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Research paper

An analysis of smart meter technologies for efficient energy management in households and organizations

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ABSTRACT

Digitization of the energy industry is the key to a successful energy transition. To this end, all consumers and generators should be able to communicate permanently with each other so that the energy system as a whole functions safely and efficiently. Smart meter technology can make a contribution to this. Unfortunately, the rollout selected in Germany initially affects only about 11% of all consumers. The objective of this paper is therefore to determine the current status of this technology in companies and to pursue the research question of which factors influence acceptance and use. For this purpose, an extensive literature search with more than 50 keywords was conducted in scientific databases. After reviewing and cleaning the literature, 47 papers were selected for the literature review and considered in detail. The literature review was conducted using eight evaluation criteria: Origin and year of publication, identification of trends with Big Data and AI (artificial intelligence), type of organization, type of data, collection method, number of participants, type of data collection, and analysis method. In order to evaluate the main statements and results of the considered works, we also performed a Strengths–Weaknesses–Opportunities–Threats Analysis (SWOT).

Our analysis showed that: (1) The studies only address households as end-users, no companies are considered as end-users in relation to smart meter technology. (2) Technical aspects and barriers were often chosen as research focus and content, and secondary data were mostly used. (3) Studies examining soft factors such as acceptance criteria in general and for decision making are rare and also focused purely on residential customers. (4) Of the studies that collected primary data as part of their research, 71% used the survey method of a questionnaire survey. Further research should investigate company acceptance criteria, as this can increase implementation and make better predictions about the technology.

1. Introduction

Smart meter technology is considered an enabler of the energy transition and a driver of digitization and energy efficiency (Westermann et al., 2013). In Germany, the smart meter rollout for consumers with an annual electricity consumption of more than 6000 kilowatthours (kWh) has been adopted in a legally binding manner. A distinction is made between modern and smart metering equipment. Modern metering devices are digital meters where consumption values can be read by the customer. Smart meters also have a communication module, a smart meter gateway, which can be used for more than just monitoring (Ghasempour, 2017).

In the European Union (EU), Germany is one of the countries that has set a deadline of 2032 for its national implementation strategy. The remaining EU countries have set a target of 80% implementation of the rollout for electricity meters by 2030 at the latest (European Commission, 2020). Thus, the majority of EU countries, with the exception of Italy and Sweden, are still in the immediate rollout process. However, in view of the rapid development of the energy transition and the digital transformation, this target is too far in the future.

Smart metering systems and modern measuring devices play a crucial role in the digitization of the energy industry. These are electricity meters with digital instead of electromechanical technology. In addition, smart metering systems can also take over control functions, which is one of the biggest differences to modern metering equipment. With the smart meter rollout, policymakers in Germany are making an important contribution to driving these developments forward (Appelrath et al., 2012).

The smart meter rollout initially affects only 11% of end users and should therefore be studied for acceptance and benefits before more end users are forced by law to adopt it (Ernst and Young, 2020).

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Private households and many small companies in the commercial, trade and service sectors often have an average electricity consumption of less than 6000 kWh per year. This means that these two consumer groups are not included in the legally required rollout for smart meters. These consumer groups can voluntarily install a smart meter. This may be one of the reasons why many studies on technology acceptance and the use of smart meters in private households are being conducted to determine their acceptance criteria for voluntary rollout. The consumer group of small companies, on the other hand, is hardly taken into account in this consideration.

There are uncertainties (in terms of data privacy Gough et al., 2022 and cost transparency) and information deficits in the companies regarding the technology and its benefits. This is true even for those companies that have a higher electricity consumption than 6000 kWh per year. While these companies are required by law to retrofit, they are not currently being educated about the technology by policymakers and academics. In addition, the courts are currently examining whether the mandatory rollout in Germany is legally enforceable at all, as it would result in disproportionately high additional costs for consumers.

Only a few studies are known to have looked at the acceptance criteria for the technology in the company environment. Rather, almost all of the studies are in the household setting and most deal with technical (Depuru et al., 2011) and economic (Brophy Haney et al., 2009) aspects as well as costs (Faruqui et al., 2010) of the technology.

Even if this policy tactic works out that companies required to install will still not actively use the technology's features. However, from a socio-political and socio-economic point of view, its use through, for example, variable tariffs, peak load reduction or shifting at companies and in the supply network, virtual power plants and the rapid rise of e-mobility, is imperative to transform the energy system digitally and sustainably.

Smart meter technology not only holds great potential in terms of achieving environmental and climate targets in an overall economic context, but also has benefits for individual end consumers (households and companies) and energy companies when deployed. The new metering systems should not only ensure secure transmission of metering data to the energy company, but also lead to increased transparency for the end customer about actual electricity consumption. In addition to providing better insight into and control over consumption data, the new applications and products can also help to reduce energy consumption and increase energy efficiency.

Variable tariffs and shifting of electrical loads can only be used if the infrastructure is available. The self-scheduling of end consumers by a home energy management system (HEMS) can be used to harness the flexibilities of these consumers (Javadi et al., 2020a). In this context, the HEMS is the user interface between the smart meter and the end consumer. Demand response programs can be used for this purpose. Time-of-use tariffs (ToU) and real-time pricing (RTP) are two such programs. Both can lead to considerable electricity savings for the consumer when used (Javadi et al., 2021b). The interaction between existing household devices and building technology can also lead to savings (Javadi et al., 2020b) without having to accept unacceptable losses in comfort (Javadi et al., 2021a).

As a study from Portugal shows, benefits can also be generated by smart metering when decentralized energy systems such as photovoltaics are used in combination with charging stations for households and companies (Almeida et al., 2020).

The service of virtual power plants, in which, for example, surplus power is collected by a company and used again for other demand cases (second or minute reserve), can also find applications. With the help of intelligent technology, a new type of energy trading model can be created in the form of local energy communities, in which the participants can reduce their total electricity bill (Javadi et al., 2022).

Furthermore, the measured data can be used to check whether the power grid is working optimally and the power held in reserve (in kilowatt) in the grid can be optimized by comparing it with real values. A reduction in the power held in reserve has a direct impact on electricity prices. Even expensive second or even minute reserves, which have to be produced by gas turbines to stabilize the grid, could contribute to low-cost supply security for all consumers through the remote controllability and short-term disconnection of consumers via a large number of smart meters. In addition, metering data could also be used to perform sizing of generation plants and storage (e.g., battery storage). This would solve the problem of missing design data for many engineering companies when planning, for example, energy concepts in practice. Similar measurement values already exist for consumers of registered power measurement, these have a meter which transmits quarter-hourly power data in kilowatt to the responsible grid operator, thereby the power grid can be operated safely, since power peaks are identified early. With this data, which can be made available to companies in csv format on request, peak load management can be optimized or even new plants can be designed. This can also be made possible for households and small companies with smart meter technology. This can replace the use of standard load profiles (without accurate power measurement), which represent an estimate of possible real curves, for small consumers. This alone could greatly optimize the power grid and make discussions about possible grid expansion and necessary storage solutions obsolete.

The original Technology Acceptance Model (TAM) by Davis (1989) and its hypotheses have already been applied several times and could be transferred to smart meter technology in a few studies. All studies, without exception, dealt with private end users. The transferability of the TAM and its hypotheses to companies is still pending (Chou and Gusti Ayu Novi Yutami, 2014). In addition, the factors influencing the adoption and use of smart meters in companies are unclear.

