Energy-Efficient Supply of Hot Water

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ENERGY-EFFICIENT SUPPLY OF HOT WATER

When a decentralized system makes sense

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ENERGY DEMAND FOR HOT WATER IS OF GROWING IMPORTANCE

In industrial countries, buildings account for some 40 percent of final energy consumption. A vast majority of this is the energy used for central heating. Nevertheless, as the numbers of modern constructions increase, whose building shells are very well insulated, the focus is shifting to the energy demands of hot water consumption, which is a steadily growing proportion in the energy footprint of a building. However, since central heating and the supply of hot water are traditionally linked systems in buildings, it remains unclear what the energy demand for warm water actually is, how this is influenced by usage of the building, and how it can be met with energy efficiency. Innovative ways to heat hot water independently from central heating are electronically regulated electric instantaneous water heaters (IWH). Since an IWH by nature is decentralized, directly heating water where it is needed, it suffers no losses from distribution or storage, compared to conventional, centralized hot water systems with storage tanks.

As the share of renewable sources in power generation increases, hot water from IWH becomes an increasingly more attractive alternative to central or decentralized systems with storage tanks. Previous studies have already demonstrated this.

MEMBERS OF THE WORKING GROUP
“ENERGY-EFFICIENT DECENTRALIZED SUPPLY OF HOT WATER”:

- PROF. DR. ANTHIMOS GEORGIADIS, Leuphana University of Lüneburg
- PROF. DR. THOMAS SCHOMERUS, Leuphana University of Lüneburg
- RICHTER GMBH, SANITARY AND HEATING ENGINEERS, Uelzen
- WILL HAUSTECHNIK GMBH, Barnstedt
- CLAGE GMBH, Lüneburg
- DR. HOLGER PETERSEN, INAMI
- MATTHIAS SCHOCK, INAMI

OBSTACLES TO OVERCOME

Nonetheless, the members of the working group “Energy-Efficient Decentralized Supply of Hot Water” in the “Innovation Network Sustainable SMEs“ (INAMI) of the Leuphana University Lüneburg saw major obstacles to the widespread use of decentralized systems of supply as efficient alternatives to traditional systems.

Despite indications that IWH did not differ greatly from central applications from a primary energy point of view, the details of how efficiently the decentralized IWH in fact worked, compared to central heating technologies, remained unclear. To this was added the question of how dependent energy efficiency of IWH is on situational parameters such as the number of persons living in a household.

Furthermore, there is a series of regulations and standards that define the central assumptions for calculating the energy efficiency of buildings. For instance, that the hot water requirement of a building is directly proportional to the floor space. It needed to be clarified whether these parameters put decentralized hot water heating at a disadvantage.

This brochure is based upon an expert study for the rational usage of energy in buildings by Dr. Bernd Steinmüller for the Innovation Incubator. As coordinator of the working group, the Innovation Network Sustainable SMEs (INAMI) commissioned his scientific support in 2012.

ASSIGNMENT: CLARIFY ENERGY EFFICIENCY AND CHECK STANDARDS

The major questions were: How energy-efficient is the supply of hot water by electronic IWH compared to conventional methods of heating water? To what extent does this depend on factors such as the number of household occupants or the assistance of a solar equipment?

Another objective was to investigate whether the contemporary standards for energy saving adequately consider the potential savings of IWH.

In order to obtain a meaningful efficiency comparison, the study should also take any “loss absorbing” effects of a building into account when calculating its energy footprint. The heat lost by a system that supplies hot water ultimately reduces the heating requirements of a building.

Moreover, it was necessary to demonstrate how hot water demand changes during the life cycle of a building. The efficiency of the system for heating hot water can change, for example, as the children in a large family grow up and eventually move out.

The primary energy factor determines the relationship between input primary energy and final energy, which consumers can use. The smaller the primary energy factor is, the more eco-friendly and efficient the use and expenditure of energy in the supply chain. In Germany, the Energy-Saving Ordinance (EnEV) defines the primary energy factors of energy carriers. Gas, heating oil and hard coal are given the value 1.1, whereas wood has a 0.2 factor. In May 2014 electricity was assigned a value of 2.4, previously it was 2.6 and this value will fall further as renewables expand in the German power generation mix.

