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Home Energy Management Systems (HEMS): 2nd Market Overview for Germany (2025)

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Abstract. The integration of increasing renewable energies requires the use flexibility on the demand side. Single-family houses (SFHs) play a key role as they connect electricity consumption with decentralized generation. Home Energy Management Systems (HEMS) are central to coordinating flexible loads, such as electric vehicles (EVs), heat pumps (HPs), heating elements, and battery storage systems (BSS), with renewable supply. HEMS enable optimization of self-consumption from photovoltaic (PV) systems and can respond to dynamic electricity tariffs and grid signals, allowing households to shift usage to periods of high renewable availability. With 13 million SFHs in Germany, HEMS offer considerable flexibility potential. Next to optimizing energy flows, they provide economic benefits by reducing electricity and grid-related costs. Despite their potential, the growing HEMS market suffers from a lack of transparency regarding available systems, functionalities, and interoperability. This makes it difficult for consumers and installers to identify and implement suitable solutions. Without HEMS, millions of decentralized generation and consumption units in SFHs would operate uncoordinated. However, operating HPs or charging electric vehicles with zero-emission electricity requires systems that can respond to the availability of renewable energy. This paper provides a comprehensive analysis of the German HEMS market. It presents current HEMS solutions, identifies and compares core system functionalities, and outlines expected developments. The study also includes insights from electrical installers and evaluates the added value HEMS can offer to installation companies.

Keywords: HEMS, Flexibility, Dynamic Electricity Tariff

1. Introduction

The expansion of decentralized PV systems, the rising share of heat pumps and electric vehicles (EVs) must be considered holistically in connection with the decarbonization of the energy system, public acceptance and integration in the smart grid. The main objective of HEMS is to use the flexibility of charging processes for EVs and the operation of heat pumps as well as heating elements (power-to-heat) in combination with electrical and thermal storage systems. On the one hand, HEMS enable cost-optimized operation by PV self-consumption and dynamic electricity tariffs. On the other hand, it is necessary to integrate flexible loads and PV systems into the smart grid. HEMS offer huge potential, particularly in view of the 13 million SFHs in Germany [1]. Currently, around 3.1 million PV systems (< 20 kWp) and around 1 million BSS (< 20 kWh) are installed in Germany [2]. In July 2024, the number of EVs was 1.5 million, with a target of 15 million EVs by 2030 [3]. Until June 2024, around 2 million heat pumps were installed, most of them (75 %) air-water heat pumps. The target for 2030 is to reach 6 million installed heat pumps [4]. Thereby, in existing buildings with fossil or biomass-based heating systems, power-to-heat systems in combination with a HEMS can contribute significantly to achieving carbon neutrality. Historically, PV systems are often combined with a BSS. However, if additional systems such as EVs or heat pumps need to be optimized centrally, a higher-level control logic in the form of a HEMS is required to coordinate the operation. Initially focused on optimizing PV self-consumption, HEMS functionalities have expanded, particularly with the introduction of §14a EnWG for limitation of power consumption and §41a EnWG, which mandates the availability of dynamic electricity tariffs from 01/2025 [5]. However, as the number of interfaces and stakeholders increases, so does the complexity of these systems.

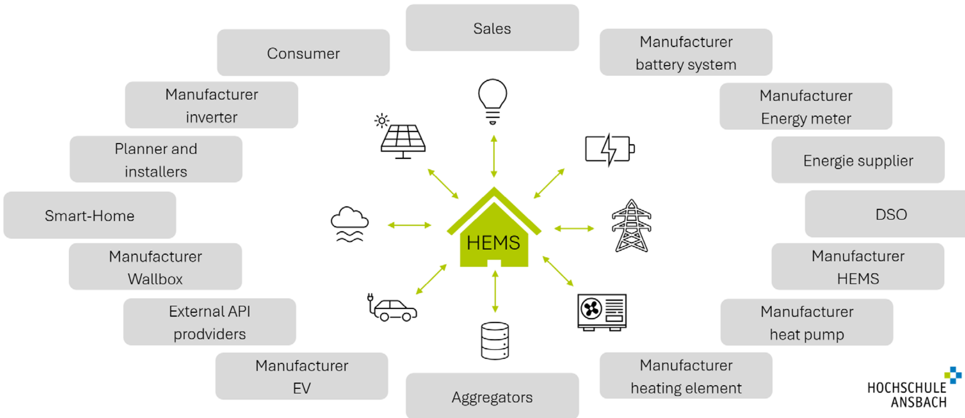

Figure 1. *The HEMS as a central interface for various actors in and outside the building.*

As a central interface, the implementation of HEMS must consider both internal building processes and external parameters (*Figure 1*). In buildings, this includes the integration of controllable loads, compatibility, installation, commissioning and the necessary expertise. Externally, the number of use cases is increasing, including compliance with legal regulations, such as the implementation of §14a EnWG in Germany. A major challenge lies in the grid-supportive and grid-friendly integration of HEMS. Here, HEMS can offer an opportunity to achieve an economic optimum between decentralized cost optimization and reduction of grid expansion costs, which are currently estimated at 300 Bio. € in Germany [6]. The importance of HEMS is also reflected in research activities: Many studies and reports emphasize their importance. These include the expert-round at the smarterE [7], studies on the integration of flexibility in distribution grids [8], [9] and projects to improve communication between distribution system operator (DSO) and HEMS [10]. As the market grows and the functions and applications of HEMS increase, so does the complexity of the systems. However, a transparent overview of the market is essential to ensure simple and large-scale implementation, in long-term to 15 Mio. buildings. Thus, the following questions arise: Which HEMS are available in Germany and how do they differ in terms of functionality and how do electricians rate the practical implementation of HEMS?

