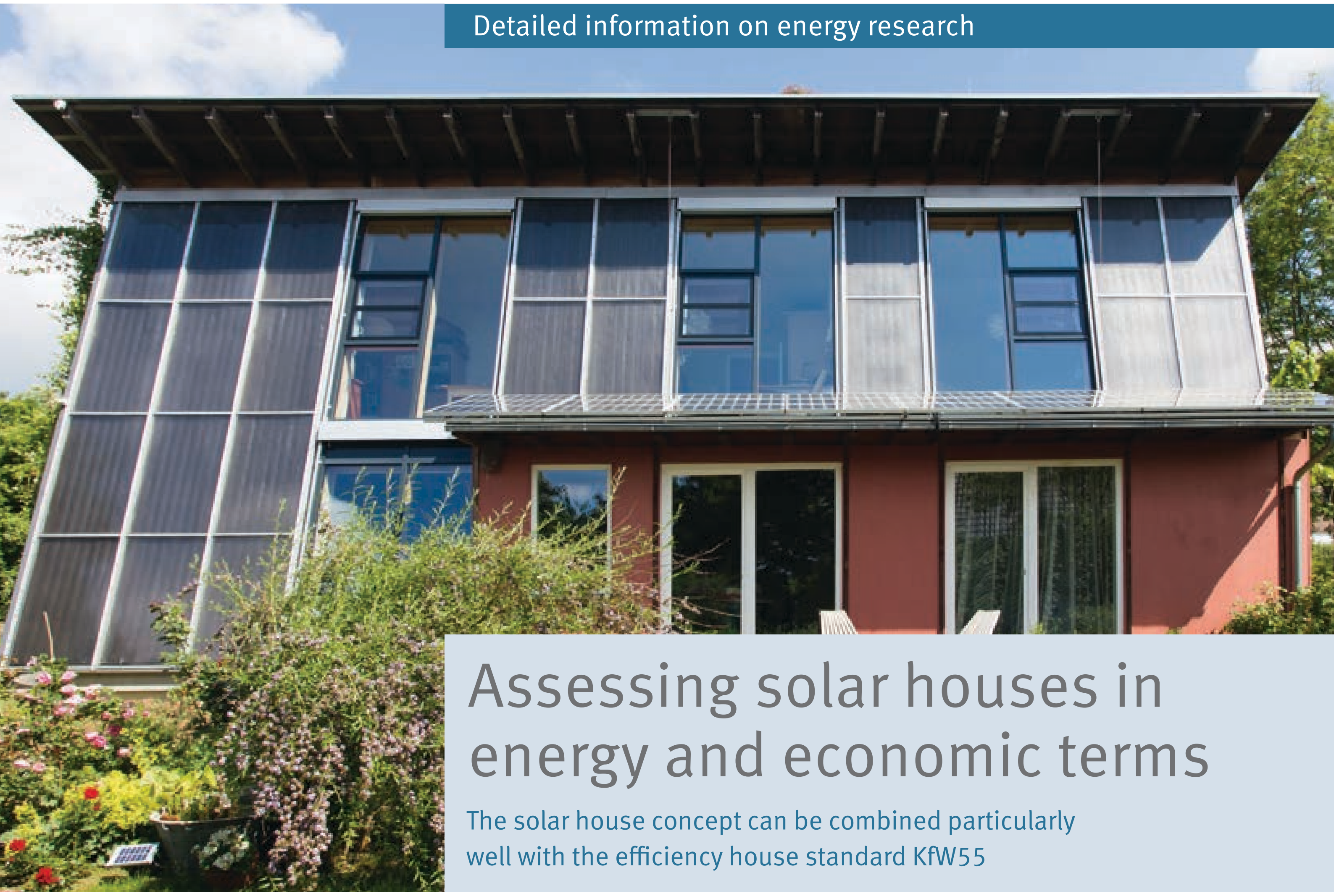
Detailed information on energy research



Assessing solar houses in energy and economic terms

The solar house concept can be combined particularly well with the efficiency house standard KfW55

BINE Information Service

With the German Energy Savings Ordinance 2016, the maximum value allowed for the annual primary energy requirement for new residential buildings has been reduced by a quarter. This is not a problem in solar houses: they require a maximum of 15 kWh/(m²p.a.) of primary energy for heating energy and auxiliary power and are therefore well below the requirements of passive houses. The cost of this good CO_2 balance can be determined using a newly developed simulation method.

