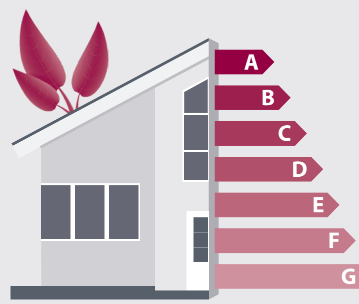
TAB
OFFICE OF TECHNOLOGY ASSESSMENT
AT THE GERMAN BUNDESTAG

Energy saving effects and cost-benefit relations of energy-efficient refurbishment of buildings



Source: happyvetor071/123RF

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Summary

- A successful heat transition is highly relevant for achieving energy and climate policy goals.
- In existing buildings, a lot of energy can be saved by means of energy-related refurbishment measures regarding the exterior walls, the top floor ceiling and the roof.
- The technology change from boilers fuelled with natural gas and heating oil to heat pumps offers high energy saving potentials.
- Significant energy savings can be achieved through measures aiming at quality assurance and system optimisation of heat generators as well as refurbishment measures.
- Changes in the price of fossil fuels and electricity might significantly increase the economic efficiency of energy-efficient and climate-friendly refurbishments – or even make this economic viability possible in the first place.

What is involved

From an energy and climate policy perspective, the reduction of energy consumption and greenhouse gas emissions (GHG emissions) in the building sector is of great importance. Considerable saving effects are seen particularly in the stock of residential buildings. In order to use investment funds and subsidies effectively and efficiently, robust data on the achievable energy savings and greenhouse gas emission reductions are needed. The TAB working report "Energy-saving effects in the building sector" shows the possible savings that can be achieved for building technology (especially heating systems) and the building envelope by implementing the various refurbishment measures available. For this purpose, two perspectives are taken into consideration: On the one hand, the perspective of the building owners is taken. The owners of a building make investment decisions regarding more or less energy-saving and GHG-saving technologies and refurbishment measures. On the other hand, the saving effects concerning energy and greenhouse gases are considered from a national perspective. This includes i. a. the perspective of policy-makers who initiate and design funding programmes for heating technologies and refurbishment measures, or who shape future energy prices via taxes and other policy instruments. It is also outlined to what extent and under which conditions the energy and climate policy goals appear achievable with the refurbishment measures considered.

Technologies and refurbishment measures considered

In Germany, the current stock of boilers in residential buildings is predominantly fuelled with natural gas and heating oil (Fig. 1). Other heat generators are heat pump systems, which have become more and more important in recent years. In addition to energy from the environment (e. g. geothermal heat) or waste heat, they always also consume electricity. Technologies that are also used in the context of energy-related building improvements are solar thermal and photovoltaic systems that provide both heat and electricity, as well as ventilation systems with heat recovery. The latter – when used appropriately and with quality assurance in planning and execution – lead to less heat loss than window ventilation by using the heat contained in the exhaust air to partially cover the heat demand of the rooms.

The energy-related refurbishment measures regarding the building envelope can be divided into the insulation of the exterior walls, the top floor ceiling, the roof, the basement ceiling and the floor slab as well as the replacement of the windows. The aim of the energy-related refurbishment measures is to reduce heat loss via the various parts of the building envelope. Most of the heat losses occur (with the same extent of refurbishment) in exterior walls, followed by the roof or the top floor ceiling. The previous or current refurbishment rate in relation to the building envelope is approx. 1 % per year. In relation to the approximately 19 million residential build-

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ings, this corresponds to about 190,000 refurbishments of the building envelope each year. A breakdown of the refurbishment rate to date between individual building components is shown in Figure 2. A doubling to 2 % per year is assumed as a refurbishment rate that would be necessary in the future to achieve the political goals. According to this, the current refurbishment rate is significantly below the value considered to be necessary (backlog of energy-related refurbishment).

The TAB report also deals with the saving effects of quality assurance measures. In case of structural measures, for example, they enable the elimination or prevention of possible deficiencies (e. g. thermal bridges). Quality assurance with regard to heating, cooling and ventilation technologies includes i. a. hydraulic balancing (optimisation of water volume flows in heating pipes and on heating surfaces) as well as an optimisation of the system temperature.

Fig. 1 Sales of heat generators in Germany in 2020

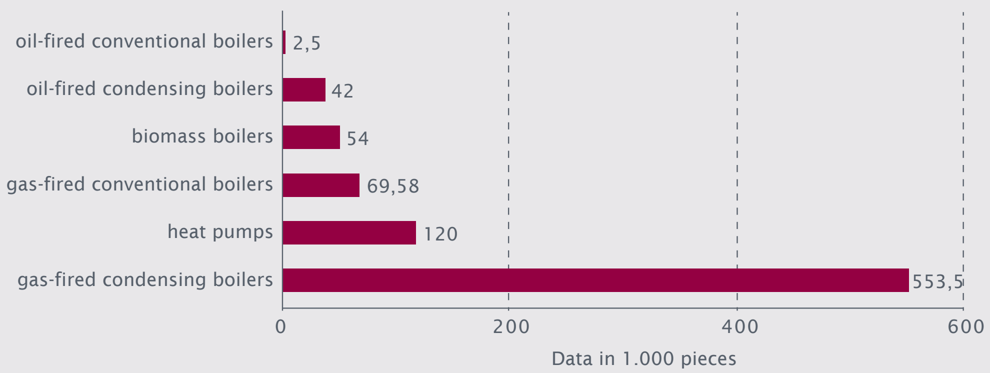


Illustration by TAB based on BDH (2021): Marktentwicklung Wärmeerzeuger Deutschland 2011–2020. https://www.bdh-industrie.de/fileadmin/user_upload/Pressegrafiken/2021/Marktstruktur_zehn_Jahre_2020_DE.pdf (22.6.2022)