2. Methodology

The companies participating in the 2nd HEMS-survey represent almost the entire German HEMS market and provide a comprehensive overview of the current state of the art and developments. The following approach was taken:

Criteria for including HEMS-Companies in the survey:

I. Large scale realisable system without specific programming effort (feasibility by installer without programming knowledge or even private person).
II. Control of two independent flexible technologies: Minimum EV + heat pump, or EV + battery, or heat pump and battery.

III. Optimized control of flexible consumers with PV surplus and, or dynamic tariffs.

Structure of the survey:

1) Expansion and refinement of the 1st HEMS survey.
2) A questionnaire with around 75 questions (with validation questions) was sent to the manufacturers via an online questionnaire, which they mostly completed in a team.
3) The contents were validated again in an interview with the respective HEMS manufacturer.
4) The HEMS-survey was conducted between December 2024 and February 2025.
5) The survey among installers took place during the Energy Management Day of EnBW e.V. in Esslingen in October 2024. Almost 300 participants took part in the survey, the majority of them electrical installation companies.

3. Results and discussion

In the 2nd HEMS survey, 41 companies participated with 43 HEMS (of which two did not wish to be named publicly.). 42 of the HEMS are in the B2B market and 13 of the HEMS also offered in the B2C market. Within the 42 HEMS in the B2B segment, 16 HEMS are offered as white-label HEMS. A comparison with the 1st HEMS-survey (26 participants) is only partially possible, as the scope and detail of the questions has improved. The following companies are currently represented in the German HEMS market.

ASKOMA	ASKO Set	KOSTAL Solar Electric GmbH	PLENTICORE G3 + KOSTAL Smart Energy Meter
Bosch Home Comfort Group	Bosch Energiemanager	KOSTAL Solar Electric GmbH	PLENTICORE G3 und KOSTAL Energy Meter
Buderus	MyEnergyMaster	LADE GmbH	LADEgenius
chargebyte	CB Energy	myGEKKO	myGEKKO Energiemanager
clever-PV GmbH	clever-PV	neoom International GmbH	neoom CONNECT
Consolinno Energy GmbH	leaflet - HEMS	openWB GmbH & Co. KG	openWB (software2)
Dafi GmbH	SMARTFOX Energiemanagement	PLEXLOG GmbH	PL
Digital Building Technology GmbH & Co. KG	wibutler energy OS	Schneider Electric	HEMSlogic
ecodata solutions GmbH	SmartDog	SENEC GmbH	SENEC.PowerPilot
energielenker solutions GmbH	Enbas	SMA Solar Technology AG	SMA Home Storage Solution
Enpal	Enpal.One	SMA Solar Technology AG	Sunny Home Manager 2.0
Enphase Energy	IQ Energy Management	Smappee NV	Infinity
EV-Autocharge	EV-Autocharge	Solar Manager GmbH	Solar Manager
Fenecon	FEMS	Solarwatt GmbH	Solarwatt Manager
gridX GmbH	XENON	sonnen GmbH	Smart Energy System
Hager Vertriebsgesellschaft	flow	TEKKO Gebäudeautomation GmbH	TEKKO Energiemanager
HagerEnergy GmbH	Integrated in the E3/DC-Hauskraftwerks	Viessmann Holding International GmbH	Viessmann Energy Management
Huawei Technologies Deutschland GmbH	EMMA-A02	Wendeware	AMPERIX Energiemanagement Sys.
kamaste.it GmbH	e-pot	Zählerfreunde	ZF-Automations
Kiwigrid	The Independent Home	Zerofy OÜ	Zerofy

Figure 2. *Participating HEMS manufacturers and the names of the HEMS models.*

A look at the HEMS manufacturers shows that, on the one hand, there are established companies in the field of energy technology, e.g. from the heating or inverter industry. On the other hand, some companies focus exclusively on HEMS. Based on several discussions, the B2C market with general manufacturers offering a HEMS in their portfolio will grow strongly in the coming years.

3.1 Analysis of the HEMS-survey

In the following, the HEMS survey is presented with a focus on the practical implementation, interoperability and interfaces, cost optimization, and network integration.

3.1.1 Analysis of HEMS system types

HEMS vary in the way they are implemented. Fundamentally, HEMS logic and control algorithms are independent of the hardware. However, HEMS are offered differently on the market for product-strategic reasons, compatibility and distribution.