THE KRANICHSTEIN PASSIVE HOUSE AS A FUTURISTIC EXAMPLE

For modeling, the passive house project planning package known as PHPP was chosen. PHPP is a software tool for architects and technical planners that makes it possible to establish the energy footprint for heating and cooling demands of a building. It has been tried, tested and approved for more than a decade and reveals in a transparent way all steps of calculation and formulae used, which can be adjusted if necessary.

Moreover, PHPP contains a preconfigured example of a family house, the Kranichstein passive house that was built in Darmstadt in 1991, which allows the demonstration of substantial energy dependencies. The Kranichstein passive house is a terraced house conceived with notional accommodation for four and a half persons and a futuristic energy specification: The annual heating requirement is less than 15 kilowatt-hours per square meter of floor space. As it is required for comparison, the building is equipped with a conventional centralized hot water system with a condensing boiler (CB) and without solar water heating. This building requires an input of 524 kilowatt-hours per annum to supply the daily needs of 25 liters of hot water with a temperature of 60 degrees Celsius.

Passive houses are buildings that have a very low demand for added warmth and so require no active heating. Such houses keep warm “passively” by deriving sufficient warmth from the existing heat within and the radiant heat of sunlight that enters the windows in combination with minimal heating from fresh air.

PARAMETERS AND KEY FIGURES OF THE SYSTEM

The primary energy conversion efficiency

An important factor for comparison of efficiency is the primary energy conversion efficiency (PECE). This ratio indicates the quality of the heating system in terms of the relationship between the primary energy supplied and the converted energy as hot water. The lower the number the more effective the system is.

To perform the desired comparison, the PECE for a conventional system is compared – in various ways – to a standard IWH system. The standard system is defined in a study published in 2011 by the Research Center for Energy Economics (FfE). It operates practically without any loss. This means its efficiency only depends on the primary energy factor. Variations of the other factors therefore only apply to the "conventional" system.

Further reading (in German):

Forschungsgesellschaft für Energiewirtschaft mbH (2011): Reduzierung von Energieverbrauch und CO_2-Emissionen durch dezentrale elektrische Warmwasserversorgung.

The primary energy factor

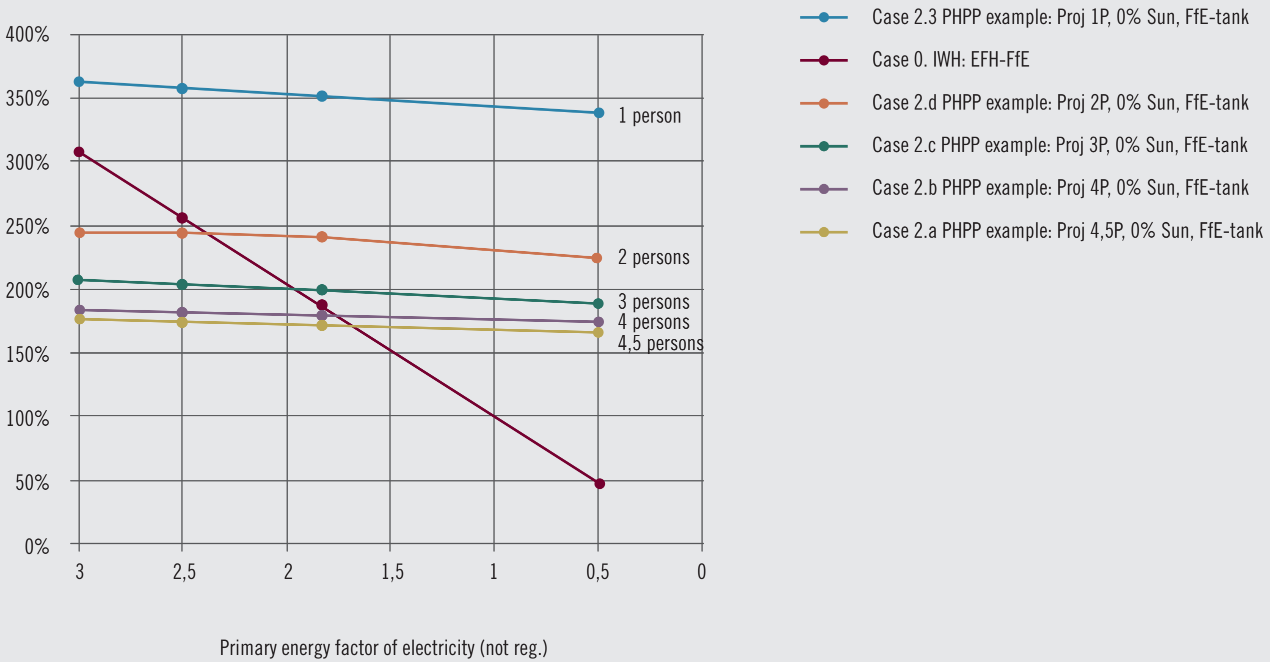
The results should show what impact the sinking primary energy factor due to the expansion of renewable sources of energy for power generation has on the efficiency of the systems to be compared. Hence the primary energy conversion efficiency as a function of the primary energy factor is presented in graphs of a consistent form. What a future falling of primary energy factor signifies for primary energy efficiency can thus also be directly ascertained from the graphs. The intersections of the IWH curve with a "conventional" curve thus indicate the primary energy factor at which IWH systems begin to be advantageous from a primary energy perspective.