Very little primary energy is required to cover the heat demand in solar houses. In the well-insulated buildings, a solar thermal system typically covers between 60 and 70 % of the heating requirement; the rest is usually met by biomass heating. With the biomass a source of energy is used which has a primary energy factor less than 1. This proportion does not considerably impact on the energy balance. The energy is mostly balanced in the form of electric auxiliary energy that is used, for example, for pumps and actuators. This is necessary in order to make the renewable energy usable for the building services equipment. This means that solar houses provide a possible alternative for meeting the criteria laid down by both the German Energy Savings Ordinance 2016 and the European Building Directive. This stipulates that from 2021 new buildings can only be built as nearly zero-energy buildings.
With solar houses, which are also known as solar active houses (SAH), the low primary energy demand entails additional costs. How high these are depends on the efficiency house standard for the respective building and the solar and heating technology used. In order to assess the additional expenditure, scientists led by the Fraunhofer Institute for Solar Energy Systems ISE have developed a simulation method. This tool determines, among other things, the additional

This research project is funded by the

Federal Ministry for Economic Affairs and Energy (BMWi)

costs annualised over the course of the year that would be incurred through integrating a large solar thermal system. All costs shown here refer to a firmly defined reference model (Fig. 1). They include, among other things, the expenditure for achieving a higher efficiency standard (e.g. for additional EPS thermal insulation, triple glazing), additional expenses for the solar thermal heat generator and for various auxiliary heat generators. Additional costs for the loss of living space through insulation and storage were not included.

Reducing the primary energy demand with solar houses

The scientists' simulations showed that the solar house concept can be combined particularly well with the efficiency house standard KfW55. This is a building that only consumes 55 % of the energy used by a comparable new-build scheme constructed according to the German Energy Saving Ordinance (EnEV).
An example: If a building is built in accordance with efficiency class KfW55 with a solar fraction of 30 % (SAH30) and a gas boiler, this enables the specific primary energy demand to be reduced by about 80 kWh/(m^2_{UFA} p.a.) compared with the reference system technology (Fig. 2). With a solar thermal solar fraction of 60 % (SAH60), this can be reduced by 105 kWh/(m^2_{UFA} p.a.). Taking the funding opportunities according to the MAP market incentive programme into account, this version has lower costs relative to the reference amounting to about 2 euros per year and square metre of usable floor area (UFA). In the simulations, a KfW55 building with a 60 per cent solar fraction turned out to be the most attractive solution. Here, a reduction of the primary energy demand can be „bought" for relatively low additional costs.
In their simulations, the scientists assumed that gas was the additional heat generator. With a primary energy factor of 1.1, this energy source has a higher value than biomass, which is usually used in solar houses.
The costs that need to be taken into account vary depending on whether financial support from the MAP market incentive programme is included in the calculations and which rate of increase for the energy price is used as the basis (3 or 8 %). With an increasing share of the solar thermal heat supply, the dependence on fluctuations in the energy prices reduces.

Additional costs for various KfW efficiency houses simulated

The simulation tool makes it possible to model the best ratio between the storage volume, aperture area and solar coverage for a predefined efficiency house. The combination with the KfW55 standard also turned out to be the best solution here. In order to achieve a solar fraction of 60 % with this building standard, home owners can expect additional costs of about two euros per year and square metre of usable floor area in accordance with EnEV (Fig. 3). With the incorporated solar technology, these include the additional financial expenditure (compared with the reference model) for a 4.2 m^3 storage tank and an aperture area of 27 square metres.
If it is intended to cover 60 % of the heating requirement with solar energy for a building with another KfW efficiency house standard, this entails additional costs between 4.48 and 5.91 euros per year and square metre of usable floor area.