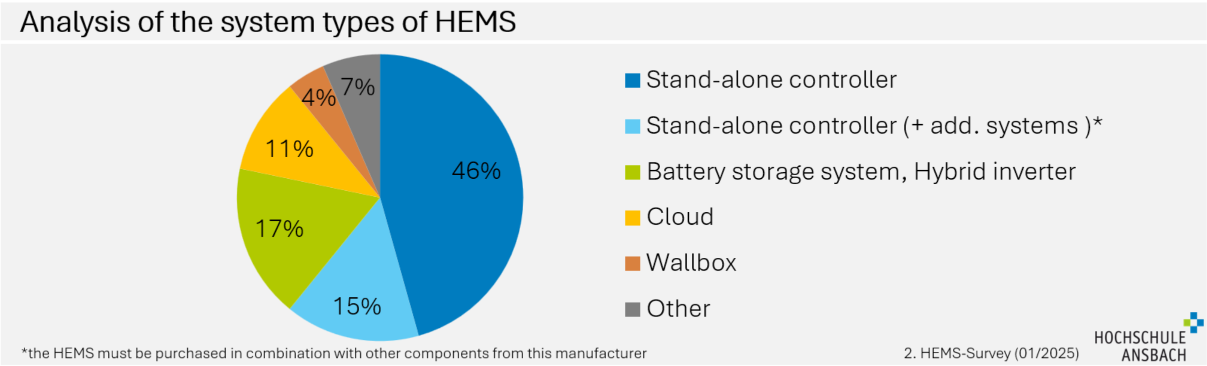

Figure 3. *Categorization of HEMS according to practical implementation.*

In general, HEMS at the consumer installation can be differentiated into hardware-based and cloud-based systems. Within the hardware-based, these can be further divided into the groups: Stand-alone controllers (total 61%), embedded systems (integrated in the BSS or in the EV charging station, further named wallbox). A further distinction can be made within the stand-alone controllers. Providers who take an open-system approach and providers for whom additional components must be purchased (e.g. the company-specific wallbox if charging is required). The category "Other" includes providers of HEMS software without specific hardware binding for the B2B application.

3.1.2 Interoperability of the HEMS

The HEMS is a central interface in the building. Communication with the following systems is of primary importance: Heat pump, EV, BSS, heating element and with the provider of dynamic electricity tariffs. Especially in buildings with existing systems, the question arises, how open or closed are the systems in terms of other manufacturers. For the assessment of the interoperability of the HEMS, the following criteria were defined: As soon as at least two manufacturers can be integrated for the respective component, it is open to manufacturers. As soon as this definition is met for all four analysed components, the HEMS was classified as “Cross-System interoperability” (*Figure 4*). The heat pump can be integrated via both SG Ready and bidirectional interfaces (e.g. Modbus TCP or EEBus). The easy-to-implement and manufacturer-neutral SG Ready interface (current version 2.0, valid since June 1, 2020) represents four operating states, which can be implemented by the heat pump via two potential-free contacts [11]. To use SG Ready, the heat pump must support SG Ready. A detailed analysis of this interface was carried out in [12] and [13]. All corresponding heat pumps are listed in the SG Ready database [14]. Due to the manufacturer-independent SG Ready interface, 79% of HEMS can be connected to at least two heat pump manufacturers. When integrating EVs and BSS, 67% of HEMS can integrate more than one manufacturer. When it comes to choosing a wallbox, some manufacturers only allow their own wallboxes to be integrated into their HEMS. When it comes to the BSS, the HEMS is sometimes part of or connected to the BSS, which therefore must be purchased as a package (BSS + HEMS).

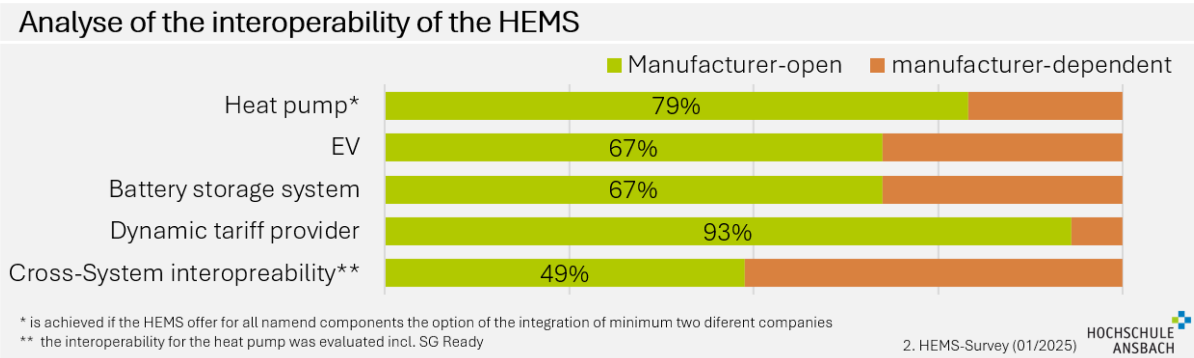

Figure 4. *Analysis of the interoperability of HEMS.*

The integration of dynamic electricity tariffs shows that 93% of HEMS can integrate at least two providers of dynamic electricity tariffs and are therefore independent of one specific supplier. A large share of the manufacturer-open HEMS with dynamic electricity tariffs integrates the EPEX day-ahead prices [15]. The cross-system analysis shows that 49% of HEMS currently follow a non-proprietary approach. Compared to the study from the previous year, the criteria have been extended here with the provider of dynamic electricity tariffs. The evaluation shows that the increase in the manufacturer-dependent HEMS has increased.

3.1.3 Photovoltaic surplus management (self-consumption optimization)

A basic function of HEMS is the use of self-produced PV energy (*Figure 5*). As soon as the PV system generates more energy than is currently being consumed, surplus energy is produced, which would initially be fed into the distribution grid without further technology.