Due to the current hype about e-mobility and own charging stations among household and corporate customers, it is urgently necessary to record the energy flows and to connect them with each other in the form of sector integration. However, this will not be fully successful if customers are only expected to do this on a voluntary basis and without additional benefits. Therefore, the study leads a discussion on whether the current rollout strategy should be reconsidered or whether the increase in acceptance and the associated additional benefits of the technology for the user should be designed more concretely. The study also discusses possible implications and applications in relation to the energy transition and digital transformation.

The aim of this work is to answer the research questions of what factors influence the acceptance and use of smart electricity meters in companies and what benefits the technology brings. The novelty of the study lies, among other things, in the fact that it shows that important consumer groups are being ignored by the planned rollout strategy. It also shows that there is a need for further research into the acceptance and use of the technology for households and companies.

Section 2 presents the methodology used in the paper. A comprehensive literature review is conducted. Integrated is a SWOT analysis of the literature reviewed. Section 3 presents the results of the study. In doing so, the eight evaluation criteria listed in Section 2 are addressed, which are used to review the publications studied. In addition, the results of the SWOT analysis are presented. In Section 4, a critical discussion of the results follows. Finally, in Section 5, the results of the study are placed in a broader context and the need for further research in the area of smart meter technology is explained.

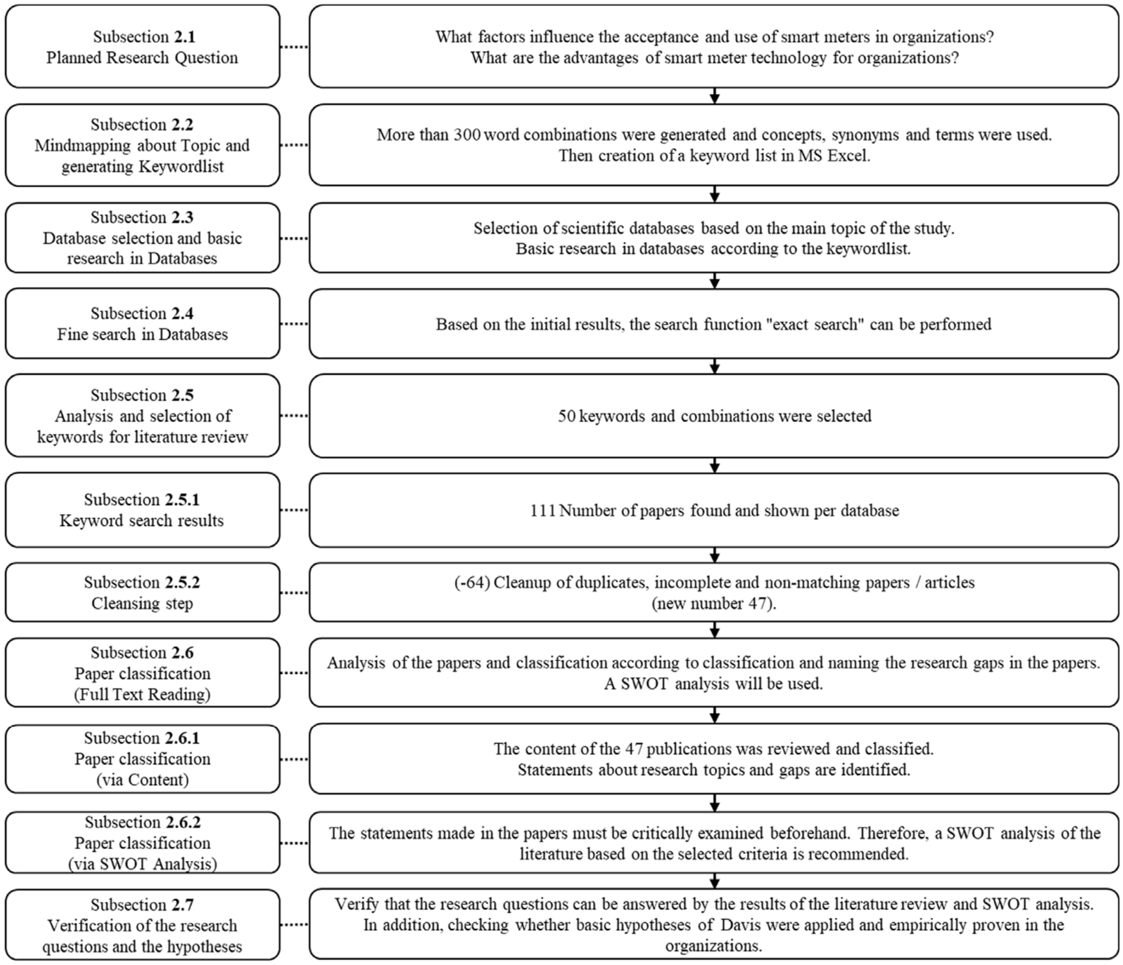

Fig. 1. Procedure literature review.

2. Methods

Sections 2.1 to 2.7 described in Fig. 1 show the process of the systematic literature review. At the beginning, the planned research questions are presented in 2.1, which are to be answered with the help of the literature found. In addition, it will be examined whether Davis' hypotheses from the technology acceptance model have already been empirically proven at the organizational level.

Subsequently, 2.2 describes how the search words and combinations are created and transferred into a keyword list with the help of a so-called mind map software.

2.3 deals with the question which databases are used for the search and how the basic search is performed. In 2.4, the fine search is performed based on the basic search.

To achieve even better search results, the exact search is used. Subsequently, in 2.5 the analysis and selection of keywords for the literature search takes place. Thereby, the search terms and combinations are determined. 2.5.1 shows the results of the search and 2.5.2 shows the cleaning of the search results.

In 2.6, an analysis of the papers and classification according to the classification and naming of the research gaps in the papers is conducted. A systematic literature review and SWOT analysis will be conducted. In 2.6.1, the content of the 47 publications is reviewed and classified. The full texts were downloaded using literature software and reviewed for the eight evaluation criteria. In 2.6.2, the strengths, weaknesses, opportunities, and threats of the 47 publications are reviewed using a SWOT analysis.

Section 2.7 examines whether the research questions posed in 2.1 could be answered by the results of the literature review and the SWOT analysis. In addition, it can be demonstrated whether Davis' hypotheses have already been empirically proven at an organizational level.

2.1. Planned research question

- What factors influence the acceptance and use of smart meters in organizations?
- What are the advantages of smart meter technology for organizations?

The research questions are to be examined in the course of the literature research and answered if necessary. The research questions have manifested themselves in the course of numerous consultations and informational events conducted specifically for organizations.

In addition to the chosen research questions, the literature review and analysis will also be used to determine whether Davis' (Davis, 1989) basic hypotheses regarding technology acceptance for organizations have already been applied and empirically demonstrated.

The following are Davis' hypotheses:
H (1): the higher the perceived benefit, the more positive the attitude towards the technology.
H (2): The higher the perceived benefit, the higher the intention to use the technology.

