. At its core, the heating and cooling strategy relies on the well-known dual strategy of the ISH Energy consisting of energy efficiency and renewable energies to achieve the climate and resource protection goals.

Whoever relies on this dual strategy, like the ISH Energy and the BDH, creates a win-win situation:

- Energy efficiency and renewable energies reduce CO_2 emissions for climate protection.
- Energy efficiency and renewable energies save scarce energy resources and reduce European dependency on imports.
- Lower energy consumption through higher efficiency and higher share of renewable energies reduce the burden on the citizens by way of cost reductions.
- Investments in higher efficiency and renewable energies create jobs in industry and trade.

Europe's efficiency is untapped

125 million heaters provide Europe's buildings with heat. Almost 80 % of these heat generators installed use natural gas as the main source of energy, followed by the energy source heating oil; however, only in a few countries such as Belgium, Austria, France and Germany. Less than 2 % of current installations rely on electricity-run heat pumps.

Climate and resource protection with energy and technology

Europe's energy consumption could be reduced drastically by employing modern heat generators, which combine efficiency and renewable energies. Up to 40 % energy savings could be achieved by replacing obsolete installations and employing modern systems. In addition, savings are achieved by improving the energy quality of the equally inadequate building envelopes.

What is Europe doing to increase efficiency in the heating market?

- Energy Performance of Buildings Directive (EPBD): Specification of the energy standards for the buildings in the EU Energy Saving Ordinance,
- Energy Efficiency Directive (EED)
- The EED makes it mandatory to the member states to realise an annual energy saving of 3 % in official buildings and of 1.5 % for end users – the latter under the responsibility of the energy supplier.
- Directive and Eco design requirement for energy relevant products (Eco ErP)
- Energy Labelling Directive

The ErP Directive lays down the minimum standards on the environmental characteristics of energy-consuming and energy-relevant products. These include heating boilers, domestic hot water preparation units, pumps, fans and domestic air-conditioning and ventilation systems.

Directive on the promotion of the use of energy from renewable energy sources (RES)

The RES Directive aims to increase the share of renewable energies in the EU substantially. It requires the member states to adopt measures with which the share of renewable energies in the EU can rise to at least 20 % on average.

Labelling Directive

The Directive is often associated with the introduction of an energy efficiency label for the concerned products.

Currently, the EPBD, EED and the RES directive are amended within the framework of EU Winter Package.

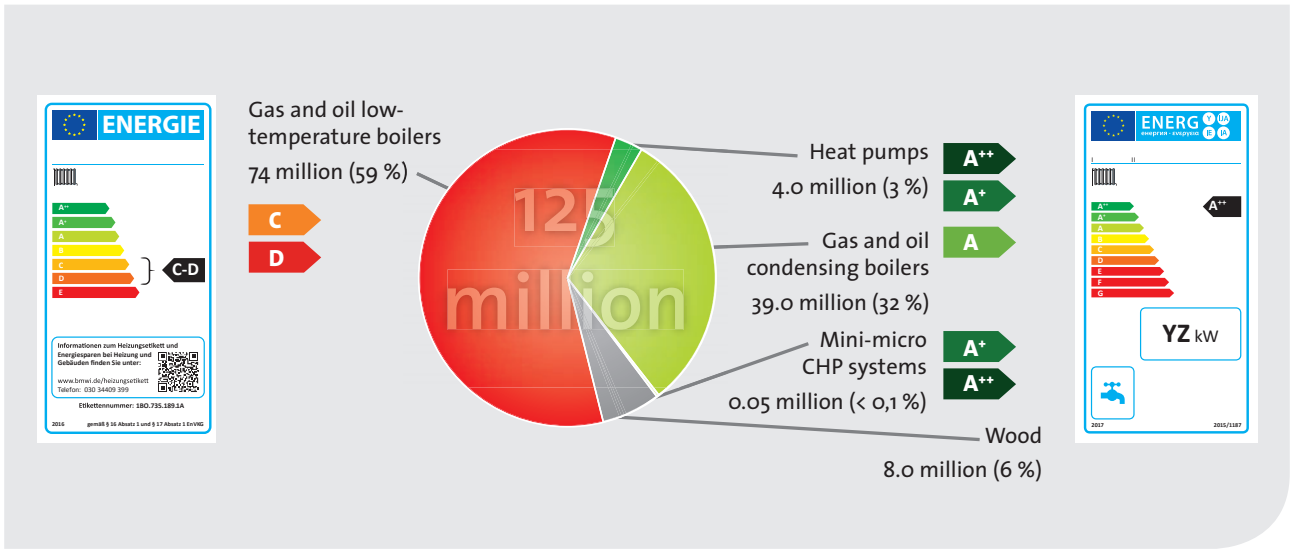
German heating market in crawling gear

Indeed, Germany decreed the so-called energy revolution; however, the actual development significantly lags behind the high expectations.

The following facts stand in the way of the energy revolution in the heating market:

- Only a third of the 21 million heating systems installed in Germany are state of the art.
- Only 4.9 million gas condensing boilers are in operation against 8.7 million standard or low temperature boilers.
- Of the approximately 5.6 million heating oil boilers installed in Germany, only about 0.6 million are energy-efficient oil condensing boilers.
- Only 0.8 million heat pumps use geothermal and ambient heat.
- Only 0.9 million biomass boilers use wood as renewable energy.
- Only about 10 % of the heat generators installed in Germany additionally use renewable solar thermal energy.

By replacing an outdated heating installation with a heating system that combines efficiency and renewable energies, up to 40 % can be saved compared to the outdated installation. Calculating on the basis of outdated installations, modernisation



Source: Federation of German Heating Industry (BDH), Association of the European Heating Industry (EHI)

Fig. 5: The European installations

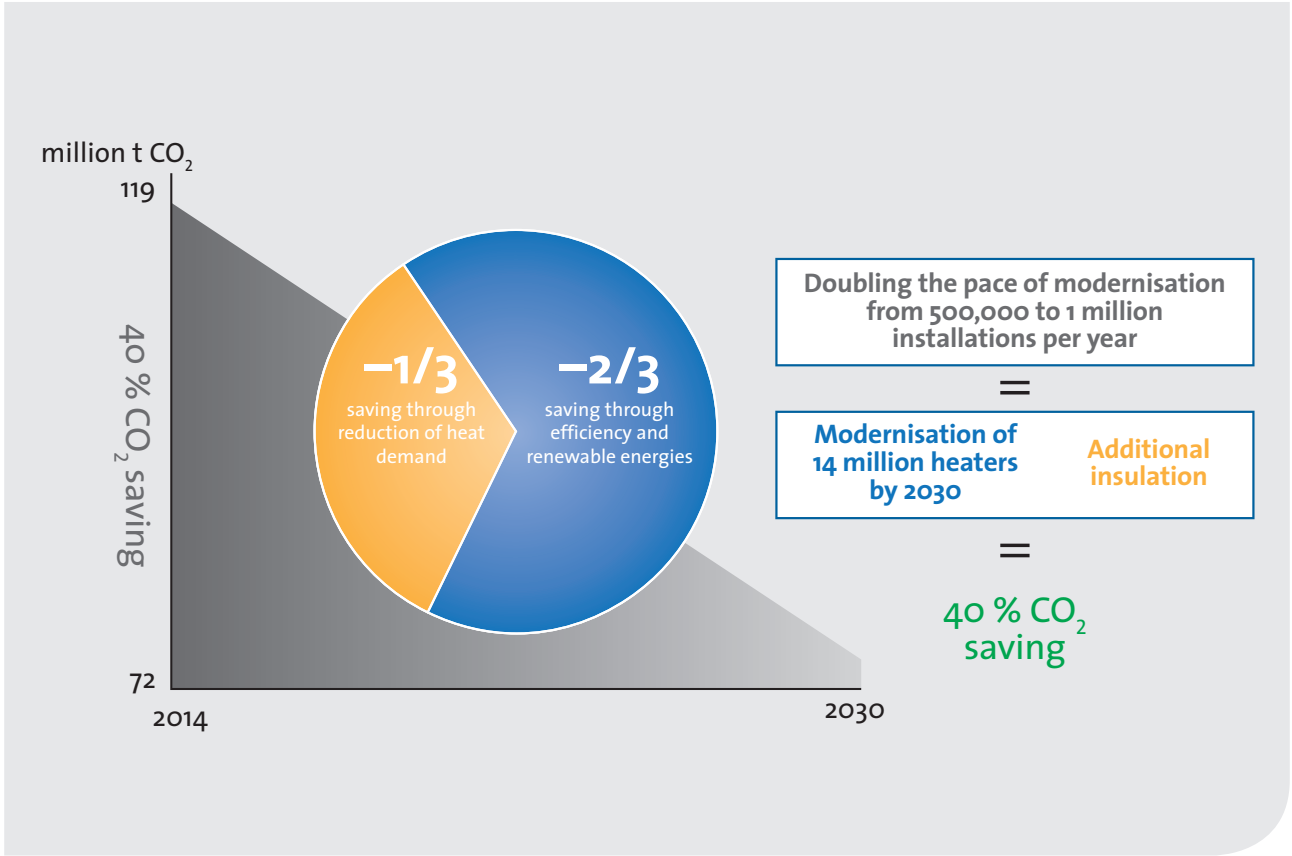


Fig. 6: The energy policy goals could be achieved by modernisation of obsolete installations

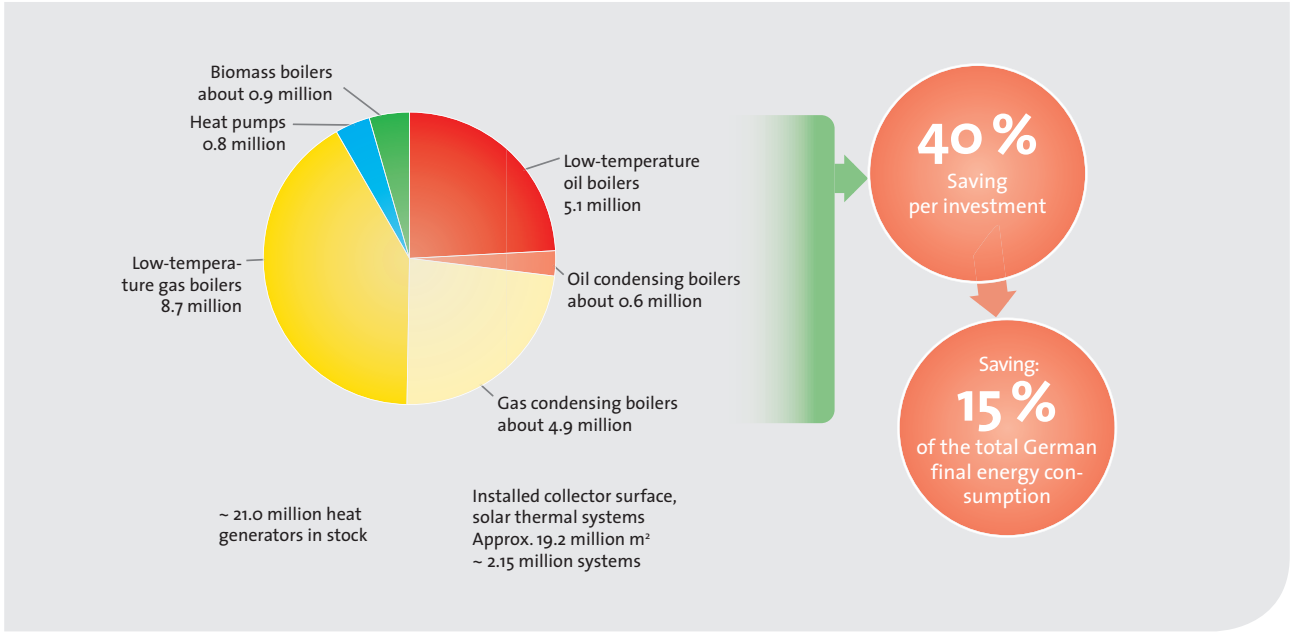
projects of this kind would cumulatively result in 15 % savings on final energy in Germany. Here, the high energy-saving potentials through energetic improvement of the building envelope have not even been taken into account.

At least the intermediate objectives of the climate protection plan for 2030 can be achieved with the available modern heating technology alone. According to the climate protection plan 2050, the CO_2 emission estimated today at 119 million tonnes is expected to be lowered to 72 million tonnes in 2030. However, the very slow "pace of modernisation" precludes this. In reality, it is at snail's pace of just 1 %, which is diametrically opposite to the ambitious goals of the EU Commission and the Federal Government.

The 1 % relates to extensive renovations, including the building envelope and plant technology. The "pace" of technical modernisation just involves the outdated gas heaters (nearly 14 million units) at 3 % and the outdated oil heaters (5.2 million units) at nearly 1 %.

Politics set ambitious goals, but create no suitable conditions for their realisation. The industry represented in the Technology and Energy Panel of the ISH Energy, therefore, unanimously calls for an attractive and perpetuated policy of incentives, which mobilises the abundantly available private capital for investments in more efficiency and renewable energies. Together with many political stakeholders at European and German level, the partners of the panel agree that special tax incentives would give the required push for efficiency and renewable energies in the heating market. That large sections of the fiscal policy makers and some federal states, on the other hand, are opposed to this with the argument that such incentives would be lost subsidies and reduce tax revenues, lacks any basis. The evaluation of the KfW programmes shows a multiplier effect of 1:10 – one euro of subsidy leads to at least 10 euros or even more of investments. Tax incentives and subsidies for investments in efficiency and renewable energies will be self-sustaining.

Climate and resource protection with energy and technology



Source: Federation of German Heating industry (BDH), Federal Association of Chimney Sweep Craftsmen (ZIV)

Fig. 7: The German Installations 2015

ISH Energy: Showcase for a market economy-based sector coupling

At the end of 2016, the European Union published the "Winter Package". This contains the amendments to the EPBD, EED and the RES directive. Essentially, the EU requests member countries to develop a carbon emission reduction strategy. The winter package is characterised by numbers and percentage goals for higher efficiency and use of renewable energies.

Since autumn 2015, the Federal Government also deals with concepts for connecting the sectors transport, industry and heat. The planned strong expansion of renewable energies like wind power and photovoltaics will allow carbon emission reduction in the mentioned sectors, where over 90 % of their energy demand are covered today by fossil fuels.

Sector coupling in accordance with the Green Paper on Energy Efficiency: All electric

Efficiency First, direct use of renewable energies, and sector coupling are the three cornerstones of the discussion paper published in August 2016 regarding the Green Paper on Energy Efficiency. Especially, Efficiency First and direct use of renewable energies reflect, at least superficially, the dual strategy of efficiency and renewable energies demanded by the BDH for over six years. However, on closer examination, based on the above chart contained in the Green Paper, it becomes evident that a rather one-dimensional technological and energetic approach forms the basis for the Green Paper. By flexible load management, the large fluctuation in high capacities of wind and photovoltaic power planned for the future are to be compensated. According to the Green Paper, this requires, in addition to the flexible load management, application of purely electricity-driven technology with high efficiencies in the heating market and, simultaneously, the practically complete abandonment of gaseous and liquid fuels. This is accompanied by halving of the heat demand of the existing buildings.

Market economy-based, open-technology strategy for the cross-sector applications

The ISH Energy and Technology Panel puts forth a market economy-based, open-technology strategy against the one-dimensional all-electric sector coupling approach.

Taking this into consideration, even today a broad energy mix exists for supplying the heating market and a similarly broad mix of technologies exists for providing heat. In spite of this, high losses occur in the building sector especially due to largely outdated system technology and energetically insufficient building envelopes.

The vision for the future is: A practically significant increase in the share of power based on renewable energy to meet the energy demand in the building sector. However, gaseous and liquid fuels from power-to-X, biomass (wood and other biomasses), as well as solar thermal energy and photovoltaics are also available

at the same time. Especially, the gaseous and liquid fuels and biomass serve as storable energy resources to cover the peak-demand at cold, dark and calm days, when no or only a very low amount of renewable energy power is available.

In the case of technology mix, the scenario assumes a really strong build-up of the stock of heat pumps together with storage (electrically and thermally). Furthermore, hybrid systems, consisting of heat pumps and backup heat generators, based on gaseous and liquid fuels as well as biomass are also available as supplement. The digitalisation of heating technology allows further saving potentials and coupling with the electrical power sector, especially to feed renewable energy power into hybrid technology.

Highly efficient technologies, such as the fuel cell and combinations of PV for self-used electricity in heat pump batteries and management by a energy master, complement the portfolio, which is already presented today at the ISH Energy.

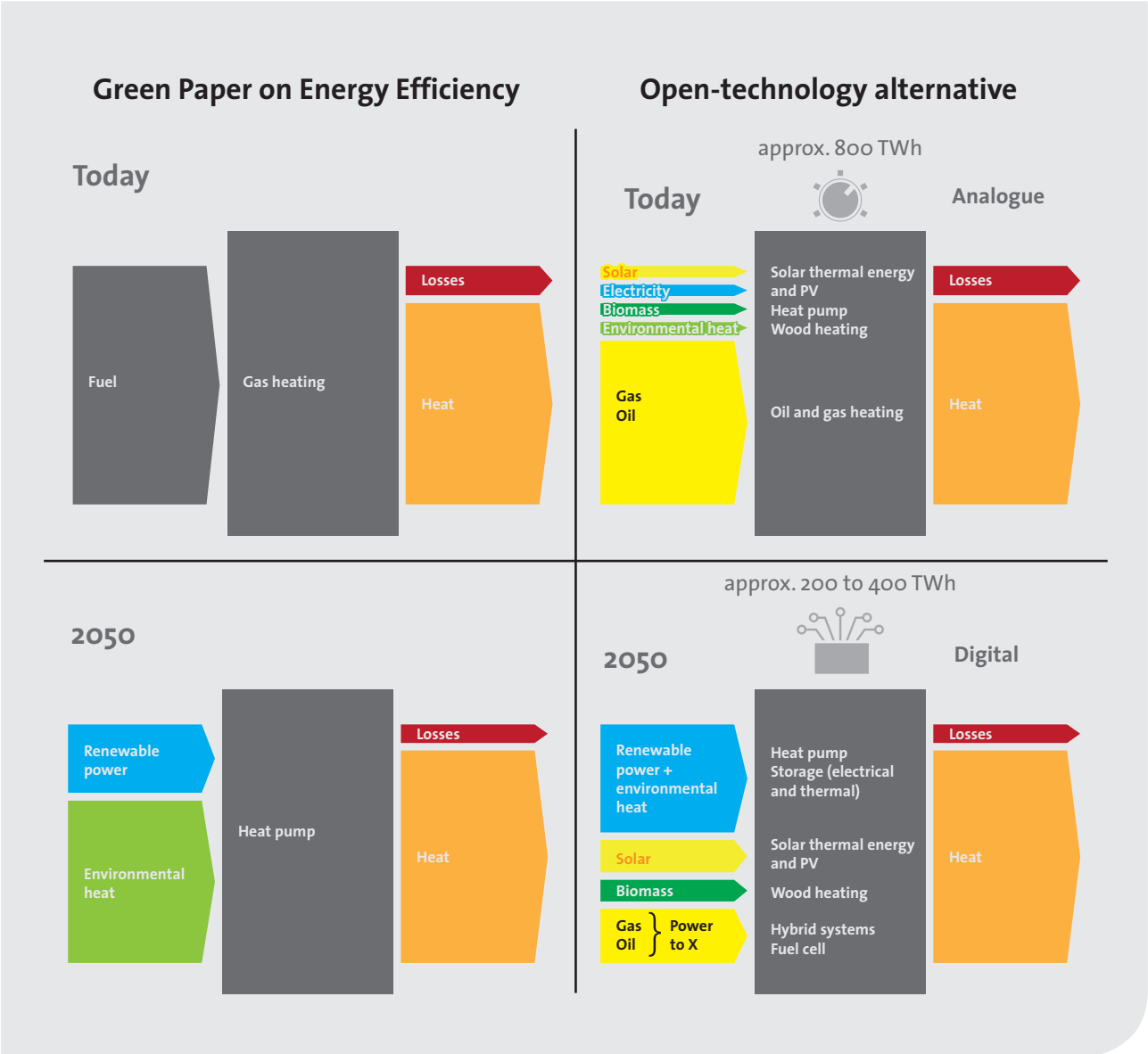


Fig. 8: The BDH is committed to an open-technology sector coupling

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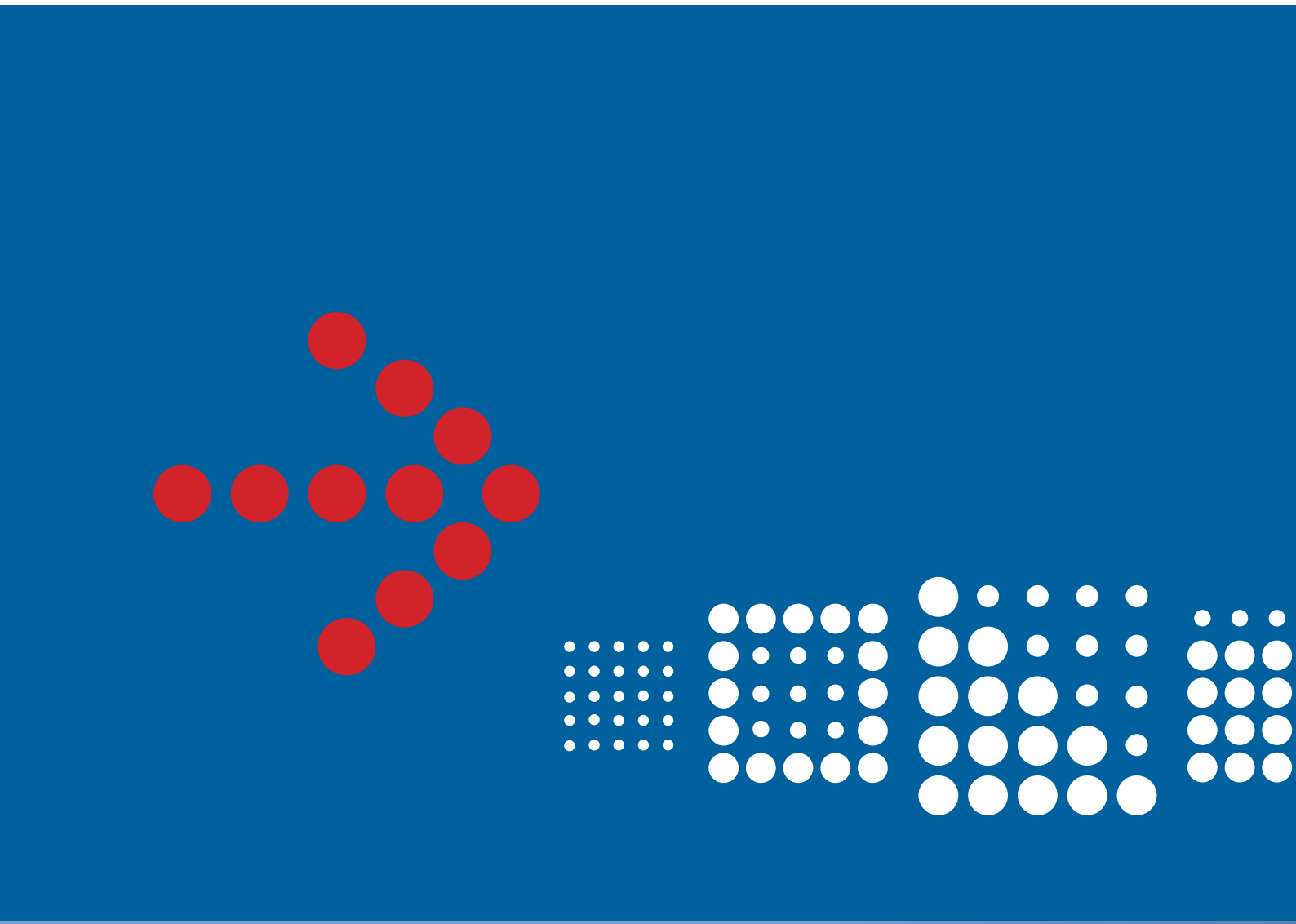


Energy label for heat generators and combination heaters

Energy label for heat generators and combination heaters

Energy label for the heating sector

End users have got used to this long time back, while purchasing washing machines, light bulbs, television sets and other household appliances: An energy label informs them about the energy consumption of the products by means of a colour scale from green to red and specification of the energy efficiency class. The energy label is intended to motivate you to choose products which consume little energy. This well-established energy efficiency label also exists in the heating sector since 2015.

As of 26 September 2015, manufacturers of boilers, heat pumps, combined heat and power plants (so-called space heaters),- combination heaters as well as manufacturers of domestic hot water heaters and hot water storage tanks must label their products. In contrast to the conventional product label, where only the product is labelled, energy labels are also issued in the heating sector for the sale of so-called product packages (space heater, combination heater or domestic water heater together with other components of the domestic hot water system). In such a case, one speaks of a product package or also a label of a combination system.

Product label

The product labels are created by the manufacturer and enclosed with the products. The energy efficiency of the relevant space heater, combination heater and/or the domestic hot water heater (rated output of up to 70 kW) and/or the heat retention losses of the hot water storage tank (up to 500 l storage volume) are determined by taking into account the energy-related product parameters. The calculation procedures for this can be found in EU Regulations (EU) No. 811/2013 and No. 812/2013, the accompanying documents of the EU Commission as well as the harmonised European standards. Based on the calculated energy efficiency, the product is classified according to the scale from G to A++ (for heaters) and G to A (for domestic hot water heaters and hot water storage tanks).

Package label (label of a composite system)

Package labels must be issued when space heaters, combination heaters or domestic hot water heaters, which are already marked with a product label, are combined with other components to form a package and are offered for sale to end users (so-called combination systems according to EU Regulations No. 811/2013 and No. 812/2013). Temperature regulators, solar packages, including solar storage units and other heat generators (auxiliary heaters) are considered as possible components. Generally, the issuance of a package label leads to a higher energy efficiency class. The installer is obligated to communicate the energy efficiency class of the combination system to the end user when preparing the offer: for example, in the case of a combination of gas or oil condensing boiler with a solar thermal system.

Special case – combination heater

Combination heaters receive a so-called “double label”: for the space heating function and for the domestic hot water heating function. An energy efficiency class is specified for each one of these two functions. The double label can be included in the product label as well as the package label.

Energy label for solid fuel fired boilers

As of 1 April 2017, solid fuel fired boilers will also receive an energy label for solid fuels with a thermal rated output of up to 70 kW. All modern split log, pellet and woodchip boilers are affected by

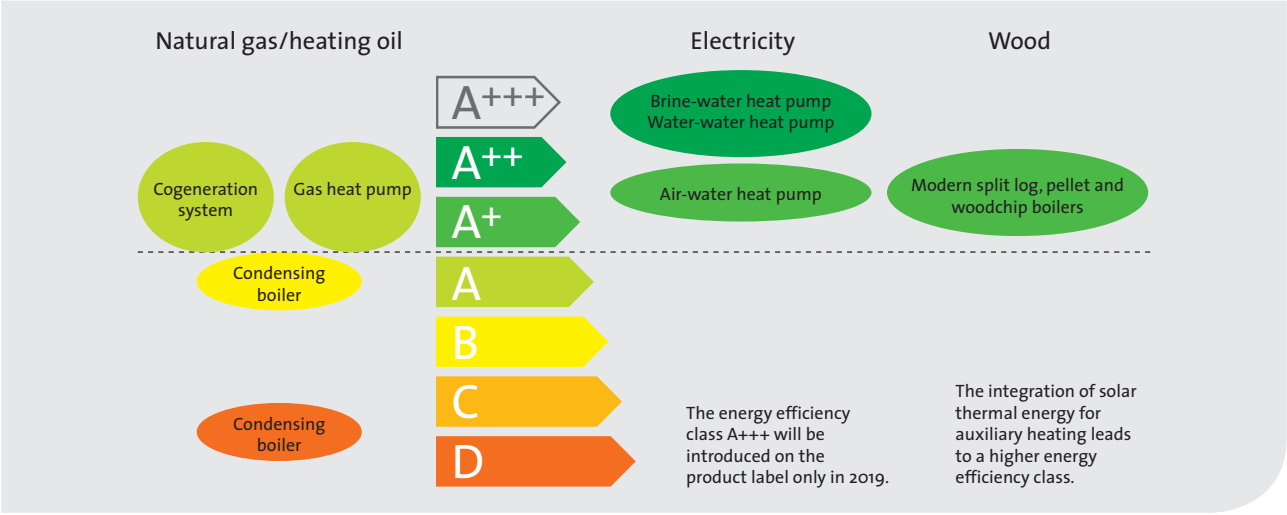
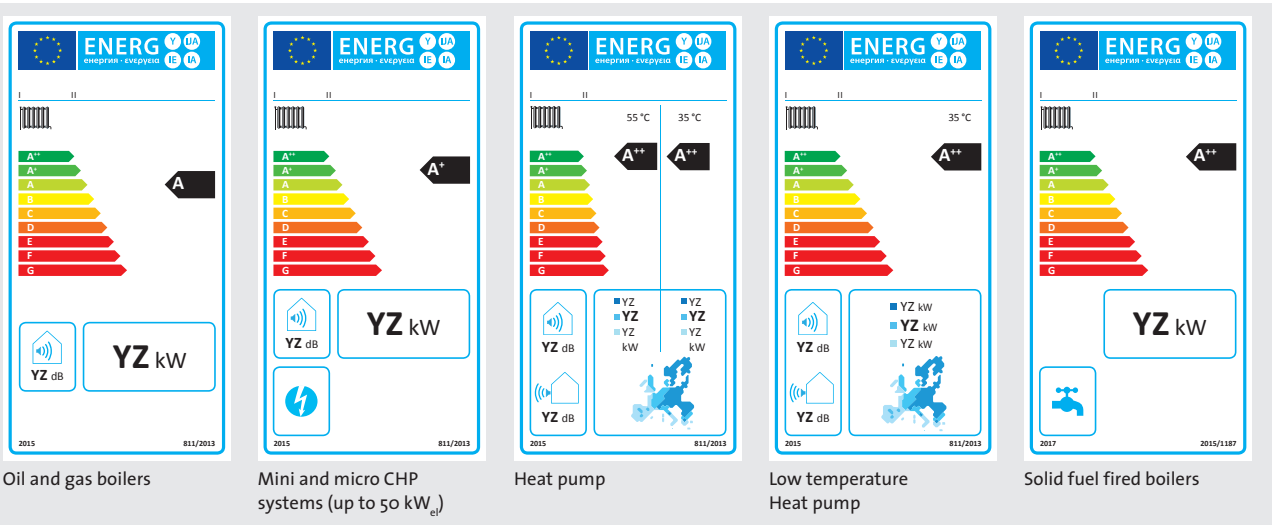


Fig. 9: Energy efficiency class of the common heat generators (only for the space heating function)

this. Modern wood boilers generally fall under the energy efficiency classes “A+” and “A++”. If the wood boiler is offered to an end user together with a solar thermal system for auxiliary heating, another heat generator (auxiliary heater) or a temperature regulator in the product package, the energy efficiency class of this product package must also be indicated.

Energy label for old boilers

As of 1 January 2016, gas and oil boilers, which are older than 15 years, have been gradually equipped with an efficiency label for old heating systems. In this way, end users are informed about the efficiency status of their heater. The so-called old heating system label takes into account the same assessment principles as the energy label for new space heaters. This gives the end users the opportunity to compare the energy efficiency class of their old boiler with that of a modern space heater. The heating system label is issued by chimney sweepers, heating installers and certain energy consultants. As of 2017, it is compulsory for district chimney sweepers to provide energy labels for old plants which have not yet been labelled. When the label is affixed, the end user receives a flyer, which explains the energy label for new devices, and refers to the energy consultancy offers and subsidies of the federal government. Other countries are in the process of introducing a similar system in their territories.



Oil and gas boilers | Mini and micro CHP systems (up to 50 kW_{el}) | Heat pump | Low temperature Heat pump | Solid fuel fired boilers

Fig. 10: Energy labels for heat generators (product labels)

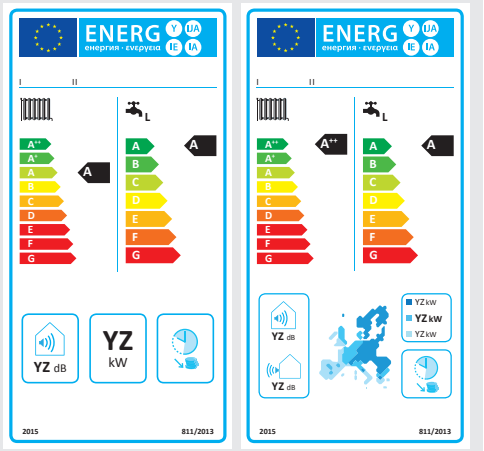


Fig. 11: Energy labels of combination heaters

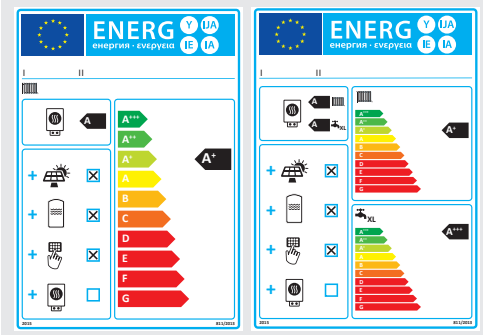


Fig. 12: Package label for space heating function and combination heating

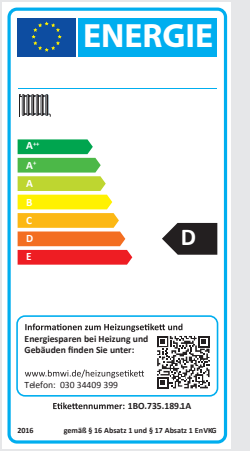


Fig. 13: Energy label for old heating systems

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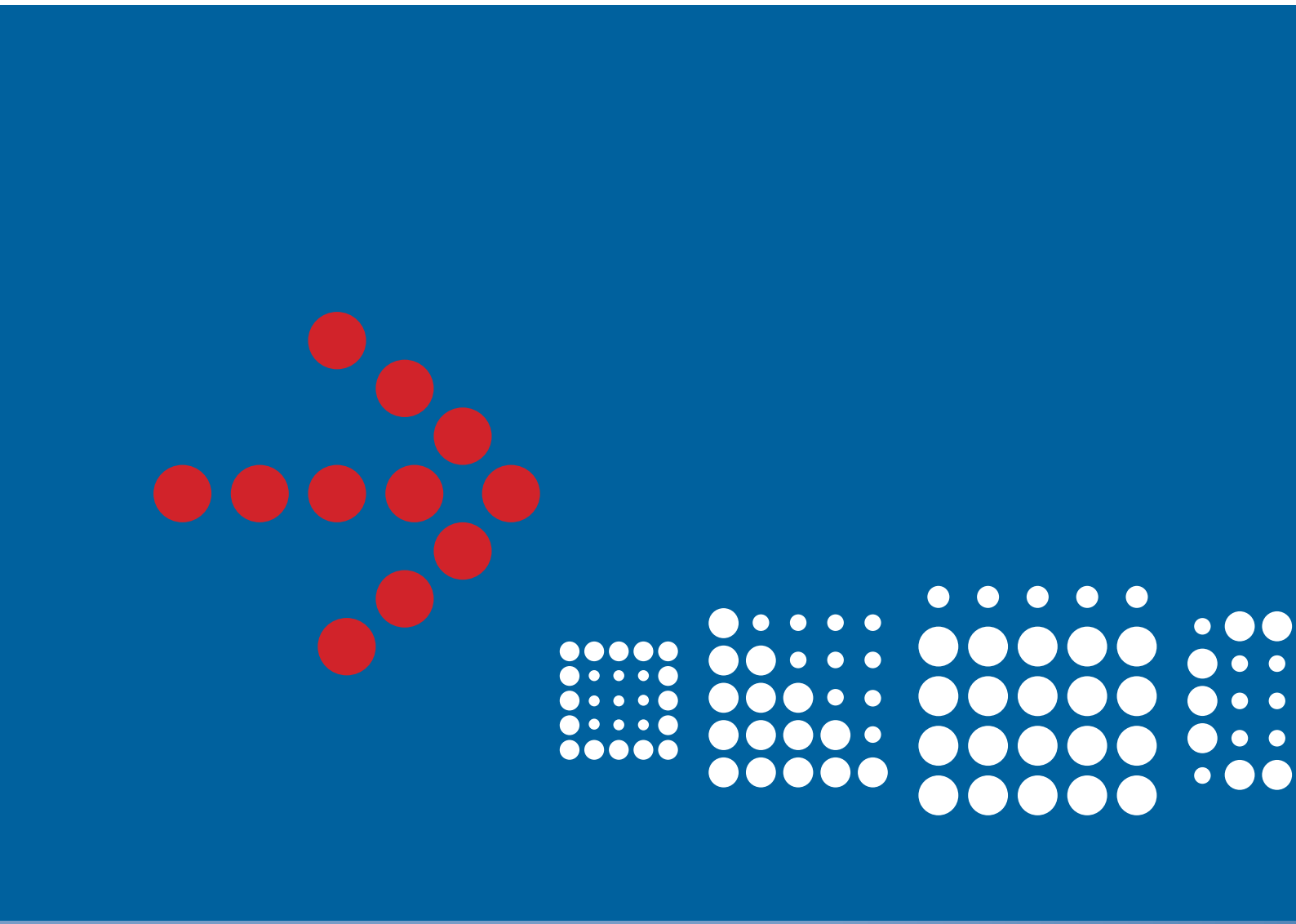


Energy sources in the heating market

- Natural gas
- Heating oil
- Wood energy
- Solar energy
- Geothermal energy and environmental heat
- Electricity in the heating market

Natural gas: high availability with integration of renewable energies

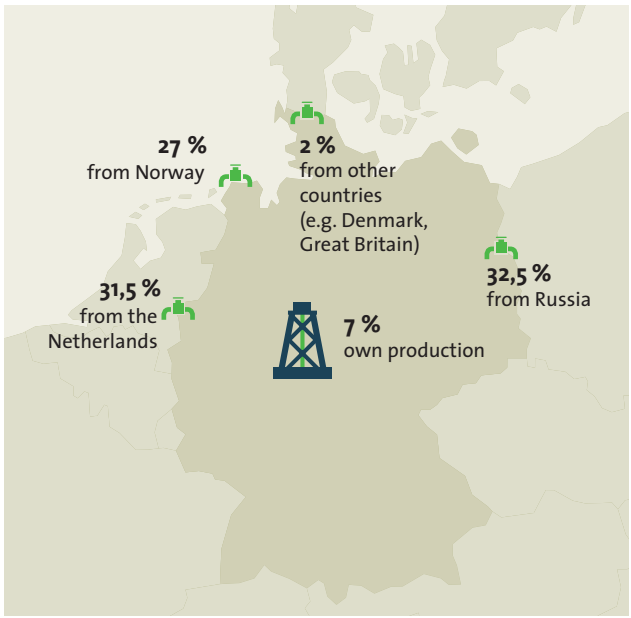
Natural gas: Properties and reserves

Natural gas is a combustible, methane-containing natural product and is the third most important source of energy in the world, next only to oil and coal. Natural gas is particularly clean, emits almost no particulate matter and causes significantly less CO_2 emission than other fossil fuels. Renewably produced natural gas, for example as bio-natural gas or through the power-to-gas process, is actually climate-neutral. Natural gas can be combined with renewable energies in a wide range of applications, making the energy medium the partner for renewable energies. The share of primary energy consumption in the world in 2015 was 24 %. The global reserves that can be tapped economically satisfy the energy demand also over the long-term. About 3,538 billion m^3 of natural gas was produced in 2015.

Gas infrastructure in Germany and Europe

Germany has an extremely well-developed infrastructure for natural gas. The transport network and infrastructure available all over the country covers a pipe system of 530,000 km. Apart from this, Germany offers the biggest natural gas storage capacities in Europe. They allow a storage of gas reserves for a period of approx. four months.

Natural gas is transported via pipelines or as liquid natural gas (LNG) in giant tankers. About 35 % of the natural gas originates from Russia, another 58 % from European countries, in particular, Norway, the Netherlands, Denmark and Great Britain. 7 % of the used natural gas is produced in Germany itself (BMWi 2015).



Source: BAFA 4/2014, BMWi

Fig. 14: How the natural gas comes to Germany

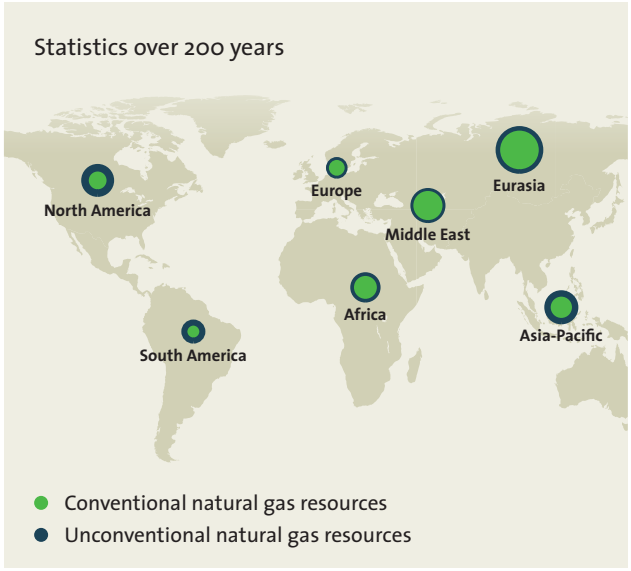


Fig. 15: The resources all over the world have a statistical range of coverage for over 200 years.