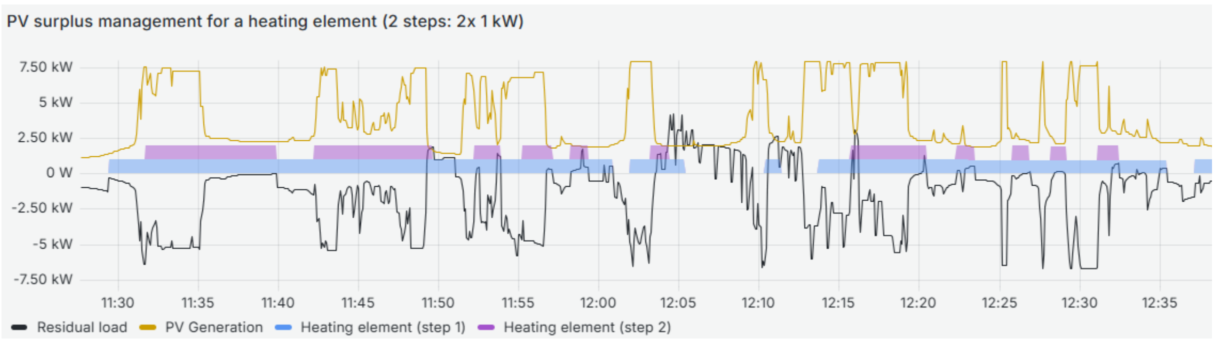

Figure 5. *Visualization of a real HEMS with PV surplus management simplified with a heating element with 2 x 1 kW (blue and purple) for a fluctuating summer day.*

In addition to the approach of optimizing PV self-consumption using a BSS, the HEMS can adjust the power of the EV charging, the heat pump, the heating element (see *Figure 5*) and other consumers to the available surplus power using smart plugs. The first HEMS-survey in 2024 [16] showed that the PV surplus management for EVs, heat pumps and BSS is implemented in almost all HEMS. For the study, the analysis of the "EV" component includes both control of the charging power via the wallbox and via the EV cloud API. When it comes to intelligent EV charging, the variant in which the charging current is controlled via the wallbox is the status quo. In almost all basic cases, BSS are fundamentally independent of the HEMS when it comes to PV surplus management (*Figure 5*). When integrated into the HEMS, a distinction can be made as to how the respective BSS is integrated in terms of read and write access to parameters. Read access is possible with almost all manufacturers (e.g. to read the state of charge or charging power). With write access for charging and discharging power, on the one hand, the prioritization of the systems (which system receives priority PV surplus) can be implemented in a more specified manner.

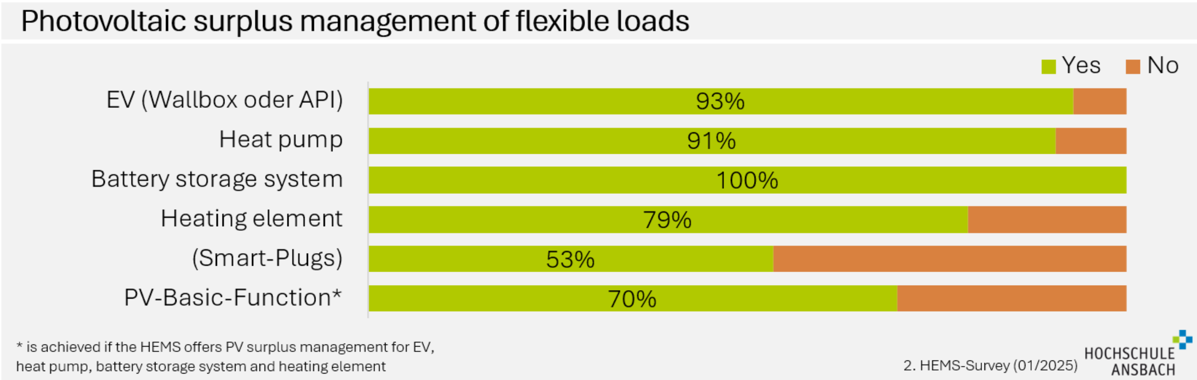

Figure 6. *Analysis of the implementation of the PV surplus management in HEMS.*

On the other hand, this function must be available if dynamic electricity tariffs are to be used for active grid charging of the BSS. The "PV-Basic-Function" defined in this study determines the combined availability of the PV surplus management for EV, heat pump, BSS and heating element. It shows that currently 70% of HEMS can control all relevant systems with PV surplus. This enables consumers to use their self-generated PV electricity across sectors and to achieve a high level of self-consumption. Even heating elements, which are often low-cost to purchase, can make a significant contribution in heating systems without heat pumps from April to October by replacing fossil or biomass fuels. The targeted use of PV electricity in the home also enables better integration of PV systems into the distribution grid [6].

3.1.4 Dynamic electricity tariff in HEMS

The mandatory offer of dynamic electricity tariffs for household customers (EnWG §41a load-variable, time-of-use or dynamic and other electricity tariffs) enables consumers to actively participate in the electricity market with flexible loads. Currently, a large proportion of the dynamic electricity tariffs offered are based on the day-ahead prices of the EPEX exchange [15]. In *Figure 7, the* day-ahead prices for October 2024 are shown as an example. In addition to the exchange prices, an offset of +20 ct/kWh was selected as an example to include levies and taxes. In addition, a static reference price of 30 ct/kWh was used for the previously standard static tariff in the visualization.