- *Residential building, size according to IEA Task 44 (140 m^2 of heated usable floor area (UFA), 160 litres of hot water at 45 °C per day), EnEV efficiency standard from 2014*
- *Supply: Gas boiler, solar thermal system with 60 % coverage of the drinking water*
- *Costs for the solar thermal system, including storage tank and assembly: 5,771 euros*
- *Gas boiler costs: 3,873 euros*
- *The expenditure for 30 kWh of electrical auxiliary power was taken into account for the operational costs*

Fig. 1 *These are the characteristics of the reference model on which the simulated additional costs are based.*

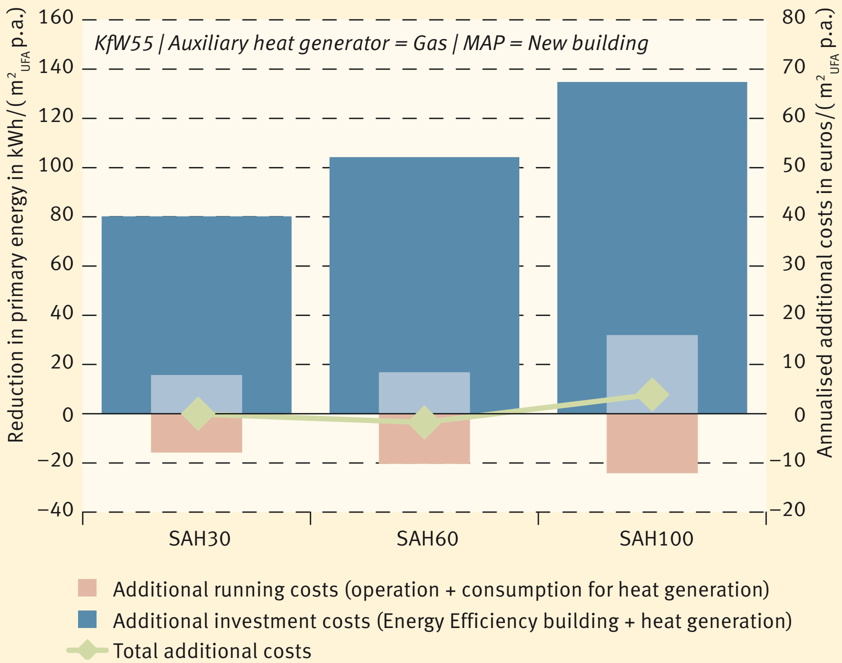


Fig. 2 *In accordance with the current funding conditions stipulated by the MAP market incentive programme, the KfW55 efficiency house standard depicted here would have optimised costs with a solar fraction of 60 %. All values refer to the reference model.*

If the funding possibilities in accordance with the market incentive programme are also taken into account in the calculations, the installation of additional solar technology is even more cost effective than with the reference model.

Comparison with other supply concepts

The scientists compared different low-CO_2 heating supply concepts and categorised the solar house concept in relation to them (Fig. 4). Biomass is very well rated in primary energy terms. Consequently, it is possible to save considerable primary energy by using wooden pellets or logs. Here it needs to be considered, however, that the cost of a pellet boiler is higher than that of a gas boiler. The annual costs are similar to an efficiency house version with a gas boiler. If, as is usual in solar houses, timber logs are used as an additional energy source, the costs reduce for the same primary energy demand. This is because wood-fired boilers and fuel are relatively inexpensive.
If a building is combined with a low KfW standard (KfW40/KfW55) and a solar coverage between 30 and 60 %, very high reductions in the primary energy demand are also possible with the additional use of gas as an energy source. With a solar thermal fraction of 60 %, more than 80 kWh per year and square metre of usable floor area are realistic.
In combination with a high standard of insulation, systems with heat pumps and a photovoltaic system but without a solar thermal system showed