Natural gas can be green

Natural gas generated from biomass is gaining increasing significance. The biomass includes residual materials such as sewage sludge, biowaste, manure or parts of plants. Bio-natural gas has a high surface efficiency and can be generated continuously over the entire year, in contrast to wind and solar power. Treated to natural gas quality, it can also be easily stored as bio-natural gas in the gas network and can be transported to the place where it is consumed via the existing infrastructure. As a result, the natural gas consumers are gradually switching to renewable energies through increased supply of bio-natural gas.

Power-to-gas: Green electricity becomes natural gas

The production of electricity from renewable sources strongly depends on the weather and the seasons. Accordingly, the returns are fluctuating. In view of the steady growth of wind power and photovoltaics with simultaneous slow expansion of the power grids, the occasionally extreme peaks in the production of electricity are not being sufficiently used. The power grids can only store a limited amount of energy. Hence, the expansion of

renewable energies urgently requires storage techniques that will help to adapt the fluctuating power supply to demand. Electric storage systems such as batteries are suitable to only a limited extent. Even pumped-storage power plants can hardly be built in sufficient quantities owing to geographical conditions.

Power-to-gas is a new option for worthwhile use of surplus wind and solar power. The synthetic production of natural gas makes the fuel a renewable resource that can contribute significantly to reduction in carbon emissions. This applies to all sectors – electricity generation, the transport sector and the heat market.

Power-to-gas technology makes it possible to store green electricity in large quantities as needed. By electrolysis, the surplus power is converted into hydrogen or further to methane. The synthetic natural gas can then be fed together with conventional natural gas into the largest energy storage facility in Germany, the gas network. This supply and energy reserve is available to all users via the extensive gas network system, that is, also to the heating market.

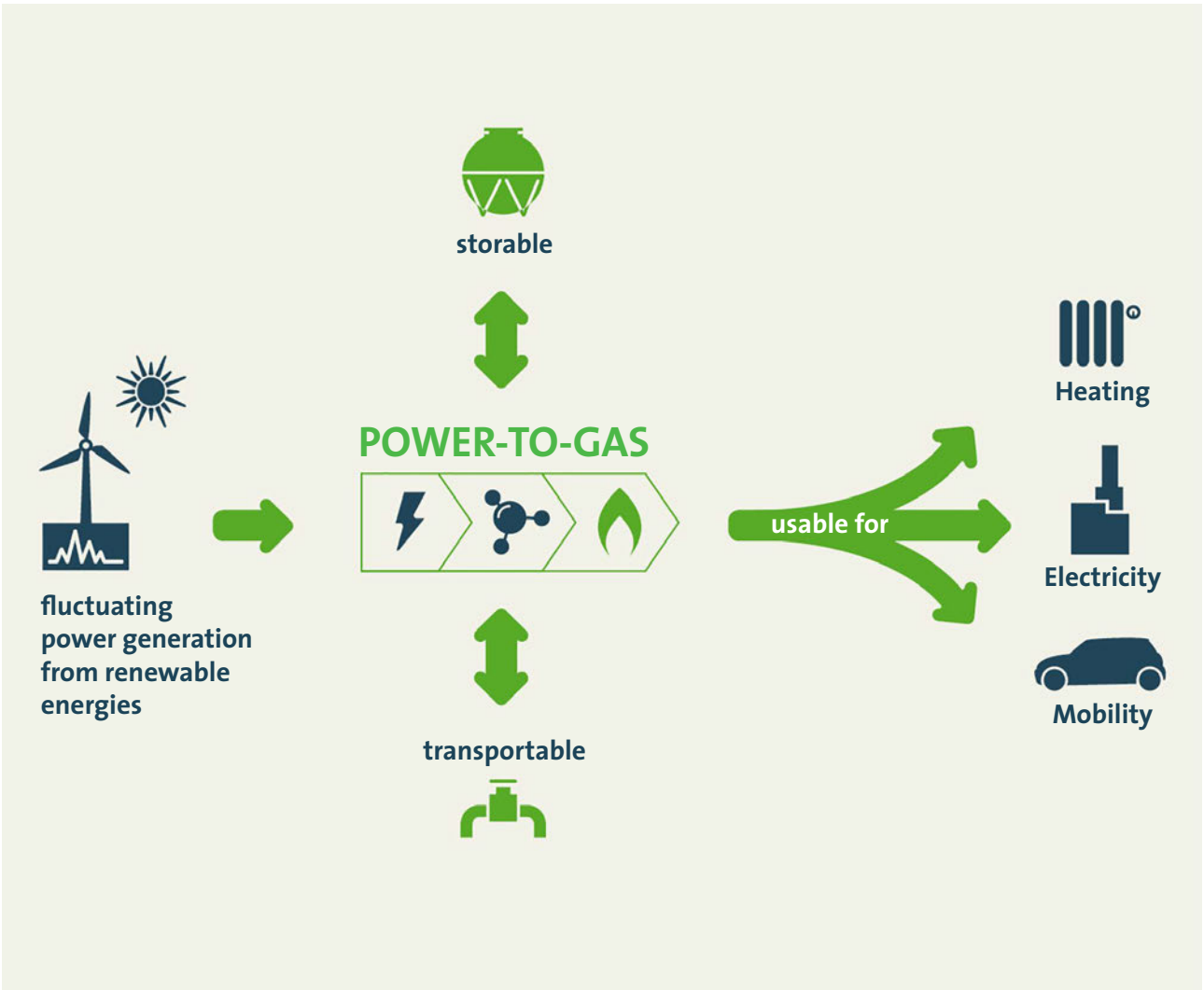


Fig. 16: Power-to-gas: Storage for excess green electricity

Heating oil turns green

Heating oil and climate-friendly liquid fuels: ideal partners for an affordable energy revolution

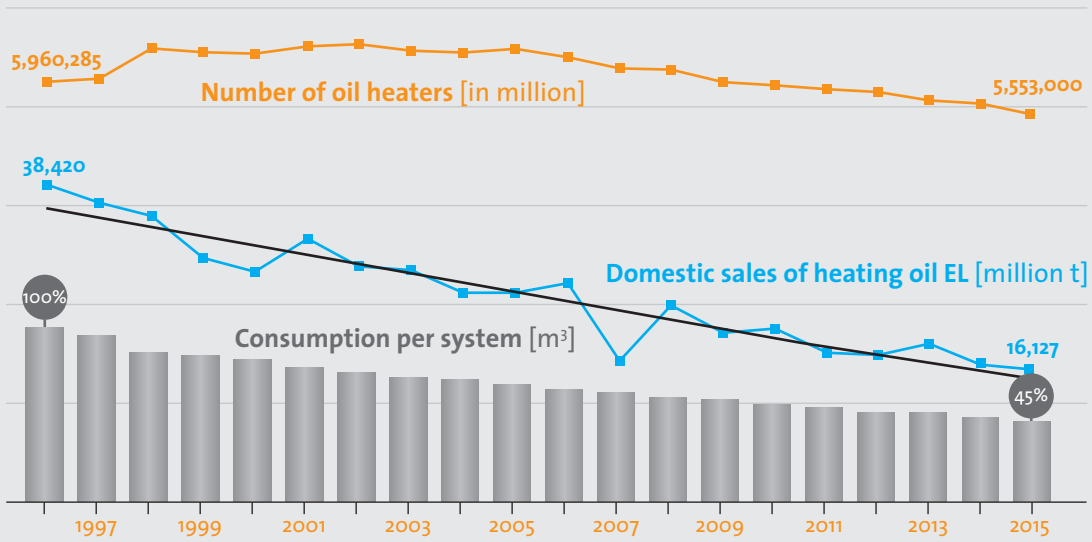
Today, heating oil offers safe and reliable heating to 20 million people, about a quarter of all Germans. The total of 5.6 million oil heating systems are used mainly in single and two-family homes in rural areas. Thanks to efficient condensing technology, which is very often combined with renewable energies, modern oil heating systems already contribute measurably to the reduction of greenhouse gas emissions. This is how heating oil consumption in Germany has more than halved in the past twenty years. Notwithstanding the fact that the number of oil heaters has remained nearly the same during this period.

Favourable entry into the energy revolution

Modernisation with oil condensing technology offers a high cost-benefit ratio. Therefore, they are ideal for entry into the energy transition process and can make an important contribution to meeting the modernisation requirements of German heating systems. Modern oil heating systems offer long-term usage due to the expansion to hybrid heating systems and the development and future use of greenhouse gas-reduced, even climate-neutral, liquid fuels.

Modern fuel for efficient technology

Every litre of heating oil contains at least 10 kWh of energy. This is, for example, sufficient for heating 200 litres of water from 10 to 55 °C. Owing to this high energy content, heating oil is particularly economical. If you order heating oil today, you will get low-sulphur heating oil. This ensures consistently high energy utilisation and therefore, decreases consumption. At the same time, it reduces the maintenance requirements for boilers and burners. Since heating oil is a safe, storable and grid-independent energy source that ensures constant supply, oil heating systems are ideally suited as the basis for hybrid heating systems, which incorporate renewable energy technology. More than 50 % of all oil heating systems today are already combined with renewable energy. Almost one million oil heaters are operated in combination with solar thermal energy.



Source: ZIV report; BAFA April 2016

Fig. 17: More efficient systems always ensure high outputs and considerably lower consumption

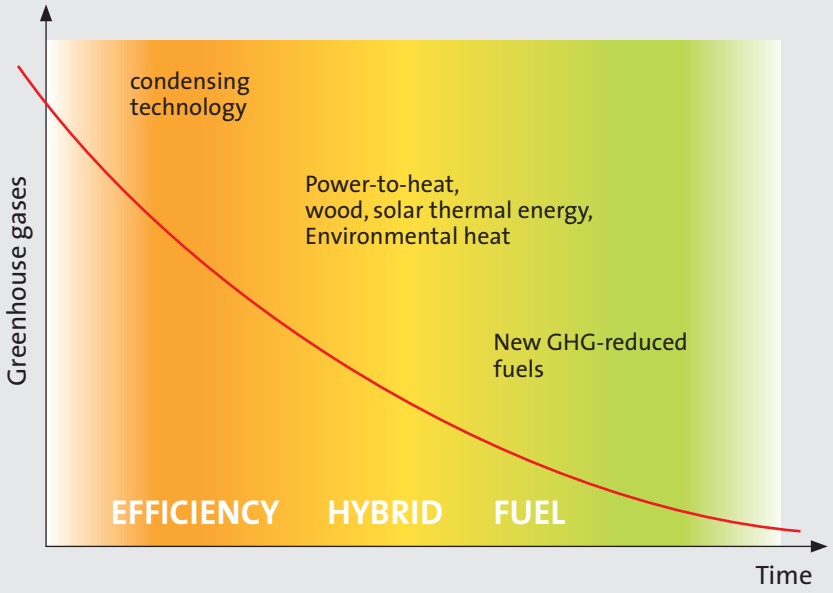


Fig. 18: The emission of greenhouse gases can also be reduced on the fuel side

Basis for new technologies

In future, these hybrid systems can be supplemented by an additional component – power-to-heat. The idea here is to convert the potential of electricity generation from economically or technically not usable renewable energy sources into heat by means of electrical heaters. Even today, more electricity is being produced locally on very windy days than what can be transported by the grid. Therefore, renewable electricity must often be "regulated" in peak times due to the lack of line capacities. However, costs are incurred for the electricity not produced. Instead of temporarily switching off renewable electricity generators such as wind turbines, a systematic activation of the power-to-heat module can be used to exploit their potential of electricity generation for heat generation. The special advantage of power-to-heat-capable oil heating systems: They do not require additional storage capacities of power plants, which would have to be kept at a high cost. On the other hand, heating oil is always available – thanks to the tank at home.

New fuels for the future

The emission of greenhouse gases can be reduced not only through highly efficient heating technology or suitable building insulation. Bio-heating oil, to which the liquid components from renewable raw materials are added, is available even today. Bearing the future in mind, work is being done on processes with which new synthetic fuels can be produced. If the supply of renewable electricity continues to grow, for example, renewable hydrogen and CO_2 could also be used for fuel production. This process is called power-to-liquids. It requires sufficient availability of renewable electricity. According to the German Mineral Oil Association (MWV), this could be used mainly in countries with significantly more solar hours where solar power can be generated at lower costs. In addition to the use of renewable hydrogen, various approaches to the development of new fuels are currently being pursued: From A as in algae use, to X as in XtL, which refers to be the production of synthetic liquid hydrocarbons from a wide variety of carbon sources, for example, from residues and waste materials. On the basis of these research projects, liquid fuels could also be used in a climate-neutral manner in the long term. Thus, in combination with fluctuating renewable energy sources, storable energy will also play an important role in the future energy mix.

Wood energy

Wood is on the rise

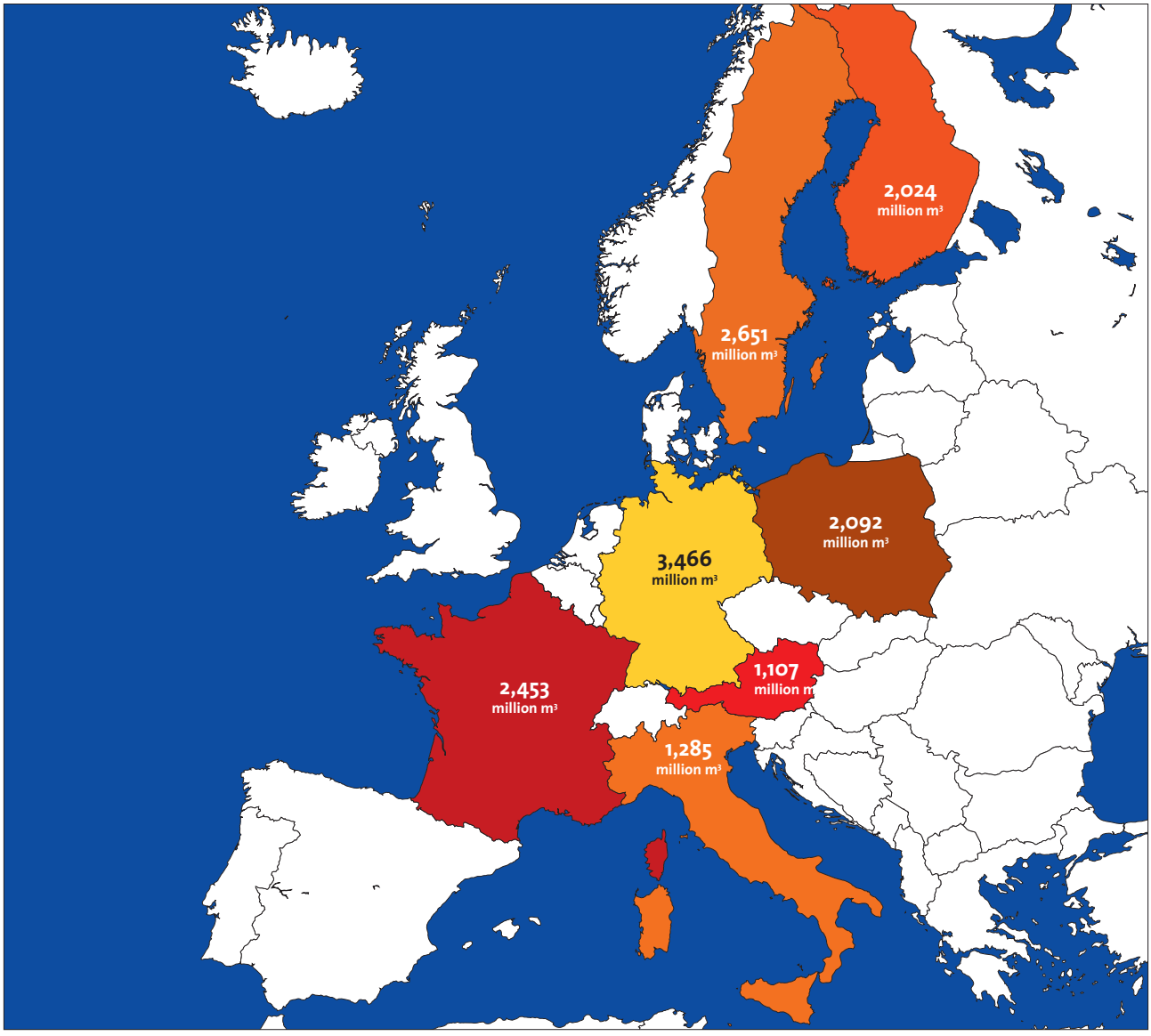
Wood is an attractive energy source: It shows a very good ecological balance and a constant price trend. Moreover, wood is an indigenous, renewable fuel, which means short transport distances, local jobs and domestic value creation. So, there are good reasons why nearly 20 % of the households in Germany rely on wood for heat generation nowadays. A fifth of these consumers even have centralised wood-fired heating, which is also used for domestic hot water heating.

No wonder: These days, modern automated fireplaces make the operation as comfortable as never before. Wood almost matches the traditional fuels, oil or gas, in terms of its comfort.

Good for the forest – good for the climate

A sustainable use of wood has positive effects on the maintenance and protection of the forest: A forest that is thinned out well, is stable against environmental impacts. Even the notions of natural forests and utilisation are not contradicting each other. On the contrary, forests subjected to sustainable use have a high ecological value. The various wood energy assortments are usually produced from non-sawable joint products, which are produced during timber harvesting or cutting in the sawmill.

Using wood is also good for the climate. This is because wood, as a renewable resource, is CO_2-neutral: When burned, only the amount of CO_2 that is absorbed by the tree during its growth is released.



Source: Eurostat

Fig. 19: Wood reserves of selected European countries in 2010

Fig. 20: Pellets

Fig. 21: Split logs

Fig. 22: Wood chips

Pellets, briquettes, split logs and wood chips

Modern heating systems use the energy source wood in the form of pellets, briquettes, wood chips or split logs.

Wood pellets are small, standardised, cylindrical pellets made from natural, untreated wood. For their production, the wood chips produced in the sawmill are first dried and then pressed into pellets in dies. The chips join naturally, owing to their own lignin. The production of pellets often takes place directly in the sawmill. 2 kg wood pellets correspond to the energy content of about 1 litre heating oil.

The production of wood briquettes is similar. These are available in various shapes – round, square, with or without a hole. They are mostly heated in single room furnaces, such as wood burners, open fireplaces or tiled stoves.

Split logs are also increasingly used for heating since a few years. Basically, any wood type is suitable for this purpose. To ensure a high energy output and a clean combustion, the wood must be as dry as possible. Two years of storage in the open air under a rain shelter are ideal. Wood with a water content between 15 % and 20 % has an average energy value of 4 kWh/kg.

Wood chips are manufactured in various ways. Coniferous wood trunk pieces that are accumulated in the saw mills and are not usable as sawn wood are chopped directly. However, they are generally used for paper making. The most common option is the crushing of the remaining non-sawable wood from the timber harvest or landscaping.

For quality assurance, the international standard ISO 17225, under which the product is defined, is available for all wood fuels. For pellets, wood briquettes and wood chips, this standard has been implemented in the ENplus certification, with a few additional specifications, such as for transport and delivery of pellets.

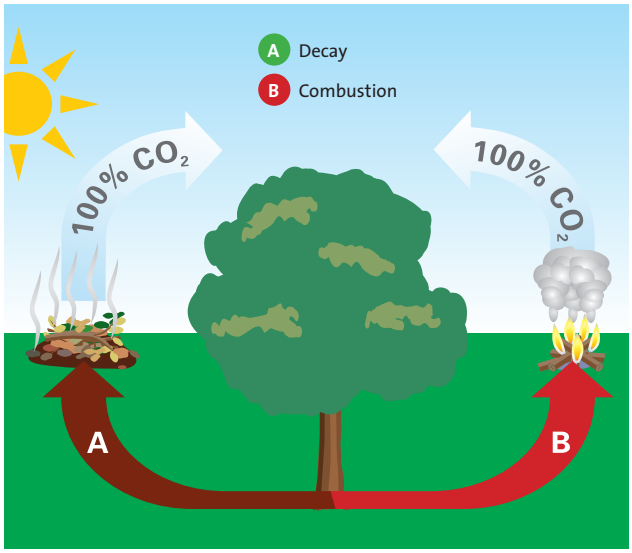


Fig. 23: If there is decay in the forest (A), the same amount of CO_2 is generated as during combustion (B)

Sustainably available

Nearly one-third of Germany is covered by forest, and this forest area has been constantly increasing over decades: After the 2nd World War, by approx. 1 million hectare. The Federal Forest Inventory 3 (BWI 3) has identified 50,000 hectares of forest growth for the period between 2002 and 2012.

The forests in Germany have a timber stock of approx. 3.7 billion m^3. Each year, more than 11 m^3 of wood are grown per hectare of forest – this amounts to more than 121 million m^3 over the entire forest area. This puts Germany in the second position in Europe, after Russia, even ahead of the "traditional" forest countries such as Finland and Sweden.

One reason for this is a legally secured sustainable management, which ensures that only as much wood is cut as can be regrown. This economic approach was first described in 1713. The BWI 3 also found that the forest in Germany has become more natural, which was achieved by an increase in foliage and mixed stocks, naturally grown forests and old trees as well as a higher proportion of dead wood.

Solar energy

Solar heat: ideal supplement for all heating systems

Solar thermal systems are used for domestic hot water heating, auxiliary heating or swimming pool heating. In Germany, about 60 % of the annual domestic hot water requirement of a single-family home can be met by a solar thermal system of typical size. Auxiliary heating solar systems of typical dimensions cover 10–30 % of the total heat demand, depending on the insulation standard of the building, while up to 100 % for passive houses. State-of-the-art heating technology is a combination of a modern condensing boiler, an efficient heat pump or a central wood-fired boiler with a solar thermal system.

In summer, a modern solar thermal system can cover the entire domestic hot water demand and heat demand of a house for four months or more. During this period, the radiators are switched off. Solar energy for the heating market can optimally support all primary heat generators on the market and its typical design substitutes up to 30 % of the otherwise used fossil fuel. In addition to preparation of domestic hot water and auxiliary heating, air-conditioning or process heat, as well as the provision of district and local heating are other applications of solar thermal energy.

Photovoltaics: Combining regenerative power and heating systems

Another use of solar energy is direct power generation with photovoltaic systems. A photovoltaic system is primarily used to proportionally meet the household electricity demand. Any excess beyond the normal consumption opens up the possibility of generating heating energy. Using this excess current for heating can be more sensible than feeding into the grid. This is all the more true since the feed-in tariff is constantly falling and has fallen by now below 13 cents for new plants up to 10 kWp.

The utilisation of the excess PV current is particularly efficient in combination with a modern electric heat pump.

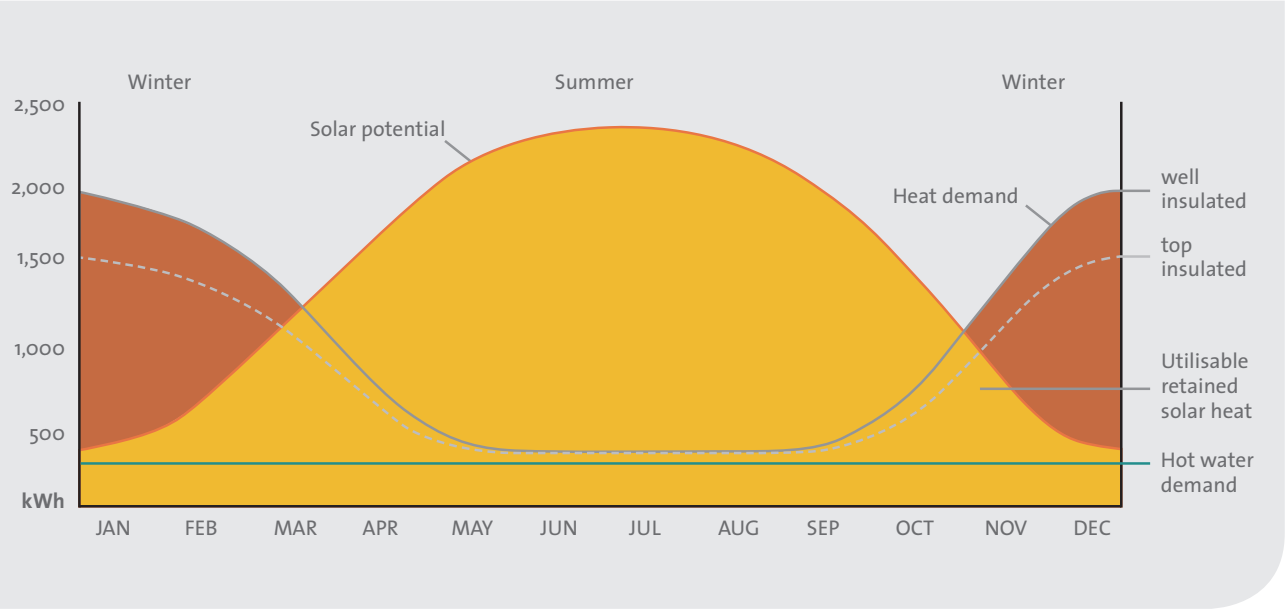


Fig. 24: The solar coverage rate during operation of a solar thermal system over a year

Geothermal energy and environmental heat

Both on the national and international level on climate and resource protection, the application of near-surface geothermal energy and ambient heat is considered and is an integral part of sector coupling. Application is usually via air-water, brine-water or water-water heat pumps, which draw up to 80 % of the energy for heating and domestic hot water from the environment and the remaining 20 % from electric drive energy. The more "green" the electricity becomes, the more environmentally friendly is the heat pump operation.

The utilisation of near-surface geothermal energy and environmental heat via heat pump systems can be optimally combined with the "Power-to-Heat" concept. According to this concept, the electricity generated in the future by wind power plants and photovoltaic systems is to be applied and stored in the form of heat. The consumption of energy can be adapted to the generation using the smart-grid-enabled heat pump, which uses geothermal energy and ambient heat. As switchable and controllable systems, they can flatten out local power peaks during power generation and store the environmental energy in the form of heat energy. With a stock of more than 0.8 million systems, heat pumps offer a lot of potential for use in smart systems even today. Heat pumps are particularly well suited for sector coupling applications at the interface between the electricity sector and the thermal market.

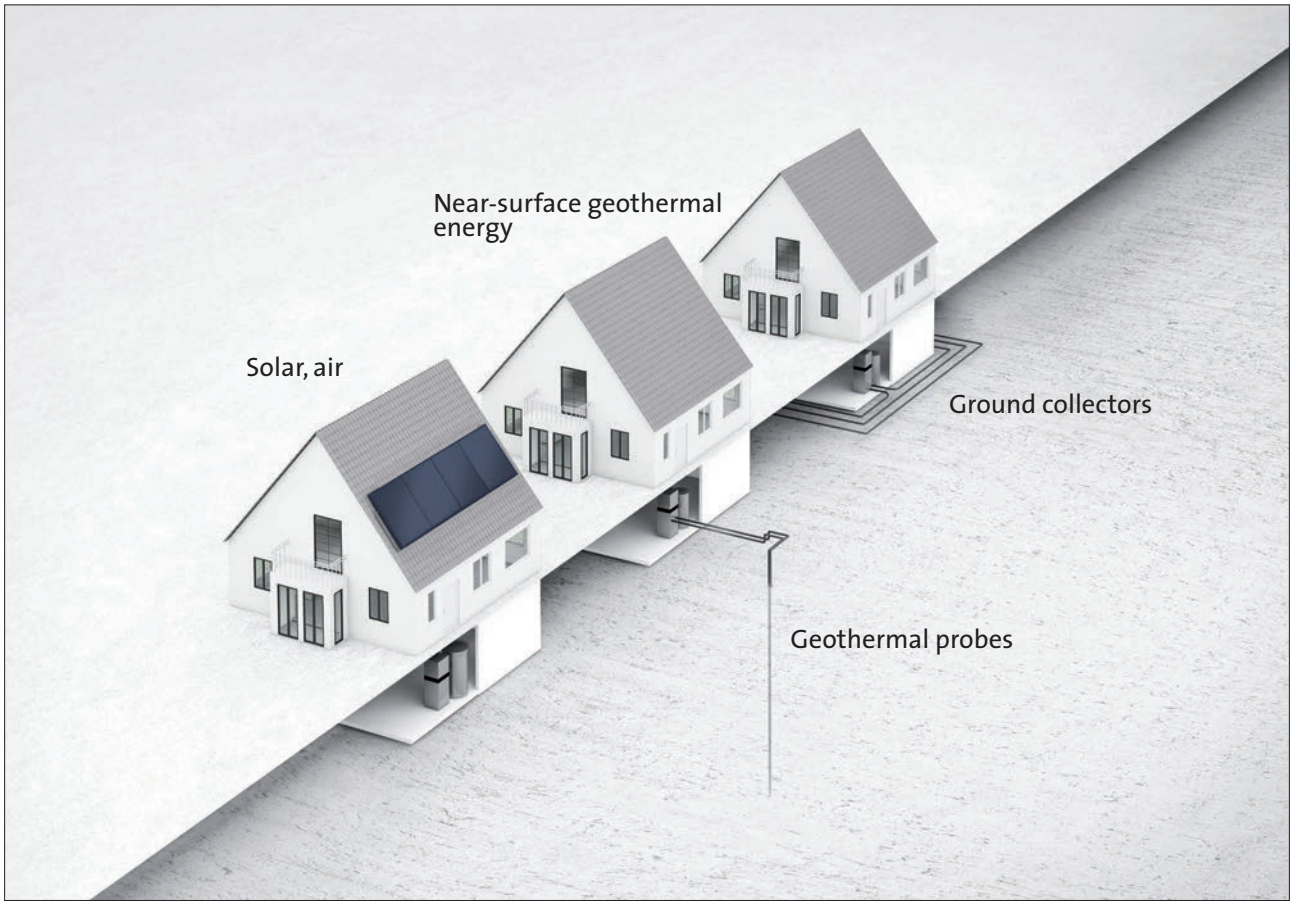


Fig. 25: Various sources of renewable energy

Electricity in the heating market

Electricity: flexible and sustainable

Electricity convinces many builders in the heating market because of its high flexibility and sustainability. Modern electrical heat applications such as the electric heat pump as well as a wide range of systems for ventilation technology and domestic hot water heating stand for energy efficiency and comfort.

Share of renewable energies is experiencing steady growth!

Today, power in Germany is generated to a large extent from renewable sources of energy with a current share of over 30 % in German electricity generation. By the year 2030, the share is supposed to reach about 50 %, and by 2050 even 80 %. This means that electricity will develop into "green energy" in the coming decades. Even today, many consumers use green electricity tariffs and thus, CO_2-free electrical energy.

Thus, the use of electrical domestic heating technology is becoming more and more environmentally friendly – as shown by an analysis of the primary energy factor, which fell from 2.4 to 1.8 in Germany due to the high share of renewable energies. Due to these developments, electrically powered heating systems with a high share of renewable energies, such as heat pumps, could continue to gain acceptance in the long term. Heat pumps are a popular heating system, particularly in new buildings. Due to the efficient building envelope specified by EnEV (Energy Saving Ordinance), the heat demand is so low that the heat pump with its low-temperature principle finds ideal conditions. Today, nearly one-fourth of the new buildings are equipped with heat pumps.

Domestic power generation is becoming increasingly popular!

More and more homeowners with a PV system are interested in using their self-generated electricity. However, self-generation has a major handicap: The current often cannot be used when the sun is shining. Therefore, an accumulator and an energy management system are necessary. The system calculates how much solar power is generated and consumed in the course of a day, and how much is to be fed into the grid or purchased. In addition, it automatically controls the loads in the household.

A heat pump can be easily integrated into such a system. In principle, approx. 30 % of the annual power requirement of a heat pump can be covered in combination with a PV system, and when using an additional intelligent management system even around 50 %.

Electricity is also produced in the building using a "power-generating heating system". As a result of the combined heat and power generation, about 60 % of the household electricity demand can be met by self-generation.

The electricity network is becoming smart!

Electricity can be used "intelligently" not only in your own home or apartment. In the future, the entire electricity market will also turn to be "smart": Intelligent electrical networks, so-called smart grids, ensure the networking and control of electricity generators, power and heat storage units and loads. This would make it easier to balance out production peaks, and to distribute energy more efficiently and thus, cost-effectively.

With appropriate interfaces, it would be possible, e. g. to put devices into operation when a particularly large supply of electricity is available and the electricity is particularly cheap. With the help of the smart grid technology, heat pumps can be used in a worthwhile way to switch the devices on when excess current is available. The use of additional heat storage units would regulate the power consumption of the heat pump and adapt it to the supply of renewable energies. Cooling and air-conditioning in conjunction with the heat pump would also be possible. Many heat pumps are already equipped with the "smart grid ready" label, which means they are designed for integration into a smart grid.

New trend: the Smart Home

Today, electrical domestic heating technology is equipped with high-precision electronic control systems and allows exact and adequate dosage of heat and hot water. No other energy source can be used as "intelligently" and flexibly as electricity, e. g. also in the Smart Home.

The Smart Home is a building in which all technical building components are networked. Electrical domestic heating technology can be integrated very well here. Many electrical devices and systems have appropriate interfaces today. A Smart Home enables comprehensive energy management that is affordable in particular in single and two-family homes: From lighting and electrical household appliances through roller shutters or awnings up to the heat pump or ventilation system, all applications can be centrally operated by wired or wireless control. They can even be controlled with a smartphone or tablet when away from home. In addition to control and programming, the operation and consumption data of the networked applications can be recorded and thus, potential savings can be identified.

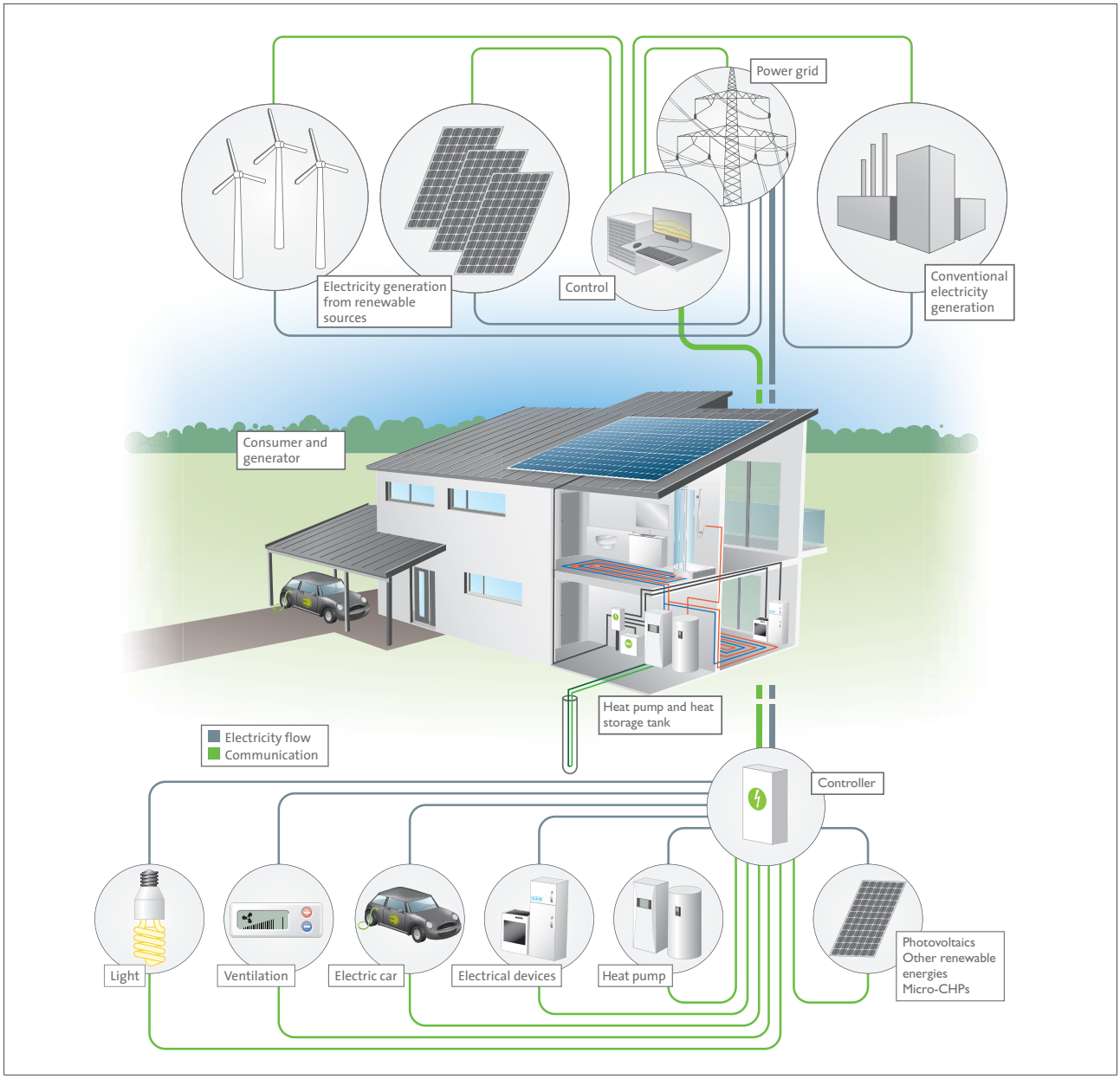
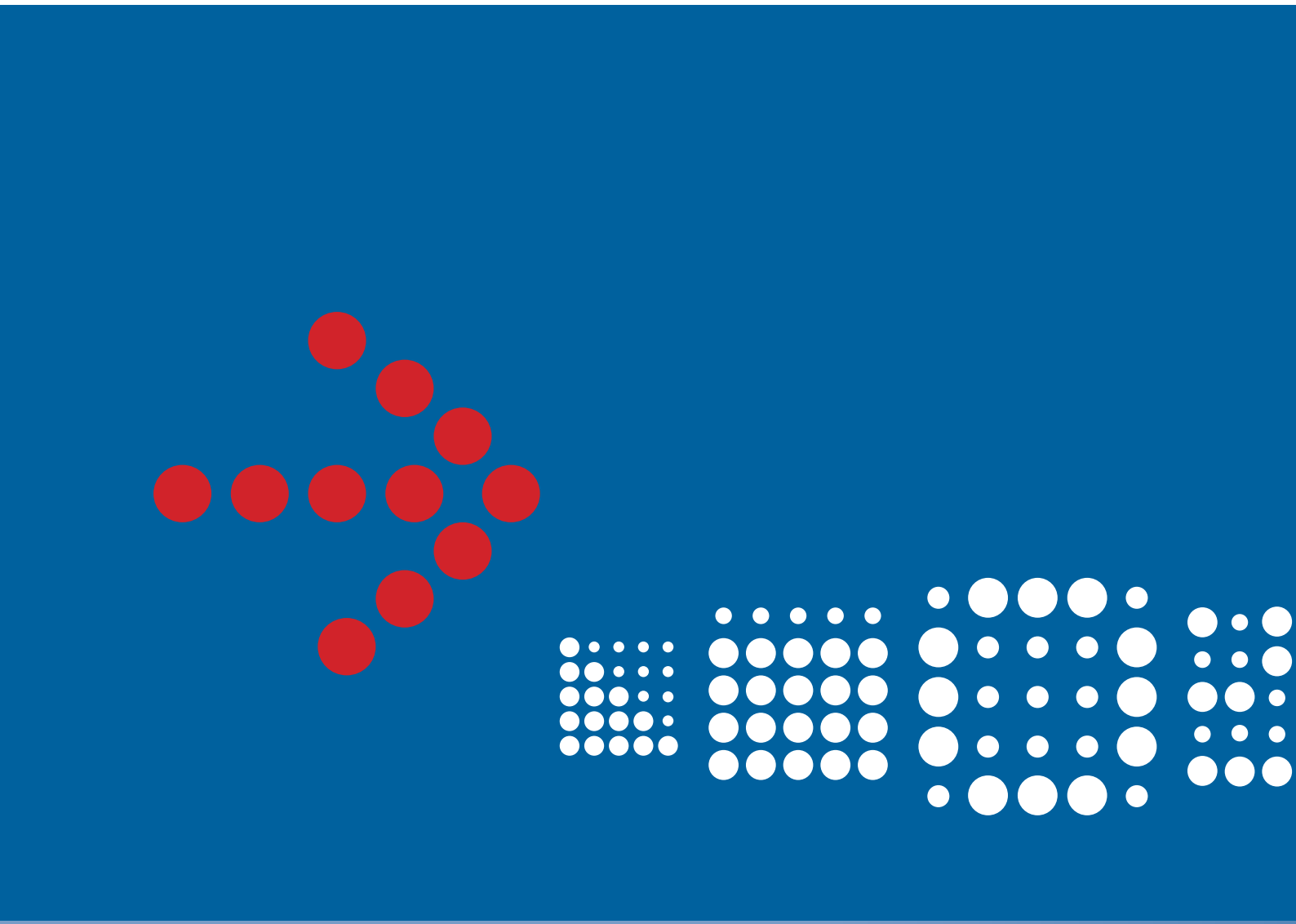


Fig. 26: Smart Grid and Smart Home layout

ISH Technology and Energy Panel



Modern heating systems

Modern heating systems

Energy efficiency and renewable energies

Today, in new construction and renovation of old buildings, optimal system solutions for heating technology are available for all fuels. Finally, the right system always depends on the framework conditions: Besides the legal requirements, the heat load of the building, its purpose of use, the user behaviour, and, of course, the preferences of building owners should be considered here in particular.
The systems presented in this brochure for the heat supply of buildings, domestic hot water and apartment ventilation are internationally considered as state of the art. They convert fuels such as gas, oil, wood and electricity very efficiently into heat and also use renewable energies (e. g. solar thermal energy, ambient heat, etc.) during this process.

The system concept is always at the forefront

All the components of the heating system must be perfectly matched to be able to realise the energy-saving potential of modern heat generators optimally. Therefore, heat generation, storage, distribution and transfer – if required – are to be considered always as a total system.