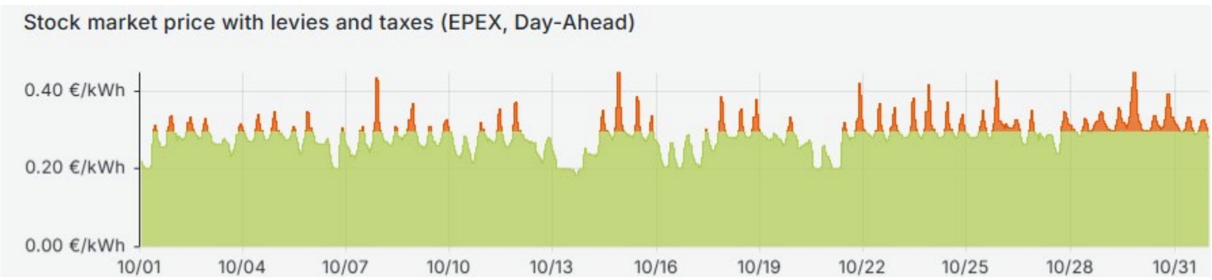

Figure 7. *Extract from the day-ahead electricity exchange price for 10/2024 with levies and taxes (offset of +20 ct/kWh) and a reference price of 30 ct/kWh.*

With a HEMS, hours with low prices can be used and times with expensive prices can often be avoided. However, it should be noted that price fluctuations are influenced by many factors. A detailed analysis of the day-ahead price and the price spreads for 2024 is presented in [17]. The "dynamic electricity tariff" function includes the control of the charging power for the EV, the heat pump, the heating element, smart plugs and the BSS based on a dynamic electricity tariff with hourly price fluctuations. The analysis in *Figure 8* shows that the control of flexible loads with dynamic tariffs is currently less integrated than the PV surplus management. As a result of discussions with HEMS manufacturers, almost all of them are actively working on integration. The specific integration of the systems shows that EV, heat pumps and BSSs are each integrated in about 60% of the systems, while heating elements and smart plugs are significantly less. Until now, BSSs in homes were used exclusively with PV surplus, therefore a large proportion of the cycles from March to October were used. With the integration of dynamic electricity tariffs, BSSs can use low-cost hours to charge from the grid all year round, while avoiding grid purchases during expensive hours (with and without a PV system). Overall, the respective implementation and the intelligence used vary widely depending on the manufacturer. The systems differ from each other, starting with simple if-this-then-that functions with the manual user entry of a threshold value for the price at which the battery should be charged to fully automated AI-controlled variants.

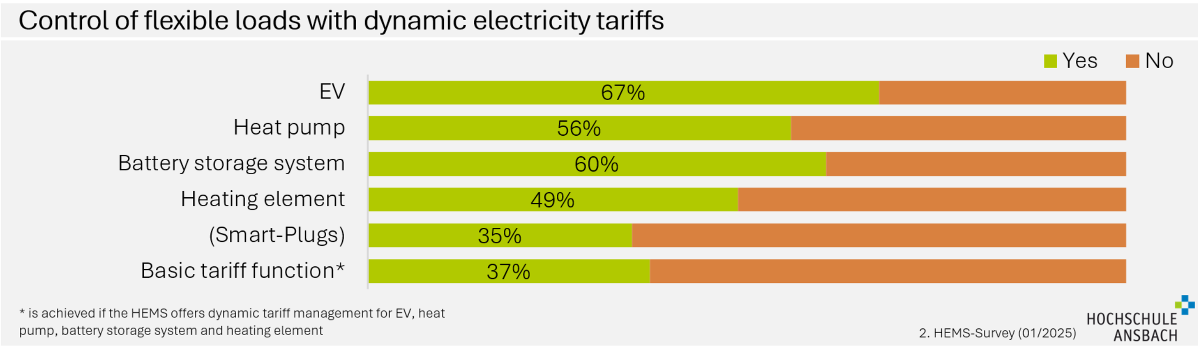

Figure 8. *Analysis of the implementation of the dynamic electricity tariff in the HEMS.*

A meaningful integration of dynamic electricity tariffs requires generation and consumption forecasts. For a complete assessment of cost optimization, the respective system efficiency, such as battery charging and discharging losses or the heat pump COP when the flow temperature increases, as well as the aging costs caused by battery cycling or heat pump compressor starts, must be considered. The “Basic tariff function” defined here, which covers EV, heat pumps, BSSs and heating elements, is currently included in 37% of the HEMS. Dynamic tariffs in the home require an interface to the energy supplier, which is necessary to record and bill the energy used per time interval. The data is transmitted via an intelligent measuring system (iMSys), which sends the measurement data to the energy supplier via the smart meter gateway (SMGW). In addition to the iMSys variant, a few suppliers currently still rely on a temporary solution via the optical interface on the digital measuring unit.