Variable and constant factors
This analysis will study how the primary energy factor is influenced by differing numbers of persons in a household, according to the positioning of pipes and tanks, as well as modifications to buildings.

The primary energy factor shall be depicted as a sliding scale, because the proportion of fossil fuel energy in the power generation mix is steadily falling. The average number of occupants will also be varied, because the number of persons in a household is shrinking statistically. The location of the pipes and the tank will be modified here, because heat lost from a tank in the warm zones of a building reduces the energy needed for space heating. Along with the building standards, it will be investigated what influence energy-oriented refurbishment has on the heating of hot water.

The following values will be regarded as constant: the necessary auxiliary electricity, the primary energy for heating hot water, the distribution and pipework losses, the technical system losses, the effective hot water energy and the circulatory losses.

Comparison of hot water systems in family houses: FfE-IWH versus PHPP-example with variations of the numbers of persons (amount of hot water used)



NUMBERS OF PERSONS AND AMOUNTS OF WATER USED

The number of persons in a household has a large impact on the energy efficiency of a hot water system, because the occupants determine how much hot water is needed. As a rule, when buildings are planned a maximum occupancy is assumed, in the Kranichstein example it is a formal 4.5 persons.

However, during the true life cycle of a house its occupancy does vary. When the children leave home, for example. There is also a social trend of smaller households.

In addition to the assumed standard usage of hot water, it can also be shown how the system behaves when the household uses water more sparingly. The primary energy cost for hot water of a family house planned for 4.5 would correspond to a single household if the family's usage was 4.5 times more sparing than standard usage expects.

Results

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In a four person household there is more frequent washing of dishes than in a single household.