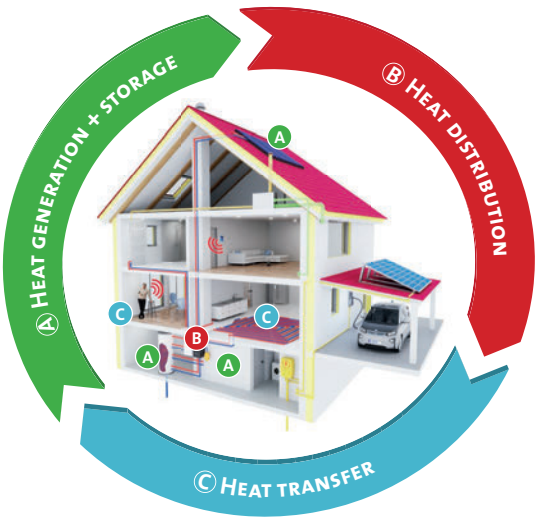


Fig. 27: The system concept is at the forefront

Heat generation and heat storage

Heat generation is the starting point for the operation of the heating system: In a centralised heat generator, the fuels (gas, oil, wood or electricity) used will be converted into heat. This is then used for heating and/or domestic hot water. Furthermore, renewable energies such as solar thermal energy, ambient heat, geothermal energy and wood are integrated into a central heating boiler or a pellet or wood burning stove with collection basin.

A special feature is shown by cogeneration of heat and power plants (CHP), which are also known as "power-generating heating systems": They produce heat and electricity simultaneously. The scope of this technology extends from the small one-family houses (micro-CHP systems, up to 2 kW_{el}) to apartment houses and medium-sized businesses (mini-CHP plants up to 50 kW_{el}) to the industrial sector. By using such systems, a total efficiency of over 90 % can be achieved.
Installing a hot water storage tank is particularly important as the heat provided by the heat generator is not always immediately used at 100 %. Today, hot water storage tanks form a central component of the heating system and domestic hot water supply system in residential and office buildings. Thanks to their great diversity of types, they can perform different functions:

- Domestic hot water storage tanks store the heated domestic hot water which is needed for showering, bathing or cooking.
- Buffer storage tanks ensure that the heating system is securely supplied with domestic hot water for a long time. Thus, they allow coupling of heat from renewable energies and CHP systems.
- Combination storage tanks combine both functions together.

The thermal losses can be kept low through an optimised heat insulation of the storage tank and an optimised heat transfer and temperature gradient in the storage tank. In this way, hot water storage tanks enable the reliable supply of domestic hot water and heat at intervals of demand and supply.

Heat distribution

The heat distribution forms the link between heat generation/storage and heat transfer. The heat distribution system includes heat circulating pumps, the forward and return flow of the hydraulic heating system and the fittings and valves.

Fig. 28: Interaction between heat generation and storage

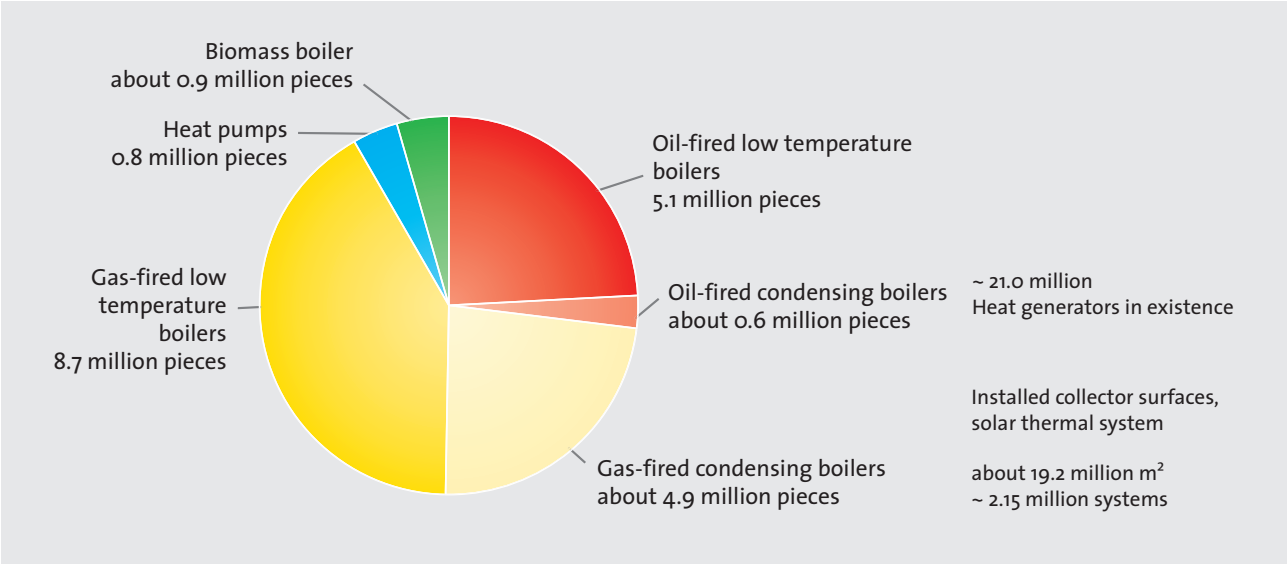


Fig. 29: Total number of centralised heat generators in Germany (2015)

Energy-efficient distribution of heat in the heating system also requires insulation of the forward and return flow as well as hydraulic balancing of the entire heating system. For optimum regulation of the ambient temperature, modern thermostatic valves, on the one hand, are eminently suitable, which distinguish themselves through their pre-settable valve bodies and visually appealing thermostat sensors. On the other hand, timed controllers are worthwhile especially for professionals who are away from home almost every day. One thing is clear: Only efficient heat distribution allows the reduction of system and indoor air temperatures and high controllability of the system.

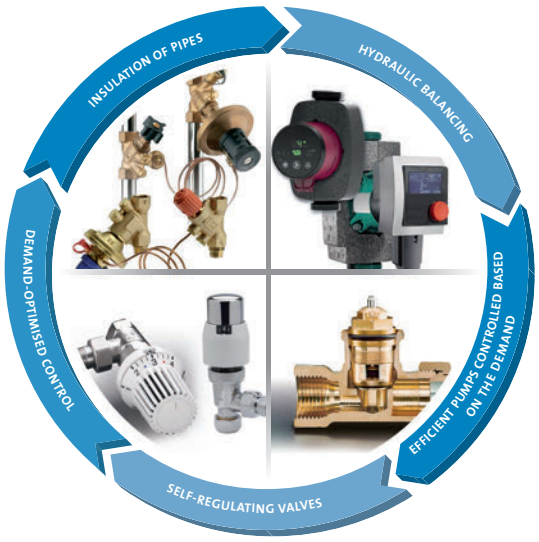


Fig. 30: Influencing factors for efficient heat distribution

In the meanwhile, digitalisation has also arrived in the field of heating technology and the described regulators can also be controlled externally, for example, using a smartphone. This allows not only a user-specific regulation of the heating system, but can also lead to energy savings in the case of optimised operation.

Heat transfer

The heat transfer is the link between heat distribution and the consumer. Either an embedded surface heating system or radiator is available as a heat transfer system. They can be installed in combination when requested.

Both systems can be combined freely with all types of heat generators of a hydraulic heating system. This makes them sustainable and future-proof.

Low system temperatures in the heating system are a prerequisite to achieve the high efficiencies of heat pumps and gas or oil-fired condensing boilers and effectively integrate solar thermal energy. Huge and properly installed heat transfer systems ensure and increase the comfort in the room and at the same time the efficiency of the heating system.

The many variations in shape, colour and design of radiators allow the builders and planners to create an attractive, individual interior design for the residents. Additional functions and smart accessories such as towel bars or racks, hooks or even lighting allow conscious setting of feel-good accents by the radiators.

An embedded surface heating system is installed permanently during the construction phase in the floor, wall or ceiling and is an integral part of the building. Apart from the heating in winter, it can also be used for cooling in summer. Thus, owners consider them as an investment for the future. The large-area installation allows a uniform distribution of heat in the room and ensures a constantly comfortable ambient atmosphere.

Modern heating systems

Fig. 31: Influencing factors for efficient heat transfer

Other components of an efficient heating system

Modern flue gas systems ensure safe removal of the flue gases and low flue gas temperatures. Stainless steel models can also provide a visual appeal to the residential buildings.
While operating an oil-fired heating system, nowadays modern oil tank systems in various variants are available to consumers. Today, double-walled tank systems made of plastic are the state of the art.

Solar thermal energy can also be used in all types of heating systems as a support for domestic hot water preparation and as an auxiliary heating system.
Independent of the heating system, facilities for controlled residential ventilation with heat recovery reduce the energy demand of the building significantly and, at the same time, ensure the required hygienic ambient conditions in the building. Here, central devices with heat recovery as well as decentralised devices can be used.
Moreover, the use of a photovoltaic system is also possible in every case: Since the generation of electricity using PV systems runs independent of the heating system, the solar power generation can be operated in parallel with all systems mentioned here and also use the generated electricity for heating the building and domestic hot water preparation with, for example, an electric heat pump.
Smart control and communication facilities enable the optimal interaction of all components. The heating can be remotely controlled and diagnosed via radio or online access. This makes operation very convenient.
However, the optimised use of modern heating systems should always be considered in agreement with the energy-related quality of the building envelope.
Examples of modernisation in the energy field are given on the pages 88–93, based on a typical, partially refurbished one-family house constructed in 1970. The examples must be seen as an approximation, considering the improvement that might take place in the quality of energy in the heating system. In the next step, an energy consultant and/or a heating specialist firm should be consulted. The following energy-related modernisation measures are taken into account:

Renovation as per the KfW Efficiency House-70-Standard, controlled residential ventilation with heat recovery	
Pages 88–89	**Variants with gas/oil condensing boilers**
	Modern gas/oil condensing boiler
	Modern gas/oil condensing boiler with solar domestic hot water heating and auxiliary heating
	Modern gas/oil condensing boiler with solar domestic hot water heating and auxiliary heating, renovation as per the KfW Efficiency House-70-Standard, controlled residential ventilation with heat recovery
Pages 90–91	**Variants with heat pumps**
	Modern air-water heat pump
	Modern brine-water heat pump
	Modern air-water heat pump, renovation as per the KfW Efficiency House-70-Standard, controlled residential ventilation with heat recovery
Pages 92–93	**Variants with wood burning systems/CHP systems**
	Modern gas/oil condensing boiler with solar domestic hot water heating and incorporation of a burning stove with collection basin
	Micro CHP system with gas condensing boiler
	Modern pellet/split log boiler with solar domestic hot water heating

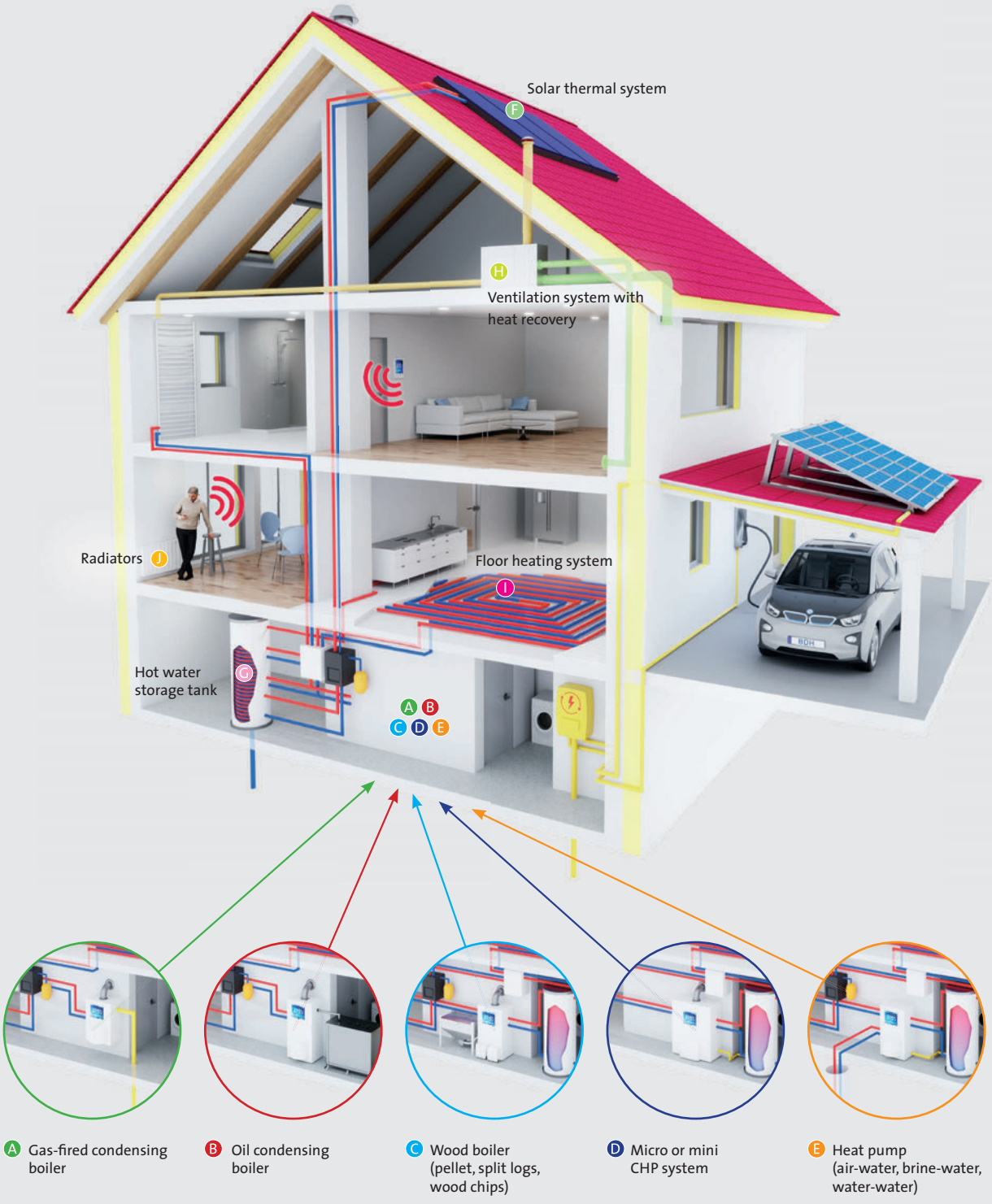


Fig. 32: Modern heating systems

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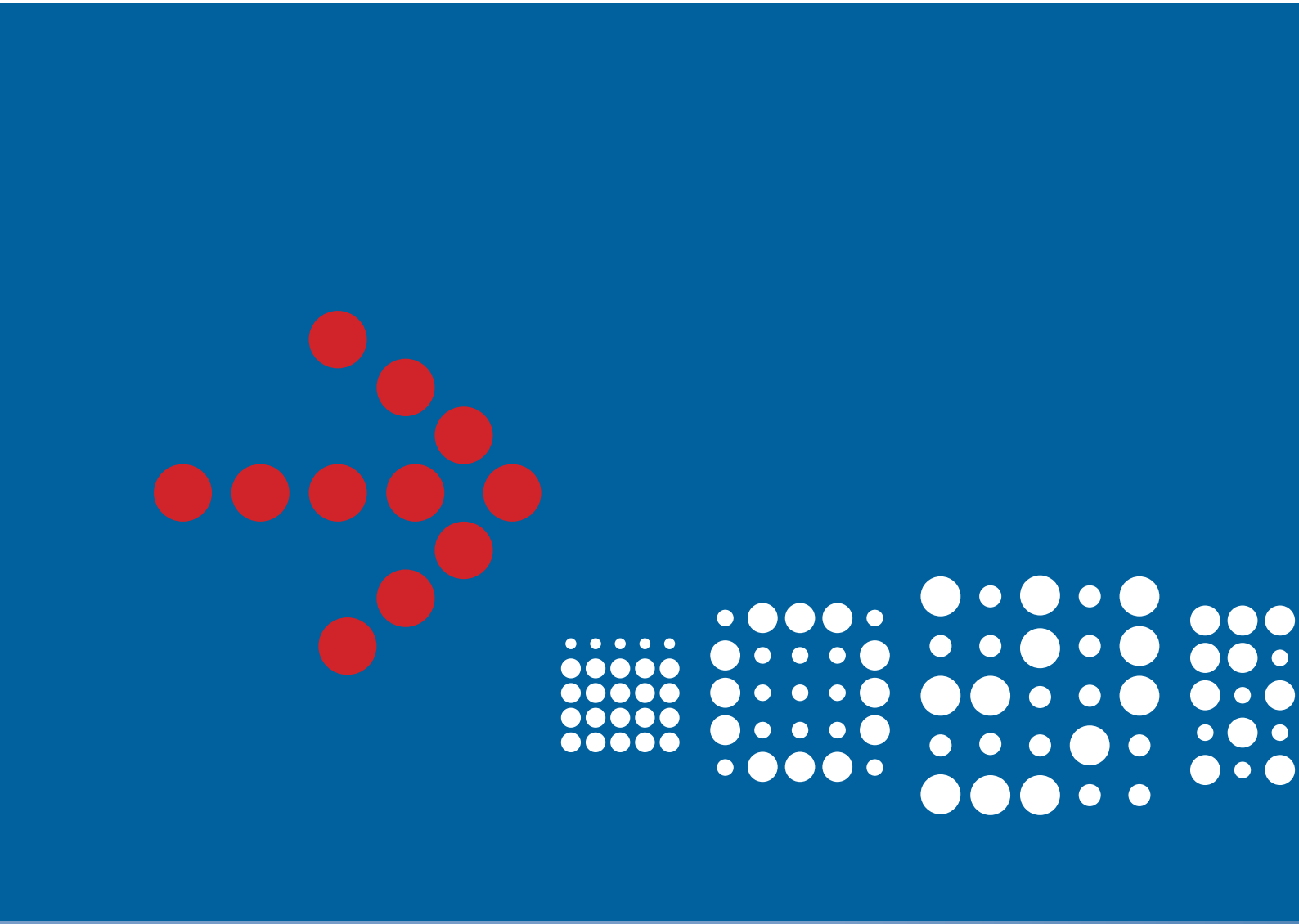

Smart Heating

Smart Heating

The digital revolution not only affects the service sector and industrial processes, but also producer durable goods such as heating systems. The hardware and software development of the last years and the Internet, which has captured virtually all areas of life, offer the great opportunity of bringing the control of the heating system out of the basement into our own hands as part of our daily life, using smartphone, internet and new, smart components. Besides, there are other positive aspects such as increasing energy efficiency, remote monitoring of the system, visualisation of savings for the operator etc.

The classic heating system

The heating system in the conventional mode of operation has a control without internet access, which includes the known functions such as weather management, room and domestic hot water temperature control, heating curve setting and switching time setting, antifreeze feature, etc. These are used to establish the functional safety of the heating system and the frost protection of the building. By connecting to the Internet, there is a clear additional benefit for heating professionals and users.

Smart Heating

Smart Heating stands for a heating system, in which the user interacts with the system and controls it individually via the smartphone, even remotely, using simple applications. Important parameters are visualised precisely to the second.

This is possible because the heating regulation and control system has a built-in or external communication module. There are different communication options. Often, the connection to the router is made via LAN cable or WLAN.

If no home network is available, many manufacturers can also connect a cell phone router.

In today's systems, the connection to the module via "plug and play" is ready in a few minutes. Hardware installation is easily done without requiring any special knowledge.

The individual installation steps are displayed clearly and intuitively in the instructions. Usually, the user will be guided online step-by-step through the installation. Downloading and configuring the apps is quickly explained to the customer. Secure Internet connections allow access of the user to the operation of the heating system from anywhere.

Monitoring the system from a smartphone or a PC

All relevant functions and parameters of the heating system can be displayed in plain text. Also interesting for the smartphone user are the status displays of operating states such as heating operation, circulation, night-time heating reduction and party operation. In addition, the system temperature, ambient temperature and time programs are visualised.

This also applies to feeding of renewable energies, e. g. in the form of illustrative diagrams for solar thermal energy or the heat pump's consumption of self-generated power. Even in case of solid biomass boilers, the fuels used can be identified as renewable energies in kilowatt hours (kWh).
The current consumption of the fossil fuels can also be read and displayed optionally in monetary equivalents as savings.

Control of the heating system functions
In the case of low-output Smart Heatings (single or two-family house), the operator is able to control or vary the heating system settings using the smartphone: The time programs or operating states can be influenced.

In the process, the set room temperature, the domestic hot water temperature and, if available, the indoor ventilation settings are adjusted and the parameters are displayed in real-time.

The system is controlled by so-called scenarios ("day", "night" and "home" or the like). When the room temperature is lowered, frost protection is ensured to the full extent.

With the temperature reduction option, substantial energy savings can be realised when the operator is absent.

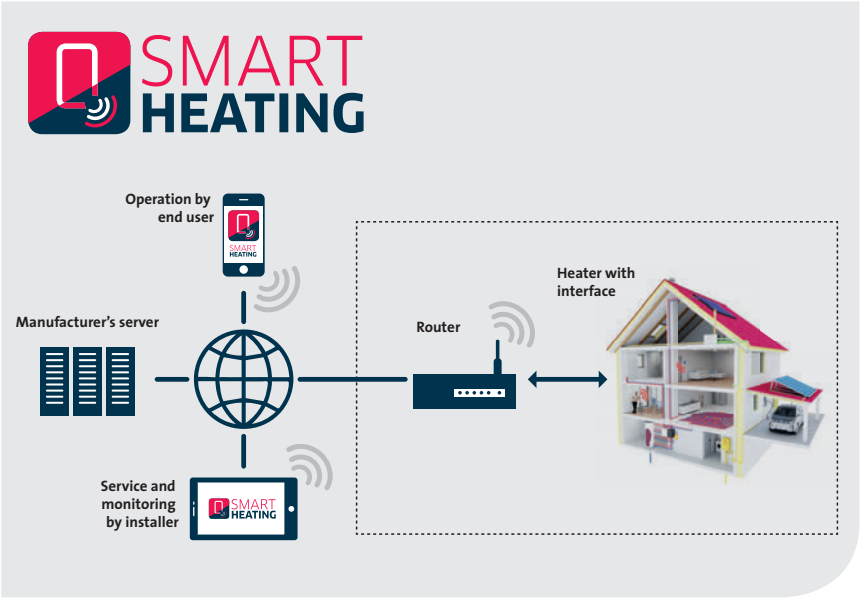

Fig. 33: Schematic diagram of the Smart Heating network

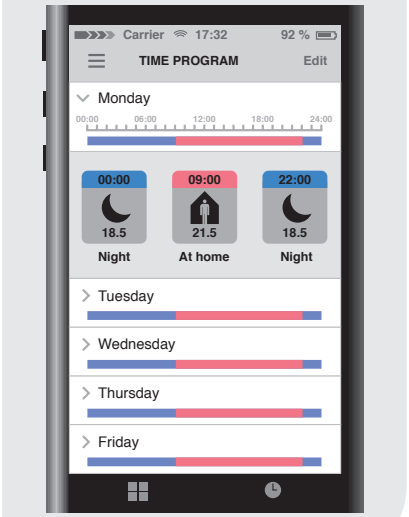

Fig. 34: Temperature pre-selection with time program in an app

Room-temperature-dependent electronic temperature controls

If a room-temperature-dependent electronic control is available, the temperature of individual rooms can be separately controlled. This is usually done in conjunction with "smart" thermostatic valves and, in some cases, also with motion sensors or window control switches for detecting persons and determining whether windows are open.

Remote monitoring of the heating system by the heating engineer

Secured data logs are used to report operating states of the heating system and, if necessary, malfunctions to the technician. Malfunctions can be remedied remotely in many cases. If this is not possible, the fault message can trigger a service call, if the operator so wishes.

Monitoring by the manufacturer or parallel monitoring by manufacturer and installer

Depending on the agreement between the manufacturer and the installer or the user, the heating system can be remotely monitored via internet by the manufacturer or simultaneously by the manufacturer and installer. Depending on the agreement, the manufacturer's field service may become active after receipt of a fault report and remedy the damage.

Data security

Even in digitalised heating systems, priority is given to ensuring full functionality at all times. This is achieved by adhering to the strictest safety requirements and continuously adapting to the latest data security standards. In view of the fact that the heating system is an essential infrastructure for the safety of the building and thus, the user, the manufacturers decouple the comfort settings of the control with the so-called basic functions of the heating system (e. g. the burner control). According to the providers, basic functions ensure the minimum temperature (at least frost protection or higher) by means of appropriate priority sensors (ambient temperature sensor).

The Internet-based part of the control is thus decoupled from the base part, which secures essential functions. The individual "smart" part enables the above-mentioned additional functions, which clearly add value to the classic heating system.

With automatic optimisation of the heating system setting, visualisation of the consumption data, adaptation of the domestic hot water preparation according to the daily routine and other technical options, the Smart Heating ensures that heat is used even more efficiently. According to a recent study, energy savings of up to 15 % can be achieved in this way.

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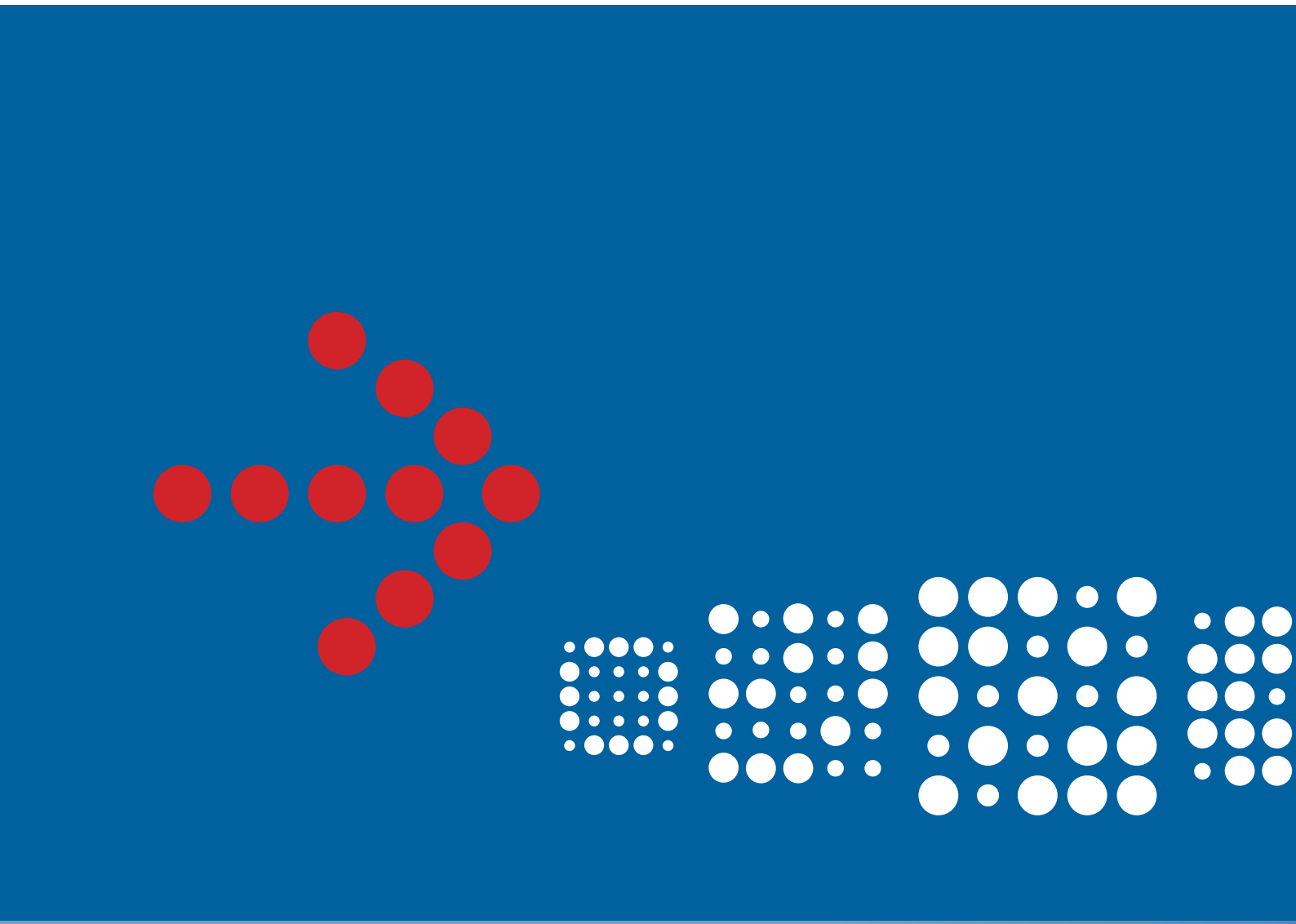


Efficient technologies and hybrid systems

- Gas condensing technology with solar thermal energy
- Oil condensing technology and renewable energies
- Principle of the heat pump and variants
- Hybrid heat pump systems
- System photovoltaics, heat pump and storage
- Gas heat pump
- Heat from wood
- CHP: The power-generating heating system
- Fuel cell heating
- Solar thermal systems

Gas condensing technology with solar thermal energy

Gas-fired condensing technology with solar thermal energy

The scope of application of fossil fuels in the building sector is increasingly determined by their compatibility with renewable energies. Natural gas technologies can be operated especially well in combination with solar thermal systems.

Solar thermal energy for heat generation

As against photovoltaic systems, which generate electricity using solar energy, solar thermal energy supports the process of heat generation. This heat can be used for preparation of domestic hot water and also for heating rooms.

In a four-person household, a solar thermal system with a collector area of four to six square metres can cover up to 60 % of the energy required for the preparation of domestic hot water over the year. Today, more than 2.0 million solar thermal systems are installed in Germany. Since 2006, their number has increased by more than double. For new buildings, natural gas condensing technology with solar thermal energy is one of the most favourable heating options for builders, considering the investment costs and heating costs.

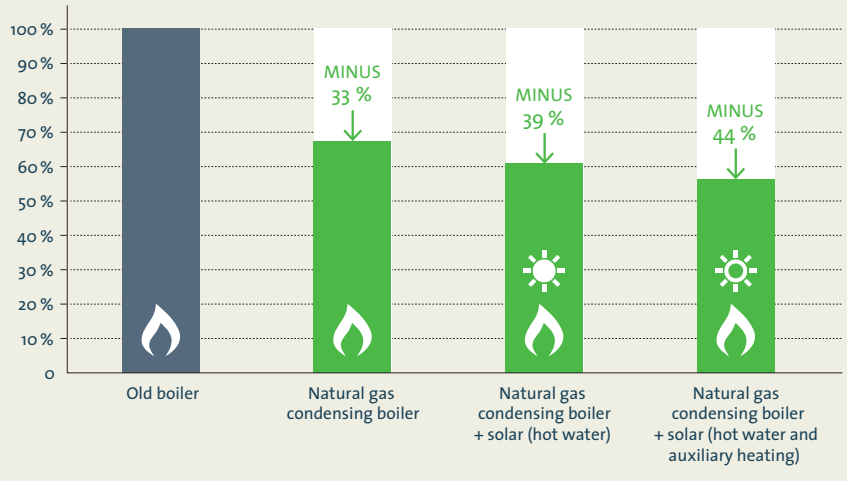
Preparation of domestic hot water is the most common form of solar energy utilisation. The installation of such a system is easy, cost-effective and the system itself is sufficiently variable to work efficiently for large buildings as well as in smaller one-family houses. During the summer months, the required domestic hot water is generated almost exclusively with solar energy. In the colder months, the gas condensing technology bridges this gap efficiently. The system operates even more efficiently if the solar thermal energy is also used for auxiliary heating.

Condensing vs. low temperature – less fuel, better output

Low-temperature heating systems are widespread in German boiler rooms and still often do a good job. Although newer low-temperature heaters consume 20–30 % less fuel than the standard and constant-temperature boilers from the 1970s, today a lot more is technically possible.

Unlike low-temperature technology, condensing boilers use the hot water vapour generated during gas combustion to improve their output. In contrast, a low-temperature boiler is designed in such a way that no condensation can take place. The flue gases, which are at a temperature of up to 200 °C, escape unused from the chimney. About 10% of the energy used is lost in the form of water vapour contained in it.

Another difference lies in the operating principle itself: Low-temperature heaters heat the boiler water to 40 to 75 °C, depending on the ambient and desired room temperature. If it is cold outside, higher flow temperatures are necessary. Compared to this, the condensing boiler provides its output independently of the ambient temperature. Compared to a low-temperature heating system, savings of up to 15 % are possible. An even higher value can be achieved in case of a standard boiler. Therefore, the costs of replacing a low-temperature heater are almost entirely covered by the lower consumption.



Source: Institute for Building Services 2016

Fig. 35: Efficient boilers reduce emissions and gas consumption

Efficient heating with oil condensing technology and renewable energies

Oil-fired condensing boilers are among the most efficient heating technologies. The highlight: While earlier heaters exhausted hot flue gas to the chimney, modern condensing boilers use the energy contained therein for heating. Condensing technology cools the hot flue gases to the extent that the water vapour generated during combustion condenses, which releases additional heat. This is the advantage of condensing technology: It uses the heating oil more efficiently. It is converted into heat almost without any losses. If old heaters are replaced with a new oil-fired condensing boiler, they can consume up to 30 % less energy. This also reduces the amount of greenhouse gas emitted by up to 30 %.

Efficient oil-fired condensing technology is suitable for both, heating modernisation – where it offers users of oil boilers a relatively cost-effective entry into the energy revolution – as well as new buildings.

Same principle, same efficiency

Oil and gas condensing technology are equally efficient: The maximum utilisation factor of 98% applies to both variants, because they work according to the same principle. Different degrees of utilisation or efficiency do not depend on the fuel, but on the design of the boiler. The energy used can never be used entirely, since surface, cooling and exhaust gas losses cannot be completely avoided in practice.

Ideal partner for renewables

The integration of renewable energies offers further potential savings. Oil condensing technology is an ideal partner for renewable energies. The basic principle is simple: Any available renewable energies are used. Nevertheless, the oil heater automatically and reliably pitches in when the sun does not shine or the wind does not blow. Therefore, a hybrid heating system always links at least two energy sources, such as heating oil with solar thermal energy, firewood or renewable electricity. With such a combination, owners of oil heaters can easily contribute to the energy revolution.

And this is where they shine: Modern oil-fired condensing boilers are in a disproportionately large number coupled with solar thermal systems. About one third of the newly installed oil-fired condensing boilers are combined with a solar system – a higher proportion than all other energy sources. In addition to domestic hot water heating, solar energy is ideally suited as auxiliary heating in single and two-family homes. Particularly in single-family homes, it is attractive to use the solar system for preparation of domestic hot water in the kitchen and bathroom. Up to 40 % heating oil can be saved in buildings with low heat demand and embedded surface heating systems, such as floor heating. Up to 50 % savings are possible if a fireplace stove is also integrated into the heating system in addition to the solar system. This way, in the summer months, the energy required for hot water can be generated almost exclusively by solar energy. During the transitional period and in winter, the wood-fired stove contributes to the heating of the building. The oil heating system is automatically switched on only when the solar system and the stove can no longer cover the heat demand.

Of course, biomass by itself already contributes to savings: Especially during springtime and autumn, a stove next to the efficient oil-fired condensing technology is the ideal heat source in the living room. If more than one room is to be heated with split logs or pellets, some stoves can feed their heat into a buffer storage tank and also make it available for the entire building and for domestic hot water heating.

Power-to-heat: Cross-sector application of electricity and heat market

Heating-oil-based hybrid systems offer a good opportunity to also use electricity from wind power and photovoltaic plants for heating purposes that is otherwise down-regulated – in keeping with the sector coupling of electricity and heat market. Up to now, wind power and photovoltaic systems are shut down if they produce more energy than the power grid can assimilate. This current can be absorbed by power-to-heat technology and used for the heat supply. Oil condensing boilers require only a hot water storage tank, in which the water is heated with an electrically operated heating element – in keeping with the sector coupling of electricity and heat market. The necessary technology could be installed as part of a heating modernisation project. There are still some hurdles to overcome before this new heating technology kicks off and the solution is ready for mass use. And of course the legislators as well must do their bit.

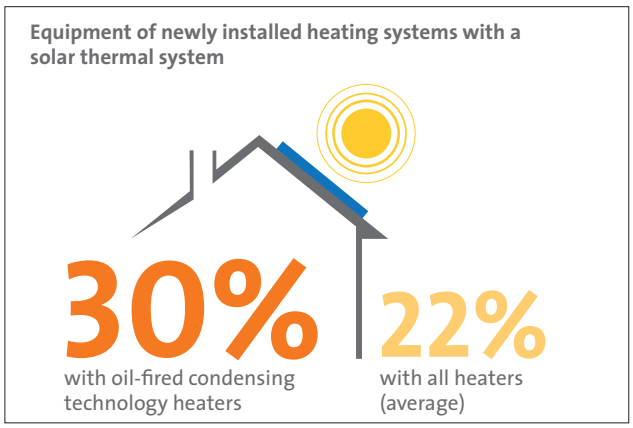


Fig. 36: Hybrid systems in modernisation of heating systems

Principle of the heat pump and variants

Free environmental energy from air, water and earth

With the help of a heat pump, the regenerative energy stored in the ground, ground water or air can be used for heating purposes.

The working principle of a heat pump is identical to that of a refrigerator or freezer. The refrigerator uses the effect of heat extraction; the heat extracted from the refrigerated product is delivered to the room as a "waste product". In case of the heat pump, the heat generated from the environment heats the hydraulic heating system.

A refrigerant extracts the ambient heat by evaporation. Subsequently, the refrigerant is compressed in a compressor. This increases the pressure and temperature of the refrigerant. The refrigerant that is brought to a higher temperature level in this way then delivers the heat absorbed to the heating water, while condensing at the same time. The cycle then restarts as the refrigerant evaporates again by means of decompression.

Electric heat pumps use electricity as a drive energy and are very economical: A heat pump with a coefficient of performance of 4.0 can generate four kilowatt-hours of heat from one kilowatt-hour drive current. The heat pump should be designed exact to the individual heat demand, so as to make them achieve this high efficiency in daily operations.

Heating, cooling and ventilation

Heat pumps work all the more efficient, the higher the source temperature. It therefore pays off using a heat source with a temperature as high and constant as possible.

State-of-the-art heat pumps heat up the drinking water as required, and can be used to ventilate and cool a building, depending on the model. In particular, a high standard of comfort is assured when using large surfaces for heat transfer. When they obtain their drive current from renewable sources such as wind power or photovoltaics, they are also emission-free and contribute even more to climate protection.

Many utility companies also offer special electricity tariffs for operators of heat pumps.

Three variants of heat pumps

Brine-water heat pumps

The brine-water heat pump uses the earth's heat (geothermal energy) or, alternatively, absorber systems as a heat source.

There are two ways to make near-surface geothermal energy usable: Geothermal probes and ground-coupled collectors.

Geothermal probes are introduced through boreholes with a depth of up to 200 m into the ground, where they use an average soil temperature of about 10 °C. If the plot of land is large enough, the ground can also be tapped by a flat plate collector.

Brine-water heat pumps use "brine" for tapping the heat source. This liquid circulates in the geothermal probes or the flat plate collector.

The heat extracted from the ground is transferred to the heating system after raising it to the heating water temperature. Brine-water heat pumps can reach a coefficient of performance of up to 5.0. They are available in different designs, with and without integrated domestic hot water storage tank.

If a cooling function is part of the heat pump, it can also be used to heat rooms in summer: The cycle is then reversed and the heat removed from the rooms is discharged via the geothermal probe or collector.

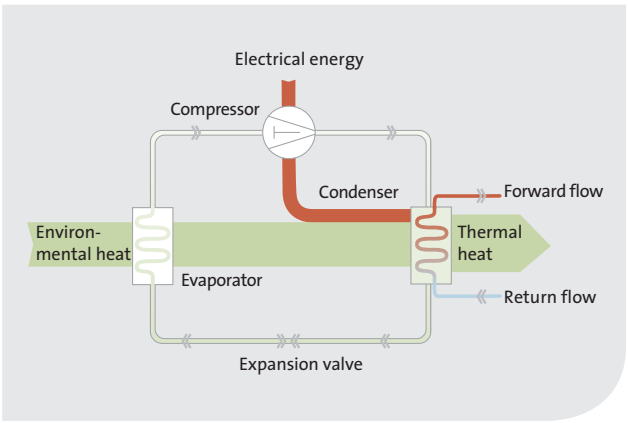


Fig. 37: Working principle of an electrically driven heat pump

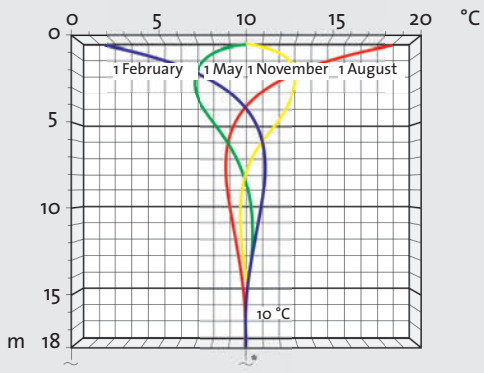


Fig. 38: Temperature increase in the soil

Water-water heat pumps

Water-water heat pumps extract the heat from the groundwater. A suction well conveys the water for heat recovery and the heat pump transfers the energy contained in the water to the heating system; then, the cooled water is fed back into the ground water through an injection well. An annual coefficient of performance of over 5.0 can be achieved because the water-to-water heat pump uses the nearly uniformly high temperature level of the groundwater of about 10 to 15 °C.

As a general rule, an approval from the local water management authority must be obtained for its installation.