3.1.5 Smart Grid Integration (§14a EnWG)

The electrification of the heating and mobility sectors is a central task of the energy transition. The increased use of heat pumps and EVs will strain the distribution grids. Particularly at the low-voltage level, higher power consumption and higher simultaneity will lead to challenges. In order not to unnecessarily delay grid access for heat pumps and charging equipment, intelligent control by the distribution grid operator is required [18]. §14a control operations are only implemented in an emergency when there is an actual risk of overload (ultima ratio measure). Until 2028, control operations can be carried out based on defined time slots (preventive control), from 2029 these must be based on real-time measurements (grid-oriented control operations). However, only a few grid operators are able and willing to execute the corresponding control operations (backgrounds are, for example, the integration and execution of processes, the necessary iMSys and consideration in grid expansion planning). When the regulation for controlling flexible loads according to §14a EnWG came into force on January 2024, new installed wallboxes, heat pumps, air conditioning systems, and BSSs, as well as existing systems in the long term, must be equipped with a control option for the grid operator from a respective power consumption of >4.2 kW [19]. The DSO can implement §14a control operations either directly via the respective control unit (direct control) or centrally via the HEMS, considering a calculated grid-effective minimum output. In this case, §14a control operations always have the highest priority for execution in the HEMS. The maximal power demand with multiple flexible loads is calculated using a formula with pre-defined diversity factors [20]. The

HEMS receives control commands from the DSO via the SMGW in combination with a CLS adapter (CLS: Controllable Local System). Alternatively, a DSO can rely on relay-based control technology on a temporary basis. In the future, additional CLS adapters, including FNN control boxes with EEBus, will be added. In addition, certification processes of the communication e.g. for §14a implementations with the LPC (Limit Power Consumption) use case are already in progress [21, 22]. The following section presents the perspective of the HEMS for the implementation of §14a control.

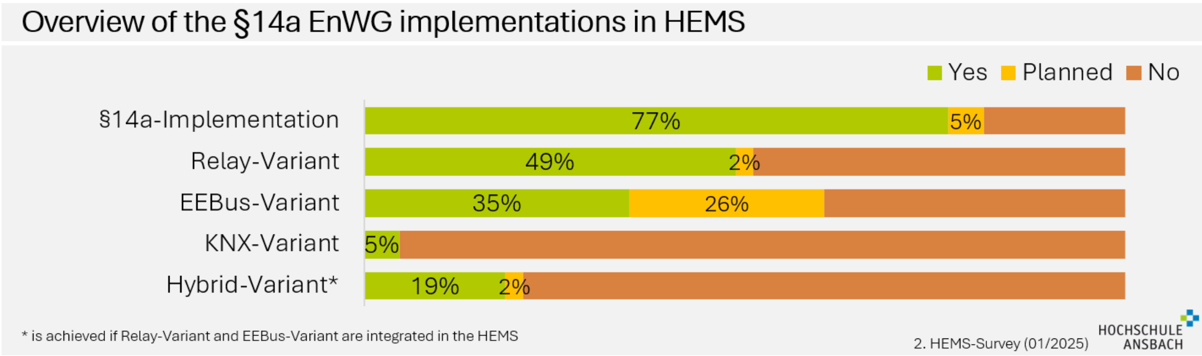

Figure 9. *Overview of the implementation of §14a EnWG control mechanism in the HEMS.*

Figure 9 depicts that 77% of HEMS are capable of receiving and executing a §14a control command. 49% of HEMS offer the variant via a relay control and 35% offer the variant via the EEBus protocol. Here, further 26% of the HEMS companies are planning to do so in 2025. The option of implementing both variants (hybrid variant) is currently offered by 19% of the HEMS. From discussions with the manufacturers, it became apparent that in some cases not all compatible control units can be operated in compliance with §14a control commands (e.g. BSS that are not fully integrated and controllable, or partly SG-ready heat pumps that cannot be switched off via the HEMS). In this case, the respective system must be controlled via direct §14a control. Currently, operators of flexible loads with §14a control mechanism receive a reduced grid fee as compensation for the grid-oriented control. Depending on the connection and consumption situation, operators can currently choose between two modules [18]: Module 1: DSO specific fixed sum (110-190 €/a, gross); Module 2: percentage reduction of the respective grid fee by 60% (a requirement for this is a separate metering point for the SteuVE); Module 3 (available from 01.04.25): time-variable grid fee. Module 3 can be selected in addition to module 1. An analysis of time-variable grid fees submitted in October 2024 with high tariffs, standard tariffs and low tariffs from 12 grid operators is shown in [23]. The integration of variable grid fees in the HEMS is already under development by many HEMS providers. The overall availability of market-oriented and now grid-oriented control of flexible loads via a HEMS will enable the use of larger price volatilities for cost-optimized flexibilization of flexible loads in the future. The requirement for the implementation of variable grid charges is the digitalization of the distribution grids and an iMSys at the end consumer's site and is therefore not possible with the introduction on the 01.04.2025 area wide. The so-called “mandatory rollout” for SMGW will come into force from 2025 [24].