POSITIONING OF TANKS AND PIPES

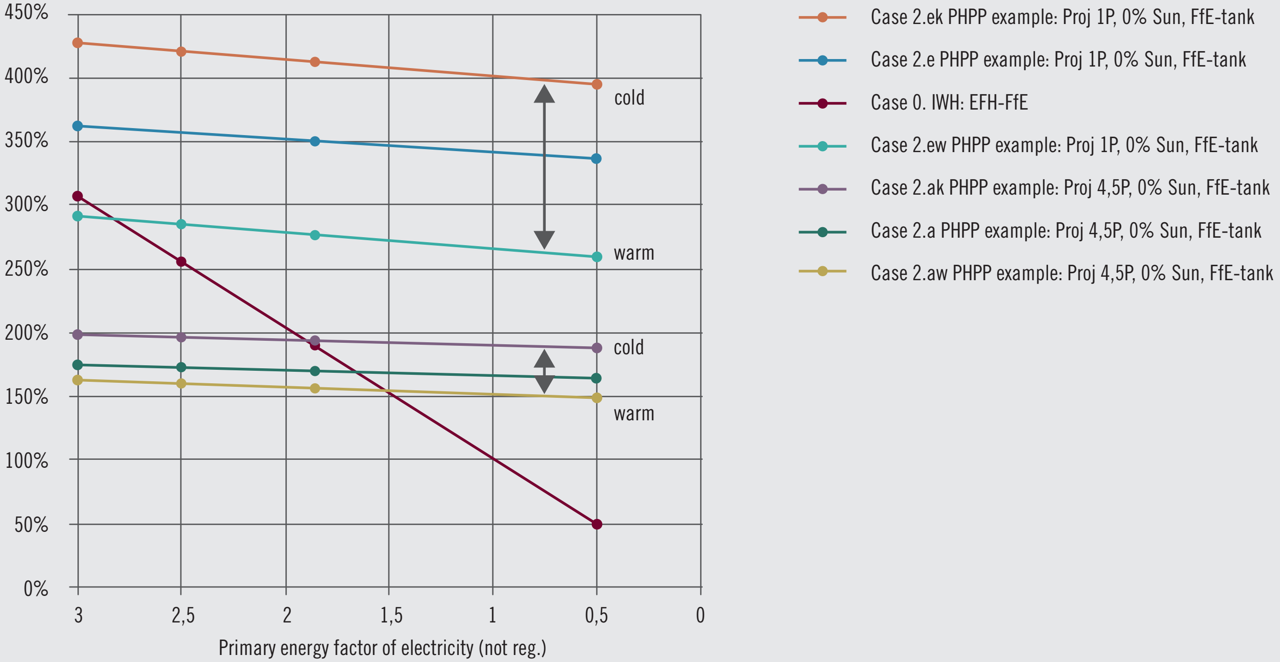
In the Kranichstein passive house the hot water tank is located in the cold zone of the building and only some of the water pipes are in the warm zone. In the cold zone, any heat leaking from the hot water system is effectively wasted. Whereas in the warm zone, such leakages of heat help reduce the heating needed. For this reason it will also be investigated to what extent the energy efficiency of the hot water system is dependent on its positioning. To cover the extremes of possibility it was required to compare the heat-leaking CB system when it is alternately positioned entirely in the warm and cold zones of the building.