Air-water heat pumps

Air-to-water heat pumps extract heat from the ambient air. They can draw energy from the outdoor air even when the temperature is –20 °C or less. The investment costs of an air-to-water heat pump are lower because tapping the heat source is not required. Due to the fluctuating ambient air temperatures that are also low during the heating period, a decrease in efficiency must be taken into account. Air-to-water heat pumps can achieve an annual coefficient of performance from 3.0 to 4.0 because the temperature of the heat source fluctuates and is often lower during the heating period than in other types of heat pumps. Air-to-water heat pumps are also available with cooling function.

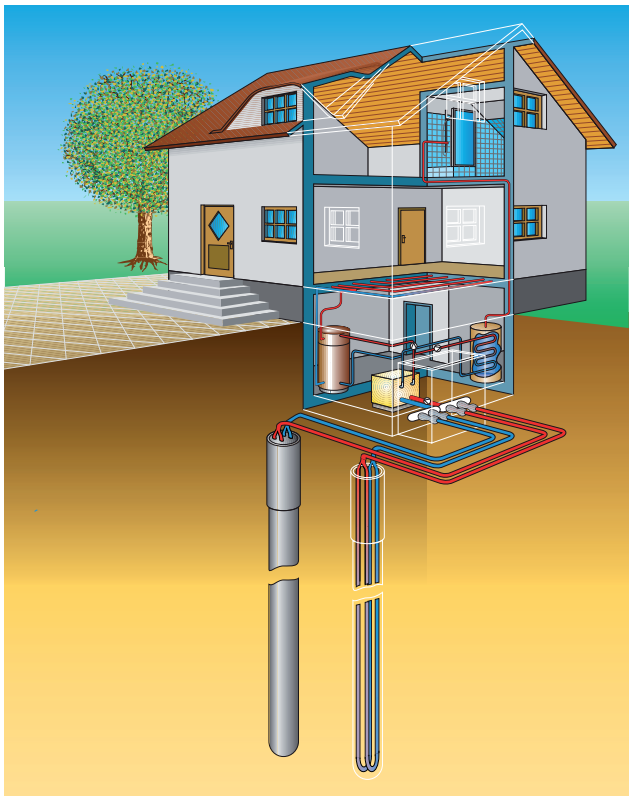


Fig. 39: Brine-water heat pump with probe system

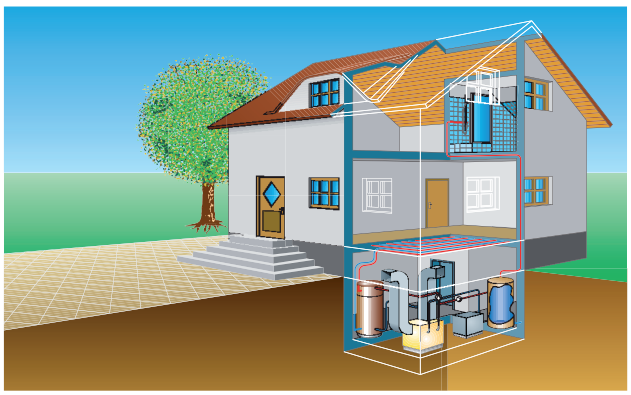


Fig. 40: Indoor air-water heat pump

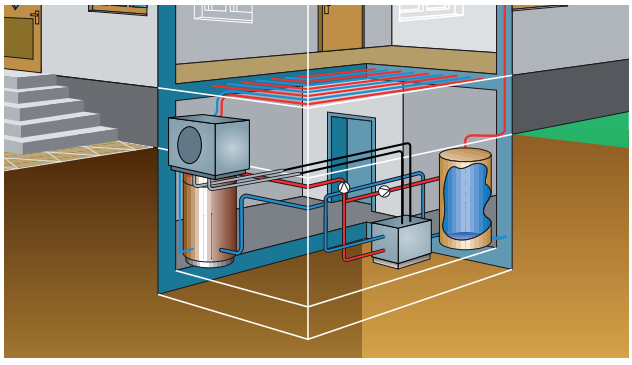


Fig. 41: Air-water heat pump as a split system

Hybrid heat pump systems

Optimum combination for optimised heating

Hybrid heat pumps are heating systems with an electrically operated heat pump in combination with at least one more primary heat generator (e. g. oil, gas or solid fuel boiler) and one comprehensive control system. Hybrid heat pumps are either available as one complete unit or are made by putting together individual components.

How it works

Flow temperature of the heating system (heating and preparation of domestic hot water):

If the heat pump is unable to provide the flow temperature required for the heating system throughout the year on its own, the second heat generator switches on. Instead of renewing the heat distribution system for reducing the system temperatures, the hybrid heat pump offers an economic alternative.

Heat output (heating and preparation of domestic hot water):
If a heat pump is unable to provide the essential heat output throughout the year on its own, the second heat generator helps in covering the peak load.

Temperature of the heat source:
If the minimum permissible heat source temperature is fallen short of (e. g. when an air-water heat pump is used in colder regions), the hybrid heat pump system balances the temperature difference.

There is a number of good reasons for using hybrid heat pumps

Optimisation of operating costs:
Depending upon the current energy prices, the hybrid system can determine on its own, which heat generator should be operated, thus reducing the operating costs.

Minimisation of CO_2 emissions:
For minimising the environmental burden, the hybrid system independently decides, depending upon the expected CO_2 emissions, which heat generator features minimum environmental burden at the current operating point.

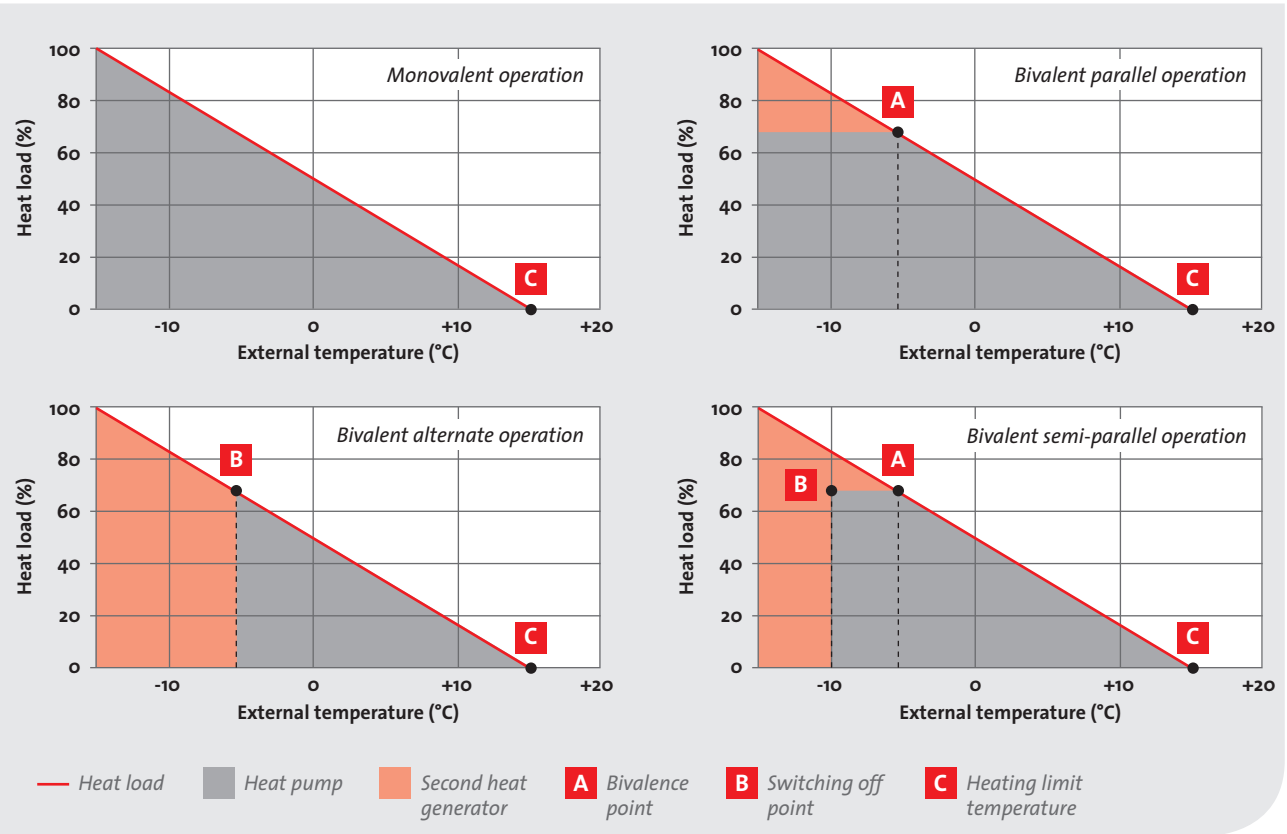


Fig. 42: Description of the operating modes for heat generation

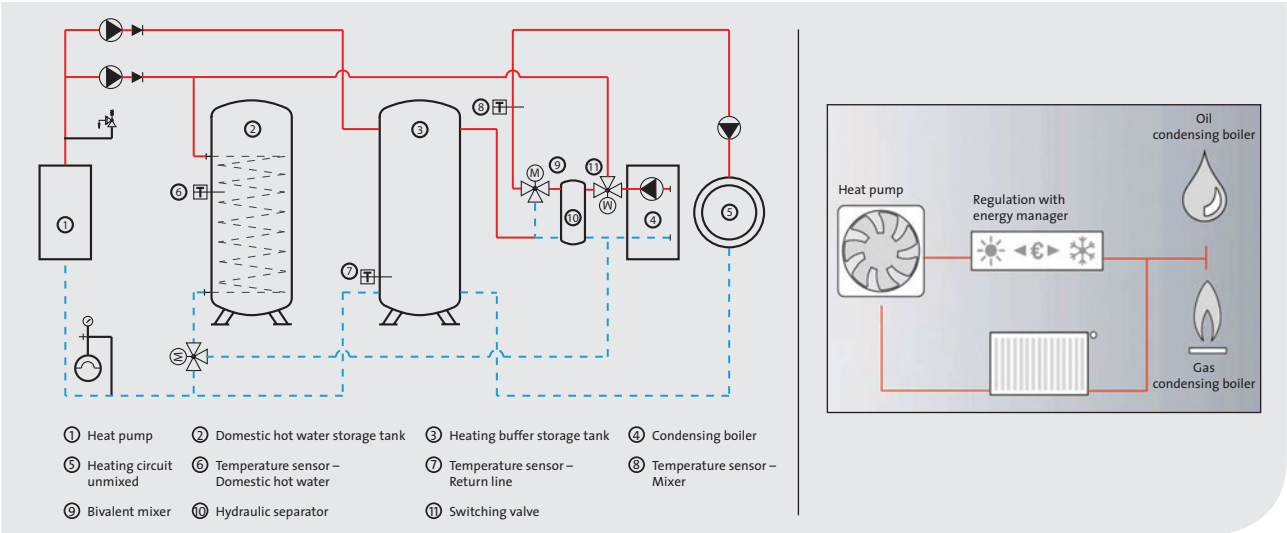


Fig. 43: Hydraulic example for bivalent mode of operation with condensing boiler and domestic hot water storage tank

Long-term sustainability due to gradual renovation:
An option for a gradual energy related modernisation is the extension of the existing heating system with a heat pump. By subsequent renovation of the building envelope, the heat load of the building reduces and the existing boiler can be put out of operation at a later point of time.

Redundancy:
Since varied fuels are used, the hybrid heat pump offers greater security of supply.

Grid capacity:
If the technical conditions for connection do not allow the operation of just a heat pump only, the bivalent operation of the hybrid heat pump reduces the maximum electrical power consumption.

Modes of operation for the production of thermal heat in the hybrid heat pump (Fig. 42):

- Monovalent operation
  The heat is made available exclusively via the heat pump. No other heat generator is required.

- Bivalent parallel operation
  Above the bivalence point, the heat is provided exclusively via the heat pump. Below the bivalence point, other heat generators are simultaneously operated with the heat pump.

- Bivalent alternative operation
  Above the switching off point, the heat is provided exclusively via the heat pump. Below the switching off point, other heat generators are used, which provide the entire thermal heat.

- Bivalent semi-parallel operation
  Above the bivalence point, the heat is provided exclusively via the heat pump. Below the switching off point, other heat generators are used, which provide the entire thermal heat. Between the bivalence point and the switching off point, the heat pump and additional heat generators are working simultaneously.

A variable system with a wide range of applications

Hybrid heat pumps are suitable for installation in new as well as existing buildings. They guarantee that the building is heated at the most favourable prices at any given point of time; because they can easily react to any fluctuations in the energy price by using the second heat generator. This function is generally integrated in the regulators of most of the hybrid heat pumps.

Basically, hybrid heat pumps could be the key to resolving the current modernisation backlog.

Fig. 44: Hybrid heat pump with split outdoor unit

System photovoltaics, heat pump and storage

Increase in own consumption

The feed-in tariff for private photovoltaic systems in Germany specified by the EEG (Renewable Energies Act) is dropping further and further. Therefore, it is more economical to consume the self-generated solar power oneself than to buy it back for more money from the energy supplier. Furthermore, the potential for increasing self-sufficient supply is growing due to falling costs of PV systems and battery storage units. By integrating accumulators, the self-supply rate including the operation of a heat pump to heat the building can be increased to up to 65 %.

Interaction of the three components

A photovoltaic system (PV), an electric heat pump (HP) and an accumulator (A) ideally complement each other in increasing self-generated energy. The PV system provides cheap power for driving the electric heat pump. The combination of heat pump and PV system increases the efficiency of the entire system. The excess solar current, which is not consumed in the building at the same time, can be used to charge the battery.

Apart from lead-gel batteries, lithium battery technology is mainly used for accumulators. Characteristics such as degree of energy efficiency, service life and cycle life are decisive.
If the battery is fully charged, the excess PV current is fed into the grid or the existing hot water storage tank is heated by the heat pump so that the stored energy can be used at a later time. The self-generated and used solar power is 100 % renewable and is generated without depending on external suppliers.

Degree of self-sufficiency of a building

The degree of self-sufficiency indicates the share of the electricity consumption, which is covered by the directly consumed PV energy or by discharging of the accumulator. It depends on the efficiency and the interaction of the individual components.
Central planning factors for the PV system are the orientation, angle of inclination and the available roof area, as well as the selection of the inverter.
The lower the proportion of the nocturnal electricity demand and the higher the proportion of summer demand for electricity in the total demand, the higher usually is the degree of self-sufficiency.

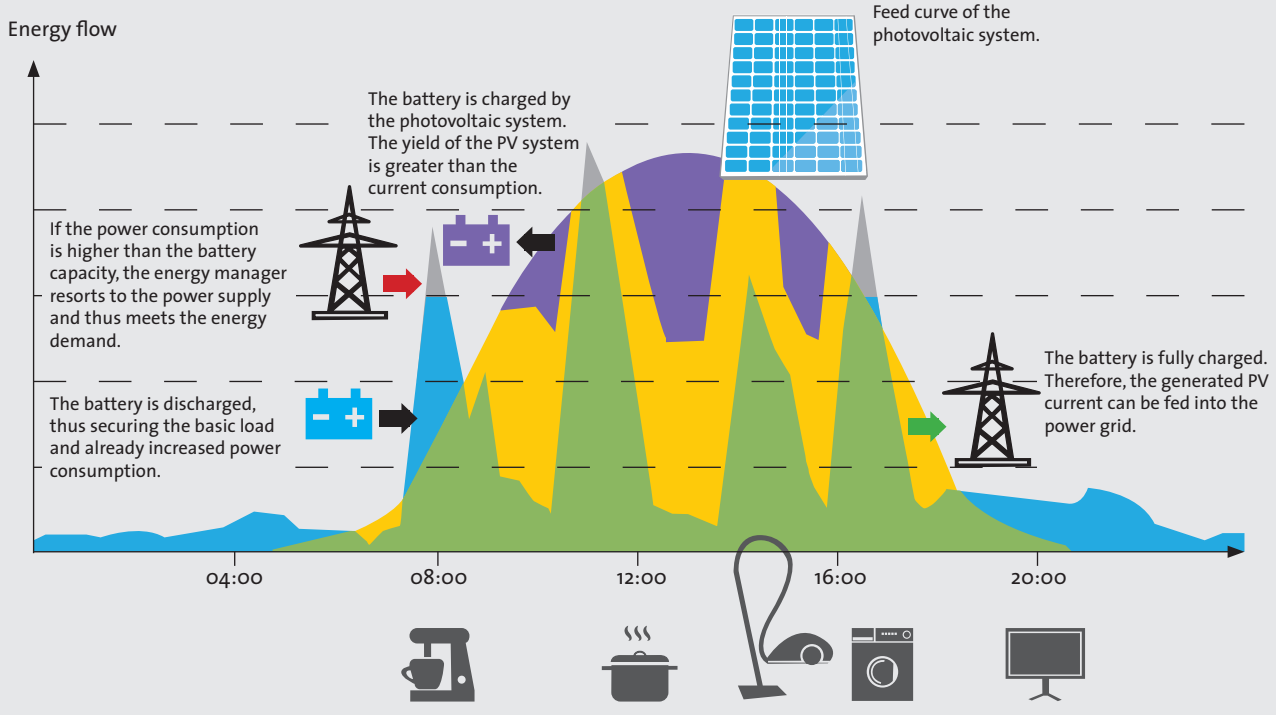


Fig. 45: Energy flow of a typical day

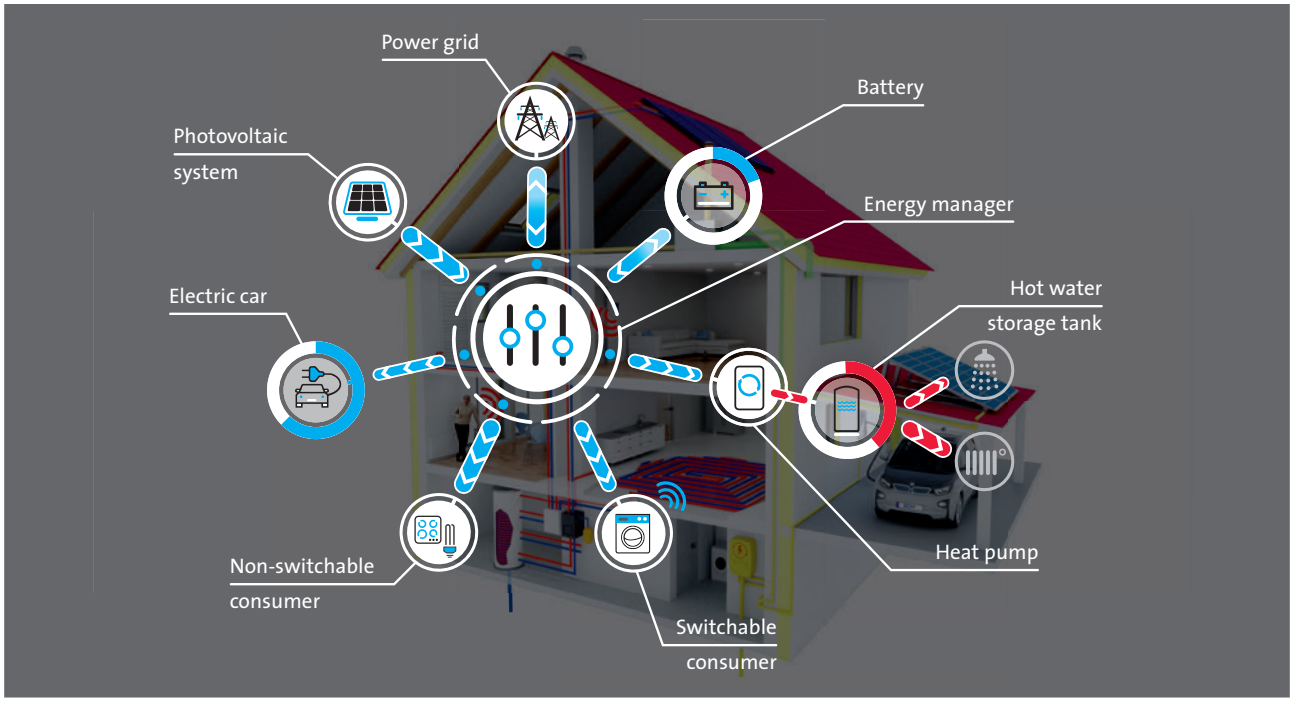


Fig. 46: Photovoltaic system with heat pump for electricity and heat supply with battery storage

Energy manager – an example of a typical day

The energy manager controls the generation, storage and consumption of the entire system. We describe below an averaged exemplary cycle (24 h) in autumn or spring. Power generation, heating requirements and self-consumption of such a system are shown.

The first sunrays received by the photovoltaic system provide consumers with electricity in the early morning. The accumulator supports the operation of the heat pump. The thermal storage has been used in the night hours to operate the heating system. In the morning, the photovoltaic system supplies a lot of electricity, which is fed into the accumulator, since the energy manager does not report any demand for space heating and the heat pump is switched off.

In the course of the morning, the accumulator is fully charged and the energy manager has determined an increased demand for heating energy for the next day on account of the weather predictions. This is why it switches on the heat pump to fully heat the thermal storage, although the space heating still does not indicate any demand.

At dusk, the electricity consumption of the inhabitants rises and is covered by the accumulator. In the course of the evening, the space heating signals energy demand. This is covered by the thermal storage tank, the heat pump remains switched off and saves electricity. Once the occupants go to bed, the heat pump can ensure operation using the energy stored in the accumulator till sunrise.

Energy manager – outlook

In future, the energy manager will be able to recognise different consumption patterns. Hot water consumption is analysed and integrated into the routines of the energy manager. In its calculations, for example, private calendars and school holidays are linked with each other and combined with weather forecasts. The energy manager always focuses on the comfort requirements of the residents and optimises energy storage and energy consumption in an efficient manner. Optimum energy consumption also means optimum cost-effectiveness and leads to high savings for the consumer as well as high comfort.

Being open to new technologies, it is conceivable to use a part of the battery capacity of electric cars intelligently and route it to households during consumption peaks.

Conclusion

An exact system planning of the home technology is a prerequisite for an efficient system. When a new building is constructed, the entire system can be planned from scratch and installed as one unit. For an existing building, existing components must be combined into a new system.

The control of a heating system offers a substantial savings potential through energy-efficient networking and energy management of the entire home installations.

Gas heat pump

Maximum efficiency with natural gas/liquid gas by using renewable energies

The gas heat pump combines highly efficient gas condensing technology with the use of ambient heat. Hitherto unreached efficiency, high share of renewable energies, high degree of suitability in practical use, thanks to versatile environmental heat sources and a very good CO_2 balance make this system one of the most economically and ecologically viable heat generator in new buildings as well as existing constructions. A distinction is drawn between two common working principles: Gas heat pumps working on the principles of adsorption and absorption.

The gas heat pump in existing buildings:

Gas heat pumps enable a simple and effective upgrade of existing gas heating systems. The existing heat distribution and transfer system, a solar system and the existing gas infrastructure as well as the exhaust system can be largely retained.

The gas heat pump in new buildings:

When constructing a new building, both the requirements of the EnEV (Energy Saving Ordinance), the EEWärmeG (Renewable Energies Heat Act) as well as the GEG (Building Energy Law) in the future must be met.
Internally, all gas heat pumps use a circulating working medium, which constantly changes its physical state by absorbing and dissipating heat: This medium vaporises when the free ambient heat is absorbed and turns into liquid when the useful heat is released.

Working principle of the adsorption gas heat pump

In the adsorption technology, the coolant (e. g. water) vaporises when ambient heat is supplied at a low temperature. The vaporous refrigerant adheres (is adsorbed) to the surface of a solid (e. g. zeolite). Heat is released at a higher temperature in this process. After the sorbent saturates, the coolant is once again released in the desorption phase. For this purpose, the heat from a gas condensing unit integrated in the device is used. The water vapour gets liquefied and the condensation heat in the condenser is released.
The process takes place at low pressure. In both the phases (adsorption and desorption phase), energy is released to the heating circuit in the form of heat.

Adsorption phase (Fig. 47):
The coolant water is vaporised through free ambient heat from outside and adsorbed by the solid material (e. g. zeolite). In this process, the sorbent is heated up to the flow temperature.

Desorption phase (Fig. 48):
The coolant (e. g. water) is released from the sorbent by heating with a gas-fired condensing heater, liquefied by the condenser, through which heating water is passed, and collected in the collecting tank.

Adsorption gas heat pumps for supplying heat to single-family houses always work in conjunction with a gas condensing boiler integrated in the device. In addition to the thermal drive energy supplied to the system, the condensing boiler also offers additional benefits as an effective heat generator to cover peak loads and for particularly high temperatures (e. g. to provide domestic hot water ≥ 60 °C).

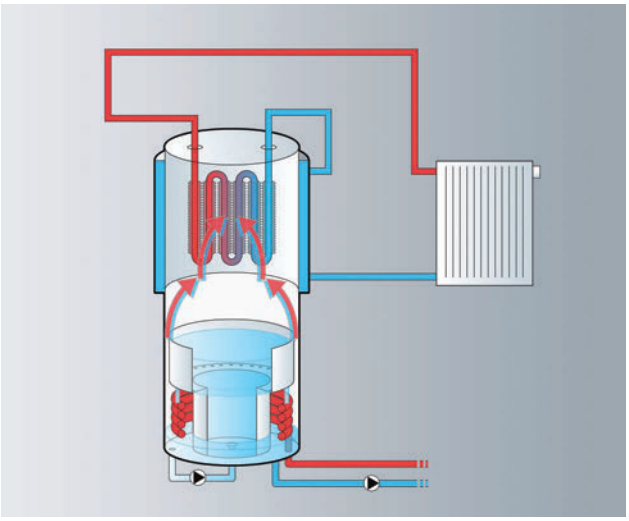


Fig. 47: Adsorption phase

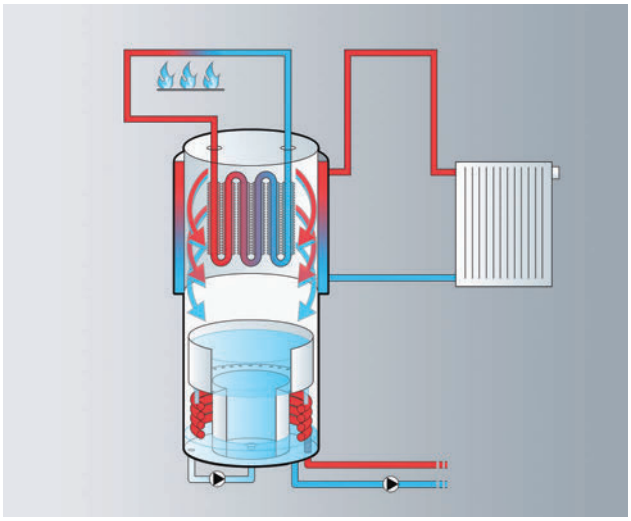


Fig. 48: Desorption phase

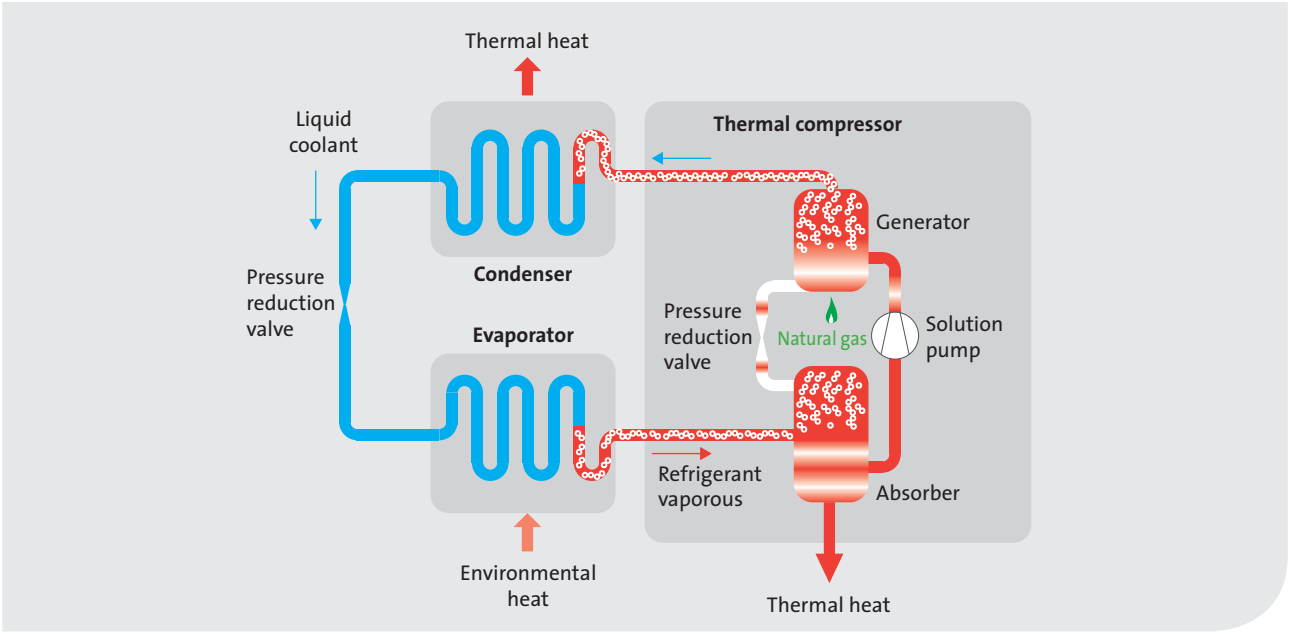


Fig. 49: Absorption gas heat pump

Working principle of the absorption gas heat pump

Absorption heat pumps (Fig. 49) operate with a continuous coolant circuit under overpressure. The required temperature level is achieved using a thermal compressor.
First, gaseous coolant (e. g. NH_3 – ammonia) is released from the solvent (e. g. water) by means of heat supplied by a built-in gas condensing device (desorption) and then condensed in the condenser by releasing the useful heat to the heating system.
Passing the expansion valve, the liquid coolant reaches the evaporator, where the ambient heat is absorbed and transmitted to the coolant. The coolant, in the gaseous state, flows to the absorber, meets the expanded solvent and is absorbed by it. The heat released during this process is also fed to the heating system.

Conclusion

Compared to all other heat systems using fossil fuels, the gas heat pump has the lowest primary energy demand and the highest heat output for each kilowatt-hour of natural/liquefied gas consumed. Very high efficiencies can be achieved in all output ranges and applications. The gas heat pump can be operated monovalently for all sources of ambient heat used and no additional heat generator is required. Other advantages:

- Use in future-oriented new buildings:
  Compliance with legal requirements for primary energy consumption and integration of renewable energies
- Use for economic modernisation:
  Existing radiators or floor heating systems, pipe networks and flue gas systems can be continued to be used most of the times. An existing solar thermal energy system can be integrated.
- Flexible combination options with all ambient heat sources, e. g. sun, earth, air and water
- Low installation and maintenance costs analogous to conventional gas condensing heaters
- The range of devices includes solutions in different device configurations and performance classes.

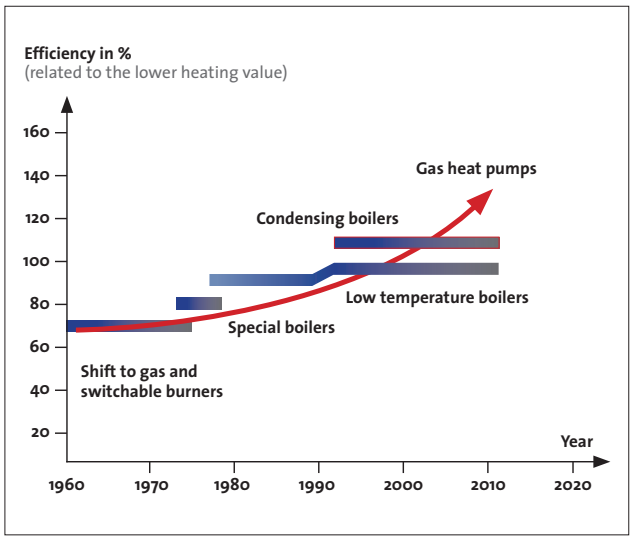


Fig. 50: Comparison of the efficiencies of gas heaters

Heat from wood

Pleasant warmth from nature

Modern heating systems were operated for many years almost exclusively with oil or gas. Today, a fuel with a long tradition is used more intensely again: Wood is a constantly renewable resource, which can be obtained relatively easily with little energy expenditure. Especially in Germany, which follows the principle of sustainable forestry, not more wood is cut from forests than is regrown. This makes wood particularly environmentally-friendly. Moreover, thanks to the high volume of wood in Europe, the long-term supply of wood is secured.

Wood can be used in various forms for heating: The most common is the use of split logs, wood pellets and wood chips. Wood is suitable for heating individual rooms and as a fuel for central heating of the entire building. The heat demand, the storage options, manual labour associated with the wood and the individual preferences of the owners and residents are primarily decisive factors for the selection of the firing installation.

Feel-good warmth – thanks to CO_2-neutral wood single room furnaces for the living space

Two effective device types are available for the heating of individual living rooms: air-guided living room devices and living room devices with collection basins. In both types, split logs, wood pellets and wood chippings are especially used.

Air-guided living room devices

This category includes especially wood burning stoves and pellet furnaces: Both fireplace types burn wood or wood pellets in a separate combustion chamber. Air ducts in which the indoor air heats up go past the combustion chamber. The indoor air is then passed back into the living room.

Moreover, the furnace itself dissipates radiant heat which is felt by many people as particularly pleasant.

These single-room furnaces with direct heat radiation have an output range of up to 10 kW. They are used primarily for heating individual rooms, as additional or transitional heating and to cover peak loads

Living room devices with collection basin

In living room devices with so-called collection basins, heating water circulates inside the fireplace. The devices are integrated into the centralised heating and hot water system of the house via a built-in heat exchanger. In addition to direct heat dissipation to the installation area, heat is also generated in the fireplace for auxiliary heating and/or for the preparation of domestic hot water.

In low-energy buildings, such a pellet furnace or wood burning stove with collection basin can significantly relieve the load of the main heating system.

If living room devices with collection basin have to be used for preparation of domestic hot water, they should also be in operation during summer – even when heating of the indoor air is not necessary. Therefore, this heating system is best combined with a solar thermal system: Thus, each of the two heating systems can prove its unique strengths during the appropriate season and completely replace the central heating system in the passive house.

Example: Pellet furnaces for the living room

Pellet furnaces for the living room offer numerous advantages: The pellets are led automatically from the storage container directly into the furnace. The control is electronic – depending on the desired room temperature. It is more accurate, convenient and efficient and features better emission properties as compared to manual firing.

Heating devices of the latest generation have high efficiencies of over 90 %, radiate a pleasant warmth and have low emissions.

Interested parties can choose from a large selection of models in different designs, sizes and price categories. The use of modern control systems, such as indoor or time-controlled thermostats, makes automatic operation particularly convenient. The latest generation of devices can even be controlled via the Internet from any device with a web browser, such as a PC, tablet or smartphone.

Depending on the model, operation that is independent of the indoor air is also possible. This allows the use in modern buildings with controlled residential ventilation, such as low-energy and passive houses.

Fig. 51: Pellet furnace with pellet storage container

Fig. 52: Wood and wood pellets are CO_2-neutral fuels

1. Primary pellet furnace
2. Adapter assembly for the hydraulic connection of the furnace to the buffer storage tank
3. Central heat generator
4. Buffer storage tank
5. Hot water consumer
6. Radiators
7. Solar collectors

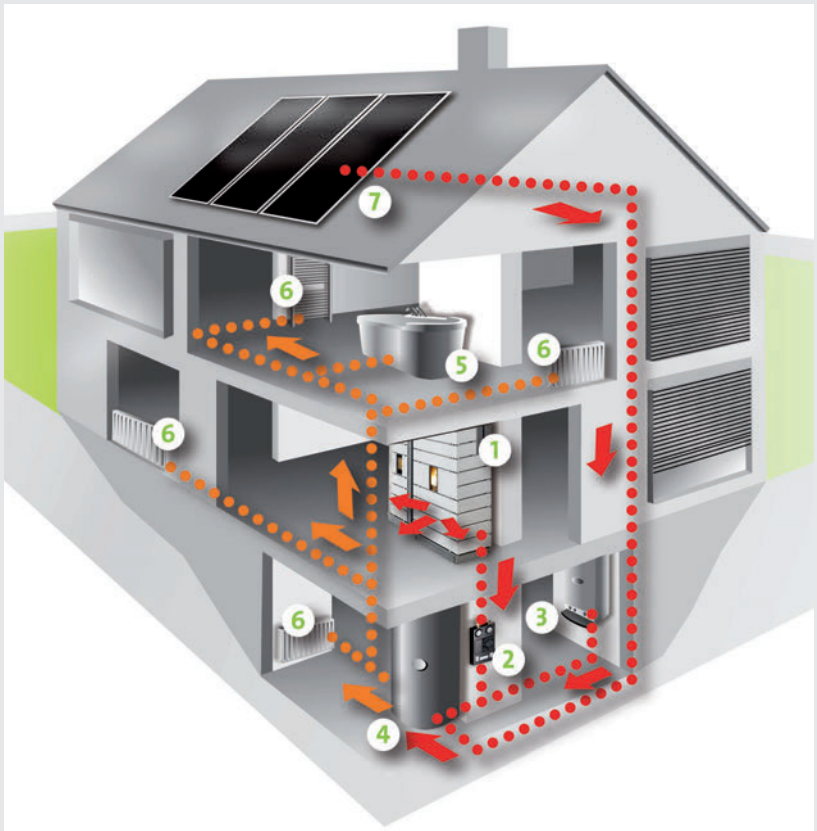


Fig. 53: Pellet fireplaces with collection basin can be integrated into the heating system. This also applies to split log fireplaces with collection basins.

Heat from wood

Wood based central heating

From single-family or multi-family house to commercial enterprises and local heating grid: Modern wood-fired central heating systems provide buildings of all sizes with heat. The big advantage: By the use of the renewable fuel, wood, heat generation takes place in a climate-friendly manner with zero carbon footprint. Besides, the option to use subsidy programmes makes wood-fired central heating systems many times the key to favourable financing options. Besides manually operated split log boilers, automatic wooden central heating systems are also available for the use of wood chips and pellets. A common factor is the advanced technology and the resultant efficient and low-emission combustion.

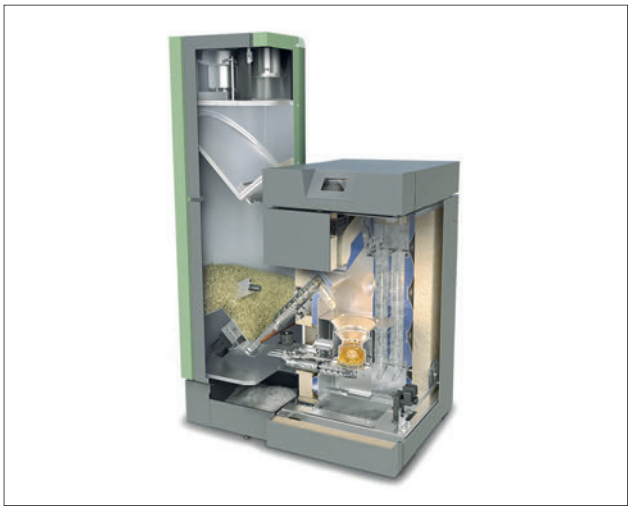


Fig. 55: An automatic pellet heating, shown here without discharge system

Split log boilers

The two stages of combustion (gasification and combustion) run locally separated from one another in modern split log boilers, also called wood gasification boilers. This efficient technology ensures high degree of efficiency, low exhaust gas temperatures and lowest emissions. It is important that the heat exchanger surfaces of the system are adequately dimensioned. The induced draught fan and the combustion air supply also have a decisive influence. They ensure an appropriate and sufficient air supply. While the primary air duct secures optimum wood gasification and therefore, the output, the secondary air feed ensures complete combustion and low emissions.

A suitably dimensioned buffer storage tank is not only required by law, but also technically necessary, because current split log boilers operate intermittently. The boiler is filled and then the fuel is completely burnt within several hours, after which it is filled again. The buffer storage tanks allow replenishment intervals once to twice daily, even in winter. This ensures a noticeably higher heating comfort.

Wood chip boilers

As in the case of pellet heating systems, the combustion material in wood chip heating systems is also automatically transported from the storage room to the heating boiler – often with a screw conveyor or using a similar technology. A microprocessor-regulated controller constantly controls the combustion to ensure high efficiency of the system. Controlled in such a way, varying fuels also do not have a decisive influence on the combustion values, and output adjustments to approx. 30 % of the nominal heat output is possible.