3.1.6 Interfaces and communication

The type of interfaces and communication of a HEMS are a central aspect both in product development and in later practical application. The selection of the interfaces depends on many factors, e.g. the market orientation, technical requirements, transmission security, reliability, regulatory requirements and ease of maintenance of the interfaces. As the discussions at the HEMS Symposium 2024 [25] on interfaces and communication, as well as the discussions with various manufacturers, have shown, the topic of interfaces and the implementation of a standard is highly relevant. The interfaces are depicted in absolute terms in relation to all HEMS. The reason for this is to provide a clear overview, as not all functions are available in every

HEMS. The analysis (*Figure 10*) of the control of the EV charging power shows that the Modbus TCP/IP, API (cloud), Modbus RTU and OCPP protocols are most used. In the control of heat pumps, on the other hand, the SG Ready variant using relay control dominates (33/43 HEMS), followed by Modbus TCP. In the grid-supporting control for §14a control operations, the relay variant as well as the EEBus variant are in the focus. The standardization of the EEBus protocol for grid-supporting control offers the possibility of integrating HEMS, wallboxes, heat pumps, BSS and control devices for different use cases [26].

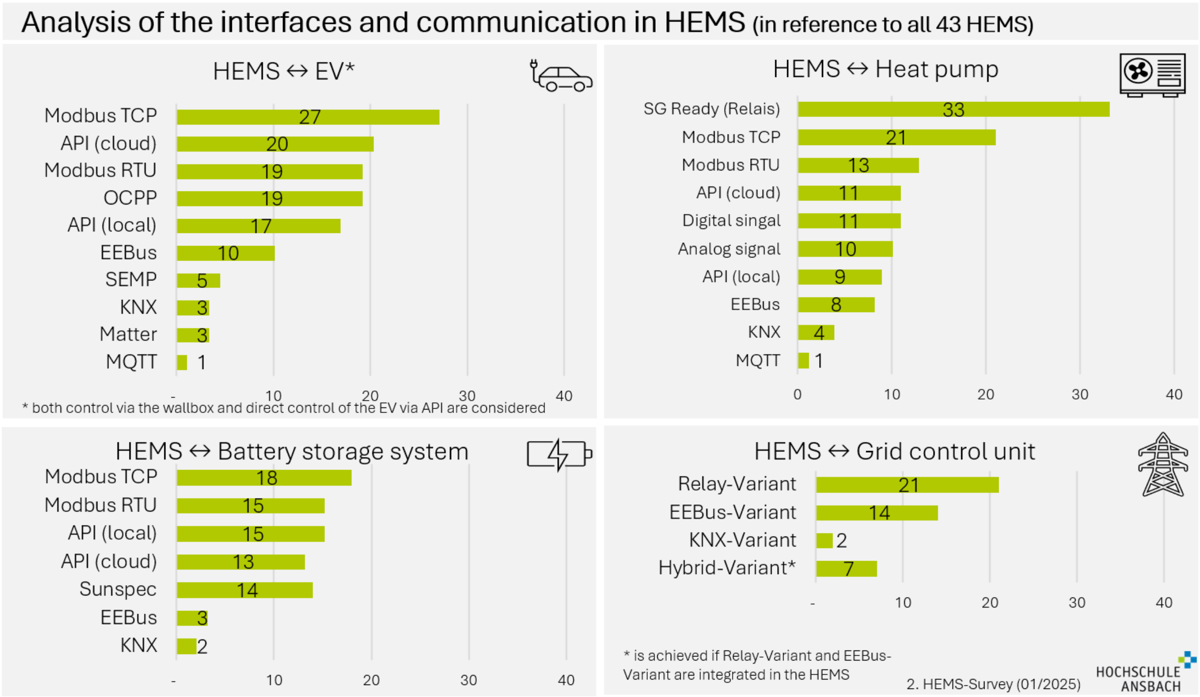

Figure 10. *Overview of the implemented protocols and interfaces in HEMS.*

A standardized solution would significantly simplify planning and implementation for developers, installers and end users. However, this would require that both the manufacturers of flexible loads and the HEMS manufacturers apply on a standard in the long term. However, the initially higher implementation costs are often named as a challenge from the manufacturers and also easier to handle communication like APIs. In the context of the FNN control box, EEBus is considered a recommended variant by the FNN and is currently widely used and planned alongside the relay solution. A general comparison with the results of the first HEMS-survey (2024) shows that Modbus TCP/IP remains the dominant solution, while the use of EEBus and cloud APIs is increasing. Relays or potential-free contacts are used for SG Ready, heating elements and for §14a control commands in HEMS. The development of standardized communication protocols will continue to be a challenge for manufacturers in the future. Furthermore, it must be taken into account that an increasing number of manufacturers of flexible loads from Asia are entering the market, and these also have to be integrated into existing systems or bring their own HEMS to market. Flexible loads with open and well-documented interfaces can gain a significant competitive advantage because they enable broad compatibility with various HEMS. The same applies to manufacturer-independent HEMS that enable flexible integration.

3.2 Analysis of the installer survey

The market for HEMS in Germany already offers a wide range of products and will continue to grow in the coming years. However, the variety of products, specific compatibility, variety of functions, as well as regulatory requirements and changes (§14a EnWG, §41a EnWG and the adjustments to §9 EEG) represent a major challenge in implementation. At the same time, the customer, their needs and their willingness to pay must be considered in the implementation. Regarding the implementation of HEMS on a large scale, it must be taken into account that the customer will change from currently often being a technically minded person to being a layperson. To get a current impression of the mood among installers, a survey with around 300 participants was conducted.