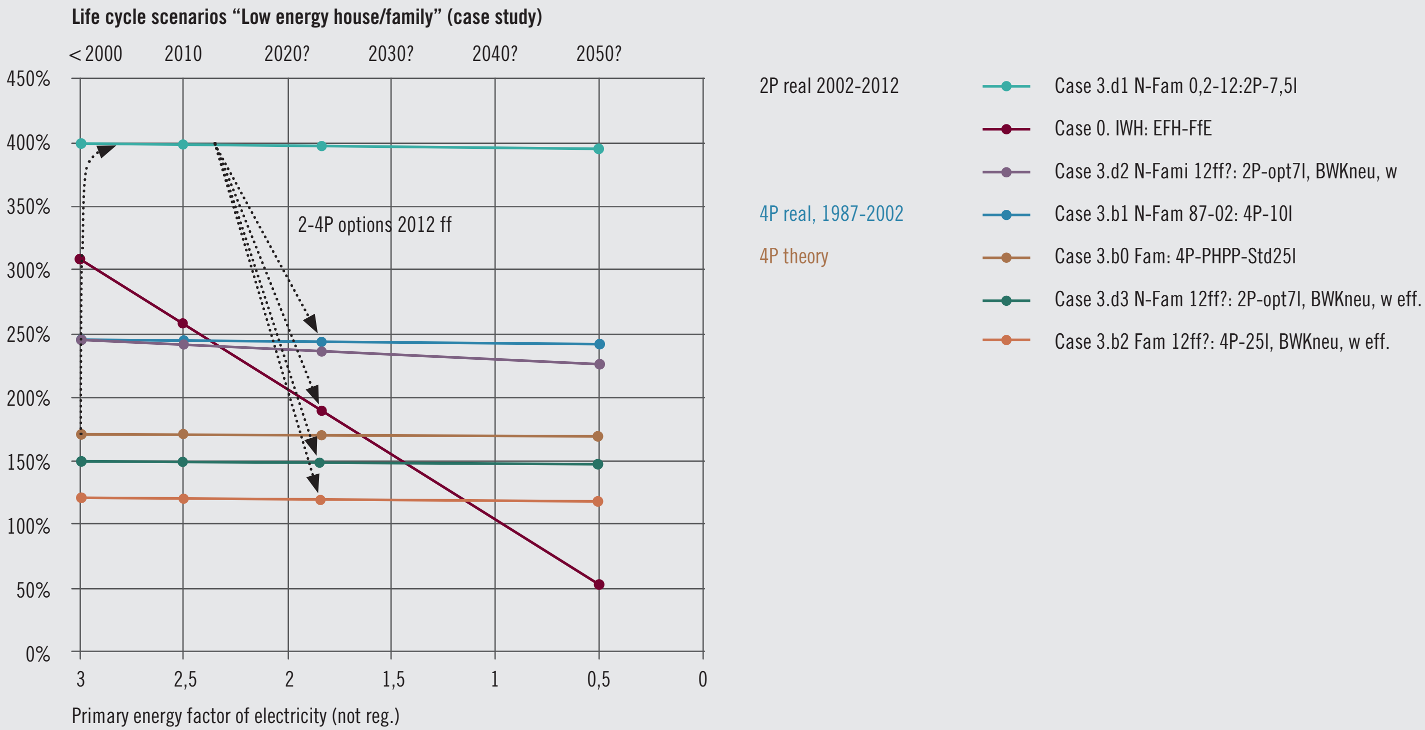
Results

The positioning of the tank and pipes plays an important role, especially when there are fewer persons in a household or when consumption is sparing. The primary energy conversion efficiency differs by almost 150 percent. The IWH system has primary energy advantages in both cases.

Even when several “standard consumers” live in the household, the PECE is influenced by up to 40 percent. Also with higher occupancy the IWH system outdoes the CB system with its benefits at the latest from a 1.5 primary energy factor.

Comparison of hot water systems in family houses: FfE-IWH versus PHPP-CBVariation: tank and pipes in cold and warm zones




Life cycle scenarios “Low energy house/family” (case study)
< 2000
2010
2020?
2030?
2040?
2050?
450%
400%
350%
300%
250%
200%
150%
100%
50%
0%
2-4P options 2012 ff
3
2,5
2
1,5
1
0,5
0
Primary energy factor of electricity (not reg.)
2P real 2002-2012
4P real, 1987-2002
4P theory
Case 3.d1 N-Fam 0,2-12:2P-7,5l
Case 0. IWH: EFH-FfE
Case 3.d2 N-Fami 12ff?: 2P-opt7l, BWKneu, w
Case 3.b1 N-Fam 87-02: 4P-10l
Case 3.b0 Fam: 4P-PHPP-Std25l
Case 3.d3 N-Fam 12ff?: 2P-opt7l, BWKneu, w eff.
Case 3.b2 Fam 12ff?: 4P-25l, BWKneu, w eff.

THE LIFE CYCLE OF A FAMILY HOUSE

The study results clearly show that the numbers of persons in a household, their hot water consumption in combination with the primary energy factor and the positioning of the hot water heating system in the building exert a large influence on the energy efficiency of such a system. These factors of influence can also change during the life cycle of buildings, as a case study shows:

In 1986 a family of four moved into a family house built ten years earlier. The family reduced the heating requirements by passive measures such as new windows, better insulation and draft-proofing. They also had a new condensing boiler installed that covered their heating and hot water needs. In this way they managed to reduce their energy consumption by a factor of four compared to the prior usage of a two-person household. With an annual consumption of less than 100 kilowatt-hours per square meter the building almost reached the level of a low-energy house. After refurbishment without separate tanks, the hot water system was positioned partly in the warm and partly in the cold zones of the house.