Database	google scholar		web of science		scopus		Wiley online library	
Keywords	Search hit	sorting by number 100.000	Search hit	sorting by number 300	Search hit	sorting by number 300	Search hit (2000-2020)	sorting by number 100.000
Smart Meter Rollout	8.000	please check	72	please check	174	please check	404	please check
Smart Meter Rollout energy efficiency	7.650	please check	21	please check	22	please check	283	please check
Smart Meter Rollout Demand	8.320	please check	27	please check	27	please check	367	please check
Smart Meter Rollout energy efficiency potential	20.600	please check	7	please check	5	please check	267	please check
Smart Meter Rollout status quo	17.200	please check	0	please check	0	please check	48	please check
Smart Meter Rollout advantages	6.740	please check	4	please check	5	please check	328	please check
Smart Meter acceptance	70.600	please check	111	please check	92	please check	11.174	please check
Smart Meter Rollout acceptance	5.530	please check	10	please check	7	please check	311	please check
Smart Meter acceptance sme	5.210	please check	1	please check	1	please check	387	please check
Smart Meter acceptance company sme	18.000	please check	1	please check	0	please check	330	please check
Smart Meter acceptance company	56.100	please check	15	please check	12	please check	5.787	please check
Acceptance Digitalisation	14.200	please check	30	please check	185	please check	2.214	please check
Acceptance Digitalisation Company	10.200	please check	3	please check	27	please check	1.083	please check
Acceptance Digitalisation private households	7.170	please check	0	please check	0	please check	220	please check
Acceptance Digitalisation municipality	6.570	please check	0	please check	0	please check	0	please check
Acceptance Digitalisation organization	18.800	please check	9	please check	27	please check	1.433	please check
Acceptance Digitalisation SME	14.400	please check	1	please check	2	please check	137	please check
Acceptance Model Smart Meter	59.700	please check	42	please check	24	please check	9.712	please check
technology Acceptance Model energy efficiency sme	42.900	please check	0	please check	0	please check	2.327	please check
Acceptance Model Digitalisation	12.300	please check	15	please check	78	please check	1.821	please check
Acceptance Criteria / Enabler Smart Meter	19.700	please check	0	please check	0	please check	4.129	please check
Acceptance Criteria Smart Meter private households	25.400	please check	0	please check	0	please check	1.256	please check
Acceptance Criteria Smart Meter public buildings	25.100	please check	0	please check	0	please check	3.146	please check
Acceptance Criteria Smart Meter companies	130.900	do not check	0	please check	0	please check	3.255	please check
Acceptance Criteria Smart Meter companies SME KMU	99	please check	0	please check	0	please check	1	please check
Acceptance Criteria Smart Meter industry	36.200	please check	1	please check	0	please check	3.556	please check
Acceptance Criteria Smart Meter municipality	18.500	please check	0	please check	0	please check	0	please check
Acceptance Criteria Digitalisation	18.700	please check	2	please check	21	please check	987	please check
Acceptance Criteria Digitalisation private households	18.400	please check	0	please check	0	please check	128	please check
Acceptance Criteria Digitalisation public buildings	18.300	please check	0	please check	0	please check	496	please check
Acceptance Criteria Digitalisation companies	14.300	please check	1	please check	1	please check	533	please check
Acceptance Criteria Digitalisation companies SME KMU	261	please check	0	please check	0	please check	0	please check
Acceptance Criteria Digitalisation industry	15.000	please check	1	please check	2	please check	543	please check
Acceptance Criteria Digitalisation municipality	4.120	please check	0	please check	0	please check	144	please check
Acceptance Model Industry 4.0	17.400	please check	43	please check	60	please check	23.988	please check
Acceptance Criteria Industry 4.0 private households	34.500	please check	0	please check	0	please check	1.897	please check
Acceptance Criteria Industry 4.0 public buildings	45.500	please check	0	please check	0	please check	4.871	please check
Acceptance Criteria Industry 4.0 companies	101.000	do not check	2	please check	1	please check	6.821	please check
Acceptance Criteria Industry 4.0 companies SME KMU	2.330	please check	0	please check	0	please check	1	please check
Acceptance Criteria Industry 4.0 industry	188.000	do not check	4	please check	7	please check	16.838	please check
Acceptance Criteria Industry 4.0 municipality	25.300	please check	0	please check	0	please check	2.103	please check
Smart Meter energy efficiency	359.900	do not check	1.982	do not check	2.200	do not check	110.041	do not check
Smart Meter energy efficiency energy saving	300.000	do not check	191	please check	215	please check	5.019	please check
Smart Meter energy efficiency advantage	239.000	do not check	67	please check	82	please check	7.074	please check
awareness of smart meter technologies	69.600	please check	88	please check	97	please check	6.418	please check
awareness of smart meter technologies companies	47.400	please check	8	please check	11	please check	4.149	please check
awareness of smart meter technologies private households	23.200	please check	1	please check	1	please check	1.498	please check
awareness of smart meter technologies public buildings	36.400	please check	1	please check	3	please check	4.107	please check
awareness of smart meter technologies organization	174.690	do not check	3	please check	3	please check	5.215	please check
awareness of smart meter technologies SME	18.500	please check	1	please check	1	please check	302	please check
Reasons for Smart Meter Technology	384.000	do not check	47	please check	66	please check	106.079	do not check
Reasons for Smart Meter Technology company	212.000	do not check	9	please check	9	please check	5.720	please check
Reasons for Smart Meter Technology SME	20.200	please check	0	please check	1	please check	403	please check
Opportunity smart meter energy efficiency	80.900	please check	71	please check	78	please check	5.282	please check

Fig. 2. Basic research in Databases.

H (3): the higher the perceived ease of use, the more positive the attitude towards the technology.

The outcome of this literature review is to confirm or reject the research gap by the existing literature and to prove whether the technology acceptance model has already been applied to organizations.

2.2. Mindmapping and keywordlist

With the help of a "Mindmap" software, the search terms were systematically collected and further developed. In addition, suitable concepts, synonyms and terms were used (Kollmann, 2016). Appendix shows how the search terms are further refined by so-called sub-nodes and sub-sub-nodes. The software is helpful at this point in the work as it continues to refine the search terms to make them suitable for one's research question. This helps in the subsequent database search. The main focus of the database search should be on the topics of smart metering and digitization in companies. The keyword list, see Fig. 2, was then created in MS Excel.

2.3. Database selection and basic research in databases

2.3.1. Database selection

Four scientific databases/publishers were used for the systematic literature search: google scholar; web of science; scopus and wiley online library. The selection made aims to find a comprehensive and up-to-date number of articles related to the research focus (in the fields of management, engineering, computer science and industrial engineering). In order to find a large number of papers, Google Scholar has been integrated into the database search. Google Scholar is the largest scientific database with about 400 million documents. In comparison, the scopus database contains about 75 million documents.

In addition, a high scientific standard and the topicality of the researched works are important. In addition to these aspects, it is elementary that the papers have been reviewed by experts from the relevant fields in a so-called peer review process. This can be achieved for the selected databases and their contributions. A critical review of the existing papers according to these basic criteria will be carried out.

2.3.2. Basic research in databases

The basic search in the databases was carried out from 15.11. to 27.02.2021. A large number of search hits were found for the 300 search terms generated. Initially, an "IF-THEN FUNCTION" was used to numerically divide the search hits in the databases into "please check" and "do not check" due to their high number of search hits. This had the advantage of removing the search hits with an excessive number of results from the search and subsequently refining the search.

The basic search could thus be continued on this basis. Samples were drawn from the databases and initial results were collected via the abstracts. These results help to conduct the fine search in a plausible and target-oriented manner.

2.4. Fine search in databases

In order to conduct the fine search in a plausible and targeted way, it is necessary to check in advance which topic areas have received less attention than others. It is precisely on these topics that a literature search should focus, because it is here that new findings and interpretations can contribute to the research. In reviewing the initial results, the following areas of focus emerged.