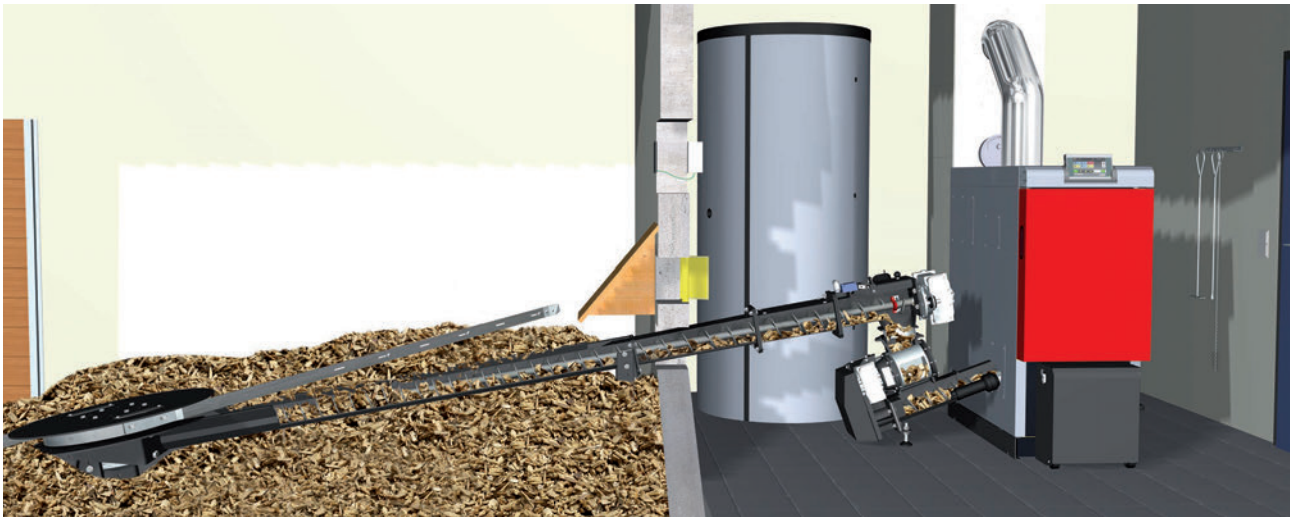


Fig. 54: An automatic wood chip heating system with spring core space discharge for transporting the fuel

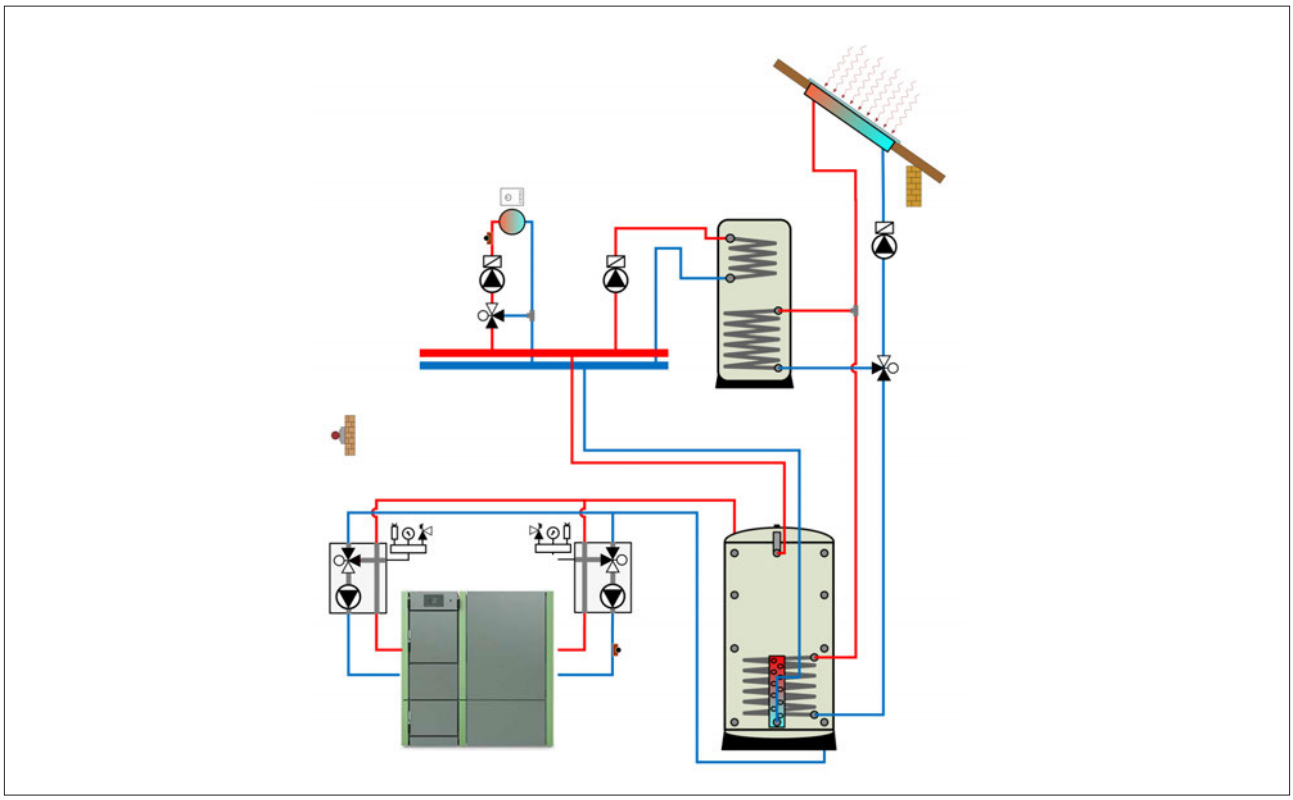


Fig. 56: Schematic representation of a combined boiler (split logs/pellet) with system storage tank, domestic hot water storage tank and integrated solar thermal system

The output range of wood chip central heating systems ranges from about 20 kW to several megawatts. Because the economic feasibility of a wood chip heater increases with its size, they are often used in multi-family homes, restaurants or large residential or business complexes. Wood-processing companies very often use wood chip heating systems, since the short transport distances of the fuel also increase the utility of the plant.

Pellet boilers

A particularly comfortable way to generate heat from wood is to use central heating systems which are operated with pellets. As a rule, the wood pellets come from the storage space or tank to the boiler via a suction or screw conveyor system. Realisation is possible for almost any facility due to the flexible discharge and conveying techniques. Pellet heaters are thus suitable for both renovated and new buildings. At low emission levels and fully automatic operation, pellet boilers achieve high efficiencies of over 90 %. These properties and the modulated output make them absolutely comparable with oil and gas firing systems.

Heat from wood in the hybrid system

Wood central heating systems can easily be combined with solar thermal systems and thus, become even more environmentally friendly. If both systems are used together, the wood heating system will be the primary heat source. When space heating is not required, e. g. in summer, the wood heating system can remain switched off – the solar system will then assume the task of supplying domestic hot water.

Even in winter, the solar thermal system can support the wood boiler with proper design. Frequently, a buffer tank is sufficient for both systems. This receives the energy from both the solar thermal system and the wood boiler.

However, a wood heater can also be combined with other firing techniques. In most cases, this is a combination of a split log boiler with an automatic pellet, oil or gas-fired heater, which serves as a “backup” or improves comfort. If the generated heat output of the split log boiler is too low, for example, because no one is in the house for refill, the pellet heater automatically starts.

The power-generating heating system

Generating not only heat but also electricity

Conventional heating systems work according to a clear principle: The used energy medium is converted into heat.

In so-called decentralised cogeneration of heat and power (CHP), the device generates electricity and heat simultaneously. This saves fuel and increases the energy efficiency of the system. Very high overall efficiency of over 90 % can be achieved through simultaneous production of electricity and heat. Losses due to waste heat, resulting in separate power generation in power plants, are avoided.

A power-generating heating system reduces energy costs and the primary energy demand, as well as climate-damaging CO_2 emissions. Thus, it makes a direct contribution to environmental protection.

The decentralised CHP is particularly profitable if heat and electricity are produced where they are needed, no heating grids are required and the equipment is operated at the base load (i. e. with operating times of more than 3,000 hours per year).

In many countries, the use of decentralised CHP is particularly encouraged. As a rule, self-generated electricity is subsidised, and there are incentives in the payment of taxes on energy.

Fields of application and their advantages

The range of decentralised CHP solutions offered is as broad as the demand:

- For single and two-family houses, there are so-called "micro-CHP systems" with an output range of up to about 2 $kW_{el.}$
- For apartment houses and small and medium-sized businesses, there are "mini-CHP systems" with power outputs up to 50 kW_{el}.
- In the industrial sector and large residential complexes, CHP systems with more than 50 kW_{el} power are used.

The decentralised cogeneration of heat and power is an important part of sector-coupling. Decentralised CHP systems can jointly act as a kind of "virtual power station" to compensate for voltage fluctuations in the public grid, for example, to absorb peak loads. This is necessary, for example, in the case of weather-related grid fluctuations – a foreseeable consequence of the expansion of photovoltaic and wind power plants.

CHP systems are designed either according to the electricity demand of a property (power oriented) or according to the heat demand of a property (heat oriented). Generally, most of the systems are designed according to the heat demand of buildings. However, the heat from decentralised CHP systems is used not only to supply the building with heat and domestic hot water. It is also used as process heat, for technical refrigeration, compressed air supply and allows other technical applications.

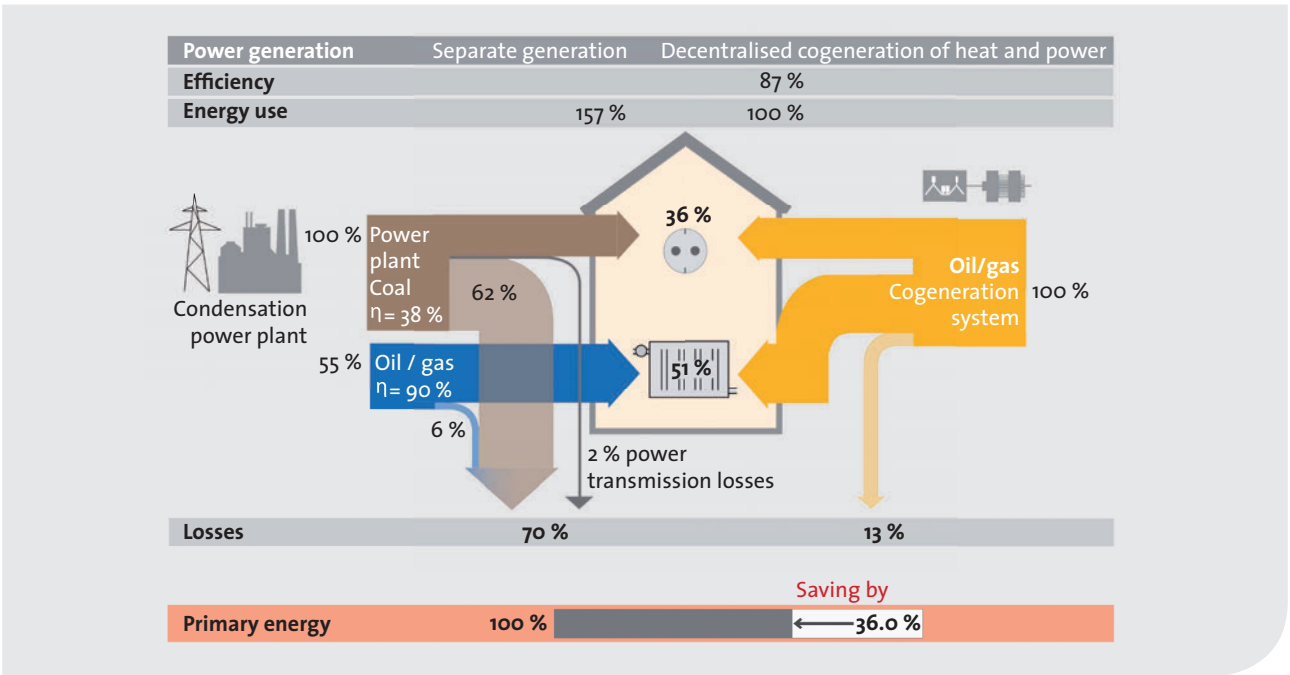
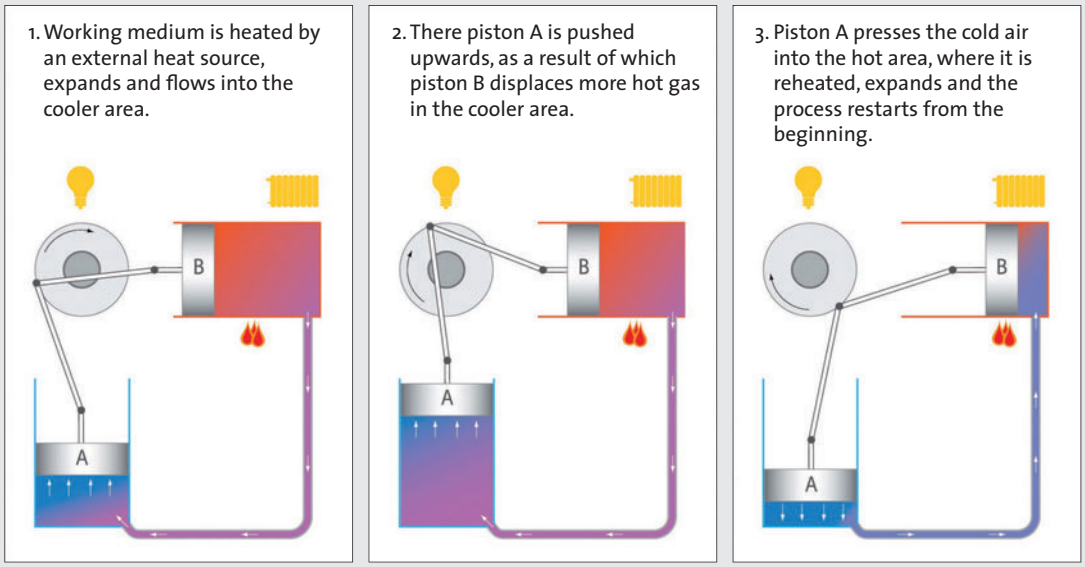


Fig. 57: Comparison on the basis of primary energy



Source: ASUE

Fig. 58: Working principle of Stirling engine

Micro- and Mini-CHP systems are generally operated with condensing devices. They are suitable for basement and roof installation. The systems are easily integrated into existing heating systems and help to reduce the purchase of electricity from the public grid. Excess power generated can be fed into the public grid. The local power utility company takes it off and pays for it as well.

Micro-CHP technologies

Many manufacturers offer micro-CHP technologies today. They can be distinguished by

- the technology used,
- their electrical and thermal output and the ratio between them (CHP coefficient),
- the modulation option and
- the used fuel.

Heat and power units and fuel cells are available as basic technologies. The heat and power units are classified as follows:

- internal combustion engines (e. g. petrol engine)
- external combustion engines (e. g. Stirling engine and steam engine) and
- micro-gas turbines.

The cutting edge, commercially available micro-CHP systems are based on combustion and Stirling engines.

Stirling engine

The Stirling engine operates with an external combustion system that heats a working gas (such as helium) from the outside. The gas expands and flows into the region, which is cooled with water from the heating circuit of the building. There, a working piston is pushed upwards, as a result of which the piston in the hot area displaces more gas into the cooler area. After the piston has reached the top dead centre in the cold region, it pushes the cooled air back into the hot area. There, it is reheated, expands and the process restarts from the beginning.

Stirling engines operate quietly, with low emissions and virtually no wear. Similar to refrigerators they have hermetically sealed workspaces, which reduces maintenance costs considerably. Relatively low electrical efficiencies (approx. 10–15 %) are in contrast with high thermal efficiencies, so that overall efficiencies of over 95 % can be achieved.

Fig. 59: Mini-CHP system with gas condensing boiler for peak load

Fuel cell heating

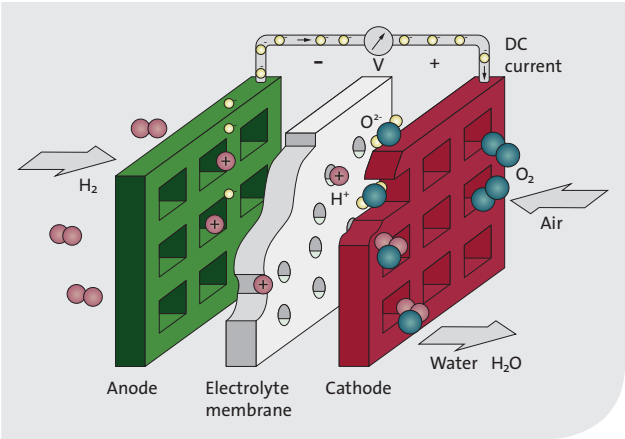
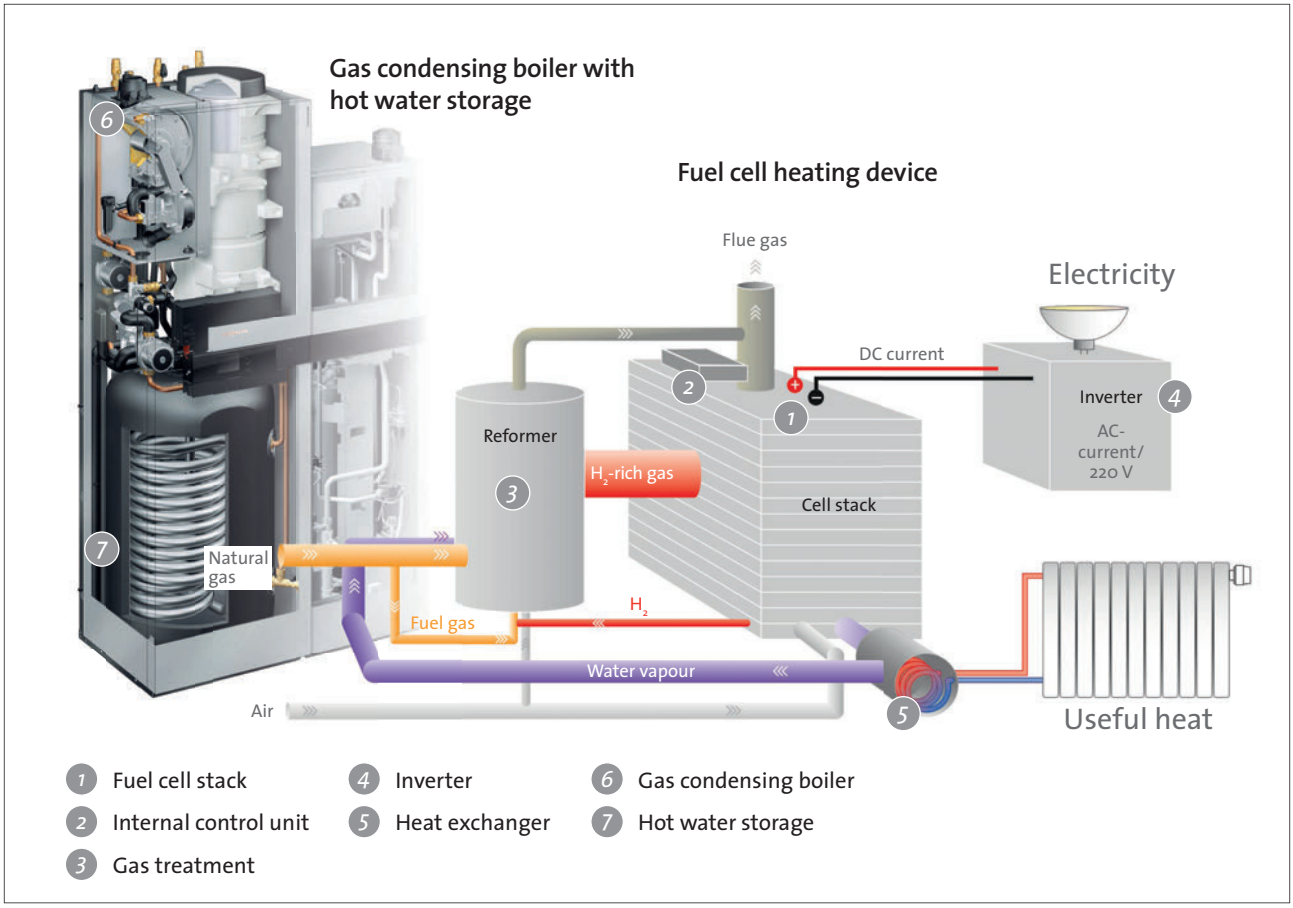


Fig. 60: Functional principle of a fuel cell

A fuel cell is made up of two electrodes – the anode (negative terminal) and cathode (positive terminal). They are separated by the electrolyte with a solid ion permeable membrane. Each electrode is coated with a catalyst, e. g. nickel or platinum. After hydrogen is supplied to the anode, the hydrogen breaks up into electrons and protons. The free electrons are used as a useful electric current by the external circuit. The protons spread to the cathode through the electrolyte. On the cathode, oxygen from the air combines with the electrons from the outer circuit and the protons. Together, they yield water and heat. Now, a voltage can develop between the anode and cathode. If both the electrodes are connected, the electrons will flow from the anode to the cathode and generate a current in this process. The heat of the reaction is used for heating and for domestic hot water preparation. The fuel cells can be operated directly with hydrogen or alternatively with natural gas using an upstream reformer.

Fuel cell heating devices make use of the principle of reversed electrolysis. This is a reaction of the hydrogen used, under controlled conditions without external power supply. This process is known as "cold combustion". In this process, electrical energy and heat as well as water are generated.

Unlike the CHP systems with a motor concept, usually, fuel cell heaters have higher electrical efficiencies due to their direct electrochemical conversion. The electrical DC voltage achieved in practice is between 0.8 and 0.9 V for a single fuel cell. The cell voltage depends on the temperature, the pressure and the gas



Source: ASUE

Fig. 61: Components of a fuel cell installation, using a PEMFC as an example

composition. Therefore, in order to achieve a higher voltage, individual fuel cells must be connected to one another. This interconnection generally takes place in a sandwich construction; that is, the individual cells are stacked on top of each other and wired in series. Fig. 61 shows the typical construction of a fuel cell heating device. The fuel cell heating device consists of several components, which together form the whole system. The most important components are:

1. Fuel cell stack
2. Internal control unit
3. Gas treatment
4. Inverter
5. Heat exchanger

The most common types of fuel cells for building heating can be classified into two groups according to their temperature level; on the one hand, into the low-temperature fuel cells and on the other, into the high-temperature fuel cells. These are PEMFC (Proton Exchange Membrane Fuel Cell) and SOFC (Solid Oxide Fuel Cell). The following are the main characteristics of the two types:

	PEMFC Proton Exchange Membrane	SOFC Oxide ceramics
Electrolyte	Polymer membrane	Solid oxide electrolyte
Operating temperature	70–90 °C	650–1,000 °C
Fuel	• Hydrogen • natural gas • Methanol • Methane	• Hydrogen • natural gas • Methane
Range of application	• Motor vehicle drive • BTTP • Micro CHP	• Power plant • BTTP • Micro CHP
System efficiency (electrical)	~ 32–38 %	~ 33–60 %

Manufacturer	**Buderus**	**HEXIS**	**Junkers**	**Viessmann**	**SenerTec**	**Vaillant**	**Elcore**
Type	SOFC	SOFC	SOFC	NT-PEM	NT-PEM	SOFC	HT-PEMFC
Model name:	Logapower FC10	Galileo 1000 N	Cerapower FC10	Vitovalor 300-P	Dachs InnoGen	xellPOWER	Elcore 2400 Max
Output (el/th)	0.7/0.62 kW	1.0/1.8 kW	0.7/0.62 kW	0.75/1 kW	0.7/0.95 kW (modulating system)	0.7/1.3 kW	0.3/0.7 kW
Thermal output of the auxiliary burner	7.3–24 kW	7–21 kW	7.3–21.8 kW	5.5–19 kW	5.2–21.8 kW	5.8–27 kW	2.9–20.0 kW
Storage tank	Hot water storage tank 75 l, Buffer storage tank 135 l	external, can be selected individually.	Hot water storage tank 75 l, Buffer storage tank 135 l	Hot water storage tank 46 l, domestic hot water storage tank optionally expandable up to 300 l, Buffer storage tank 170 l	300 l Buffer storage tank with fresh water station	external, can be selected individually.	Elcore energy storage with hygienic domestic hot water preparation: 560 l, 820 l, 2 x 320 l, 820 + 320 l, 2 x 820 l
Electrical efficiency	45 %	35 %	45 %	37 %	37.7 % (full load)	33 %	32 %
Total efficiency	85 %	95 %	85 %	90 %	90 %	93 %	104 %
Dimensions in mm (W x D x H)	1,200 x 600 x 1,800	620 x 580 x 1,650	1,200 x 600 x 1,800	1,085 x 595 x 1,998	Fuel cell heating device: 453 x 728 x 1,054 Entire system 1,250 x 1,060 x 1,800	599 x 693 x 1,640	600 x 550 x 1,050

Fig. 62: Device overview of available fuel cell heating devices for domestic use in Germany

Solar thermal systems

Application in the system

In solar thermal systems, the solar energy is used to extract thermal energy. Solar collectors convert sunlight into heat that is used for heating buildings. This saves a lot of energy and thus, fuels as well.

Solar thermal systems are usually designed bivalent. Thus, to make use of solar thermal energy, the system must be well-matched with the other heat generators – the components should not work against each other. Because in the end the desired savings can be achieved only with an overall system with optimised control technology and hydraulics.

Domestic hot water preparation

For preparing domestic hot water, collectors are installed on the roof. They heat a heat transfer medium and deliver the extracted heat to the solar tank via a heat exchanger. Only when the solar energy is not enough, the conventional heat generator is turned on.

Other components of the system are pumps, temperature indicator, expansion tank, vent and controller for regulating the solar pump.

Auxiliary heating

If space heating is required besides preparation of domestic hot water, the collector surface must be increased by 2 to 2.5 times. Depending on the heat insulation of the building, this saves 10 to 30 % of fuel. In case of low-energy buildings, you can save up to 50 % on fuel.

Fig. 63: Solar system for one-family house

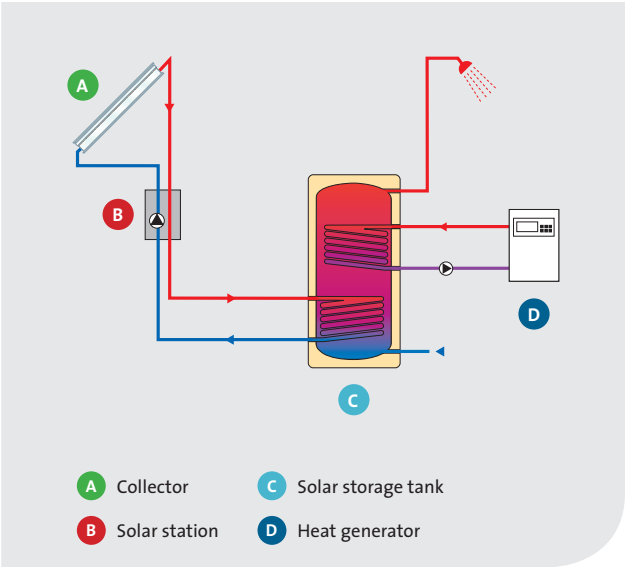


Fig. 64: Standard solar system for domestic hot water heating in one-family house

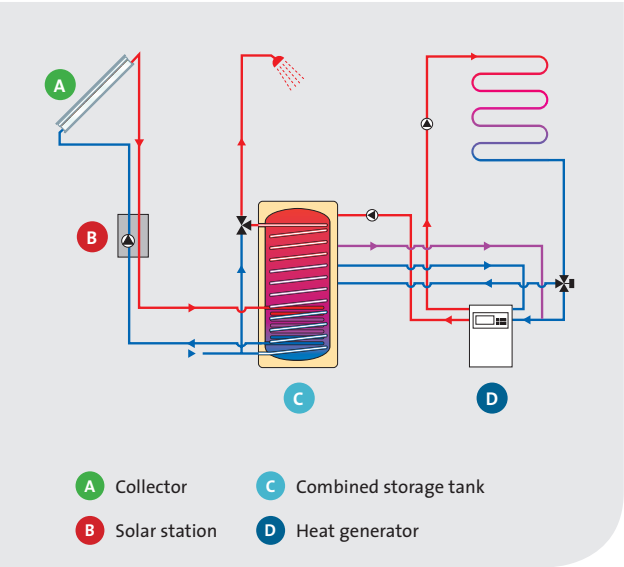


Fig. 65: Solar thermal system for supporting space heating and domestic hot water heating with combined storage tank

Large potential

Solar thermal systems for preparation of domestic hot water and auxiliary heating are now mainly installed in residential buildings – especially in one and two-family homes. They are also very well suited for multi-storey residential buildings.

Grants and low-interest loans accelerate this trend. Even hospitals, hotels and sports facilities can save energy using a solar system. Almost all heat consumers make use of auxiliary heating using solar thermal energy.

Compliance with legal requirements

The energy requirements for new buildings and system modernisation all over the world are increasing. Often, solar thermal systems help in fulfilling these requirements. As regards classification of the energy label, the use of solar thermal energy ensures a higher energy efficiency class of the original heat generator.

Other applications

Solar collectors can also produce hot water for outdoor and indoor swimming pools, thus saving a substantial part of the energy costs.

Using solar thermal energy to support commercial or industrial processes offers huge potential.

Wide scope of applications

Almost all the requirements and technical systems in the heating market can be meaningfully combined with a solar thermal system. Ready-made system solutions are now available for most applications. These pre-assembled systems shorten the set-up time significantly.

The unit pre-assembled as a solar station allows quick and safe commissioning. High workmanship and good material ensure reliability and secure the energy savings over decades.

Flat plate collectors

Flat plate collectors are currently the most widely used collector type in Germany and Europe. During operation, selectively coated high-performance absorbers always ensure maximum possible heat yields.

Besides, these collectors allow versatile architectural design options and are suitable for both in-roof installation as well as on-roof or flat roof mounting.

Solar thermal systems

Fig. 66: System example – Flat plate collector

Vacuum tube collectors

Vacuum-assisted insulation (evacuated glass tube) allows achievement of high outputs in applications with high target temperatures. In standard applications, the vacuum tube collector requires a smaller area than a flat plate collector, based on the average annual output.

Storage tank

For all applications, sophisticated types of storage tanks are available to the consumers (bivalent domestic hot water storage tank, buffer storage tank and combined storage tank). Common quality characteristics are their slim, tall design and seamless insulation, with which the stored heat can be best maintained. All systems are available with layer loading facilities.

Regulator

Modern controls ensure safe and efficient operation of the entire system. Often, the functions of the solar system are already integrated in the control for the heating system. This guarantees the perfect interplay of all components.

Fig. 67: System example – Vacuum tube collector

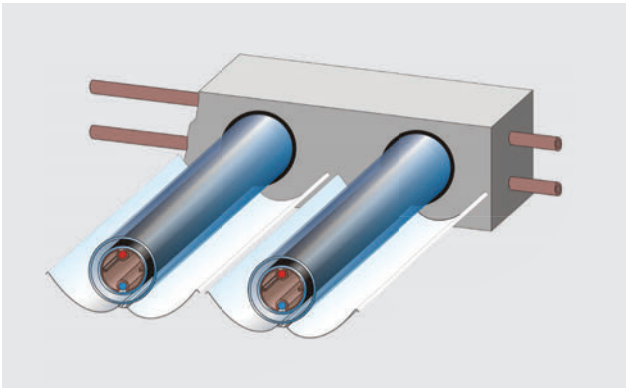


Fig. 68: With an external reflector

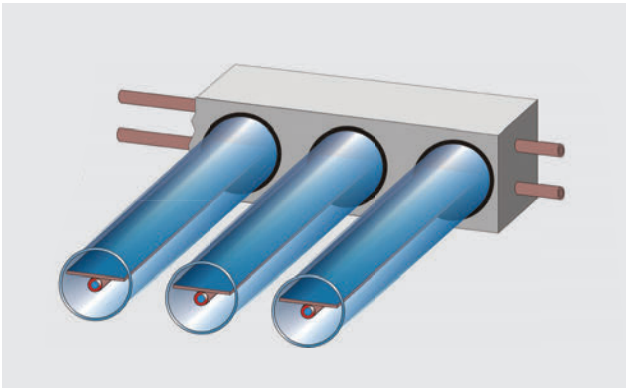


Fig. 69: Without reflector

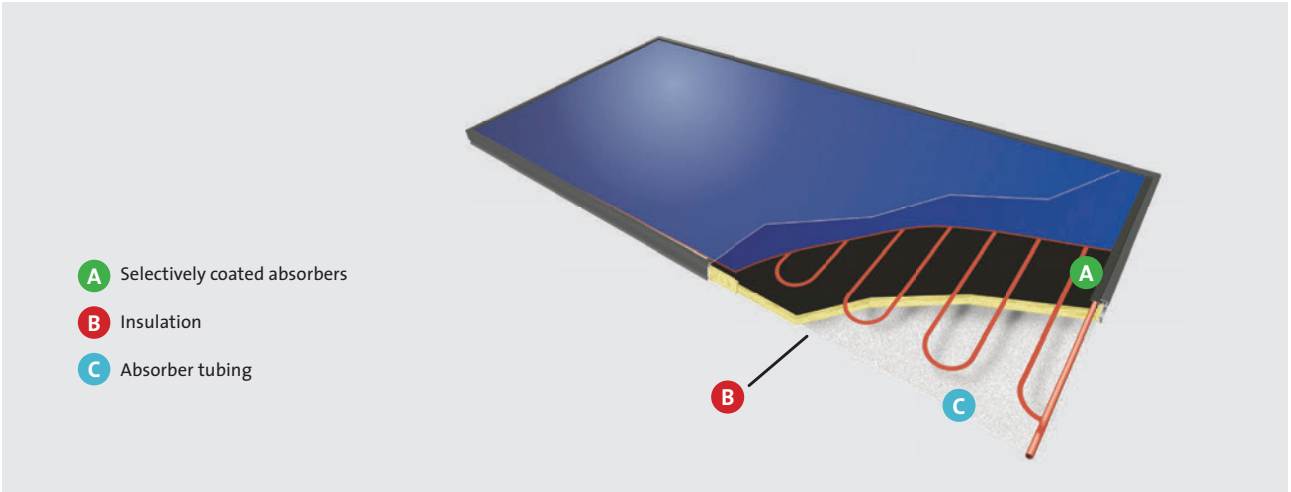
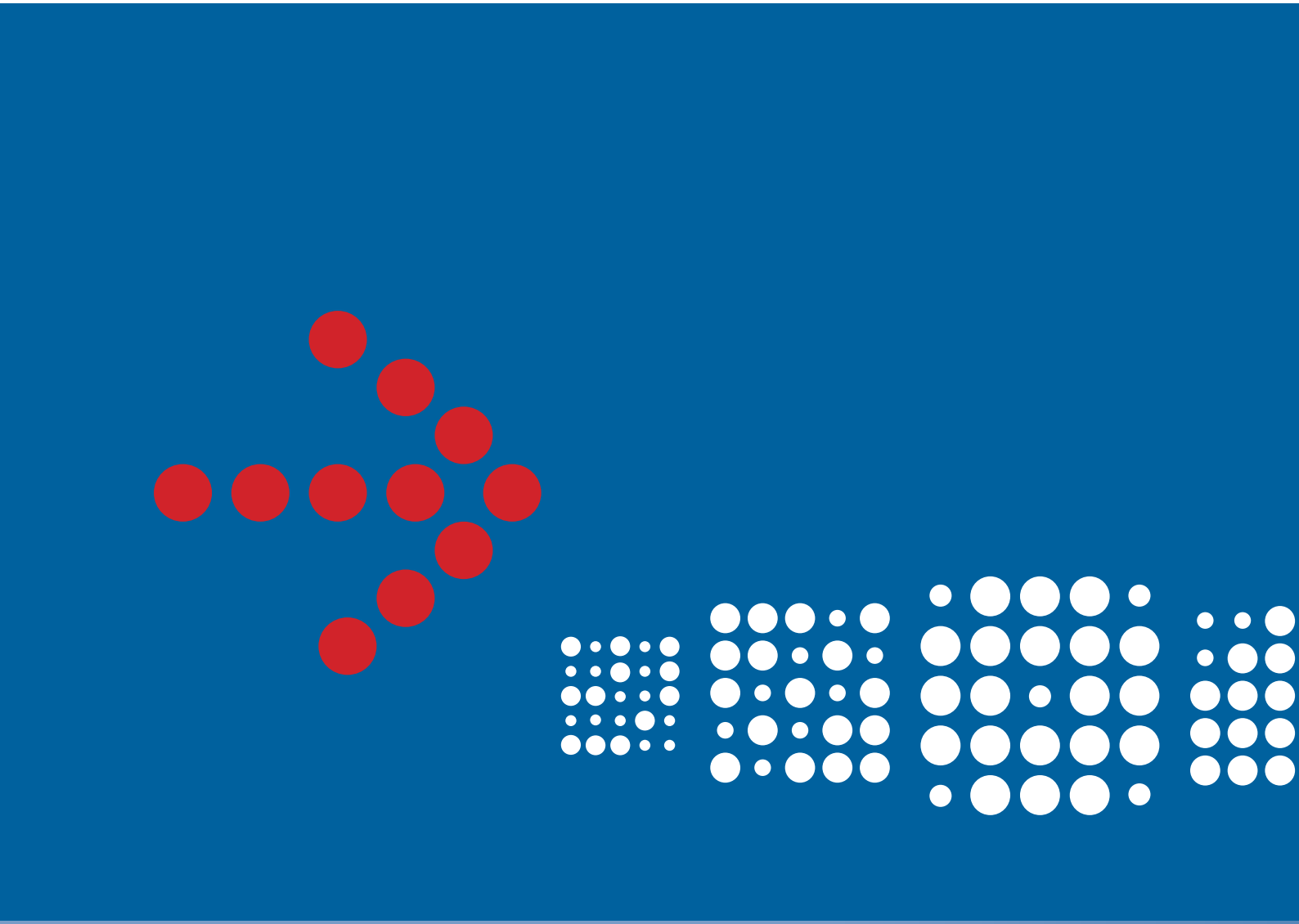


Fig. 70: Installation of a flat plate collector

ISH Technology and Energy Panel



Heat distribution, heat emission, system components

- Heat distribution
- Hydraulic balancing and high-efficiency pumps
- Embedded surface heating and cooling system
- Radiators
- Residential ventilation systems with heat recovery
- Storage technology
- Flue gas systems
- Tank systems

Heat distribution

Components

Heat distribution ensures that the required energy is transported from heat generation to the heat transfer system. In addition to the pipes, the (circuit) control valves and the pumps are mainly used for heat distribution in a hydraulic heating system.

Line layout

For the construction of the pipes of the heating system, there are various ways of laying the pipes between the heat generator and the heating surface. Usually the ascending pipes are arranged in a shaft centrally in the building. The horizontal distribution is carried out as a single or two-pipe system within the insulation layer of the screed or in a suspended ceiling below the raw ceiling up to the heating surface.

Pipe network calculation

A pipe network calculation must be carried out within the scope of the system planning to dimension the line cross-sections in such a manner that the specified heating water volume is fed to the heat transfer unit. During the calculation, no excessively high flow rates should be selected so that no undesired noises occur during operation and the pressure losses are kept within limits. The result serves as a setting value for the control valves.

Fig. 72: Radiator thermostatic valve

Insulation of pipes

For the energy-efficient installation of the heat distribution, requirements for the thermal insulation of pipes and fittings are defined in the EnEV (Energy Saving Ordinance). It precisely specifies the insulation thickness to be maintained for a specific inner pipe diameter. A professional implementation for avoiding heat

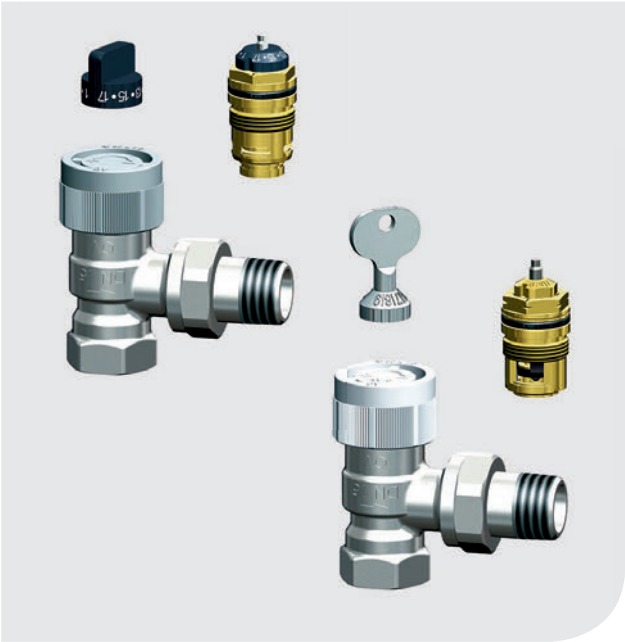


Fig. 71: Fittings

Fig. 73: Valve with valve core that can be preset for adaptation of the volume flows to the required heat load

bridges is of crucial importance. Pipes in wall and ceiling ducts have to be provided with an elastic enclosure to prevent the transmission of structure-borne sound between the building structure and the pipe. When subsequently plastering the lead-through openings, care must be taken that no sound bridges are formed.

Control valves

Valves are used for shutting off pipes or regulating the flow rate or pressure. As control valves in the heat distribution system, differential pressure or mixing valves as well as circuit control valves are used. Differential pressure valves are necessary to ensure optimum pressure conditions in the heat distribution. Depending on the system size, the differential pressure control can be carried out centrally or decentrally. Mixing valves are required to mix heating water at different temperatures, so as to obtain a desired system temperature as a result. A three or four-way mixer for embedded surface heating systems is a typical application.

In individual distribution pipes/lines of a heating system, circuit control valves are installed to optimally balance the volume flows as needed. As a result, equal pressure losses can be adjusted throughout the entire pipe network, which assists in the hydraulic balancing and the efficient distribution of the heating water is ensured. This is the prerequisite for the efficient use of heating pumps.