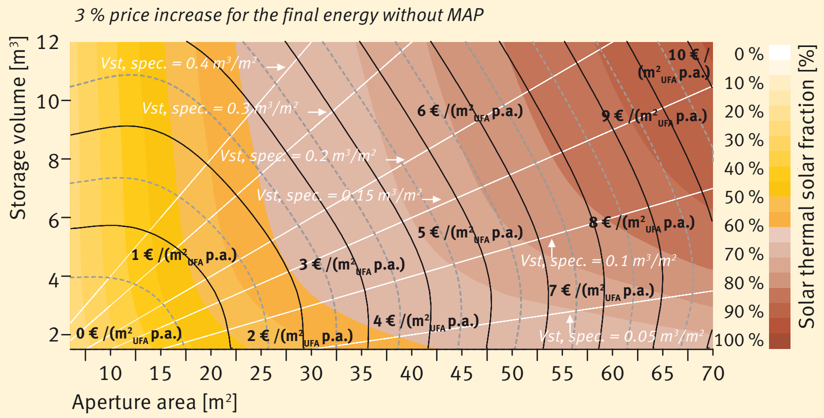


Fig. 3 *Simulated combinations of collector and storage tank sizes for a KfW55 building in Passau (140 m² of heated usable floor area). The stated costs are additional costs relative to the reference model.*

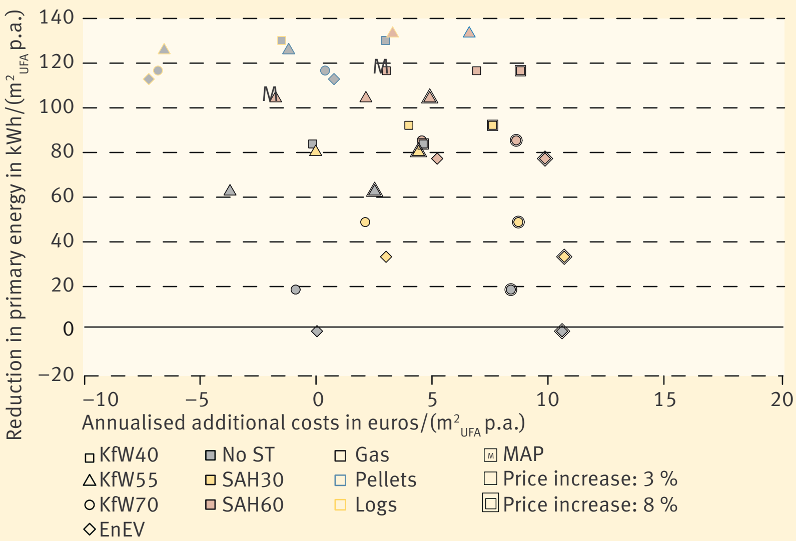


Fig. 4 *Solar houses have a very low primary energy demand.*

Solar houses and solar active houses

According to the guidelines of the Solar House Institute, the heating in a solar house should be entirely met by renewable energies, whereby at least 50 % should be covered by a solar thermal system. A typical solar house has a compact, elongated structure with a steeply sloping roof to the south that provides the winter sun with as much surface area as possible. The passive use of solar energy with an energy-optimised arrangement of the glass surfaces forms part of the concept. Inside the building, a water tank provides heat storage. The specific transmission heat loss HT for a new-build scheme must be at least 15 % less than the HT for the EnEV reference building. The typical annual primary energy requirement per square metre of usable floor area for a new building ranges between approximately 5 and 15 kWh. The solar active house concept prescribes that solar thermal heat should meet at least 50 % of the heating demand.

Fig. 5 *Schematic of a solar house*

that they also provide an inexpensive way to reduce the annual primary energy demand significantly. As the electricity requirement and the electricity supplied by PV systems are not always congruent time-wise, a primary energy assessment based on annual values is not expedient here and further evaluation procedures need to be developed.