The influence of standard assumptions

The standard assumption for consumption of hot water heated to 60 degrees Celsius by a family of four is 25 liters per person per day, for this the equivalence point lies at 1.7 – as is the case with the illustrated “4P theory” line. That means that as of a primary energy factor of 1.7 the IWH system is beneficial.

According to a VDI standard, taking a shower consumes 12 to 60 liters of hot water. Although in reality much less than even the lower value may often be the case.

When the actual hot water consumption per day under the same conditions falls below 10 liters, this results in the blue line “4P real, 1987-2002” in the illustration. From the equivalence point in this case a primary energy factor of 2.3 now applies.

After 15 years, the children leave home and the hot water consumption sinks to around 7.5 liters per person per day, the equivalence point reaches a primary energy factor of 4. In this case, the IWH system would be significantly more primary energy efficient. In the illustration this is depicted as the “2P real, 2002-2012” line.

After 25 years, the hot water system is due for a partial replacement. What effect this has on the primary energy requirements depends on the sinking primary energy factor and future usage. The options are shown here as dotted black arrows.

Sampling hot water demand

At the end of 2011, the family and guests in the house were asked to take part in sampling their hot water consumption. The results stake no claim to be representative. However, they did point out that much less water is potentially required and consumed than, for example, the VDI 2067 standard assumes. While this standard assumes that 12-60 liters are needed for showering, the samples showed that the family only used between 5 and 13 liters. This means the standard consumption figures need critical appraisal and possibly modification to match individual habits and modern water-saving technology.

THE ROLE OF THE STANDARDS

The statutory specifications relevant to hot water supplies that applied during the period of investigation were above all the Energy-Saving Ordinance (EnEV) and the associated DIN 4701-10 and DIN 18-599 standards. Based on the findings of this study the following elements of these standards are problematic: The effective energy for hot water is prescribed according to floor space as between 12 and 16 kilowatt-hours per square meter. These standards suggest that on the one hand the hot water needs of a building increase in direct proportion to the floor space, and on the other hand that the ratio of these values is constant nationwide. These assumptions do not correspond to real conditions and hence are inaccurate. Thus, they lead to modeling and planning of buildings that is divorced from reality. The errors that arise from this become even more discrepant with falling hot water consumption and so must be corrected.

Realistic consumption estimates

The consumption of the effective energy in hot water should be determined and defined as it relates to persons. Realistic life cycle variations and further measures should also be determined and defined, which will promote increasing energy efficiency in the supply of hot water. This is a particularly decisive factor for fostering innovation.

Start-up wastage due to slugs of water in long pipes has yet to be explicitly recorded in the relevant DIN standards and so do not figure in calculations of kilowatt-hours per month. Assessment of this factor would be preferred.

In the standards mentioned, the future primary energy conversion efficiency will be calculated with primary energy factors that are based on the present. Future expansion of renewable energy over the next ten years will lead to significant reductions of this factor, but the standards reflect only the present status. Furthermore, the central component of a hot water system has a useful life of several decades. In comparison with conventional systems an IWH system will become increasingly more primary energy efficient during its useful life.

The Association of German Engineers (VDI) standards
VDI 2067 Blatt 12 is also of fundamental importance for the primary energy efficiency of the hot water supply. This standard specifies certain ranges of values and mean values for the “reference usage” of water and the demands for hot water. However, it does not sufficiently differentiate between types of usage and the corresponding amounts of water. Accordingly, and as the case more often is, a quick shower suffices to clean the body. Whereas with the more infrequent “feel good shower” a lot more hot water is consumed. The sampling mentioned earlier certainly indicated that the demands and consumption are considerably over-estimated.