The basic research helped to narrow down the topic area and define focal points. Subsequently, as described in Table 1, the fine search was started and the exact search was applied. In this study, exact search means searching with the help of operators. Here, AND, OR, NOT operators are used in the search to reduce and concretize the search results. In addition, the search results were limited to the years 2000–2021, especially in the large databases (for example, google scholar and Wiley online library). 50 search terms and combinations were used for the literature search.

This resulted in significantly fewer documents per subject area and database. The selection of search terms is shown below.

2.5. Analysis and selection of keywords for literature review

The 50 selected search terms and combinations from Table 1 result in a solid base of 4.6 million documents in total. This is shown in Table 2. It turned out that with the help of exact search this number could be reduced by 99.97% to about 1490 documents. This selection could be reduced again by about 92,55% to about 111 documents by refining the search again and partially delimiting database results (e.g. from google scholar).

2.5.1. Keyword search results

See Table 2.

2.5.2. Cleansing step

The process of data cleaning, see Table 2, was applied to the 111 hits from the database search. The goal of the data cleaning was to find and eliminate multiple publications in the databases and to evaluate and review the titles and abstracts of the remaining publications for thematic relevance. Overall, the data cleaning resulted in a set of 47 publications, while 64 hits from the online search were not followed up because they either appeared multiple times in the sample (as they were listed in more than one of the selected online databases) or because their content was not specifically related to the topic at hand. These studies were cleaned up from the literature search.

2.6. Paper classification (full text reading)

Analysis of the papers and classification according to the classification and naming the research gaps in the papers. A systematic literature review and SWOT analysis were conducted.

2.6.1. Paper classification (via content)

The content of the 47 publications was reviewed and classified. The full texts were downloaded using literature software and reviewed for the following eight evaluation criteria and the strengths, weaknesses, opportunities, and threats of the publications. The contents were colored differently using the marker function. Subsequently, the contents could be evaluated as described in Section 3. This resulted in the statements on research topics and gaps.

1. Origin and year of publication

The origin of the paper shows in which country the topic of smart meter technology is important. The year of publication shows the development of the topic. This allows conclusions to be drawn about the political and economic orientation of the individual countries. Suitable papers from all over the world were found and evaluated.

2. Identification of trends with Big Data and AI (google trends)

In order to examine the search terms and results from the database search for their trend effect and to make them plausible, the free software google trends is to be used. The software works with large amounts of data (Big Data) and links these with artificial intelligence (AI).

With it the scientific data base search is to be accomplished a plausibility check with the two search terms "intelligent meter" and "smart meter". The analysis of the data is to check a correlation between the general trends in google search and the scientific publications from criteria 1 origin and year of publication. These data should be taken with caution and can only be used as a first indicator in a scientific paper. It should be checked in which years with which frequency a search term appeared in the search. In addition, the search is to be applied worldwide and specifically to Germany.

The tool should not be used for more than that in this paper, since the risk of misinterpretation is very high and the traceability is still too low ("black box").

3. Type of organization

It is examined which actors were the subject of the studies and papers found. Possible actors are private households, companies and public properties. These are differentiated into residential and non-residential buildings. All actors are nonetheless end users.

4. Type of data

The data basis used for the respective studies is to be examined. A distinction is made between primary and secondary data. Were the data collected by the authors themselves or were data from previous surveys and studies used? This distinction is initially value-free, since both data have their raison d'être. Primary and secondary data can, for example, be interpreted and processed in different ways and thus promote a new perspective on a subject area.

5. Collection method

The collection method of the data is a meaningful tool for the literature review. It sheds light on the quality of the data. It is examined by which methods the respective author comes to the data used by him. An absolute and relative evaluation should take place.

6. Number of Participants

Studies are available in which the data collection was generated via the participants. The absolute number of participants per study, the average participants and the range should be presented.

7. Type of data collection (subjective or objective)

The distinction between subjective and objective data collection always depends on the respective perspective. Therefore, it should be noted that subjective data collection in this literature review means data collection that was conducted by the actor himself. That is, if the author of a study sends a questionnaire to the actor and the actor completes it, then it is subjective data collection in this literature review.

The danger with subjective data collection is that the same setting will score differently when evaluating, for example, acceptance criteria for a technology. This can lead to a study losing its actual validity. In practice, this means that data are misinterpreted and thus weaknesses in the research orientation are

Table 1
Fine search.

Database	Google scholar			Web of science		Scopus		Wiley online library	
Keywords	Search hit	Search hit "exact search"	Search hit "exact search" 2000–2021	Search hit	Search hit "exact search"	Search hit	Search hit "exact search"	Search hit (2000–2021)	Search hit "exact search"
Advantage smart meter	327.000	0	0	833	0	1.599	0	13.110	0
Benefit smart meter	337.000	5	0	698	0	795	3	312.203	0
Smart meter variable tariffs	1.570	1	0	0	0	0	0	1	0
Smart meter empirical studies	68.700	0	0	66	0	73	0	4.778	4
Smart meter empirical studies private households	27.100	0	0	1	0	1	0	1.034	0
Smart meter empirical studies companies	34.700	0	0	6	0	5	0	2.254	0
Smart meter empirical studies SME	17.900	0	0	2	0	1	0	153	0
Smart meter empirical studies organization	41.000	0	0	3	0	3	0	3.171	0
Smart meter empirical studies municipalities	18.500	0	0	0	0	0	0	0	0
Smart meter empirical studies public buildings	29.100	0	0	2	0	2	0	2.314	0
Smart meter rollout energy efficiency potential	20.700	0	0	7	0	5	0	267	0
Smart meter rollout efficiency potential industry	18.500	0	0	2	0	2	0	236	0
Smart meter rollout energy efficiency potential sme	13.900	0	0	0	0	0	0	34	0
Smart meter rollout energy efficiency potential companies	18.300	0	0	1	0	2	0	231	0
Smart meter rollout energy efficiency potential households	18.300	0	0	1	0	0	0	129	0
Smart meter acceptance obstacles enabler	21.600	0	0	0	0	0	0	1.698	0
Smart meter acceptance obstacles privacy	17.900	0	0	2	0	0	0	462	0
Smart meter acceptance obstacles data protection	21.400	0	0	0	0	0	0	1.430	0
Smart meter acceptance obstacles costs	123.500	0	0	1	0	1	0	1.884	0
Smart meter acceptance obstacles usage	20.200	0	0	1	0	0	0	2.072	0
Smart meter rollout	8.000	1.233	0	72	17	174	29	404	15
Smart meter rollout energy efficiency	7.650	0	0	21	0	22	0	283	0
Smart meter rollout demand	8.320	0	0	27	0	27	0	367	0
Smart meter rollout energy efficiency potential	20.600	0	0	7	0	5	0	267	0
Smart meter rollout status quo	17.200	0	0	0	0	0	0	48	0
Smart meter rollout advantages	6.740	0	0	4	0	5	0	328	0
Smart meter acceptance	170.600	141	1	111	3	92	6	211.174	0
Smart meter rollout acceptance	5.530	0	0	10	0	7	0	311	0
Smart meter acceptance sme	5.210	0	0	1	0	1	0	387	0
Smart meter acceptance company sme	18.000	0	0	1	0	0	0	330	0
Smart meter acceptance company	56.100	0	0	15	0	12	0	5.787	0
Acceptance criteria smart meter private households	25.400	0	0	0	0	0	0	1.256	0
Acceptance criteria smart meter public buildings	25.100	0	0	0	0	0	0	3.146	0
Acceptance criteria smart meter companies	130.900	0	0	0	0	0	0	3.255	0
Acceptance criteria smart meter companies SME KMU	99	0	0	0	0	0	0	1	0
Acceptance criteria smart meter industry	36.200	0	0	1	0	0	0	3.556	0
Acceptance criteria smart meter municipality	18.500	0	0	0	0	0	0	0	0

(*continued on next page*)

Table 1 (*continued*).