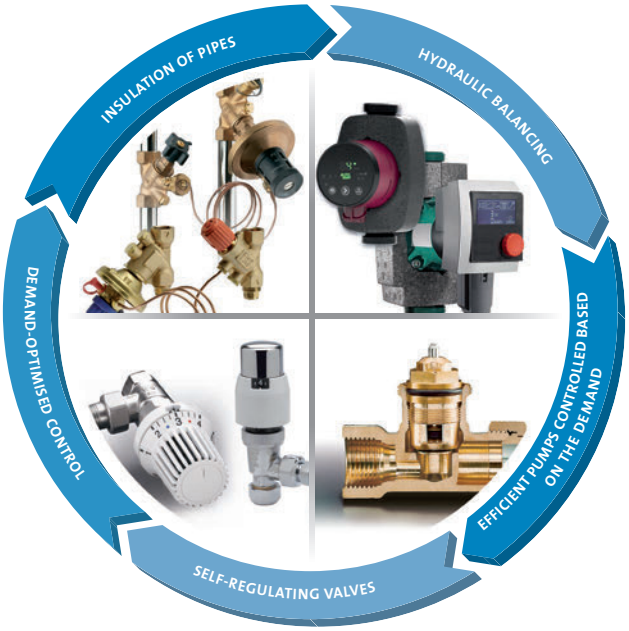


Abb. 75: Influencing factors for efficient heat distribution

Fig. 74: Electronic radiator valve

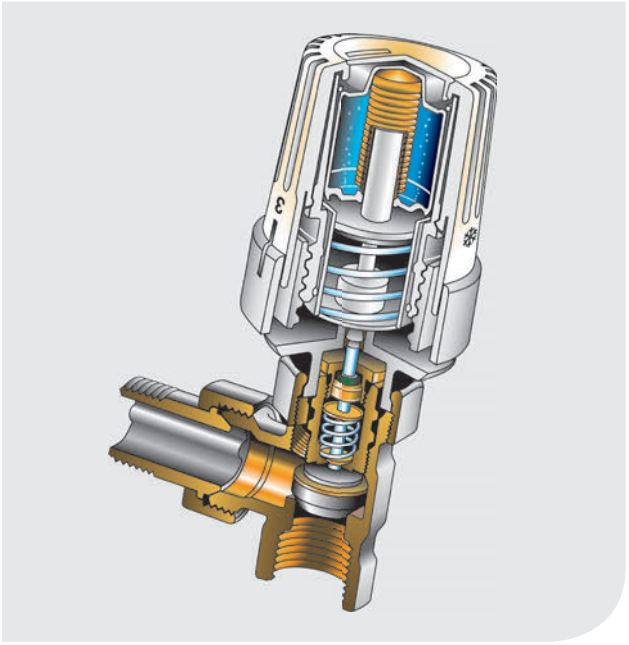


Abb. 76: Sectional model of a radiator valve

Hydraulic balancing and high-efficiency pumps

Hydraulic balancing enables comfort and saves costs

A major part of the energy utilised in Germany, is consumed by residential buildings, particularly as heating energy. Hydraulic balancing is an effective means of saving heating energy. In hydraulic balancing, the aim is to coordinate the individual components of a heating system exactly in such a way that the heat reaches, where it is required. For hydraulic balancing, modern thermostatic valves or lockshield valves on the heating surfaces are required. Hydraulic balancing with corresponding declaration can be carried out according to DIN EN 14336.

The path of least resistance

With hydraulic balancing, a uniform heat distribution can be achieved in a building. Here, the heating system setting is such that the system made up of pipes, pumps and valves offers minimum possible resistance to the circulating water. This is because the water in the heating system takes the path of least resistance, with the consequence that the heating surfaces in distant rooms are occasionally not heated properly. More powerful circulating pumps must compensate for this. The price of this is very high: Energy consumption and electricity costs shoot up, since the heating pumps consume more electricity than required.

Moreover, a non-balanced system can significantly reduce the efficiency of condensing devices: Oversupply to certain heating surfaces leads to higher return temperatures in the system. The water in the flue gases of the heating system can condense only in a limited manner or not at all. Therefore, less heat is used and the savings that are usually achieved with a condensing device are nullified.

Sounds as indicators

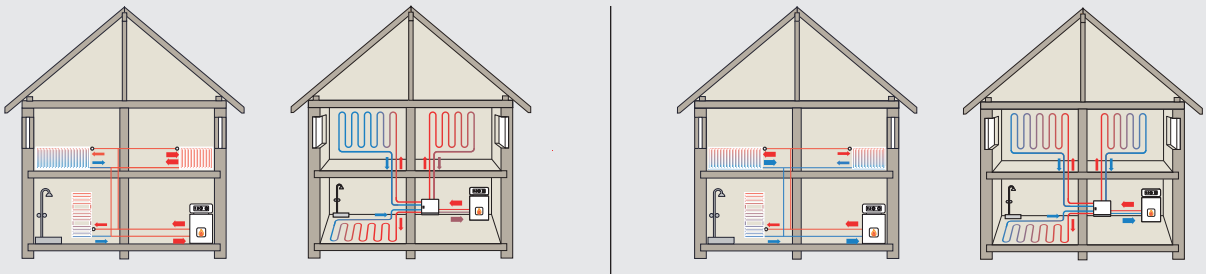
The typical signs for absence of hydraulic balancing are, for example, radiators which do not heat up whereas others are oversupplied. Also, noises in valves or pipes indicate that the differential pressure in the valve or the velocity of flow is too high. It may also happen that the radiator valves do not open or close at the desired inner temperature due to excessive differential pressure. Hydraulic balancing offers several advantages to the residents: The system can be operated with optimum system pressure and a lower volume flow rate. This reduces the energy and operating costs: Saving of up to 15 % of the heating energy costs is possible.

EnEV, VOB & Co.

The EnEV (Energy Saving Ordinance) requires that technicians confirm in writing, as part of the subcontractor declaration, that their services comply with the ordinance, that the hydraulic balancing has also been executed, in case it has been included in the verification procedure. Even according to the German Construction Contract Procedures (VOB) Part C and DIN 18380, it is mandatory for technicians to balance the heating pipe networks hydraulically. In addition, it is required by all relevant funding programmes of KfW or the Federal Office of Economics and Export Control (BAFA).

Calculating the heating load, adjusting the heat output

For hydraulic balancing, it is first necessary to calculate the heat load for every room in the building, taking into account the external surfaces, walls, ceilings, windows and doors. According to the calculated heating load, the heating surface with the required



Heating surfaces (left: radiator or right: embedded surface heating and cooling) –
volumetric flow rates poorly balanced – warm return flow

Heating surfaces (left: radiator or right: embedded surface heating and cooling) –
volumetric flow rates well-balanced – cold return flow

Fig. 77: Hydraulic balancing

heating output is chosen. Additionally, the different pressure drop en route the heat generator to the heating surface should be taken into account. The setting values for the individual heating surfaces are derived from all these parameters. Hydraulic balancing is achieved when all parallel systems have the same hydraulic resistance.

Thermostatic valves or lockshield valves on the radiators that can be preset, support the hydraulic balancing. It is also important to determine if the concerned system is a dual pipe system, because a single pipe system allows only restricted balancing. The data for a single-family house is recorded in about one and a half hours and analysed in about 1-2 hours. The setting is done in just five minutes for each heating surface. The costs for hydraulic balancing depend upon the size of the building; the costs for a single-family house amount to approx. EUR 500.00, which can however be redeemed quickly, thanks to the energy savings.

Inspection of the installed heating pump is always a prerequisite for hydraulic balancing. Overdimensioned and unregulated pumps need to be replaced so that the benefits of hydraulic balancing can be fully utilised.

High-efficiency pumps: Efficient and regulated according to demand

A heating pump in a heating system has the task of ensuring the flow of the heat transfer medium (heating water) through the system. The pump ensures smooth circulation of the heating water from the heat generator through the heat distributors to the heating surfaces in the room within the heating circuit. The efficiency of a heating pump can be seen when looking at the required electric current. While older models are true power guzzlers, so-called high-efficiency pumps need much less energy.

Four different circulating pumps can be installed in an existing heating system. Unregulated heating pumps always work with full output. During the heating period, they often run at a fixed output level during continuous operation. In the case of multi-stage pumps, the output can be regulated in steps. However, many of these pumps run at the highest level. Electronically controlled pumps automatically control the speed and thus, also the electrical power consumption according to the set demand value. The high-efficiency pumps adapt themselves to the actual requirements by means of electronic control.

A high-efficiency pump allows efficient control of both the heating circuit and the drinking water circulation. The high-efficiency pump only works when the heat transfer medium is required. The pump reacts automatically and quickly to the changes in the water pressure in the lines and adapts the pressure conditions to the new status. Especially in the so-called partial load range, i. e. the period during which the pump does not have to work at full output, the pump output is continuously reduced to the minimum energy by short reaction times. This partial load range can account for approximately 90 % of the total operating time, so that considerable energy savings can be achieved by adapting the pump output as needed.

From August 2015, in accordance with the European EC 641/2009 Ordinance, the market has access only to circulating pumps with an energy efficiency index better than 0.23 – the so-called high-efficiency pumps. These are much more efficient and adapt to changing performance requirements of the system continuously. Thus, they not only save valuable electrical driving power in the full load state, but also in the predominantly encountered partial load condition of the heating system. Compared to conventional pumps they use 80 % less electricity.

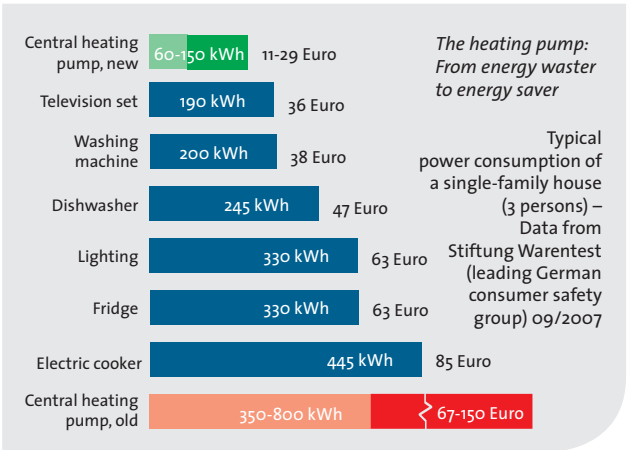


Fig. 78: Savings potential of pumps

Fig. 79: High-performance pumps according to Eco-Design Directive 2013

Embedded surface heating and cooling system

Heating and cooling in one system

A majority of builders opt for an embedded surface heating and cooling system for new buildings. The heating system is permanently installed in the floor, wall or ceiling during the construction phase itself. Because of the large-area span, the embedded surface heating and cooling system is able to bring about a uniform distribution of temperature, thus, ensuring a pleasant temperature throughout the year. Considering larger window areas and increasing building insulation, the option of cooling with the same system in summer is constantly gaining importance. This functionality is not only applicable in apartments, but also in office buildings or halls. Also, as a rule, the service life of the embedded surface heating and cooling is to be equated with the economic life of the building, making it a solution that is at the same time sustainable, efficient and convenient.

Wide range of solutions also for building stock

For existing buildings, suitable systems are offered for subsequent integration in floor, wall and ceiling without any structural changes. The versatility of wet systems (screed or plaster), dry systems and special thin-layer systems offers optimum solutions to the builder for the use in new buildings as well as for modernisation. The dual function of heating and cooling can be used also in the application in existing buildings.

Practically unlimited range of application

Apart from the already described field of residential buildings, the embedded surface heating and cooling system can be used in office buildings and halls. As part of a central heating system, the embedded surface heating and cooling system also ensures a pleasant atmosphere throughout the year as well as energy efficiency.

Fig. 80: Dual function "heating and cooling"

More comfort, less costs

In embedded heating systems, only low system temperatures are generally required (35 °C flow temperature/28 °C return temperature). Thus, they are an energy-efficient supplement for condensing boilers, heat pumps and solar thermal systems. The low system temperatures benefit the residents in two ways: they provide for a large energy savings potential and an enormous increase in cosiness and comfort. This can be additionally supported with intelligent single-room controls.

Last but not the least, the invisible embedded surface heating and cooling system in the floor, wall and ceiling offers the advantage of leaving ample space for the residents for interior decoration.

Effective cooling in summer

In summer, the embedded surface heating system can also be used for simple room cooling, cost-effectively, with the help of an extra "Cooling" function. In this process, cold water circulates through the pipes and lowers the temperature of the floor, wall or ceiling and thereby of the rooms by up to 6 Kelvin (K) – without the occurrence of any draughts.

The efficiency of an embedded cooling system is determined by the difference between the flow and return flow temperature of the coolant. While the temperature difference during the heating process is about 8 K normally, an embedded cooling system should not be operated with a spread of more than 3 K. Due to the low temperature difference between the temperature of the coolant and ambient air, e. g. 18 °C coolant flow temperature, an embedded cooling system is also ideal for making use of natural heat sinks such as ground water or soil for allowing an energy-saving cooling operation.

Due to these temperature differences between the coolant and room air, an embedded cooling system is very well suited in terms of thermal comfort and energy efficiency to contribute to room cooling. The area-specific cooling capacity has a positive effect on the well-being of the users.

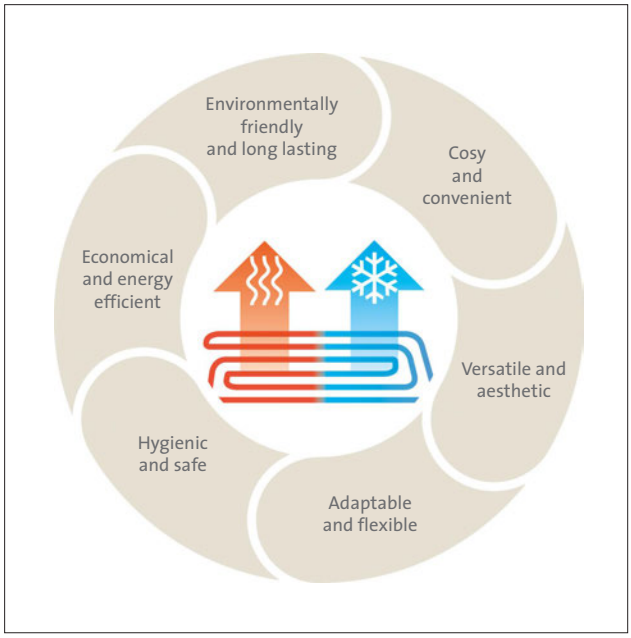


Fig. 81: The features of an embedded surface heating and cooling

Controller prevents condensation

A controller which covers both the heating and cooling functions is required to regulate the system temperature during cooling operation. The controller maintains the temperature of the embedded cooling system above the dew point, thus preventing condensate formation on distribution pipes and transition areas.

The different designs of the embedded cooling system in the living areas of a residential building or office building reach a cooling capacity of about 35 W/m² in the floor, about 35 to 50 W/m² in the wall (depending on the layout) and about 50 to 110 W/m² in the ceiling (depending on the layout) on an average.

Remote-controlled room temperature control

The options offered by the current control technology for embedded surface heating and cooling systems can be utilised fully only in combination with state-of-the-art communication technology. Thus, the embedded surface heating and cooling system can be controlled from home, remotely or via app, through WLAN, or also via Internet when not at home. An embedded surface heating and cooling system can be controlled from a central computer that manages all data, programmes and information. In principle, such an "on-board computer" can be intuitively operated via a touch screen.

Thus, residents can create individual heating profiles for every room and also modify them, define a basic temperature or adjust the same or control the functionality of the entire system (e. g. day mode/lower mode/frost protection mode). Sensors detect the ambient conditions, which are evaluated by the system and implemented accordingly. Thus, the control and communication technology facilitate an energy management system that is tailored precisely to the needs of residents.

Conclusion

The heat load of a building is always fully covered by using an embedded heating and cooling system. In summer, the ambient temperature can be reduced to a comfortable/pleasant level. Thus, the ambient temperature can be set to a comfortable range throughout the year – in apartments and office buildings as well as halls.

Fig. 82: Easy installation of the embedded surface heating and cooling system with different installation systems

Radiators

Efficient, comfortable and sustainable

Modern radiators can be used flexibly and integrated in a sustainable and long-lasting way in any heating system, irrespective of the source of energy. For long-lasting benefits, heating surfaces that can react quickly to changes of the heat demand are required. This requirement is fulfilled by modern radiators with low installation depths, low water content and high transmission areas. There is a wide range of solutions for new buildings and renovation projects, extending from products for low temperature ranges to systems suitable for remote heating, e. g. when using a heat pump. With the appropriate design, the desired additional function, and the optimum technology, the ambient temperature can be adapted instantly to the wishes of the residents creating maximum cosiness through radiant heat, thereby saving energy.

Quality, efficiency and design

However, the quality is not only determined by the output of a radiator: The heat can be optimally delivered only if the radiator is mounted at the right place. The classical space under the window is still recommended. The right positioning from the energy aspect combined with the design demands to the room gives an optimum tailored solution. For efficient heat dissipation, the radiator should not be hidden behind furniture or curtains.

Comfortable temperature exactly to the degree

A heating system works through the interaction of many components – from the heat generator over thermostatic valves to the individual radiators. Maximum efficiency of the system can be achieved when all components are precisely matched with each other in terms of both energy and hydraulics.

An important role in this is played by thermostatic valves that keep the indoor heat constantly at the desired temperature. For this purpose, they have to rely on the correct differential pressure on the radiator, which is determined by hydraulic balancing: It ensures a uniform flow through the heating system and improves controllability. It eliminates noise and helps to reduce the consumption of energy and operating current.

In order to achieve maximum heat dissipation even with reduced water flow, modern thermostatic valves and fittings for hydraulic balancing support the heating system in exactly setting the individual “comfortable” temperature also at different heating times. Time-controlled thermostatic valves preset the time at which the radiator should start with the heating – accurate to the degree, including automatic shutdown.

Beautiful design and intelligent features

The many variations in shape, colour and design allow an attractive, individualised interior and create new scopes of designing for the residents, since the radiators fit seamlessly into the architectural environment. New radiators are available in many colours – chrome versions are also possible. If you want something special, the radiator can e. g. be powder-coated with a matt finish or made available in a stainless steel design. Additional features and smart accessories such as towel rods, mirrors or racks, hooks and lighting create feel-good accents. Often radiators are also used as design objects which fit into the ambience and match with the colour and design of the room.

Fig. 83: Innumerable design options and intelligent accessories

Fig. 84: Modern radiators for individual living comfort

Between modernisation and comfort

Radiators are subject to wear and tear, which affects notably their quality and functionality. Thus, the increase in the service life often is accompanied by a higher energy consumption, increased wear and tear of heating components as well as loss of comfort. Therefore, modernisation of existing equipment aims at increased efficiency through energy-saving operation and optimum heat transfer using modern radiators.

When planning the modernisation of heating systems, owners particularly weigh the costs against the benefits. This is because renovations, disturbances, dirt and noise are often unavoidable during modernisation. The fitting accuracy to the existing connections is taken into account while planning and designing new radiators, so that the replacement of old radiators with new high-performance models is no longer a problem in practice. Simple and quick installation of the radiators is the rule: empty, unscrew, screw, fill – done!

Fig. 85: Fitting accuracy at the time of modernisation of the radiators

Fig. 86: Easy replacement

Residential ventilation systems with heat recovery

Comfort without limitations

Fresh and hygienic air is crucial for our well-being indoors. Ventilation systems with heat recovery guarantee this quality of air and thus, the well-being of the residents.

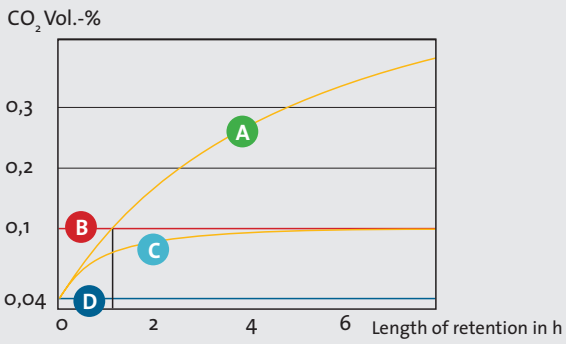
Daily use gives rise to carbon dioxide (CO_2) and water vapour. For proper control and a good comfort level, the rooms must be sufficiently ventilated.

Ventilation systems with heat recovery are capable of doing this automatically and help to save heating energy by heat recovery.

- They provide fresh outdoor air to the rooms, ensuring controlled air exchange.
- Pollutants in the indoor air are discharged outside.
- Windows no longer have to be opened in case of controlled residential ventilation. This provides additional protection against noise and burglary.
- Thus the building is also protected. Accumulated moisture in the air, e. g. caused by showering or cooking, is reliably dissipated to the outside. This removes the nutrient medium for ventilation-induced mould growth.

If desired, the outdoor air can be cleaned additionally by a pollen filter, which limits the exposure to pollen and allergens largely.

Thus, house ventilation systems offer numerous opportunities to find a customised solution for each individual requirement.



A Air exchange = 0

C Air exchange = 0.4 per hour recommended

B Hygienic limit value

D CO_2-content in fresh air

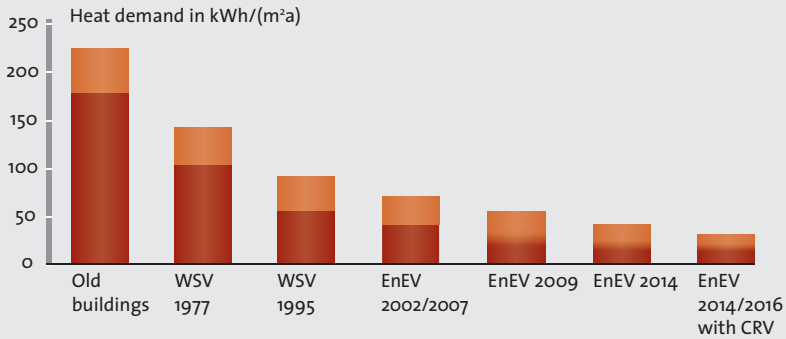
Other influencing parameters: Number of persons and room size

Fig. 88: Increase in the CO_2-concentration because of a resting person

Systems with heat recovery (HRS)

You can't do without ventilation. With normal window ventilation, it is associated with thermal loss because fresh air flows from the outside into the building. Only automatically operating ventilation systems can guarantee optimum balance between the required outdoor air supply and minimal thermal loss.

Maximum energy savings results when the energy of the warm extract air is used to preheat the cooler outdoor air (HRS). Modern systems are able to recover up to 90 % of the heat present in the extract air.



Ventilation heat demand

Transmission heat losses

CRV = Controlled residential ventilation

Current share of ventilation heat losses without heat recovery, up to 50 % of the heating output, reduction up to 50 % possible

Fig. 87: Energy share of ventilation heat loss in heat demand

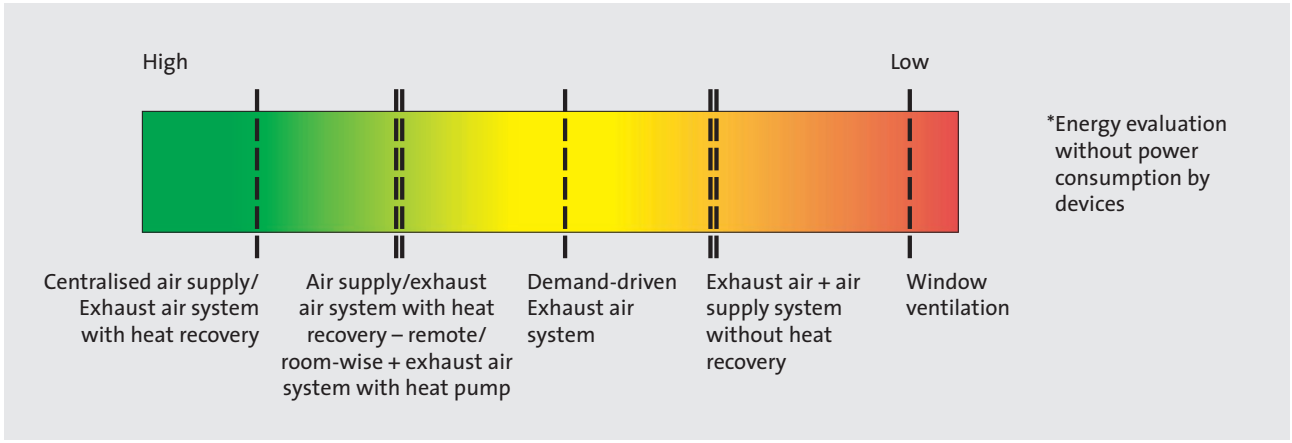


*Fig. 89: Reduction of ventilation heat losses**

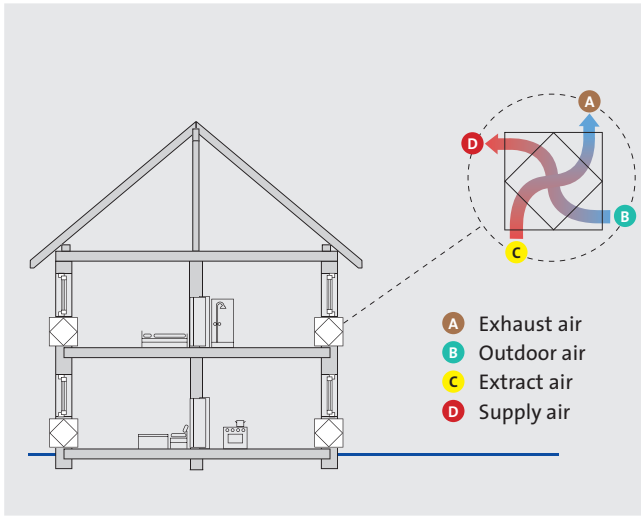


Fig. 90: Fresh air and exhaust air system, room-wise (decentralised) with HRS

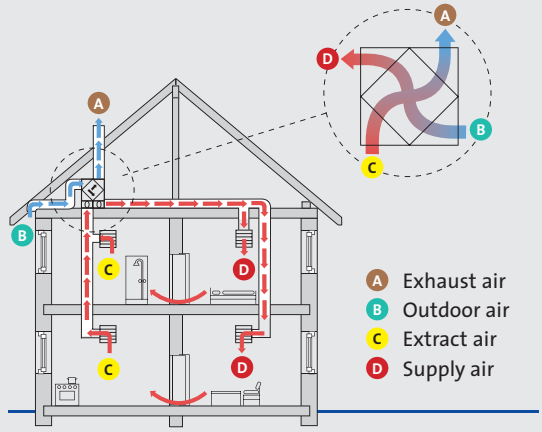


Fig. 91: Fresh air and exhaust air system, centralised with HRS per living unit

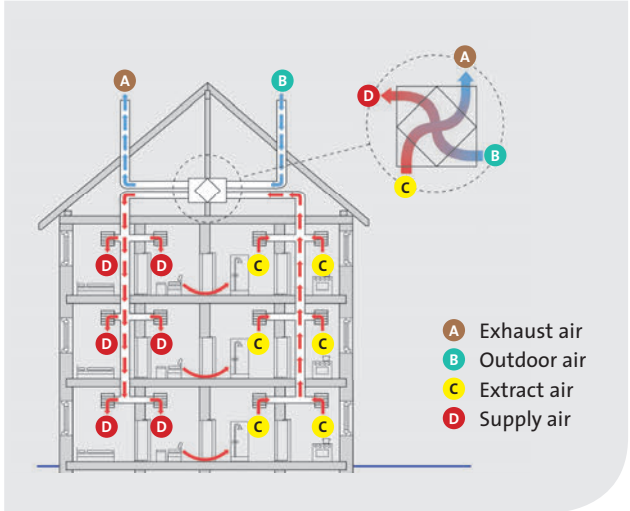


Fig. 92: Supply air and exhaust air system, centralised with HRS for multi-family houses

Residential ventilation systems with heat recovery

In case of mechanical ventilation systems, we distinguish between decentralised/room-wise and centralised ventilation systems per residential unit or for a multifamily house.

Room-wise/remote ventilation systems

In the corresponding fresh air rooms and extract air rooms, individual devices are installed in every room, directly in the outer wall. Thus, no air distribution system is required.

Here, one can select from two modes of operation: Devices, which secure a parallel flow of supply and extract air in every room and regulate the flow of fresh air and extract air alternately: Two devices, which correspond with one another are necessary for a balanced ventilation. Both operating modes are equipped with a heat recovery of up to 90 %. An air distribution system is not necessary.

Since they are mounted in the outer wall, decentralised ventilation devices are particularly suitable for the subsequent integration during the process of modernisation.

Centralised ventilation system with heat recovery

Centralised ventilation devices transport the air via an air distribution system: While one fan draws in the outdoor air into the building, another one discharges the hot extract air from the rooms. A heat exchanger ensures that the heat from the extract air is transferred to the outdoor air coming in. In this way, up to 90 % of the heat is recovered and used to heat the outdoor air. The effect: Up to 50 % of the heating energy can be saved.

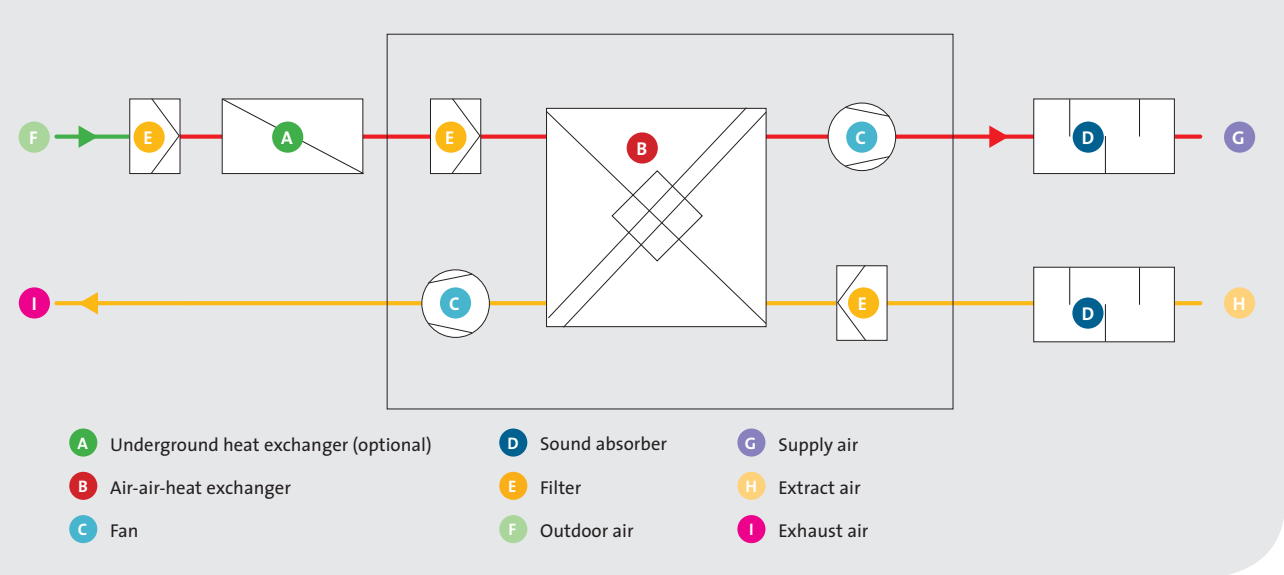


Fig. 93: Schematic diagram of the centralised ventilation system with heat recovery

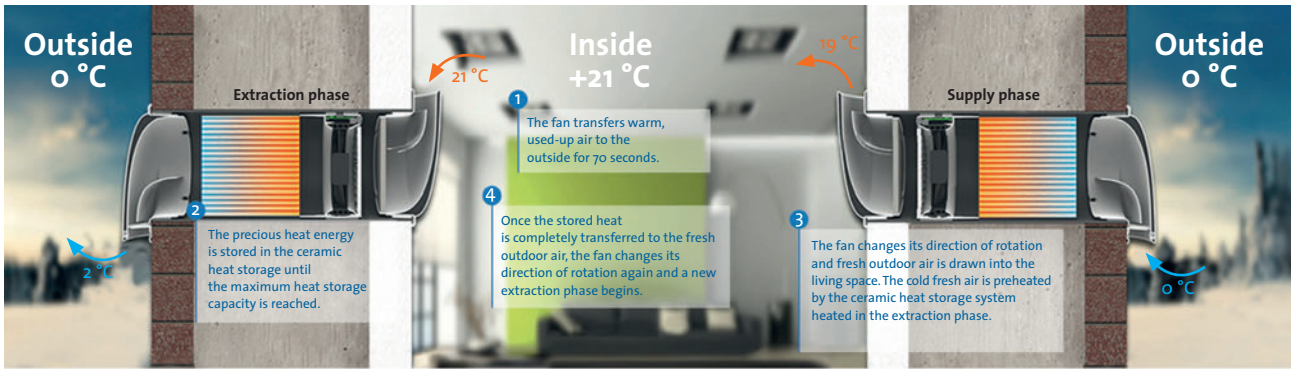


Fig. 94: Schematic diagram of the room-wise/remote ventilation in alternating operation

Plan early and save

Builders and home owners should inform themselves right at the beginning about modern and reliable ventilation systems, while planning or upgrading a building. Thus, the energy-saving potential will be optimally utilised and costs minimised.

In any case, a ventilation concept must be drawn up beforehand to check whether an air ventilation measure is required and if yes, which solution is really suitable.

Benefits at a glance

In addition to high energy and cost savings, users of ventilation systems can also enjoy a higher comfort level:

Modern systems ensure optimum air quality and a comfortable indoor climate with excellent sound insulation at the same time. Other advantages are thorough sanitation, pollution reduction and protection against pollen, mites and mould formation.

Fig. 95: Builders and planners consider the planning of ventilation systems at an early stage

Storage technology

Hot water for all purposes

Domestic hot water storage tanks act as a central component of a modern heating and hot water supply system in residential and office buildings. They can perform different functions due to their great diversity of types.

Domestic hot water storage tanks heat and store the domestic water, which is needed for showering, bathing or cooking.

Buffer storage tanks ensure heating water supply to the heating system over a long period. This allows coupling of heat from renewable energies and CHP systems.

So-called combined storage tanks combine both functions.

Modern hot water storage tanks have high energy efficiency. They are characterised by minimal thermal loss and optimised heat transfer and temperature gradient. All the hot water storage tanks in the market meet the highest standards of domestic hot water quality and sanitation.

Hot water storage tanks also play an important role in connection with cross-sector applications. Excess renewable electricity, e. g. from PV and wind power plants, can be converted into heat and stored in the form of thermal energy in hot water storage tanks (power-to-heat). The conversion usually takes place via efficient heat pumps.

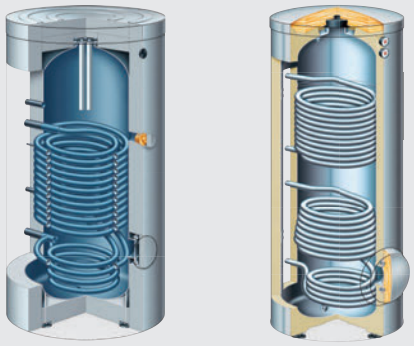
Heating domestic hot water

Hot water storage tanks for domestic water heating store the domestic hot water required in the household or in a building, so as to make it available round-the-clock. There is a distinction between monovalent and bivalent domestic hot water heating.

In the monovalent domestic hot water heating, the domestic water in the storage tank is heated by a heat exchanger. This is supplied with heat by a centralised heat generator such as a gas or oil-fired boiler, a heat pump or alternative energies.

On the contrary, in the bivalent storage tank, the domestic hot water is heated by two heat exchangers: Heat recovered from solar energy is introduced via a heat exchanger to the lower portion of the hot water storage tank. With sufficient exposure to sunlight, the total storage volume can be heated with recovery of heat. In the upper part of the storage tank, there is a second heat exchanger, by means of which the standby part of the storage tank is maintained at a constant temperature through reheating by the centralised heat generator. This ensures the supply of domestic hot water even if the solar energy supply is insufficient.

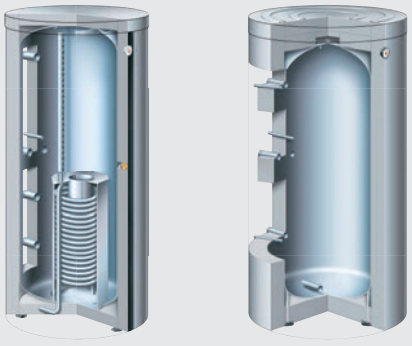
For hygienic reasons, either standard or stainless steel tanks coated with enamel or plastic, are used for domestic hot water storage tanks.



Monovalent
(one heat exchanger)

Bivalent
(second heat exchanger
for solar input)

Fig. 96: Domestic hot water heating



Buffer storage tank

Fig. 97: Energy storage

Storing thermal energy

A buffer storage tank in a heating system is a heat storage tank, which is filled with hot water for heating. It can combine heat from various sources and discharge the heat at intervals.

The buffer storage tank helps compensate for differences between the amount of heat generated and consumed, and thus, level out power fluctuations in the heating system. Thanks to it, heat generation can be operated largely independent of consumption, resulting in better operating characteristics and greater energy efficiency for many energy sources. The continuous thermal loss through the outer surface of the storage tank can be minimised through good thermal insulation and avoidance of thermal bridges.

Multitalent combined storage tank

Combined storage tanks allow domestic hot water heating and energy storage in a single device. With the integration of solar thermal energy, combined storage tanks are used for both heat storage for auxiliary heating and preparation and storage of domestic hot water. It is distinguished between different types of domestic hot water heating.

Combined storage tank with fresh water unit

Here, the domestic hot water heating is via an external heat exchanger: If domestic hot water is required in the kitchen or bathroom, cold water flows through a high-performance plate heat exchanger, which is located outside of the storage tank. There, it is heated by the heating water, which is prepared in a buffer storage tank, directly to the desired hot water temperature.

Combined storage tank with built-in internal heat exchanger

In this model, the domestic water is heated by an internal heat exchanger: By using solar energy, the combined storage tank is charged through a heat exchanger in the lower area of the device. Optionally, a heat conduction tube is used in the stratifier lance technology. If the solar radiation is not enough for domestic hot water heating, reheating is done by the centralised heat generator in the upper region of the storage tank. If sufficient energy is available in the storage tank, the supply of the heating circuit is also via the storage tank. The centralised heat generator is turned on only when the temperature set for the heating circuit in the storage tank is undershot.

Tank-in-Tank system

In this system, there is a second smaller inner tank for domestic hot water inside the buffer storage tank, which holds the heating water. Thus, the solar system can heat the heating water and domestic hot water in one step. The heating water in the outer jacket of the storage tank is heated by a heat exchanger using solar energy. This heat reaches the domestic hot water via the surface of the inner storage tank.

Internal domestic hot water storage tank (Tank-in-Tank system)

External heat exchanger (fresh water unit)

Internal domestic water heat exchanger

Fig. 98: Combined storage tank (domestic hot water heating + energy storage)

Versatile flue gas systems

Refurbishing chimneys with stainless steel

The increased demand for heating systems with solid fuels and wood burning stoves place chimneys once again in the focus of builders and planners.
The flue gas systems of heating systems need to be optimally adapted to the type of firing. The use of stainless steel in flue gas systems is highly popular today: The material is durable, requires little space and can be used in all structural conditions. Flue gas systems made of stainless steel are suitable for both new constructions and subsequent integration, and for both the interior as well as the exterior.

Meeting all requirements

Besides high temperatures, flue gas pipes are also exposed to chemical attacks caused by the flue gases – it is especially about the acids in this case. If the dew point is undershot, these acids act aggressively on the flue gas pipes through condensation. However, contemporary stainless steel flue gas systems easily cope with the condensing operation of heating systems used today.

Suitable for every heating system

Stainless steel flue gas systems have many capabilities and are suitable for all approved fuels.
Various manufacturers offer systems that differ in the pressure and temperature range. Designs that withstand the maximum flue gas temperatures of 200 °C are suitable for oil-and gas-fuelled fireplaces. If a solid fuel system – such as a wood burning stove or a split log boiler – is to be connected, the flue gas line should be designed to withstand a temperature of 400 °C in vacuum.

In a pellet-fired heating system, the formation of condensate inside the chimney has to be taken into account because of the low flue gas temperatures. Therefore, the flue gas system must be insensitive to moisture. If very high demands are placed on the pressure resistance due to the operation of a cogeneration of heat and power system or the connection of an emergency generator or combustion engine, there are special systems for overpressure of 5,000 Pa and flue gas temperatures of up to 600 °C.

Single-walled, double-walled and flexible

Flue gas systems made of stainless steel are available in single and double-walled designs. They are suitable for both interior and exterior installation and are often used deliberately as an architectural feature in buildings. Single-walled stainless steel flue gas systems are inexpensive and easy to process. Depending on the design, they are suitable for operation at low and excess pressures in conjunction with gaseous, liquid or solid fuels.
The biggest limitation is the relatively high minimum distance to other flammable components that needs to be maintained. Therefore, single-walled solutions are usually installed in chimneys, which already have a fire protection function and also allow any rear ventilation required.

Double-walled systems for the inlet and extract air

Double-walled chimneys made of stainless steel can be mounted both, within the building as well as on the outer wall. Their flexibility in terms of alteration, extension or even dismantling throws light on another advantage of light flue gas systems. They are also suitable for retrofitting, if no suitable chimney is nearby.