OBSTACLES AND OPPORTUNITIES FOR INSTANTANEOUS WATER HEATERS

The primary energy efficiency of hot water systems depends on a number of factors – as seen in the examples given here. For many types of application, IWH systems already give primary energy advantages over other decentralized as well as “conventional” central systems.
The advantages of IWH significantly increase with a reducing hot water consumption and with a reducing primary energy factor. This offers opportunities for IWH. However, risks lie in load management of the power grid, which could force power to become more expensive at certain times of the day.
The technical literature analyzed and the standards applicable during the period of investigation insufficiently address the structure, extent and functional dependencies of hot water demand. As a result the development of unconventional systems is more hindered than fostered.

PRACTICAL EXAMPLE: MANUFACTURERS AND USERS OF INSTANTANEOUS WATER HEATERS

The product portfolio of the Lüneburg-based family business of CLAGE GmbH, founded in 1951, includes electronic IWH that harmonize energy efficiency with hot water convenience and economic efficiency. Prior to the study described here, CLAGE's product communications were based on a comparative analysis of the German association for Efficient Application of Energy (HEA). The HEA analysis compared the energy consumption of different water heating installations in a three-person household living in a detached house. The HEA report was able to demonstrate the energy efficiency of decentralized and electronic IWH systems, but not the differences between different household sizes.

The influence of norms

For more than 10 years, Germany's Energy Saving Ordinance (EnEV) has been defining maximum values for the energy use of new buildings. Its focus on primary energy, however, is difficult to understand for consumers. "If the consumer were only to look at the number of kilowatt-hours consumed then instantaneous water heaters would already be more efficient than conventional systems, because they produce no intrinsic energy losses", says Joachim Gerdes, managing director of CLAGE. "Due to the political focus on primary energy it was necessary to provide more transparency about the conditions under which instantaneous water heaters already operate more primary energetically efficient than conventional systems."

The INAMI report demonstrates that IWH are already more primary energy efficient in two-person households than conventional systems. "As soon as the electricity receives a primary energy factor of 1.5 then instantaneous water heaters are generally more efficient than any other solution," Gerdes says. According to the INAMI report, consumers should not only opt for a water heating system on the basis of the EnEV, but rather in accordance with their actual consumption.

The energy efficiency label

The EU energy efficiency label also assesses the energy efficiency of energy-consuming products. From September 26, 2015, it will also be mandatory for hot water heating devices. The on-demand IWH is classified under the best energy efficiency class A.

However, this also shows that a label cannot entirely retain transparency: "In practice, within efficiency class A, on-demand heating systems allow for up to 30 percent of further energy savings compared to hydraulic instantaneous water heaters," explained the managing director of CLAGE. The energy label does explicitly illustrate this advantage.

FROM THE VIEWPOINT OF A BUILDINGS ENERGY CONSULTANT

"For us there are two main reasons why instantaneous water heaters are gaining importance," says Jörn Leuschner, the CEO of RICHTER GmbH, sanitary and heating engineers in Uelzen.

"The energy efficiency of instantaneous water heaters is largely dependent on the number of occupants of an apartment or house," he discovered from participation in the working group for "Energy-efficient Decentralized Supply of Hot Water" in the INAMI of Leuphana University of Lüneburg. He sees a further argument in favor of the decentralized supply of hot water in the hygiene of drinking water: "It is very much easier to tackle drinking water hygiene with the short hot water channels of a continuous water heater than it is with large central tanks."

Even so, for many clients IWH has the reputation of an electricity guzzler. That is especially true for renters, who still use obsolete and inefficient IWH systems. Here he sees good application prospects for IWH over the next few years. In particular for small apartments. It also removes the need for several 80-liter hot water tanks.

"When I explain clearly and objectively to my clients the advantages of instantaneous water heaters, such as for a single person apartment, they are happily convinced," finds Leuschner. The central specialist information for his work he gathers from his trade association, from current laws and regulations as well as from manufacturers such as CLAGE and Stiebel Eltron.

JÖRN LEUSCHNER is master engineer for heating and ventilating since 1996 and buildings energy consultant (chamber of crafts certified) since 2007.

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