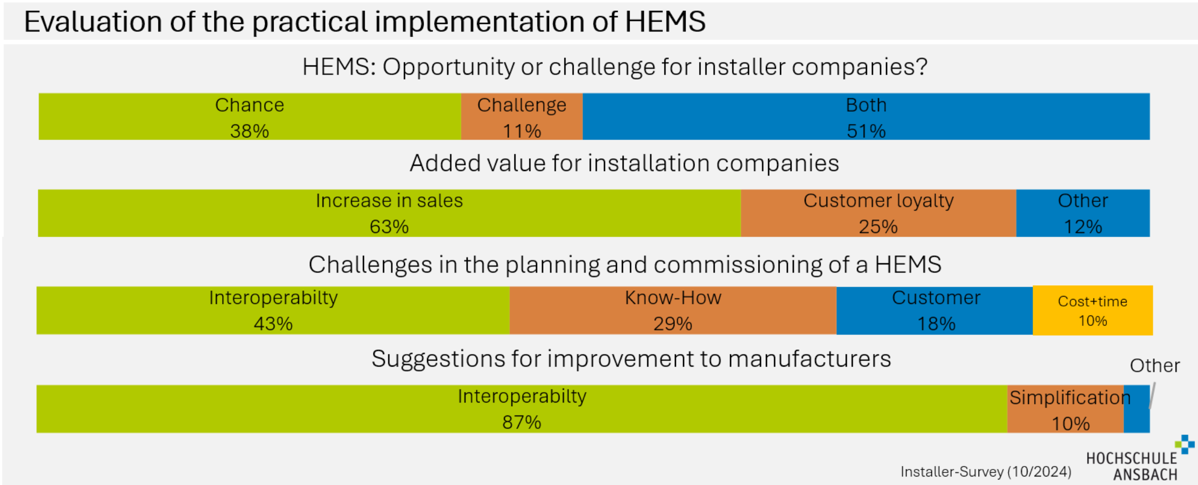

Figure 11. *Evaluation of the installer survey with around 300 participants during the Energy Management Day of the EnBW 2024 on the implementation of HEMS in practice.*

The results of the survey show a mixed view of HEMS. While 51% of the participants see HEMS as both an opportunity and a challenge, only 38% see HEMS as a clear opportunity (*Figure 11*). As an opportunity, the potential economic added value in the form of increased sales and stronger customer loyalty are in the foreground. However, the main challenges mentioned during planning and commissioning were interoperability and the expertise required to implement the systems. The lack of interoperability between HEMS and flexible loads was also addressed as a major point of criticism to both the manufacturers of HEMS and the manufacturers of flexible loads and formulated as a suggestion for improvement. However, appropriate offers must be made available for this purpose [27], [28]. On the other hand, the manufacturers of HEMS and flexible loads are called upon not only to standardize the systems to a greater extent but also to improve transparency regarding the compatibility and functionality of their products. One specific aspect here is to offer a clear and up-to-date compatibility of the systems. In the B2C distribution of HEMS, larger companies, so called one-stop-shops" with their own sales organization, their own planning and their own implementation of HEMS solutions in conjunction with PV systems and additional systems are particularly active. To keep up with this trend, small installation companies must follow the state of the art at an early stage.

4. Trends in the HEMS-Market (2024-2025) and discussion

The HEMS market has grown significantly, increasing from around 35 providers to about 45 within one year. The survey covers approximately 90% of them. The distribution of system types has remained stable. However, there is a light trend toward manufacturer-dependent systems, partly due to bundled device offerings (2024: 40% to 2025: 51%). However, this increase must be considered with the new survey participants, especially in the field of B2C. A direct comparison of PV surplus management and dynamic electricity tariffs is difficult because the question details have changed. However, nearly all systems can now handle PV surplus with all relevant flexible consumers. The adoption of dynamic tariffs has grown significantly and is expected to be available in almost all HEMS by the end of 2025. A major trend is the intelligent operation of the BSS with a dynamic electricity tariff. Due to unclear definition of §14a in the end of 2023 there was a high degree of uncertainty in the implementation by the HEMS-companies. Thus, no publication was made regarding §14 EnWG in December 2023.

However, in almost all systems, the §14a EnWG implementation took place in 2024. However, it must be mentioned that not all compatible devices can automatically be operated in compliance with §14a, especially BSS. In 2025, the questions about the communication were extend more specific. For the 1st and 2nd survey the three most used ways to communicate / to control are Modbus TCP/IP, relays and cloud APIs. However, EEBUS is the defined standard for the §14-control unit. One area that has not significantly progressed is the automatically integration of an EVs state of charge (SoC) based on the ISO 15118-20 between the EV and wallbox. Similarly, thermal buffer storage is rarely used, and the flexibility of thermal building mass remains largely untapped. In addition to the §14a EnWG, which regulates power consumption limitations, the next major step—driven by recent amendments to the EEG — is the introduction of limitation of the power production / feed-in of PV-Systems (§9 EEG). Nevertheless, the interoperability and compatibility of the systems is still a key challenge.

Data availability statement

The specifications of all HEMS are public available at database.hems-finder.org.

Author contributions

Conceptualization (T.H.; J.J), data curation (T.H.), formal analysis (T.H), supervision (J.J), funding acquisition (T.H.; H.V), methodology (T.H.), validation (T.H.), visualization (T.H.), writing (T.H), review and editing (J.J; G.H; H.V.),

Competing interests

The authors declare that they have no competing interests.

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