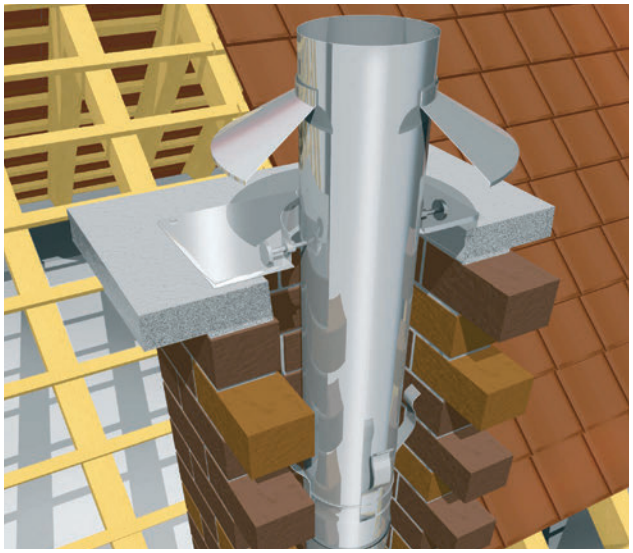


Fig. 99: Existing shafts

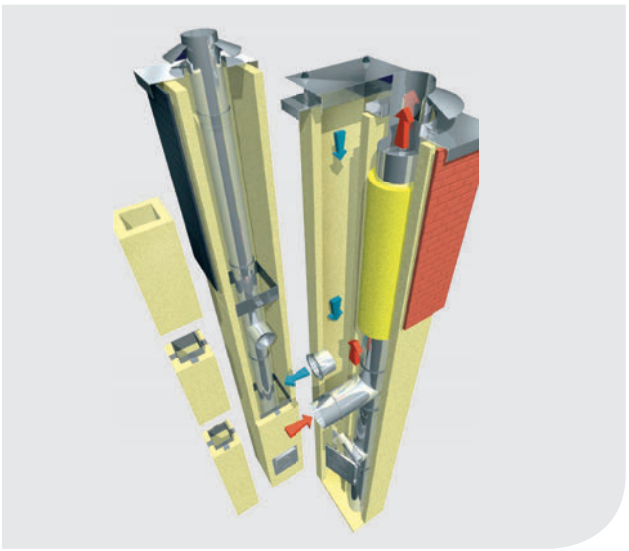


Fig. 100: Air flue gas systems

Double-walled chimneys can also be used for operation independent of the indoor air: In such air-flue gas systems, the hot flue gases and the cold supply air for the heating system are led via two separate pipelines. Thus, the residual heat can be removed from the flue gases.
Separate air-flue gas systems can be installed in ducts, stoves or chimneys as part of the modernisation measures. In new buildings, they are created newly as a system chimney.

Flexibility in focus

Flexible piping systems made of stainless steel are used especially if inclined guides are necessary for chimney restoration or if unfavourable, for example, rectangular dimensions exist. Flexible piping systems are manufactured in single or double-layered design, and thus have a corrugated or smooth inner surface. Special folding and joining techniques allow safe and yet flexible pipe runs.

CE marking on flue gas systems indispensable

All building products, including flue gas systems, may be used in conformance with the Model Building Regulation or State Building Regulations for the installation, alteration or maintenance of structural works only if these are suitable for the purpose of application. According to the European Building Products Ordinance for all products which are manufactured according to a harmonised European standard, the product specifications must be indicated in a "Declaration of Performance" by the manufacturer as proof of "suitability" and these products must bear the CE mark. This also applies to flue gas systems which are manufactured according to a corresponding harmonised European standard. According to the provisions of the European Building Products Ordinance, e.g. for flue gas systems, "use" means that they are commissioned.

App for determining the equipment identification of stainless steel flue gas systems

According to German building regulations, flue gas systems designed in Germany must be labelled with an equipment identification, that contains the performance characteristics which are important for the assessment of the plant. The equipment identification is of particular importance in the case of a replacement of the fireplaces. If, for example, a flue gas temperature limit of 200 °C is noted in the equipment identification (due to the given distances to combustible building materials), then no fireplace which can produce a higher flue gas temperature can be connected to this flue gas system. In this respect, a non-existent or incorrect equipment identification can be extremely problematic and lead to preventable fires or accidents.

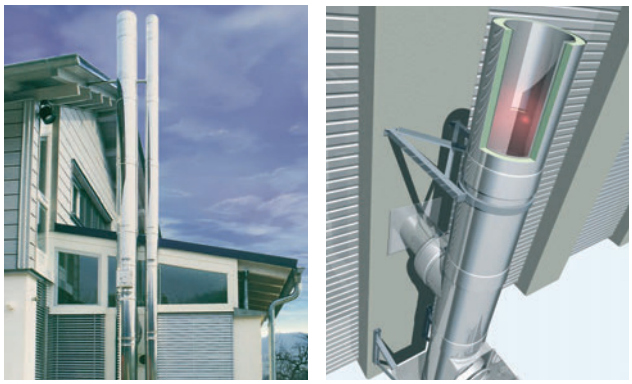
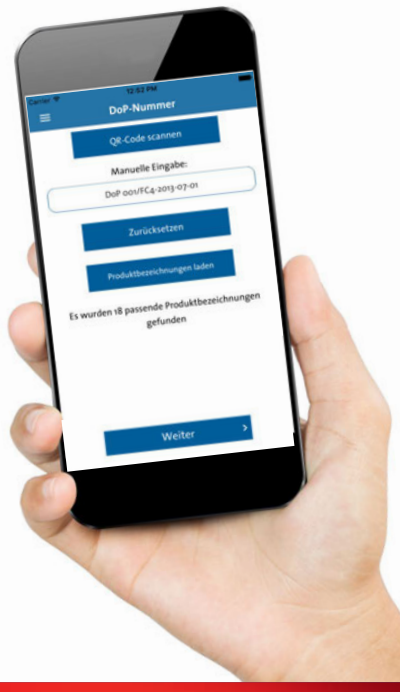


Fig. 101: Double-walled systems

The type of the equipment identification and the performance characteristics to be specified therein are described in DIN V 18160-1 and in Supplement 1 and the corresponding corrections. The regulation for the implementation of the equipment identification is to be found in the German building regulations in the "List of technical building regulations". It lays down rules of application, which must be observed in the application of building products in accordance with the harmonised European standards. This also applies to the harmonised European standards for flue gas systems.
The correct specification of equipment identification is complex due to the supplements and corrections to DIN V 18160-1 to be observed. That is why the BDH has published an app for easy and simplified creation of the equipment designation for "Metallic flue gas systems". This app helps in determining the equipment identification for all "Metal flue gas systems" produced and distributed by the BDH member companies.



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Tank systems

Storing heating oil safely

Heating oil can be stored in different ways. Here, the personal preferences for the installation site, the individual structural conditions and economic considerations are decisive.

Modern tank systems for heating oil ensure maximum security of supply and economic independence. They form an ideal basis for an economical and environment-friendly supply of heat.

The separate tank offers operators of oil heating systems the free choice of suppliers and the option of making a reasonable purchase, because the consumer is free to decide the time of delivery and is also able to safely store a larger stock of fuel.

Modern heating oil tanks, according to the state of the art, are double-walled tank systems that do not require more collection space. The factory production and testing ensures an extremely safe tank system that guarantees the secondary protection required by law for the storage of heating oil for decades. In old single-wall tanks, often the secondary protection by the on-site collection trough is no longer ensured.

Unfortunately, most of the operators of an oil heating system are not aware that they are completely responsible for proper and safe operation and are even personally liable in the event of damage. Environmental damage can quickly lead to unpleasant amounts of total damage for the operator. An oil tank insurance also will usually not pay for damages, if the system does not correspond with the state of the art.

Requirements

Heating oil can be stored either underground or aboveground. An oil storage tank is considered to be underground, if it is completely or partially embedded in the ground. Storage tanks that are usually set up in closed rooms are considered aboveground, even though the cellar is below the ground level.

Heating oil storage in an underground double-walled steel tank is rather rare in the private sector. Aboveground storage in the basement is common. Formerly, there used to be a separate heating oil storage chamber (walled collection space); today the storage facility is mostly in the boiler room itself. Basically, the legal requirement of secondary protection that is achieved by the double-walled characteristic of the tank system with an additional leak detector or leak detection system applies here.

The previously common, single-walled tanks made of metal or plastic, which require a collection chamber for secondary protection, are still found in the old stock of many cellars. However, this collection chamber is deemed as an acceptable secondary protection only if the sealing surface is made of approved materials. Moreover, the wall should be sufficiently stable, there should not be any damages and the collection chamber should be maintained leak-proof permanently.
For more than 40 years, plastic storage tanks have been used for storing heating oil. They are mainly installed in the cellar or boiler room. Today, as per the statistics of the association of chimney sweeps, Germany has approx. 5.8 million oil heating systems and a corresponding number of heating oil storage tanks (2–3 tanks per system on an average) in the cellars of German one-family houses and apartment houses.

From 1970 to 1990, single-walled plastic storage tanks, which were mounted in walled collection troughs (collection space) as secondary protection, were sold for the storage of heating oil. Since 1990, factory-made, double-walled and odour-proof tanks have established themselves in the market and completely replaced the old single-walled tank in sales.

The replacement of the single-walled tanks after 30 years of service life is strongly recommended by experts, since the safety and the functional capability of the tank system as well as the collection space can no longer be ensured.

Investigations of the TÜV in Bavaria and Hesse have proven: More than 80 % of the tested collection troughs did not show the required secondary protection any more.

Besides, a modernisation backlog can be seen today in the heating oil tanks: Around 45 % of all plastic storage tanks are 25 years old or even older.

By buying a modern double-walled heating oil tank, consumers invest in a high-quality product that guarantees easy and safe supply of fuel even in the future. This modernisation measure is usually even associated with significant space saving through the simplified installation in the boiler room that is possible now.

Mounting on double-walled safety tanks

The principle of double safety applies to storage of heating oil. Thus, a collection space is required by law for single-walled tanks: It prevents release of oil in the water in case of any leakage. This collection space must be oil-tight, have an approved intact coating and be accessible for inspection. Moreover, the wall should be structurally sufficiently stable in the case of a leak. The single-walled tanks should be mounted at a sufficiently large distance from the walls to allow inspection.

In contrast, double-walled heating oil tanks come with the capability of absorbing oil spills completely, already delivered ex-factory. Moreover, they save a great deal of space when installed: clear advantages which are of great importance to the consumer. Double-walled heating oil tanks are available in different models –

versions with inner and outer tank made of plastic, or with the facility of translucent leak detection, or as metal-cased plastic tanks with optical leak detection.

All double-walled tank systems have a long service life and provide maximum safety without any maintenance cost, which is unavoidable in walled collection areas. Practice has proved that collection areas often lose their protective properties after years of use. Therefore, double-walled tank systems clearly offer safety.

Small dimensions, high flexibility

Modern insulation and increasingly efficient heating systems ensure continuous reduction in fuel demand in a lot of buildings. This also reduces the storage quantities of heating oil.

New tank systems require less space, home owners gain valuable space. Thanks to the compact dimensions of double-walled tank systems, subsequent integration is also possible. Besides, modern tanks are also approved for low-sulphur heating oil and for oil with biological additives under construction and water law. The tank systems are equipped with limit switches and partly with other safety equipment to prevent an overfill when refuelling.

Several automatic monitoring devices ensure easy and safe control. The heating oil storage can be controlled at all times with the level indicator.

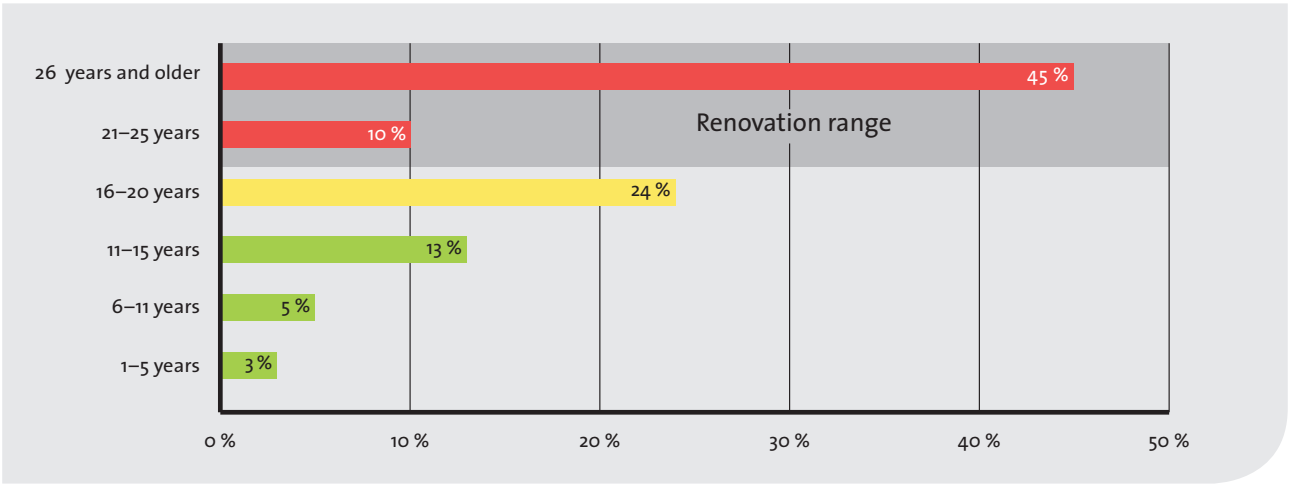
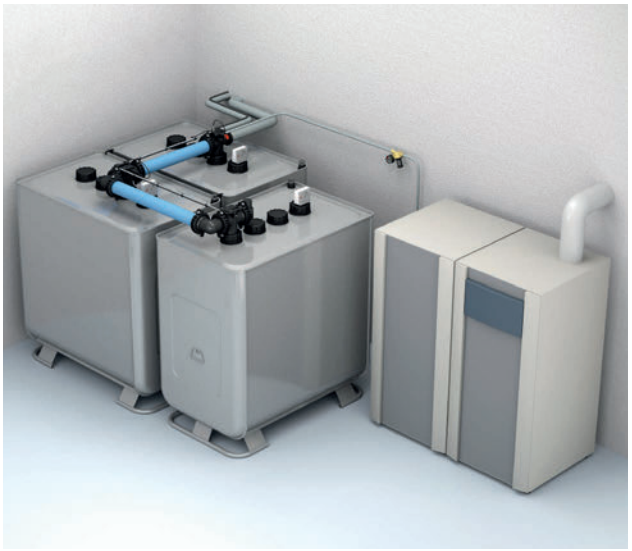


Fig. 102: Ageing structure of the plastic storage tank in the market since 1970



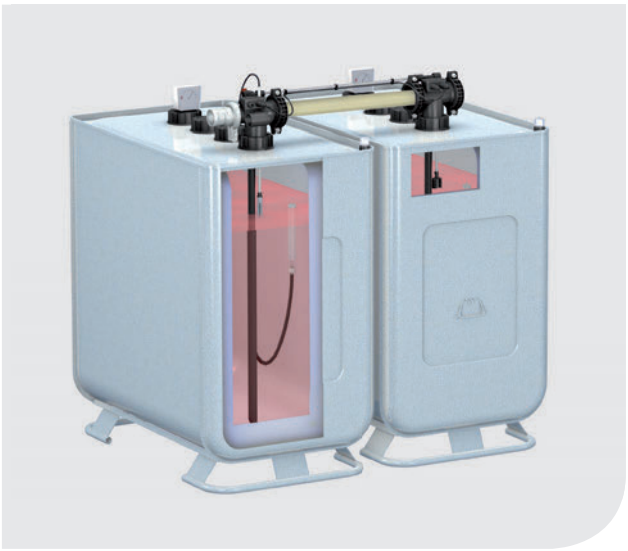
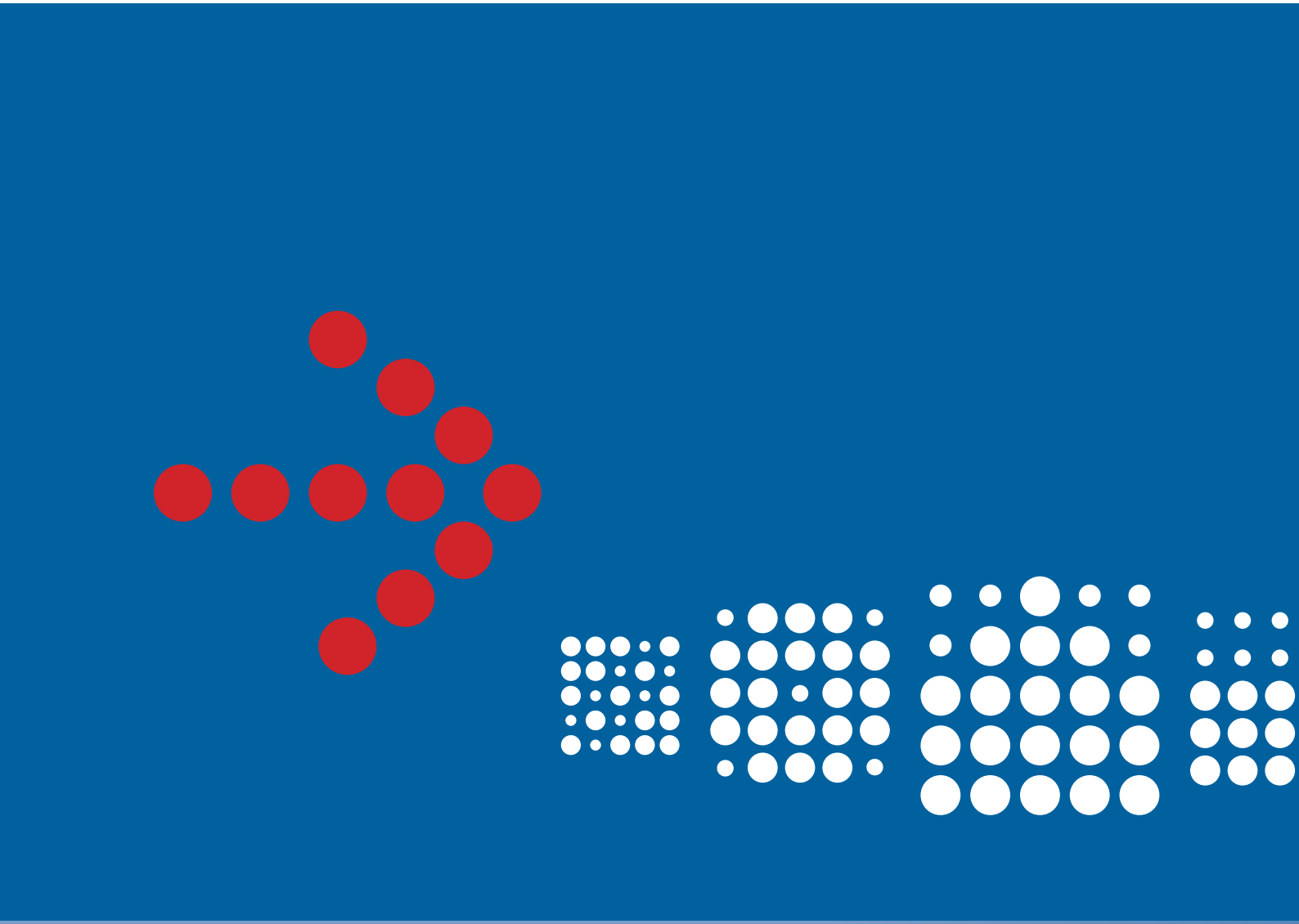


Fig. 103: Modern single- and double-walled safety tanks

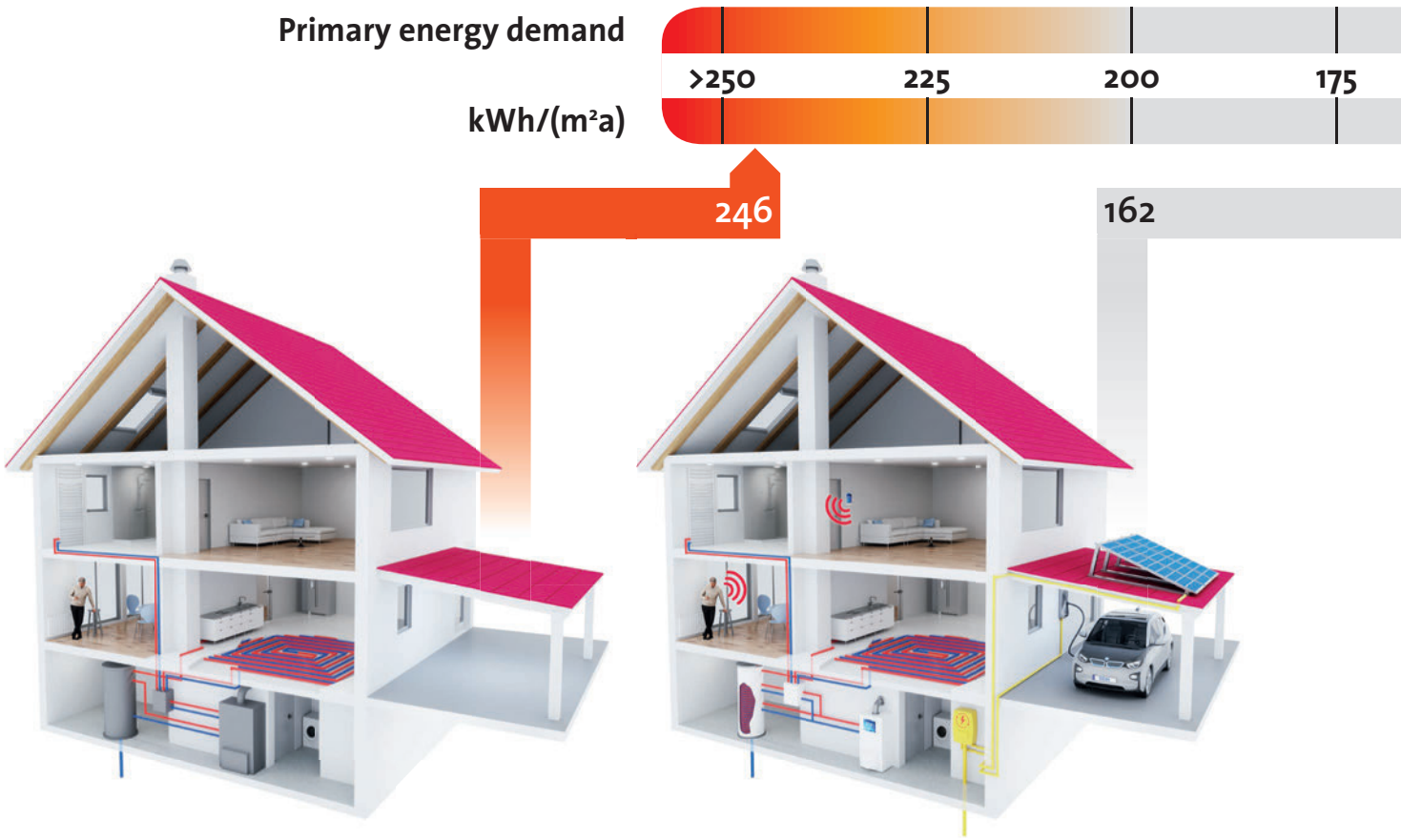
ISH Technology and Energy Panel



Examples of modernisation

- Examples of modernisation – Variants with gas/oil condensing boilers
- Examples of modernisation – Variants with heat pumps
- Examples of modernisation – Variants with wood burning systems/ CHP systems

Examples of modernisation – Variants with gas/oil condensing boilers



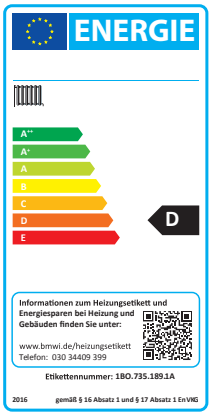
House before the renovation

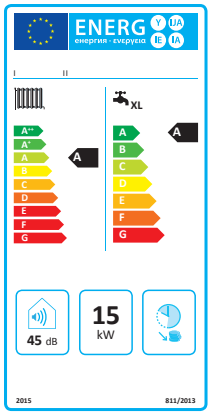
Partially renovated detached single-family house, year of construction 1970, usable floor space 150 m², solid construction/plastered, standard boiler – oil/gas, with indirectly heated domestic hot water storage tank, unregulated circulation pump.

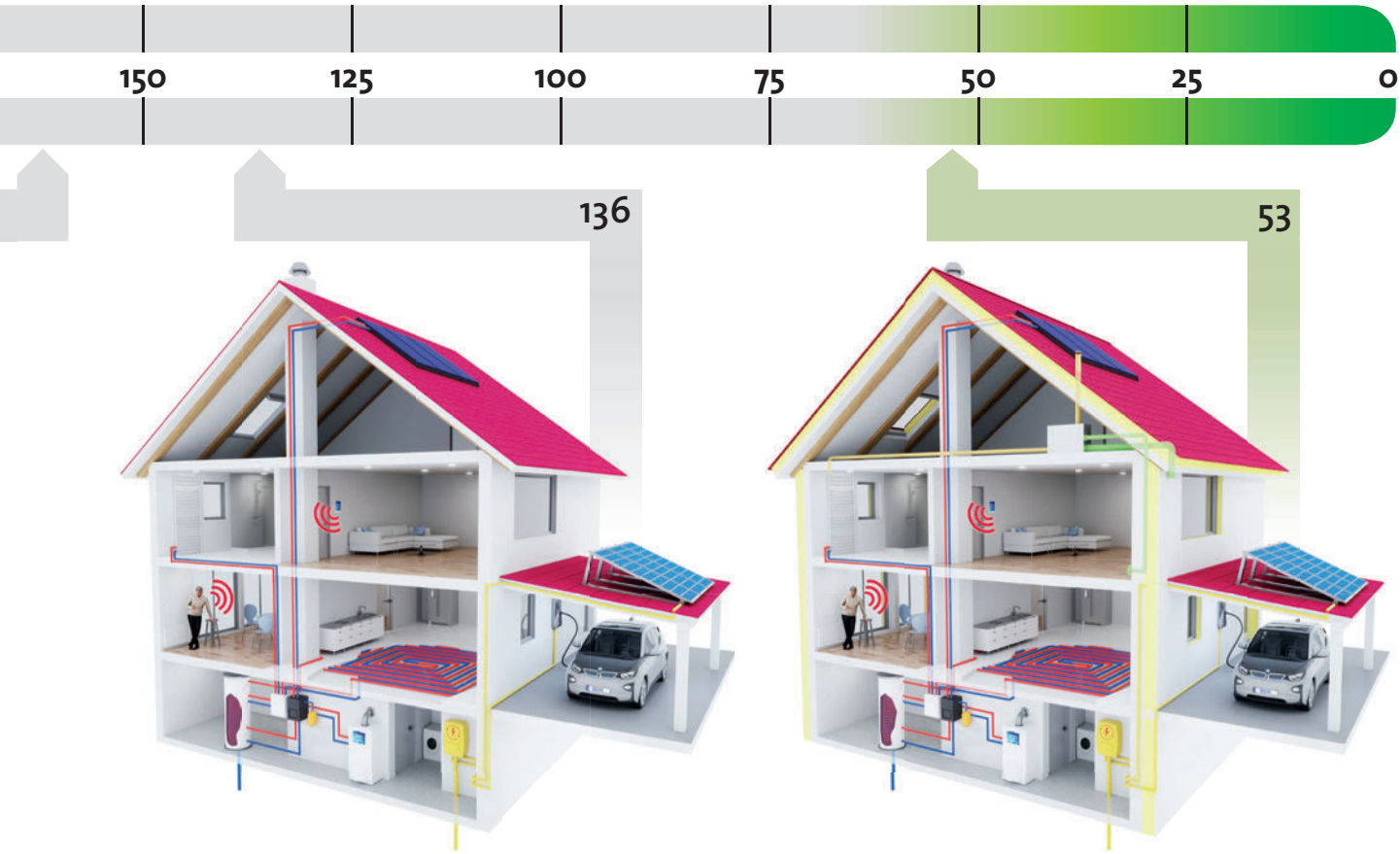
Renovation variant – gas/oil condensing technology

Modern condensing boiler (oil/gas) and indirectly heated domestic hot water storage tank, adaptation of the heating surfaces, high-performance pumps, new thermostat valves, insulation of the distribution pipes, hydraulic balancing, modern flue gas system.

Annual oil consumption	3,263 litres	2,126 litres	
Annual gas consumption	3,263 m³	2,126 m³	
Annual saving of oil	–	1,137 litres	
Annual saving of gas	–	1,137 m³	
Primary energy saving	–	83 kWh/(m²a)	
Energy efficiency class for space heating	D	A	
Energy efficiency class for domestic hot water heating	–	A	







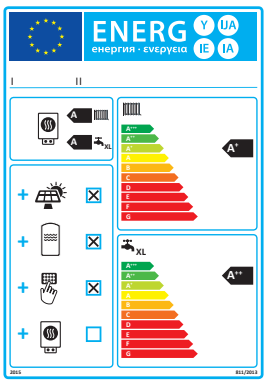
Renovation variant – gas/oil condensing technology with solar thermal system

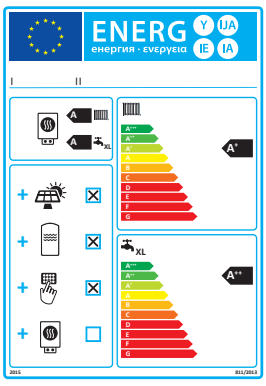
Modern condensing boiler (oil/gas), solar thermal system for domestic hot water and auxiliary heating, adaptation of the heating surfaces, high-performance pumps, new thermostat valves, insulation of the distribution pipes, hydraulic balancing, modern flue gas system.

Renovation variant – gas/oil condensing technology with solar thermal system, controlled residential ventilation and renovation of the building envelope

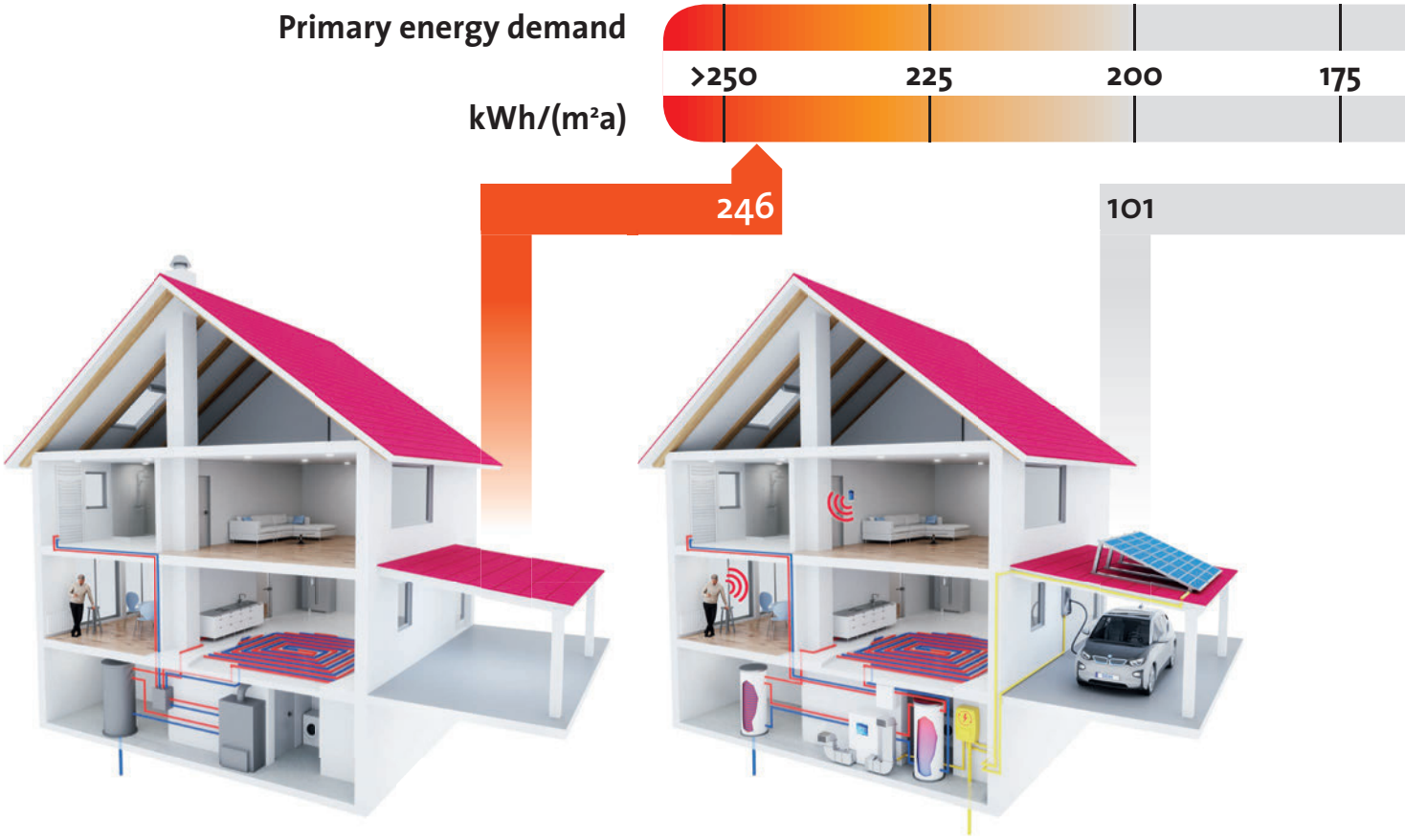
Modern condensing boiler (oil/gas), solar thermal system for domestic hot water and auxiliary heating, adaptation of the heating surfaces, high-performance pumps, new thermostat valves, insulation of the distribution pipes, hydraulic balancing, modern flue gas system, additionally controlled residential ventilation with heat recovery and renovation of the building shell in conformance with KfW-Efficiency House-70 standard.

1,775 litres	602 litres
1,775 m³	602 m³
1,488 litres	2,661 litres
1,488 m³	2,661 m³
109 kWh/(m²a)	193 kWh/(m²a)
A+	A+
A++	A++





Examples of modernisation – Variants with heat pumps



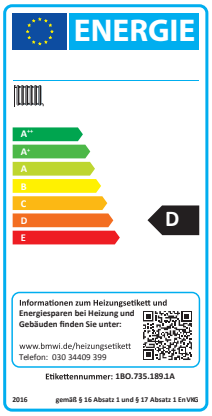
House before the renovation

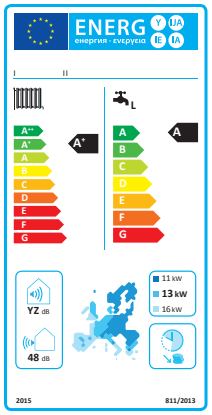
Partially renovated detached single-family house, year of construction 1970, usable floor space 150 m², solid construction/plastered, standard boiler – oil/gas, with indirectly heated domestic hot water storage tank, unregulated circulation pump.

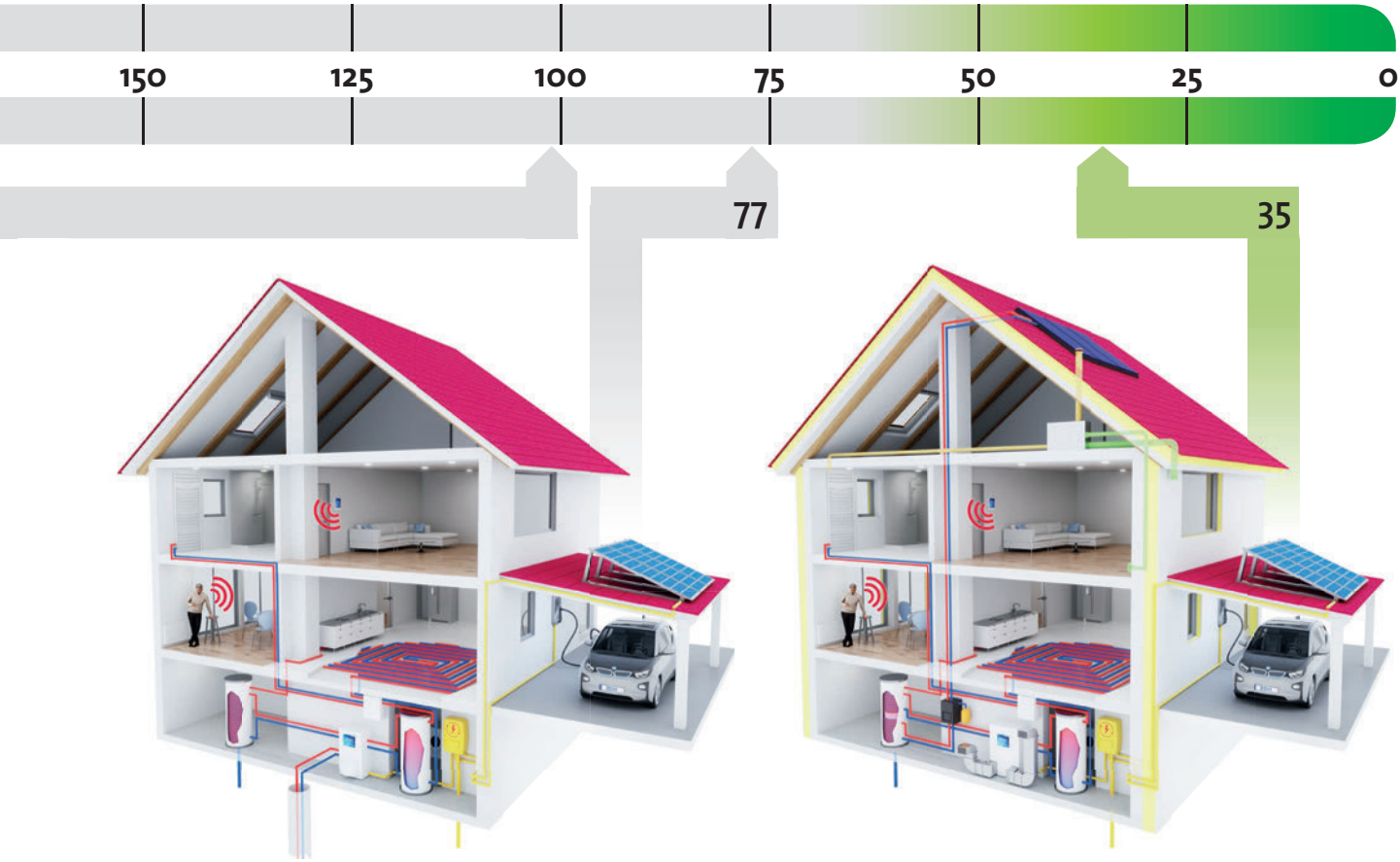
Renovation variant – Air-water heat pump

Air-water heat pump, buffer storage and domestic hot water storage tank, adaptation of the heating surfaces, high-performance pumps, new thermostat valves, insulation of the distribution pipes, hydraulic balancing.

Annual oil consumption	3,263 litres	–	
Annual gas consumption	3,263 m³	–	
Annual electricity demand	–	8,100 kWh	
Primary energy saving	–	144 kWh/(m²a)	
Energy efficiency class for space heating	D	A+	
Energy efficiency class for domestic hot water heating	–	A	







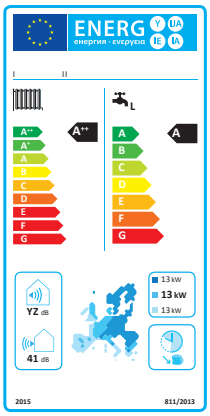
Renovation variant – Brine-water heat pump

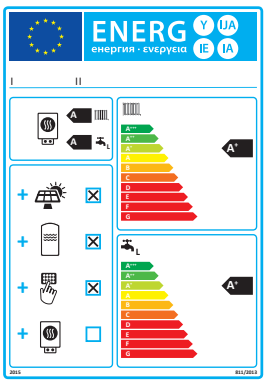
Brine-water heat pump, buffer storage and domestic hot water storage tank, adaptation of the heating surfaces, high-performance pumps, new thermostat valves, insulation of the distribution pipes, hydraulic balancing.

Renovation variant – Air-water heat pump with solar thermal energy, controlled residential ventilation and renovation of the building shell

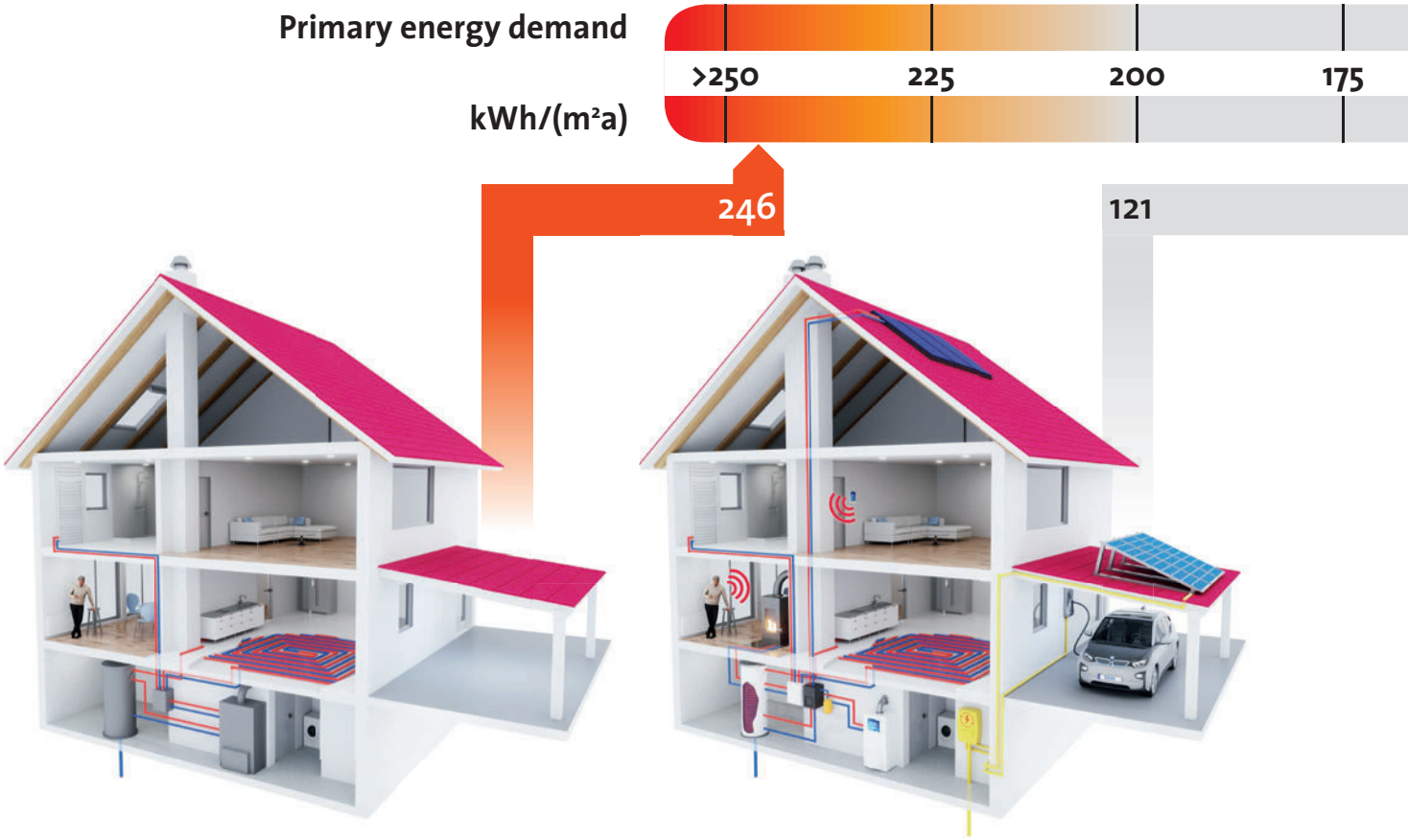
Air-water heat pump, buffer storage and domestic hot water storage tank, adaptation of the heating surfaces, high-performance pumps, new thermostat valves, insulation of the distribution pipes, hydraulic balancing, additional solar domestic hot water system, controlled residential ventilation with heat recovery and renovation of the building shell in conformance with the KfW-Efficiency House-70 standard.