Causes of deviations in the calculated saving effects of individual buildings

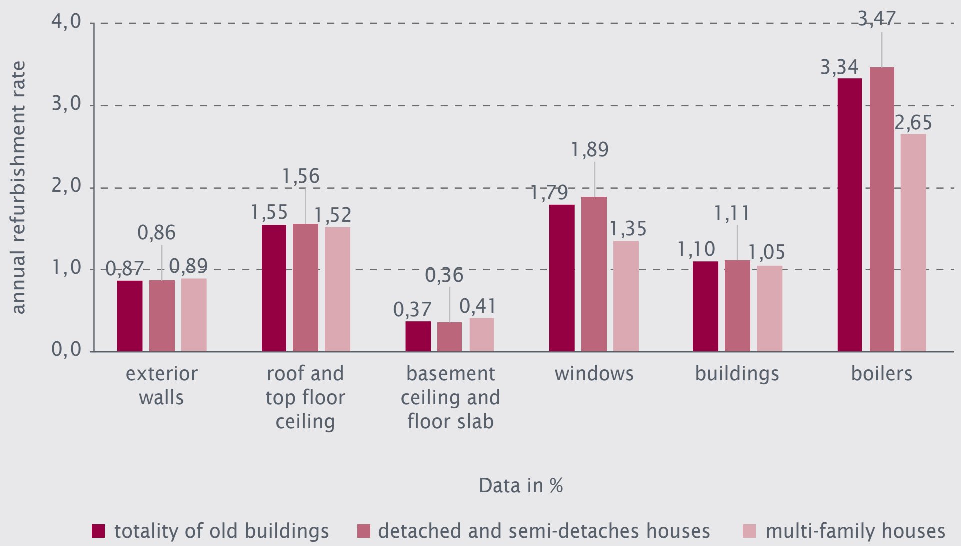
Studies have shown that – in individual cases – the realised savings (energy, costs, emissions) can be significantly lower or higher than the balanced saving potentials. These deviations are attributed, among other things, to the standardised assumptions on usage behaviour stated in the standards and regulations for balancing – which do not adequately reflect the real usage behaviour. Thus, for example, the balances are based on average room temperatures of 19 to 20 °C, which are too low. The lack of data on the actual condition of the building and the efficiency of the systems used also means that the balances do not accurately reflect reality. In the building technologies used and the implementation of the refurbishment measures, deficiencies as well as suboptimal operation of the building technology contribute to an overestimation of the energy saving potentials.

Saving effects thanks to heating technologies and building refurbishment

The following results of the TAB report refer to typified average buildings. In individual cases, the deviations may be considerable:

- Energy savings of 60 to 75 % can be achieved by changing from boilers fuelled with natural gas and heating oil to heat pumps. With 15 to 60 %, the emission reductions are lower. This is due to the fact that – in view of the current electricity mix in Germany (to which coal still contributes significantly) – the greenhouse gas emissions caused by the electricity consumption of the heat pumps are relatively high. By using one's own electricity from a photovoltaic system, electricity-related emissions can be avoided completely. Only if the building envelope is sufficiently refurbished and if the building is usually equipped with an underfloor heating, a heat pump will become economical – as this keeps electricity costs low.
- Significant reductions of greenhouse gas emissions can be achieved by changing from gas or oil boilers to renewable fuels, e. g. wood logs or wood pellets. Due to the generally poorer efficiency of wood-fired boilers, however, this mainly results in additional energy consumption. Moreover, the biomass potential of renewable trees is limited and the combustion of wood involves particulate matter emissions.
- Depending on the initial condition of the building, the refurbishment of the exterior walls of an average detached or semi-detached house can reduce the annual energy losses and, to the same extent, the greenhouse gas emissions by up to 40 %. If the top floor ceiling or the roof is insulated, saving potentials of up to 30 % can still be achieved for detached and semi-detached houses and up to 22 % for multi-family houses.
- For heating systems, between 2 and 20 % energy can be saved in an average residential building by means of hydraulic balancing.