Database	Google scholar			Web of science		Scopus		Wiley online library	
Keywords	Search hit	Search hit “exact search”	Search hit “exact search” 2000–2021	Search hit	Search hit “exact search”	Search hit	Search hit “exact search”	Search hit (2000–2021)	Search hit “exact search”
Smart meter energy efficiency	359.000	32	32	1.982	0	2.200	0	110.041	0
Smart meter energy efficiency energy saving	300.000	0	0	191	0	215	0	5.019	0
Smart meter energy efficiency advantage	239.000	0	0	67	0	82	0	7.074	0
Awareness of smart meter technologies	69.600	1	1	88	0	97	0	6.418	0
Awareness of smart meter technologies companies	47.400	0	0	8	0	11	0	4.149	0
Awareness of smart meter technologies private households	23.200	0	0	1	0	1	0	1.498	0
Awareness of smart meter technologies public buildings	36.400	0	0	1	0	3	0	4.107	0
Awareness of smart meter technologies organization	174.690	0	0	3	0	3	0	5.215	0
Awareness of smart meter technologies SME	18.500	0	0	1	0	1	0	302	0
Reasons for smart meter technology	384.000	0	0	47	3	66	0	106.079	0
Reasons for smart meter technology company	212.000	0	0	9	0	9	0	5.720	0
Reasons for smart meter technology SME	20.200	0	0	0	0	1	0	403	0
Opportunity smart meter energy efficiency	80.900	0	0	71	0	78	0	5.282	0
	3.721.909	1.413	34	4.365	20	5.601	38	839.668	19

Table 2
Fine search and search results.

Database	Search hits	Search hits “exact search”	Search hits “exact search” 2000–2021	Publications studied
Google scholar	3.721.909	1.413	*34*	–
Web of science	4.365	*20*	–	–
Scopus	5.601	*38*	–	–
Wiley online library	839.668	*19*	–	–
1. Results fine search	**4.571.543**	–	–	–
2. Results fine search (exact search hits)	–	**1.490**	–	–
3. Final search results	–	–	***111***	–
4. Result after cleaning step	–	–	–	**47**

overlooked. As a result, this can lead to a strategy that is not goal-directed.

In the literature review, we speak of objective data collection when the data collection is carried out by an expert. This can be done on site or by interview. The expert always proceeds in the same way and can always make an equivalent assessment from his empirical values.

8. Evaluation method

The evaluation methods used in the studies and papers considered are examined. The most important evaluation methods are listed and evaluated. An absolute and relative evaluation is to take place.

The individual statistical evaluation methods, which are treated in the considered studies and papers, are to be counted together as statistical evaluation.

The results of the eight evaluation criteria listed are presented in results 3.1.

2.6.2. Paper classification (via SWOT analysis)

The statements made in the papers must be critically examined beforehand. Therefore, a SWOT analysis of the literature based on the selected criteria and in the context of smart meter technology is recommended.

The SWOT analysis is a strategic planning method (Hill and Westbrook, 1997; Weihrich, 1982) and is an acronym representing strength, weaknesses, opportunities, and threats, which characterize the dimensions along with the entities or situations.

The SWOT analysis is summarized in Section 3.2.

2.7. Verification of the research questions and the hypotheses

This last step 2.7 of the method checks if the research questions could be answered by the results of the literature review and the SWOT analysis. If the research questions can be answered, it is proven that the research gap has already been considered and answered by another research work. Nevertheless, in this case, another work in the same direction with a different focus can be purposeful.

Furthermore, it can be answered whether Davis’ hypotheses have already been investigated and empirically proven in the business environment.

The results of the considerations made in Section 2.7 are discussed and interpreted in Section 4.

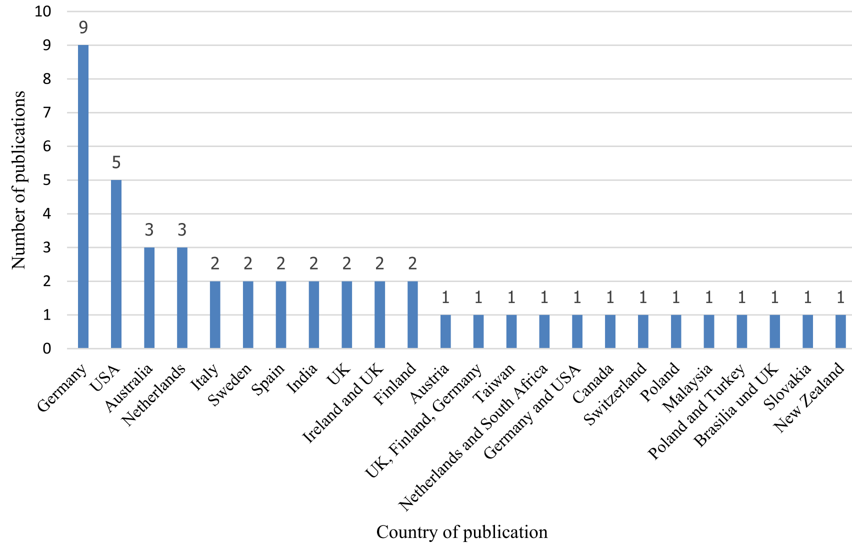

Fig. 3. Countries of studied publications.

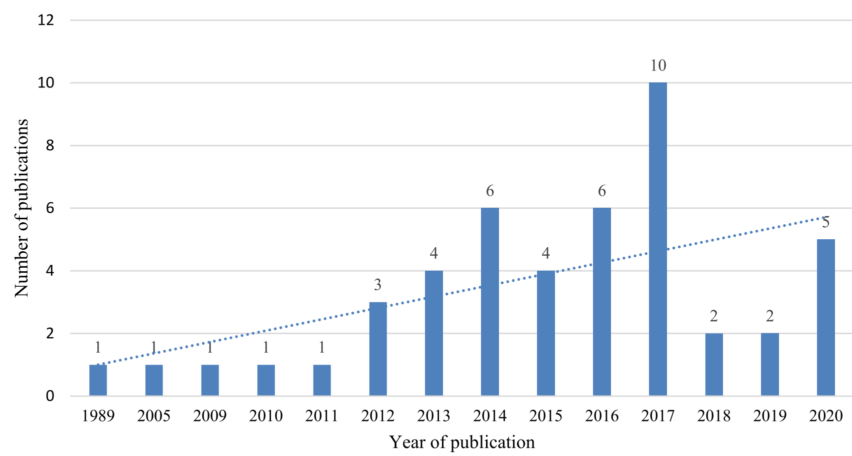

Fig. 4. Year of studied publications.

3. Results

3.1. Results of the literature review

1. Origin and year of publication

Fig. 3 shows the number of publications by country. Most of the 47 papers reviewed were from Germany (9 papers) followed by USA (5 papers) and Netherlands (3 papers). Together, these papers account more than one third (36,2%) of all papers in this literature review. If the participation of these countries in other studies and papers is added, the number increases to 11 for Germany, 6 for USA, and 4 for Netherlands, resulting in a total share of nearly the half of the papers reviewed (21 papers; 44,6%).