Countering surplus heat

The starting point for developing the simulation method was provided by investigations of conceptually different solar houses. These comprised three apartment buildings and six single-family homes, which the scientists measured over several heating seasons. Based on the collected operational experience and monitoring results, they derived various optimisation suggestions.

High solar yields can only be achieved throughout the year with relatively large collector surface areas. These are used when there is a high heating requirement. In summer this produces surplus heat that could cause stagnation of the system if it is not removed, for example, with methods such as night-time cooling. An alternative is a steeper arrangement of the collectors (cover image: solar house in Rottenburg). Here the collectors were integrated into the facade. In summer, parts of the collectors are shaded by a roof overhang, but in winter when the sun is low the solar irradiation is incident on the collector surface at an optimum angle. This therefore minimises stagnation problems in the system. Facade-integrated collectors can also be additionally used as thermal insulation.

Alternative storage systems possible

High solar fractions are only possible with large storage systems, since these make it possible to bridge periods with low solar irradiation.

The storage tanks are usually located in the stairwells of the residential buildings. In winter, the heat radiated by them can meet up to 20 % of the space heating requirements and thus make a significant contribution to the building heating. Because conversely there is a problem of overheating in summer, the scientists recommend having sufficient storage tank insulation. At the moment the risk of overheating is prevented by ventilation systems above the storage tanks.

In future, alternative storage types are conceivable. These include vacuum insulated storage tanks, which have very low heat losses. Another alternative is provided by thermochemical storage systems, which have a higher storage capacity. Both storage systems are being developed at the Institute for Thermodynamics and Thermal Engineering at Stuttgart University.

Meeting the electricity requirement as well

There are many other approaches for meeting not only heating but also electricity demands with solar energy. Energy self-sufficient buildings, for example, are aimed at having a heating and electricity supply that is 100 % self-sufficient, i.e. largely independent of public supply systems. Here the buildings primarily rely on solar energy. As part of a monitoring project run by the Technische Universität Bergakademie Freiberg, scientists are investigating an energy self-sufficient building. Here a 46-square-metre collector surface area and a nine-cubic-metre long-term heat storage system provide 65 per cent solar coverage of the heat demand. The remaining heat requirement is met by a stove. An 8-kWp photovoltaic system is integrated into the roof. With corresponding batteries, it is designed to provide complete coverage of the electricity requirements. Surplus electrical energy can be used, for example, for recharging an electric car.

To enable them to assess the technical and economic potential for utilising thermal and electrical solar energy in general terms, scientists at the Technical University of Braunschweig have carried out a simulation study. In the „future: solar – System analyses for solar energy provision“ research project, they investigated the role that solar energy can play in 50 or 100 per cent local, renewable energy provision. The results for a standard new building showed that in order to achieve a 50 per cent share of renewable energy in the total energy demand, the combinations solar thermal/gas-fire condensing boiler/PV and heat pump/PV are economically equivalent. If 100 per cent renewable energy provision is sought, the heat pump/PV option would be the most favourable.

Alternative possibilities for storing heat in solar houses are currently being investigated by the Institute for Solar Energy Research in Hamelin. Here scientists have developed a solar house where the building itself serves as the heat storage and heating element. They are combining an approximately one-cubic-metre thermal storage tank with direct, solar thermally driven component activation of solid floors in the building. They are currently evaluating the concept based on a building prototype.

Imprint

Project organisation
Federal Ministry for Economic Affairs and Energy (BMWi)
11019 Berlin
Germany

Project Management Jülich
Forschungszentrum Jülich GmbH
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Project number
0325971A

ISSN
0937-8367

Publisher
FIZ Karlsruhe · Leibniz Institute for Information Infrastructure GmbH
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Links and literature (in German)

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Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

Concept and design: iserundschmidt GmbH, Bonn – Berlin, Germany · Layout: KERSTIN CONRADI · Mediengestaltung, Berlin, Germany