Fig. 2 Annual refurbishment rate of the building envelope in residential buildings built until 1978 (in the period from 2005 to 2008)



Source: Jagnow, K.; Wolff, D. (2020): Energiespareffekte und Kosten-Nutzen-Relationen in der energetischen Gebäudesanierung, Braunschweig

Economic efficiency and cost-benefit relations of technologies and refurbishment measures

The early replacement of an old fossil fuel boiler with a modern boiler usually involves small to moderate savings in energy costs. In most cases, the costs for the new system – compared to the longer operation of the old boiler – cannot be refinanced. Under the current market conditions (energy prices until the end of 2021), the replacement of a boiler with a heat pump and the associated change of energy source to electricity were beneficial for the climate, but mostly not economical. However, by using a photovoltaic system in combination with a heat pump, the economic efficiency can be improved significantly. Even a decentralised electric hot water supply in existing buildings often only becomes economical with a photovoltaic system being integrated. The provision of solar heat through solar thermal systems, on the other hand, is usually not economical.

Quality assurance measures concerning the replacement of technical installations and structural refurbishment measures usually involve low to moderate additional investment costs, which, however, lead to considerable energy savings and are therefore economical. System-optimising measures, e. g. hydraulic balancing or adjusting the system temperature, can contribute to a reduction in operating costs. Both measures can and should be carried out regularly. The costs incurred for this are rather low.

The implementation of major refurbishment measures on the building envelope involves high costs. In particular, the refurbishment of the top floor ceiling and the roof as well as the insulation of the basement ceiling and the exterior walls can be economical. The initial condition of the building and the timing of the measure taken (in relation to the service life of parts of the building) are decisive factors with regard to the resulting economic efficiency.

Future scenarios for achieving the energy saving goals in Germany's residential building sector

It strongly depends on the framework conditions which technologies and measures can or will contribute significantly to achieving the goals in the future and which technologies and measures will be sufficiently economical. Future energy prices in particular will have an impact on energy consumption and greenhouse gas emissions. There are uncertainties in scientific scenarios i. a. regarding the development of energy prices for district heating and electricity. In the corresponding studies, two types of scenarios for future development are described:

- Scenarios based on electricity are mainly characterised by an increase in the use of (electrically powered) heat pumps. The assumed enormous market growth would require considerable capacity expansions on the manufacturers' side. Moreover, it would be necessary to ensure that specialist companies are adequately qualified, that coordinated quality assurance measures and systems are in place, and that capacities for tapping ambient air and soil as heat sources are expanded. A characteristic feature of electricity scenarios is the assumption that – in more than half of the refurbishments – a photovoltaic system will be installed for power supply. A photovoltaic system can be installed not only in connection with a roof refurbishment, but also when refurbishing the external wall insulation or replacing the windows (using transparent solar cells) – provided there is sufficient solar radiation.
- In contrast, the technology mix scenarios focus on maintaining existing gas grid structures, expanding district heating and combined heat and power (CHP), and producing and using synthetic gases (mainly as imports). This would largely preserve the current energy industry, the supply structure for buildings and the current heating technologies. The necessary expansion of the renewable energy industry would have to be significantly more substantial than in the electricity scenarios (more photovoltaics and wind power),

because the production and supply of renewable gases is much more energy-intensive than that of renewable electricity.

However, both development scenarios require an expansion of renewable energy sources. Moreover, the following generally applies to both options: Since the politically targeted increase in the building refurbishment rate from 1 to 2 % of the residential building stock is considered by experts to be difficult to achieve, increased quality levels can be implemented alternatively or additionally for refurbishments of the building envelope (which are carried out anyway).

Options for action for politics

The following options for action can be derived in order to contribute to an energy-efficient and climate-neutral residential building stock in a sufficiently effective and (in the long term) cost-effective way and thus to meet the energy and climate goals envisaged:

- The requirements for refurbishment on the part of legislation and funding could be significantly increased in the near future, e. g. with regard to the quality of insulation, airtightness, ventilation, heating and lighting.
- Funding programmes and conditions could be made conditional on CO_2 savings. Alternatively, individual requirements could be established for which a CO_2 saving effect is known and recognised. Moreover, another option would be to base the amount of subsidies for investments not only on the investment costs, but also on the costs per tonne of CO_2 avoided.
- A consumption-based monitoring – encouraged by incentives or mandatory – of the success of refurbishment measures, which includes the phase of use, can provide a reliable data basis for the adaptation of regulations and funding programmes as well as for the information of residents and owners.

TAB report no. 200

Energiespareffekte und Kosten-Nutzen-Relationen der energetischen Gebäudesanierung

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Website of the project

www.tab-beim-bundestag.de/en/ese-bs

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- Digital, smart and networked technologies (smart meters, apps, etc.) are necessary for the provision of user-related energy consumption data, which promptly reflect consumption behaviour and provide information on potential improvements.
- Quality assurance could be integrated even more into the design of funding programmes, but also into regulation via the German Buildings Energy Act (e. g. related to leakage measurement of buildings, optimisation of thermal bridges, hydraulic balancing or other optimisation of heating systems and the installation of meters). Furthermore, quality assurance could be made mandatory as part of planning.
- With regard to the future development of prices for fossil fuels and electricity, the German Renewable Energy Sources Act ("EEG"), energy taxes and grid charges in the electricity sector could be decisive factors. A stronger coupling of energy prices to greenhouse gas emissions could help to ensure that electricity prices would be significantly lower (than at present) as the share of renewable energy sources increases.

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