Fig. 4 shows the number of publications studied by year of publication. The oldest publication dates from 1989, in which a model for measuring acceptance by Davis (1989) was developed. A positive trend (dotted line) can be derived to date, as this model for measuring acceptance of technologies has been applied and expanded again and again.

Between the years 2012 to 2017 inclusive, a large number of studies have been published.

In Germany in particular, the smart meter rollout has not yet been fully completed.

2. Identification of trends with Big Data and AI (google trends)

Premises used

The period from January 1, 2012 to January 1, 2020 was considered. A search was carried out firstly in Germany and secondly worldwide. The "web search" was used as the setting.

Definition by google trends: The values indicate the search interest relative to the highest point in the chart for the selected region in the specified time period. The value 100 represents the highest popularity of this search term. The value 50 means that the term is half as popular and the value 0 means that there was not enough data for this term (Trends, 2021).

Germany

Fig. 5 shows the time course of the two search terms (Intelligent meters in blue and smart meters in red) and their interest in Germany. The interest peaks in the years 2012–2015 and in 2017. This temporal overlap coincides with the papers found and their publication years.

Worldwide

Fig. 6 shows the time course of the two search terms (Intelligent meters in blue and smart meters in red) and their interest in the world. It has increased continuously over the period under

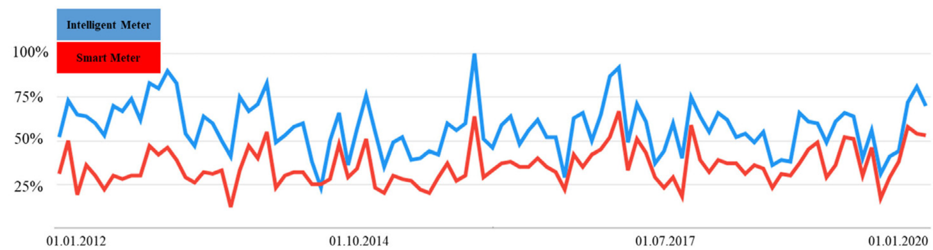

Fig. 5. Time course of search terms in Germany.

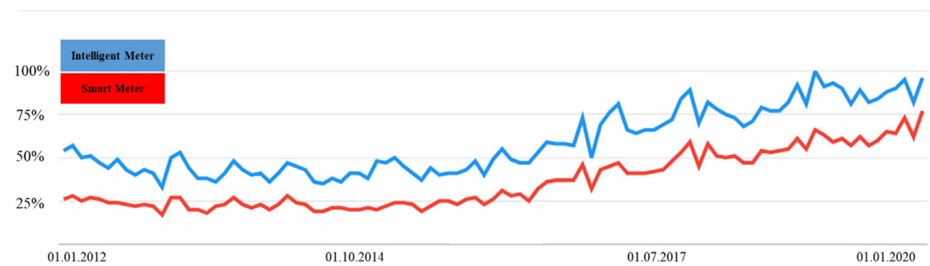

Fig. 6. Time course of search terms worldwide.

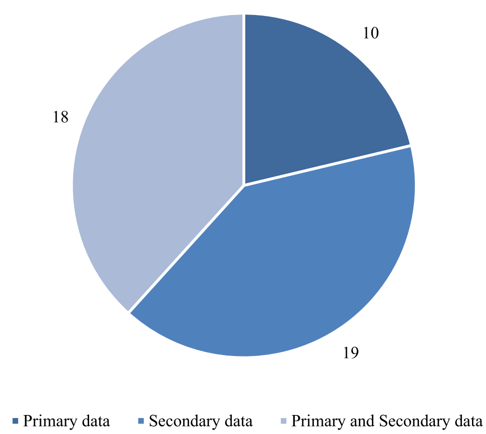

Fig. 7. Type of data of studied publications.

consideration. This is also congruent with the papers found and their publication years.

Thus, a similar trend can be observed between the scientific papers found from the database search and the google trends search.

3. Type of organization

All 47 works deal with end users. The end consumers are all private households. No companies are examined.

4. Type of data

When looking at the data used, there is a clear tendency towards secondary data (see Fig. 7). Secondary data was used more frequently. Looking at the absolute number of cases, 40% of the data used came from secondary data and 21% from primary data.

If one looks purely at the number of pure primary data and the pure number of secondary data without the paper using both data, the proportion of secondary data increases relatively to 66%. This underlines the high data usage of about two thirds secondary data of the 47 papers considered. Table 3 shows the type of data specifically by author.

5. Collection method

Fig. 8 shows the type of collection method in the publications studied. The 47 papers are distributed among three types of methods. The most common method is literature search with 75% (35 papers). Also frequently used was a questionnaire/survey (online or by telephone). This was used in 15% (7 papers). Another 10% (5 papers) were identified where the authors used data from previous projects and studies.

6. Number of participants

Fig. 9 shows the number of participants in the 19 publications studied. The participants of the 19 papers that used the questionnaire/survey method were examined. A range from 11 participants (Weck et al., 2017) to 1349 participants (Eseonu and Cotilla-Sanchez, 2014) was possible. The average number of participants can be given as about 360 participants. Table 4 categorizes the publications studied by average participants. There are 7 publications higher than the average and 12 lower than the average of 360 participants.

7. Type of data collection

The collection method, questionnaire/survey is to be tested for subjectivity of data collection. Of the 19 papers that used the questionnaire/survey method, 17 were completed by the actors themselves. Therefore, 89% of these data were collected subjectively.

This has to be critically questioned, since due to subjectivity even exactly the same situations can be evaluated completely differently in terms of technology acceptance. This deviation can be significantly increased by the strong heterogeneity of the actors and their individual know-how.

8. Evaluation method

Fig. 10 provides an overview of the evaluation methods used for the publications studied. 31 papers were evaluated by means of a literature analysis. 16 papers dealt with the statistical methods mentioned in 2.6.1. Table 5 presents the two evaluation methods sorted by authors of the studied publications.

Table 3
Classification of articles by type of data.

Type of data	Author
Primary data	Picot and und Simon Bilecki (2009), D'Oca et al. (2014), Davis (1989), Eseonu and Cotilla-Sanchez (2014), Gerpott and Paukert (2013), Kranz et al. (2010), Höhn (2016), Anda et al. (2013), Waeresch et al. (2017), Arafat et al. (2015)
Secondary data	Batalla-Bejerano et al. (2020), Karlin (2012), Carroll et al. (2018), Glachant et al. (2010), Jegen and Philion (2017), Julija et al. (2016), Khadar et al. (2017), Kollmann and Moser (2014), Campbell et al. (2015), Wunderlich et al. (2019), Pullinger et al. (2014), Yesudas (2015), Sovacool et al. (2017), Spodniak et al. (2014), Trindade et al. (2016), Uribe-Pérez et al. (2016), van Aubel and Poll (2019), Vine et al. (2013), Zhou and Brown (2017)
Primary- and secondary data	Albani et al. (2017), Alkawsi et al. (2020), Carroll et al. (2013), Chawla et al. (2020a), Chawla et al. (2020b), Chen et al. (2017), Chou and Gusti Ayu Novi Yutami (2014), Fürst et al. (2018), Hargreaves et al. (2010), Hellmuth and Jakobs (2020), Janíček et al. (2015), Stromback et al. (2011), Riester (2017), Arkesteijn and Oerlemans (2005), Wunderlich et al. (2012), Pillai et al. (2017), Vassileva and Campillo (2016), Weck et al. (2017)