–	–
–	–
5,910 kWh	2,310 kWh
168 kWh/(m²a)	210 kWh/(m²a)
A++	A+
A	A+





Examples of modernisation – Variants with wood burning systems/CHP systems



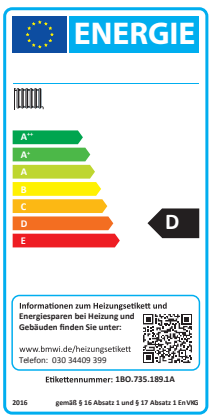
House before the renovation

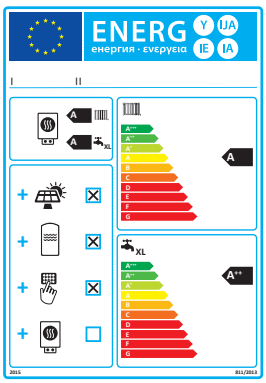
Partially renovated detached single-family house, year of construction 1970, usable floor space 150 m², solid construction/plastered, standard boiler – oil/gas, with indirectly heated domestic hot water storage tank, unregulated circulation pump.

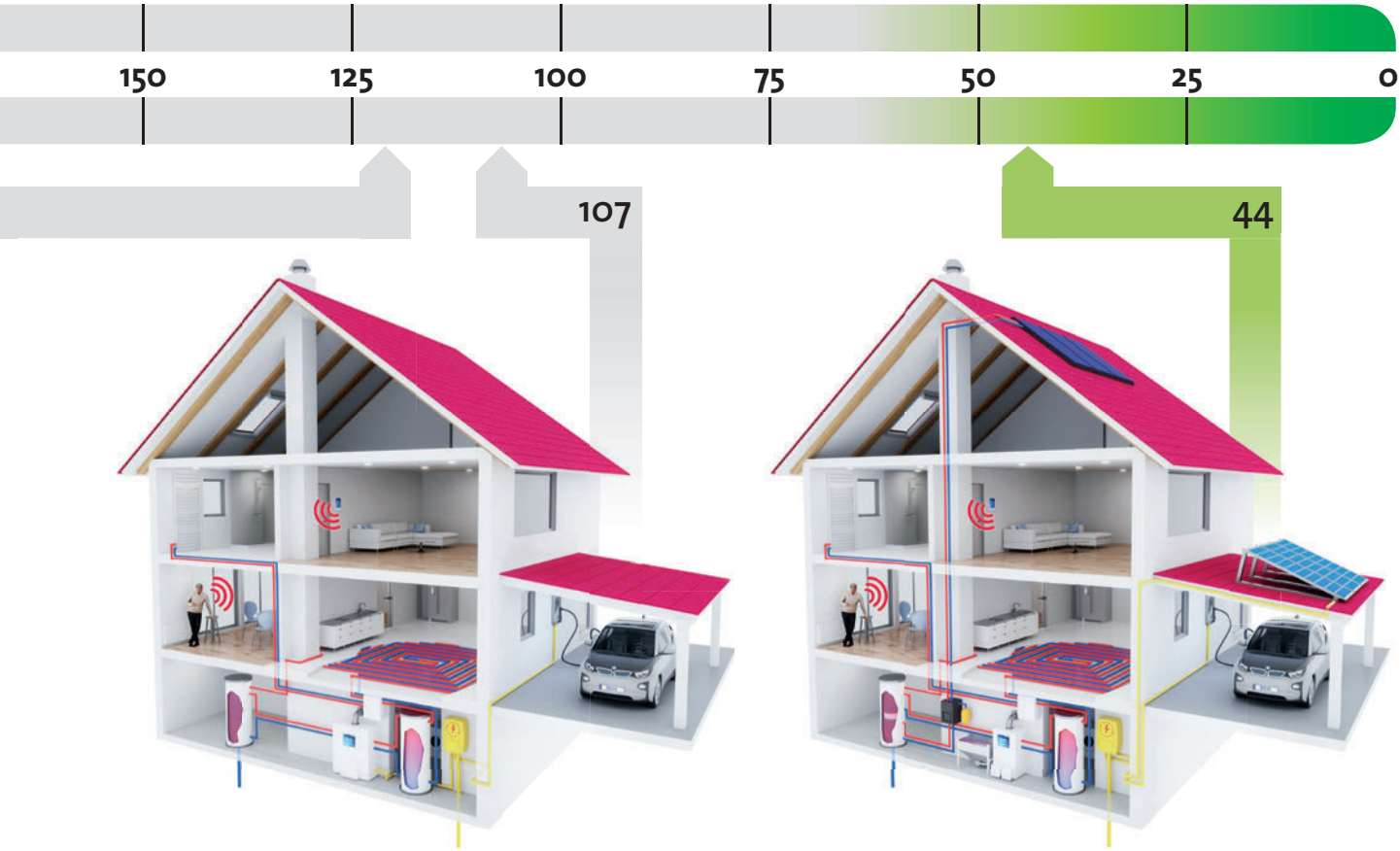
Renovation variant – gas/oil condensing technology with solar thermal energy and wood burning stove/ pellet furnace with collection basin

Modern condensing boiler (oil/gas), solar domestic hot water system, pellet furnace/wood burning stove with built-in collection basin, adaptation of the heating surfaces, high-performance pumps, new thermostat valves, insulation of the distribution pipes, hydraulic balancing, renovation of the flue gas system.

Annual oil consumption	3,263 litres		1,352 litres
Annual gas consumption	3,263 m³		1,352 m³
Annual pellet/split logs demand	–		2.0 t/5.0 Rm
Amount of electricity produced annually			–
Primary energy saving	–		124 kWh/(m²a)
Energy-efficiency class for space heating	D		A
Energy-efficiency class for domestic hot water heating	–		A++





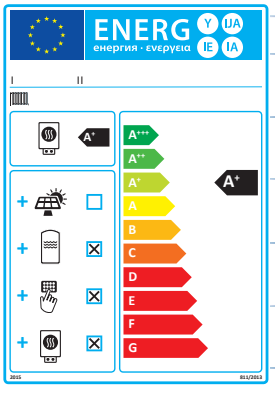
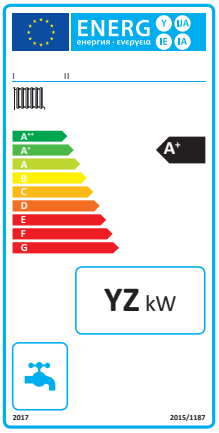


Renovation variant – micro CHP system

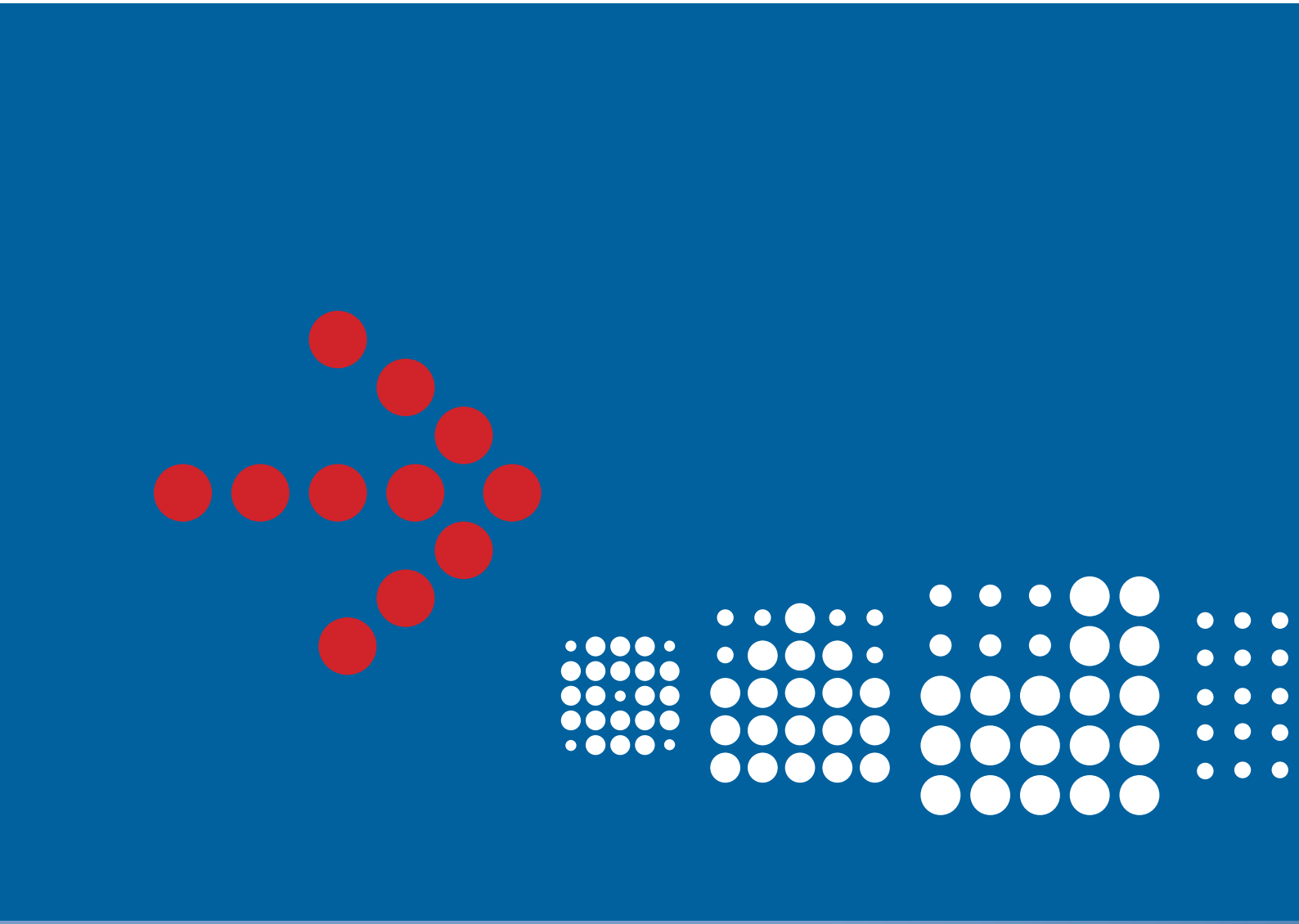
Renovation variant – pellet/split log boiler

Micro CHP system with modern gas condensing boiler, buffer storage tank and domestic hot water storage tank, adaptation of the heating surfaces, high-performance pumps, new thermostat valves, insulation of the distribution pipes, hydraulic balancing, renovation of the flue gas system.

Wood pellet/split log boiler and solar domestic hot water system, adaptation of the heating surfaces, regulated pumps, new thermostat valves, insulation of the distribution pipes, hydraulic balancing, renovation of the flue gas system.

–		–	
3,017 m³		–	
–		4.8 t/12 stère	
6,353 kWh		–	
139 kWh/(m²a)		201 kWh/(m²a)	
A+		A+	
–		–	

ISH Technology and Energy Panel



Industrial heat generators/ Standardisation

- Large firing systems
- From Smart Heating to the energy network
- Standardisation in heating, ventilation and air-conditioning technology

Large firing systems

The energy efficiency initiative of BDH with dena: Efficient heat supply systems reduce costs and emissions

The energy and cost-intensive generation of large amounts of process heat for numerous technical processes and methods in industry and manufacturing can be significantly reduced by an overall energetic optimisation of the heat supply system – on average by 15 %. These kinds of energy efficiency measures are highly profitable and generally redeem their cost within one to four years.

However, the emissions of these combustion plants are also drastically reduced in the same step due to the lower energy consumption.

High energy consumption of process heat

Depending on the application, process heat is required at very different temperature levels. It is produced from various energy sources, e. g. with electricity, oil and/or gas, and transported in various ways, by warm or hot water, as steam or hot air.

To supply thermal processes, a total of about 400 TWh final energy is used up each year in Germany. The economic energy savings potential in the industrial sector is at least 30 TWh per year (i. e. 7.5 %) for thermal processes. Additional 96 TWh (i. e. 24 %) can be saved every year by increasing the energy efficiency in the provision of space heating. Of course, the emission loads of the firing systems are also reduced.

Steam and hot water production

The most widespread processes for process heat generation include steam and hot water boilers with a share of around 30 %. However, 80 % of these industrial heat and steam generation plants in Germany are now older than ten years and do not correspond to the current state of the art. If these old plants were refurbished to the state of the art, an annual energy saving of 9.6 TWh could be achieved. That alone adds up to 2 % of the total energy consumption of process heat in Germany. On average, energy consumption in steam and hot water generation, including heat recovery, could be reduced by 15 %.

Analysis of potential savings

It can be assumed that nearly 300,000 heating systems in the power range between 100 and 36,000 kW are used in larger commercial buildings and in the industrial sector of the German heating market. This is the result of an in-depth research using information from the chimney sweep trade (ZIV), the inspection bodies of the TÜV and the sales of BDH members. 80 % of the installations in the heat market, i. e. approx. 250,000 systems, no longer correspond to the state of the art.

The following calculations were made on the basis of the above stock figures and provide the following high potential savings:

- Reduction in annual consumption of heating oil: 810,000 t/a
- Reduction in annual consumption of natural gas: 4.43 billion m^3
- Reduction in CO_2 emissions: 16.3 million t/a
- Reduction in nitrogen oxide emissions (NO_x): 34,885 t/a
- Reduction in the installed power output: 398 MW

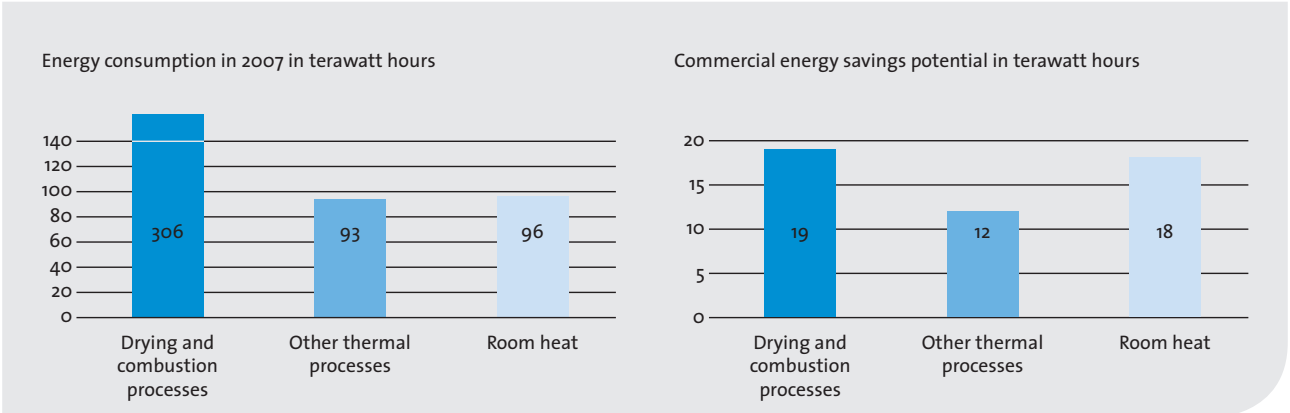


Fig. 104: Energy consumption and potential energy savings in industrial process heat applications

Fig. 105: By far the largest energy demand in industry and manufacturing is attributable to the generation of heat for technical processes

Using 2008 as a basis, this constitutes a possible reduction in heating oil consumption of 3.3 % and a reduction in natural gas consumption of 4.6 %. In total, the use of efficient technology in the largest technical combustion systems can lead to annual final energy savings of 175 PJ. However, the potential reduction in CO_2 and NO_x emissions is also highly significant.

It should be emphasised that the highest energy and cost reductions are achieved if the heat supply system is holistically optimised by adapting and coordinating all of the components. Only the optimum combination of all components of a firing system ensures a potential savings of 15 % on average, taking heat recovery into account.

Procedure for system optimisation

Measures to enhance energy efficiency within the heat supply system should always be considered as elements of optimising the overall system. Increase in energy efficiency can only be achieved by coordinating all of the components and optimising system control and regulation.

All of the facts come to light by a detailed state analysis of the system's energy consumption, the heat demand and the individual system components. Additional savings can be achieved by optimising the control and regulation of the individual firing systems and any other firing systems connected.

Whenever constructing new systems, even the preliminary plans should take care to ensure energy efficiency of the components and the overall system.

Sensible use of waste heat by heat recovery

As things stand, roughly 40 % of the energy used in the generation of industrial process heat is lost in the form of waste heat. Measures targeted at heat recovery maximise the efficiency of the overall system and therefore the system's energy efficiency.

In the event that upstream measures to reduce thermal loss have been exhausted, it is certainly worthwhile to exploit the waste heat by means of heat recovery. Generally, the following applies: Heat recovery is all the more worthwhile, the greater the difference between waste heat temperature and the required temperature. It is helpful in this context to create a heat circuit diagram, presenting all temperatures and the heat volumes transported and transferred within the process.

A pinch analysis can then be used to determine the most efficient method for exploiting the waste heat available in every case. Thermal potential should be used locally and as directly as possible. For instance, waste heat can be used to heat industrial or process water, for preparing domestic hot water, to preheat combustion and drying air or as room heat. It is also worthwhile to use an economiser, for example to preheat the feed water.

Large firing systems

In condensing technology, an additional heat exchanger is fitted downstream from the economiser, which cools the flue gases to below the condensation temperature of water. This means that the condensation heat of the water contained in the flue gas can also be exploited.

Optimising the overall system

Prior to the optimisation of the individual components of a heat supply system, measures for minimising heat demand and losses should be implemented first. Here, the following applies: Electrical energy has a higher value than steam, which in turn has a higher value than hot water. Therefore, the supply medium with the lowest possible value should be selected in each of the respective process stages, depending on the requirements.

By using hot water instead of steam, the efficiency of the firing system can be increased by 10 to 15 %. In many cases, a reduction in the temperature of the supply medium enables the use of heat recovery and the cogeneration of heat and power for further reduction of the energy demand of the entire system.

In order to minimise losses, the heat insulation on the heat generators, the pipes and also the heat storage should be analysed and improved wherever necessary.

Using energy efficient components

Equally, the target in using energy efficient components should always be the optimisation of the overall system. This is achieved by effectively streamlining all new and existing components.

Modulating (controllable) burners can be operated in many partial load ranges and are far more efficient than burners that have to be fired up and shut down individually.

Flue gas temperatures and energy consumption can be reduced using boilers with large heat transfer surfaces.

It is sensible to use energy efficient condensing boilers in hot water systems, as their deployment leads to significantly lower flue gas temperatures. Furthermore, their efficiency is substantially higher. Speed controlled drive motors for forced air burners and pumps also permit pronounced savings in energy consumption.

Optimising regulation and control

Large combustion systems should always be tailored to suit the actual heat demand. For example, a multi-boiler control ensures that only the actually required number of boilers is switched on at all times. Installation of flue gas sensor control ensures continuous measurement of the flue gas composition. Air intake control takes place in line with the best possible oxygen ratio in the flue gas at any given time (O_2 ratio). Simply cutting the O_2 ratio by just one percentage point leads to increased efficiency, by 0.5 to 1 %, depending on the age of the system.

Controlling and managing other combustion parameters such as CO content, flue gas temperature, soot figure or combustion chamber pressure as well as the installation of automatic flue gas or combustion flaps can cut the energy consumption still further.

Reducing emissions at the same time

The efficiency measures described not only reduce fuel consumption, but also the emission of anthropogenic emissions. In particular, the CO_2 and NO_x emissions generated during combustion can be reduced to a minimum by the use of modern and optimised combustion plants. This also ensures compliance with the national legal framework for the operation of firing systems, among others, the 1st BImSchV (German Federal Immission Protection Ordinance), TA-Luft (Technical Instructions on Air Quality Control), etc. The national regulations also adopt the legally stipulated European framework conditions and as a so-called standard-defining administrative regulation, they have a binding effect on the courts; see also Article 48 BImSchG (Federal Immission Control Act).

Existing old systems are addressed besides the new systems, e. g. the European Directive (EU) 2015/2193 of the European Parliament and of the Council dated 25 November 2015 on the limitation of emissions of certain pollutants from medium-sized firing systems into the air. Following certain output-dependent, differentiated deadlines, old systems must also comply with the European emission limit values. Timely planning of a measure for retrofitting, conversion or new construction of the firing system is recommended.

Fig. 106: Five gas-operated high-pressure steam generators, each of which produce 16 tonnes of steam per hour at an operating pressure of 10 bars

Fig. 107: 167 tonnes of hot steam per hour can be supplied by the boiler for the propulsion of the steam turbine and supporting the district heating supply

From Smart Heating to the energy network

EEBus – The communication solution for interfaces in energy management

Everyone is talking about "Smart Home". Automatic heating control is an important component in building automation. Almost every smart home solution now allows the heat supply to be optimised with the help of schedules, room sensors and other automatic functions.

However, in reality only very few of these systems are truly smart in the sense of universal connectivity. Generally, they view the building heating system as an isolated task, open and close the thermostatic valves or switch on and switch off the boiler depending on the schedules or the room temperature. Such systems fulfil the requirements of the energy revolution with respect to a more flexible use of energy only rudimentarily at the most.

True advancement from customised control to production-optimised energy consumption will be possible only when heating and domestic hot water – interlinked with heat and energy storage devices, generation facilities and consumers – are considered as an in-house energy network. Herein lies one of the main challenges of the energy revolution.

EEBus provides a common language for energy

The prerequisite for a functional energy network is a common language, in which all devices and installations communicate about their energy capacity, their demands and their environmental conditions.

More than 60 European companies from all areas of home automation and the big players in the smart home market work together as a part of the EEBus initiative on interfaces for devices and installations at home which communicate with each other. The EEBus initiative is organised into different working groups for each particular area of application, e. g. "photovoltaics and storage" or "networked heating".

Within the working groups, use cases are defined and corresponding communication rules developed, which are technically specified and finally standardised. The entire industry can then freely use the results.

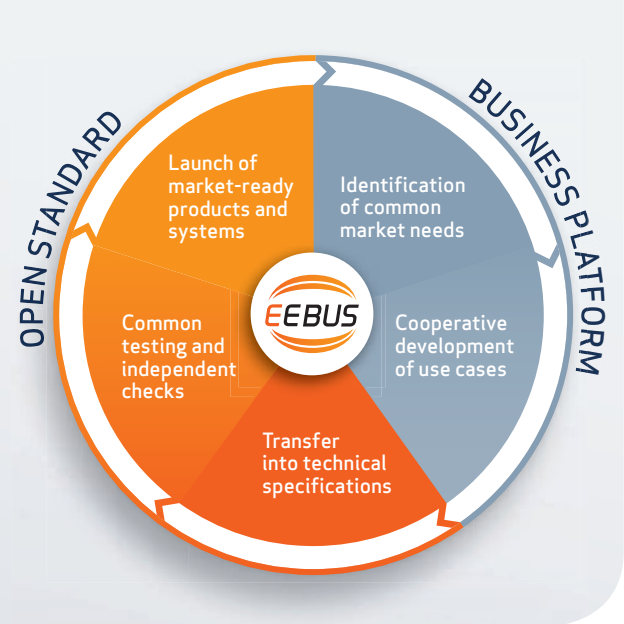


Fig. 108

Working group HVAC: EEBus and BDH have a common goal

Since early 2016, BDH and its member companies are involved in defining the area of application "Heating, Ventilation, Air-conditioning" (HVAC). The results of this work are now ready to be standardised. Some initial products which exchange data, operating conditions and other information with adjacent devices and control systems on the basis of these open interface, can already be seen at the ISH 2017.

In the course of development, the EEBus Initiative, being an European association with German roots, focuses on open systems, democratic decision making processes as well as the free availability of the final standard. This is also to be seen as an alternative to the closed communication platforms in the "Internet of Things", which some big companies put on the market with a lot of pressure.

Applications of the heating interface

This involves all the information which a heating system and a domestic hot water system in a networked home must exchange with other devices for their optimum operation. This includes not only simple data such as the operating state (on, off, auto, eco) or the desired room temperature, but also complex data sets like schedules for the space heating or the expected heating demand.

In the first step, the EEBus interface defines HVAC-specific control data in order to operate heating systems directly, e. g. via smart home systems. These use cases enable a comfort-based control across all systems by means of the large platforms of internet or mobile service providers, without binding themselves to their proprietary protocols. Examples are operation from outside or even automatic presence and absence scenarios.

Another area is “Energy Management”. In this area, the information with which the heating system can be integrated into a control system is defined. The use case “consumption forecast” for instance demonstrates how the heating energy demand for the next few hours or days is reported to an energy management system. This can then prioritise the energy demand of the heating with that of other devices and thus optimise the own power consumption of a photovoltaics system.

For the purpose of communication, it does not matter whether the energy manager is a part of the heating system, a photovoltaic installation or a completely independent device. What is important is that all components support the common EEBus interface and literally speak the same language.

In other use cases, the data of external sensors can be imported, e. g. online weather data or data from a solar heating system for optimising or predicting the heating operation. Apart from this, interfaces are being defined for other EEBus applications such as the connection to “battery systems”, “electric mobility” as well as for applications like “smart metering” and “smart grid ready”.

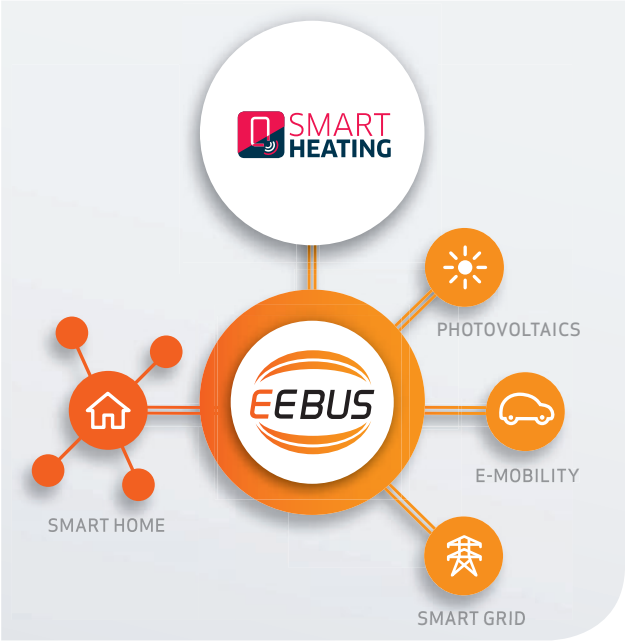


Fig. 109

Manufacturers have the last word on their device functions

All use cases have been defined, translated into technical specifications and tested jointly by the participating member companies of the BDH and EEBus. During the actual implementation, each manufacturer is free to decide which use cases they will actually implement in their devices. Even the functions within the heating system are totally left to the discretion of the manufacturer.

In this manner, the EEBus standard provides a shared communication basis on the one hand and on the other hand, allows manufacturers all options of differentiation and gradation within the product series.

With the help of the defined use cases, the functions offered by each of the devices within the scope of the EEBus standard can be depicted easily – similar to the various application profiles of the Bluetooth standard known worldwide.

The EEBus standard and its contents for HVAC are under constant development. All players in the market are invited to collaborate by joining the EEBus initiative and actively participating in the various working groups. Initial requirements for new use cases are already available, for example, direct inclusion in the smart grid or integration of battery storage units in the energy management of the heating system. The main focus thereby is always on the practical needs.

Standardisation takes place as per the wish of the BDH and EEBus members and not according to any provisions of any technical platform.

Standardisation in heating, ventilation and air-conditioning technology

Questions and answers

Standardisation in the field of heating, ventilation and air-conditioning technology is carried out by the DIN Standards Committee for heating and ventilation and air-conditioning technology and their safety (NHRS). The NHRS processes all standardisation applications in the field of heating and indoor air-conditioning systems and their components (including the control, protection and safety devices). Some of the fundamental questions will be addressed in the following, because the topic of standardisation can lead to uncertainty or misunderstanding in many users.

Fundamental purpose

Through standardisation, technical standards are defined and made available for everyone. This allows a large group of users to resort to the same know-how (for example, dimensions and tolerances, or testing and safety requirements).

Why participation in standardisation work is worthwhile

Active participation in standardisation work provides many advantages to users and final consumers, as well as manufacturers, designers, executors and authorities. Besides the information advantage concerning future technical regulations, which contributes significantly to the planning security, the following points are listed:

- Monitoring trends in the industry
- Good basis to implement the company technologies on the market
- Shaping the future technical regulations
- Prerequisite for the global market access

The liability of standards

Standards do not have any legal liability as such. Therefore, the standards are applied at first for everyone on a voluntary basis. However, the user can be confident of acting in a technically proper manner when observing the standards.

A standard is always mandatory only if it is bindingly cited or included in, for example, laws, ordinances, administrative regulations or contracts.

The tasks of the NHRS

The work of the NHRS is classified under five divisions:

- Division 1 – heating technology
- Division 2 – ventilation and air-conditioning technology
- Division 3 – ICA for heating, ventilation and air-conditioning technology
- Division 4 – facility management
- Division 5 – total energy performance of buildings – system standardisation

Each of the five divisions is composed of several working committees, where the actual standardisation work is done. A detailed list can be found on the NHRS website (www.din.de/go/nhrs). Anyone who wants to participate can send an application for participation at any time to the respective working committee. Besides small- and medium-scale enterprises, mainly industry and trade associations are committed towards standardisation. One of them is the Federation of German Heating industry (BDH – Bundesverband der Deutschen Heizungsindustrie e. V.), which brings along a broad spectrum of views and experience in the standardisation work.

Financing

The DIN group (DIN e. V., Beuth Verlag GmbH, DIN Software GmbH) gets 70 % of the funds from its own returns, obtained from the products and services it offers. At NHRS, the ratio of DIN is roughly 43 %. A slightly larger proportion, currently approx. 45 %, comes from project funds of the industry. The remaining funds are obtained via public funding.
The standardisation work in the NHRS is also directly sponsored by associations and companies. Therefore, the non-profit "voluntary foundation to promote standardisation work of the NHRS" (VF NHRS) was founded. It takes care of the promotion of science and research in the field of heating, ventilation and air-conditioning technology as well as their safety and the financial support of the NHRS. The BDH is a member of VF NHRS.

Fig. 110: The development process of standards at DIN

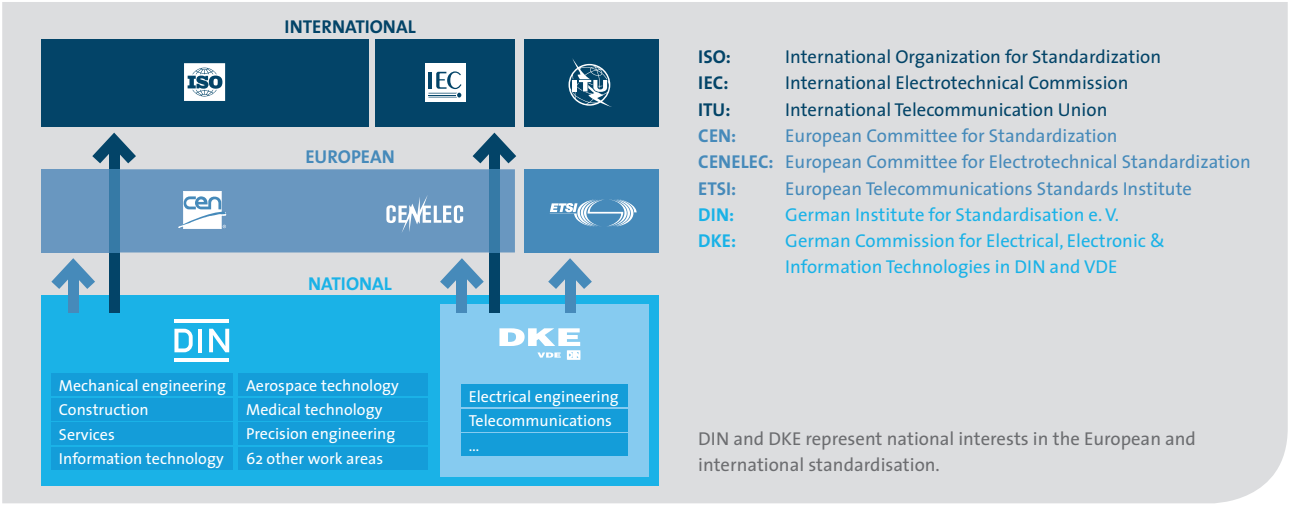


Fig. 111: Representation of national interests by DIN at Europe and international level

Benefits

In the following, with reference to some industry-specific examples, the benefits of standardisation are shown.

DIN V 18599 "Energy efficiency of buildings – Calculation of the energy needs, delivered energy and primary energy for heating, cooling, ventilation, domestic hot water and lighting"

The pre-standard series DIN V 18599 was revised at the end of April 2016 by the responsible joint working group for the "Energy assessment of buildings" of the DIN standards committee "Construction" (NABau), "Heating, ventilation and air-condition technology and their safety" (NHRS) and "Lighting technology" (FNL) for a revised re-publication. The documents were updated and adapted to the technological developments. Further, the new edition replaced the versions of 2011 and 2013.
The calculations allow the assessment of all quantities of energy, which are necessary for heating, domestic hot water preparation, air-conditioning and lighting of buildings. While doing so, DIN V 18599 also takes into consideration the mutual influence of energy streams and the resulting consequences for design plans. Besides calculation methods, usage-related boundary conditions are also specified for a neutral assessment to determine the energy demand (independent of individual user behaviour and local climate data). The pre-standard series serves the purpose of determining the long-term energy demand for buildings or even sections of buildings and for assessing the possible application of renewable energies for buildings. The normatively documented algorithms are applicable for energy balancing of:

- Residential and non-residential buildings
- New constructions and existing constructions

DIN EN 12828: Heating systems in buildings – Design for water-based heating systems

Due to the low strain capacity of pipes, the change in volume of the water caused by change in the temperature may lead to the fact that the pressure is increased greatly even with slight temperature increase. Without additional measures, such as expansion tanks, this increase in pressure can lead to the destruction of pipelines and pressure vessels. Diaphragm pressure relief vessels help to compensate for these changes in volume of water in piping systems.
DIN EN 12828 gives clear indications how diaphragm pressure relief vessels must be designed and allows correct dimensioning. Without a correct dimensioning, there is a danger of pipe break. Dimensioning according to EN 12828 provides confidence to both the user and the designer: After all, any diaphragm pressure relief vessel properly designed according to DIN EN 12828 can be considered technically reliable.

DIN EN 12831: Heating systems in buildings – Method for calculation of the design heat load

The heat load calculation, basis for the layout of each heating system is carried out today according to the accepted method defined by DIN EN 12831. Thus, DIN EN 12831 contributes significantly to the fact that heating systems are designed so that they reach the design internal temperature required. EN 12831 provides a uniform applicable method that allows the comparison of different systems. So EN 12831, in simple terms, ensures that the heating system is able to heat apartment and building to a comfortable temperature in winter.

BDH Members

AEROLINE Tube Systems Baumann GmbH

AFG Arbonia-Forster-Riesa GmbH

ait-deutschland GmbH

ATAG Heizungstechnik GmbH

Austria Email AG

BDR Thermea
- August Brötje GmbH
- Remeha GmbH
- Oertli Rohleder Wärmetechnik GmbH
- SenerTec GmbH

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BTD Behälter- und Speichertechnik Dettenhausen GmbH

BWT Wassertechnik GmbH

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DL Radiators SpA

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Wolf GmbH
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Federal Ministry for Economic Affairs and Energy

www.bmwi.de

BDH Federation of German Heating Industry

www.bdh-koeln.de

Energieeffiziente Gebäude BDI initiativ

www.bdi.eu/themenfelder/umwelt/gebaeudeenergie-effizienz/

BSW GERMAN SOLAR ASSOCIATION

www.solarwirtschaft.de

bwp German Heat Pump Association

www.waermepumpe.de

DEPV Deutscher Energieholz- und Pellet-Verband e.V.

www.depi.de

DIN NHRS

www.nhrs.din.de

DVGW

www.dvgw.de

INITIATIVE EEBUS

www.eebus.org

Fachverband Gebäude-Klima e. V.

www.fgk.de

geea Die Allianz für Gebäude-Energie-Effizienz

www.geea.info

HEA Fachgemeinschaft für effiziente Energieanwendung e. V.

www.hea.de

HKI

www.hki-online.de

iwo Institut für Wärme und Oeltechnik

www.iwo.de

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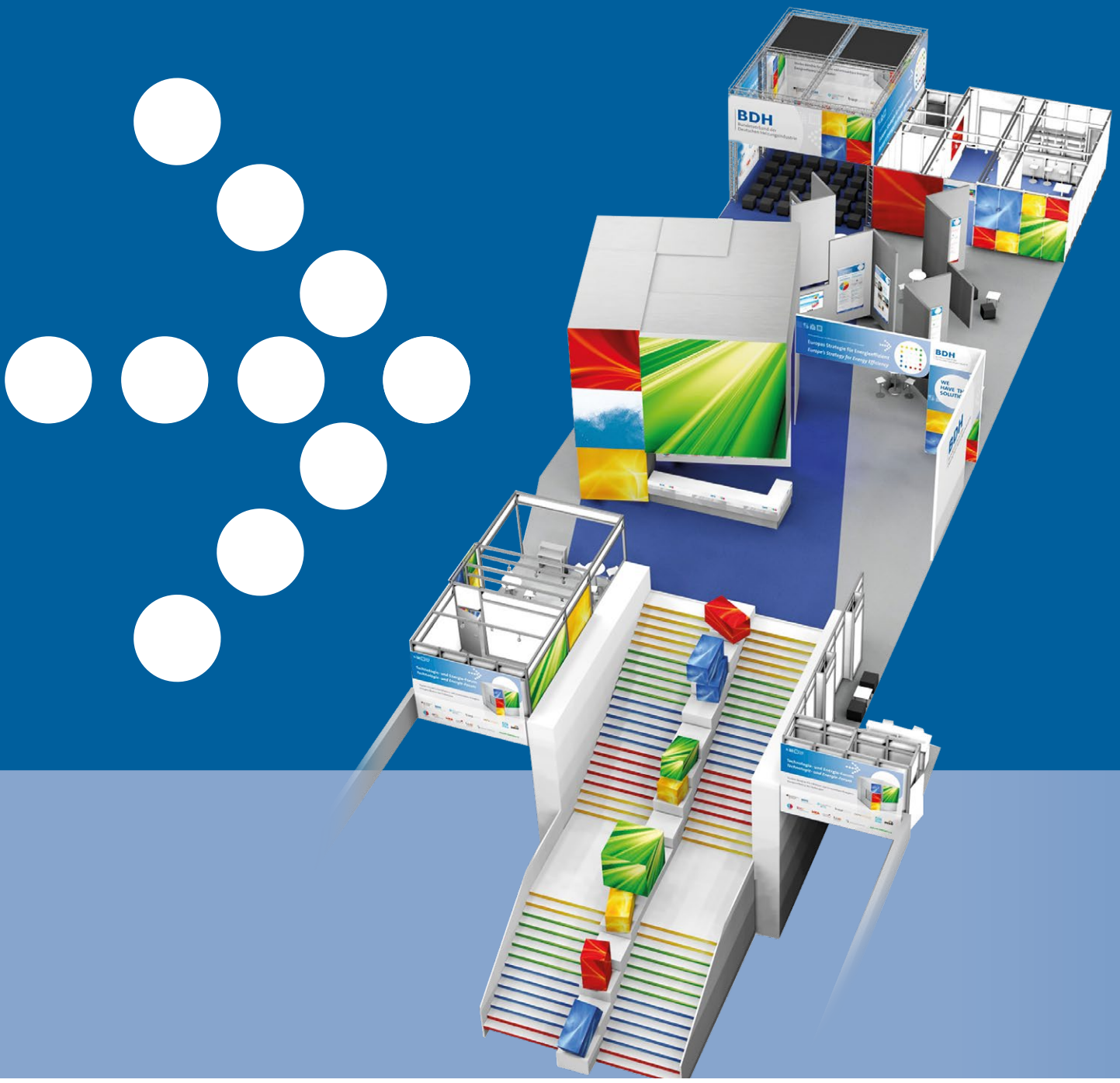

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BSW German Solar Association

bwp German Heat Pump Association

DEPV Deutscher Energieholz- und Pellet-Verband e.V.

DIN NHRS

DVGW

Initiative EEBUS

Fachverband Gebäude-Klima e. V.

geea Die Allianz für Gebäude-Energie-Effizienz

HEA Fachgemeinschaft für effiziente Energieanwendung e. V.

HKI

iwo Institut für Wärme und Oeltechnik

messe frankfurt

Zukunft ERDGAS e.V.