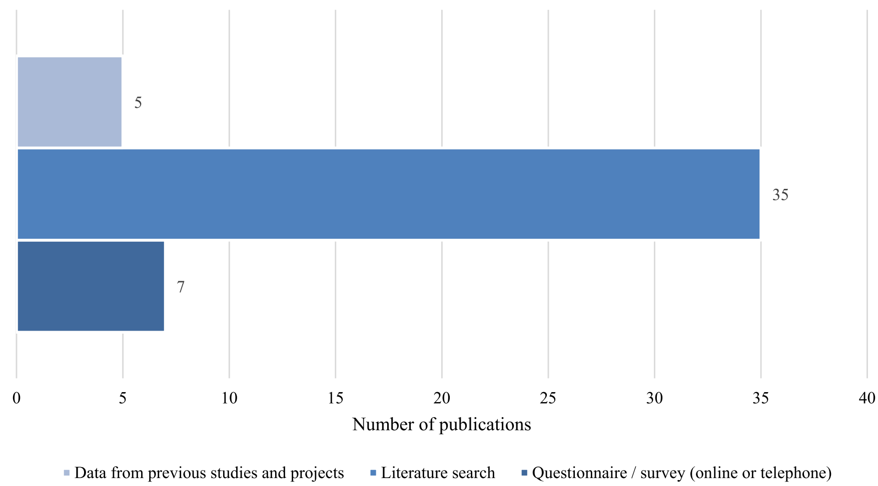

Fig. 8. Type of collection method of studied publications.

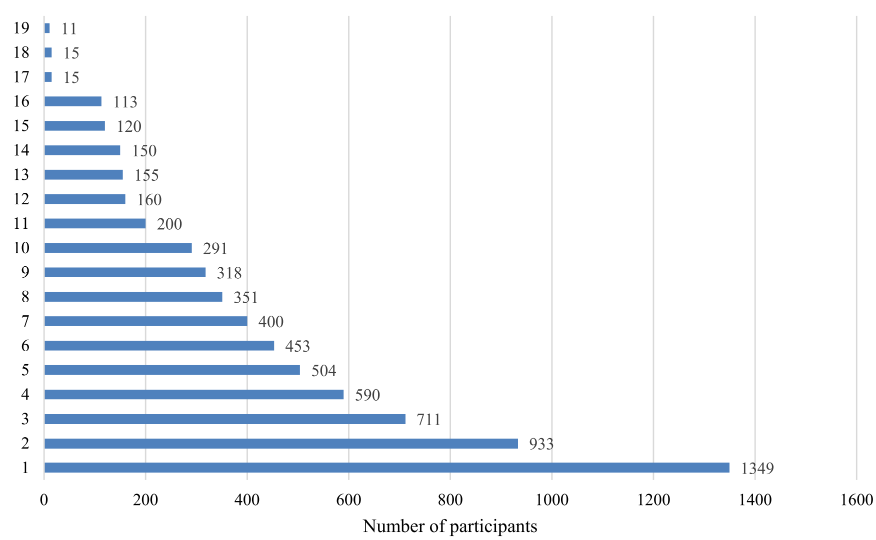

Fig. 9. Number of participants in the 19 publications studied.

Table 4
Classification of articles by number of participants.

Number of Participants	Number of papers
Higher than average (> 360)	7
Lower than average (< 360)	12

3.2. SWOT-analyze of the papers reviewed

The SWOT analysis takes the main statements and most important results of the studies reviewed in relation to our own research questions and divides them into the four categories of strengths, weaknesses, opportunities, and threats.

The works reviewed are intended to provide evidence that smart meter technology has been underrepresented in organizations and that further research efforts should be extended

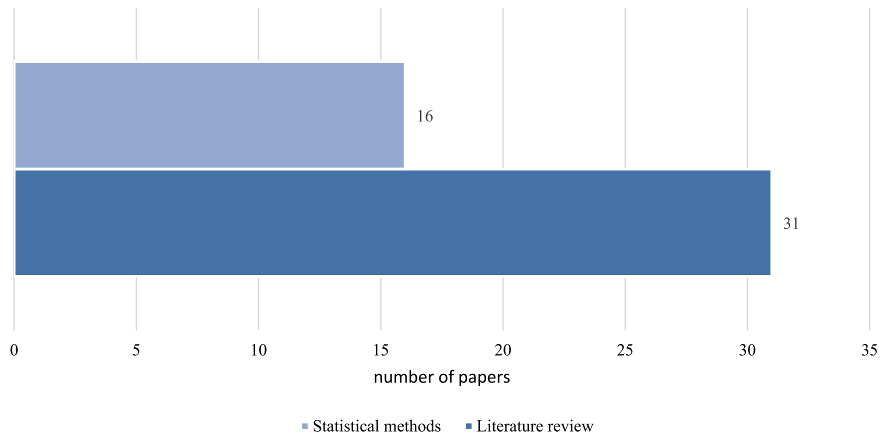

Fig. 10. Type of evaluation method in publications studied.

Table 5
Classification of articles by research approach.

Evaluation method	Author
Literature review	Albani et al. (2017), Alkawsi et al. (2020), Batalla-Bejerano et al. (2020), Karlin (2012), Carroll et al. (2013), Chawla et al. (2020a), Chawla et al. (2020b), Chen et al. (2017), Fürst et al. (2018), Hargreaves et al. (2010), Janíček et al. (2015), Glachant et al. (2010), Jegen and Philion (2017), Stromback et al. (2011), Riester (2017), Julija et al. (2016), Arkesteijn and Oerlemans (2005), Khadar et al. (2017), Kollmann and Moser (2014), Campbell et al. (2015), Wunderlich et al. (2019), Pullinger et al. (2014), Yesudas (2015), Sovacool et al. (2017), Spodniak et al. (2014), Trindade et al. (2016), Uribe-Pérez et al. (2016), van Aubel and Poll (2019), Vine et al. (2013), Weck et al. (2017), Zhou and Brown (2017)
Statistical methods	Picot and und Simon Bilecki (2009), Carroll et al. (2018), Chou and Gusti Ayu Novi Yutami (2014), D'Oca et al. (2014), Davis (1989), Eseonu and Cotilla-Sanchez (2014), Gerpott and Paukert (2013), Hellmuth and Jakobs (2020), Kranz et al. (2010), Höhn (2016), Anda et al. (2013), Wunderlich et al. (2012), Pillai et al. (2017), Vassileva and Campillo (2016), Waeresch et al. (2017), Arafat et al. (2015)

to other stakeholders, such as companies, to specifically identify the acceptance and benefit criteria of this technology in organizations.

Table 6 provides a comprehensive overview of the publications covered in the SWOT analysis. It shows which publication was used in which category of the SWOT analysis. The following summarizes the results of the SWOT analysis.

Strengths

- 22 of the studies have a good data basis (19x questionnaire/survey, 3x Data from Projects) and a high number of participants (10 participants Anda et al., 2013 to 1500 participants Albani et al., 2017) in the methods used. This results in a high informative value and enables transferability to other areas.
- (Carroll et al., 2013) Consumption feedback significantly increases household knowledge, but the improvements do not correlate with observed demand reductions.
- (Davis, 1989) Davis developed a model to measure user acceptance called TAM.
- Chou and Gusti Ayu Novi Yutami (2014) are concerned with the acceptance of private households to use the new measuring technology. Four hundred Indonesian households were surveyed to obtain factors favoring acceptance. The authors conclude that perceived usefulness, ease of use, and perceived risks influence acceptance. Thus, they confirm a transferability of the TAM to smart meter technology in the context of private households.
- (Eseonu and Cotilla-Sanchez, 2014) The factors influencing the social acceptance of smart meters were investigated in a survey with 1349 participants.
- (Hargreaves et al., 2010) Measurement technology and intelligent energy monitors (displays) were installed in 15 British households. This allowed data to be collected and matched with interviews.
- (Stromback et al., 2011) Several consumer groups (not only households) should be combined in future research. This is necessary since commercial and (small) industrial customers are underrepresented, although they have the best cost–benefit ratio. Strategic targeting of smart metering programs to a cross-section of consumer groups is an under-researched area with high potential.
- (Kranz et al., 2010) Perceived usefulness, ease of use and subjective control are considered as possible factors influencing acceptance. This makes the study one of the few to deal specifically with the acceptance of smart meters by end consumers.
- (Riester, 2017) The research questions are answered, evaluated and verified with the help of an extended Technology Acceptance Model (TAM). This makes this work one of the few in Germany.
- (Julija et al., 2016) The analysis shows that there is generally a positive attitude among consumers, but there are still misunderstandings regarding trust and transparency, which negatively affects implementation and acceptance of the technology.
- (Arkesteijn and Oerlemans, 2005) Perceived environmental responsibility, high past knowledge of renewable energy and sustainable behavior significantly increases the probability of smart meter adoption.
- (Höhn, 2016) Overall, more participants were in favor of a smart meter gateway than against it.

Table 6
Comprehensive SWOT-Table of the studies reviewed.

Study	Strengths	Weaknesses	Opportunities	Threats
Anda et al. (2013)	X			
Albani et al. (2017)	X	X		
Carroll et al. (2013)	X			
Davis (1989)	X			
Chou and Gusti Ayu Novi Yutami (2014)	X		X	
Eseonu and Cotilla-Sanchez (2014)	X			
Hargreaves et al. (2010)	X		X	
Stromback et al. (2011)	X			
Kranz et al. (2010)	X		X	
Riester (2017)	X		X	
Julija et al. (2016)	X			
Arkesteijn and Oerlemans (2005)	X			
Höhn (2016)	X			
Chen et al. (2017)	X			
D'Oca et al. (2014)	X			
Kollmann and Moser (2014)	X			
Wunderlich et al. (2012)	X			
Jegen and Philion (2017)	X			
Trindade et al. (2016)	X			
Uribe-Pérez et al. (2016)	X			
Wunderlich et al. (2019)		X		
Sovacool et al. (2017)		X	X	
Spodniak et al. (2014)		X		
Arafat et al. (2015)		X		
Khadar et al. (2017)		X	X	
Karlin (2012)		X		
Alkawsi et al. (2020)			X	
Picot and und Simon Bilecki (2009)			X	
Fürst et al. (2018)			X	
Glachant et al. (2010)			X	
van Aubel and Poll (2019)			X	
Hellmuth and Jakobs (2020)			X	X
Gerpott and Paukert (2013)			X	
Campbell et al. (2015)			X	
Pillai et al. (2017)			X	
Janíček et al. (2015)			X	
Vassileva and Campillo (2016)			X	
Zhou and Brown (2017)			X	
Chawla et al. (2020b)			X	
Waeresch et al. (2017)			X	
Yesudas (2015)			X	
Weck et al. (2017)			X	
Batalla-Bejerano et al. (2020)				X
Chawla et al. (2020a)				X
Vine et al. (2013)				X
Pullinger et al. (2014)				X
Vassileva and Campillo (2016)				X

- (Chen et al., 2017) The majority of participants support smart meter technology and are willing to adopt the technology. Two perceived technology attributes – usefulness and privacy risk – had a direct impact on support for smart meter installation.
- (D'Oca et al., 2014) The study concludes that energy-related communications can reduce household electricity consumption by -18% on average and up to −57%.
- (Anda et al., 2013) The participating households reduced their consumption by 12%.
- (Kollmann and Moser, 2014) The savings potentials achieved are between 0 and 4.5%, mainly due to low use by consumers. There is also a low willingness to pay for consumption feedback systems. Interest in technology and in environmental and energy issues increases savings potential and willingness to pay.
- (Wunderlich et al., 2012) Environmentally friendly behavior is more important for acceptance than financial aspects and policy recommendations. Intrinsic motivation and environmental awareness strongly influence participants' intention. Privacy risks have no negative influence on technology adoption.
- (Jegen and Philion, 2017) Social acceptance has become an important criterion in the introduction of new energy infrastructures and technologies.
- (Trindade et al., 2016) Planning and operational tasks of distribution system operators can be improved by generating data volumes.
- (Uribe-Pérez et al., 2016) The main drivers of smart meter technology in different countries are highlighted.

Weaknesses

- (Wunderlich et al., 2019) Most studies on smart meter technology worldwide are only conducted with household customers. In fact, in the publications reviewed in this study, it is only household customers and not companies. In Germany in particular, however, these customers are not even directly affected by the smart meter rollout, since the consumption limit is greater than 6000 kWh of electricity per year. Nevertheless, these results are directly transferred to companies, for example.

- (Sovacool et al., 2017) Only households and not companies are studied in the context of smart meter technology. In addition, the main focus is usually only on technical but not on social aspects.
- (Albani et al., 2017) However, implementation of the new metering infrastructure is making little progress and often focuses only on technical aspects.
- (Spodniak et al., 2014) Focus too strongly on technical, economic and financial challenges and benefits. Social and consumer-related aspects have so far been neglected.
- (Arafat et al., 2015) The technical aspect of whether a large number of smart meters have an effect on the voltage quality in the grid is examined. At the same time, it is noted that there are too few smart meters in use to test this.
- (Khadar et al., 2017) Few studies exist on energy efficiency. Currently, the majority of research focuses on the use of smart meters, which extract consumption data and use some kind of communication medium to transmit the consumption data back to the customer.
- (Karlin, 2012) Despite similar technological design, public acceptance of smart meters varies widely across regions and service areas, suggesting that some differences can be attributed to rollout strategies.

Opportunities

- (Alkawsi et al., 2020) Smart meter manufacturers should develop products with better user requirements, which would increase user engagement. In addition, governments should set standards for the use of Consumer data should be set to protect consumer privacy and reduce fears of use.
- (Picot and und Simon Bilecki, 2009) It is recommended to implement the introduction of end-customer-specific and load-dependent tariffs. In addition, open standards and interfaces should be agreed upon to ensure rapid market penetration.
- (Fürst et al., 2018) The availability of consumption data, installation and rental costs, and time-variable tariffs are particularly relevant for smart meter customers.
- (Glachant et al., 2010) Variable tariffs to reduce load are a useful measure.
- (van Aubel and Poll, 2019) Dynamic tariffs are to be introduced to generate energy savings.
- (Chou and Gusti Ayu Novi Yutami, 2014) Evidence of the transferability of the Technology Acceptance Model (TAM) to the enterprise level is still pending.
- (Hargreaves et al., 2010) Energy monitors in combination with smart meters create greater awareness of energy consumption and potential savings.
- (Hellmuth and Jakobs, 2020) There is a need for research into how information can be prepared for different target groups so that they can obtain information about the technology and its use at as low a level as possible, depending on their needs, situation and level of knowledge.
- (Kranz et al., 2010) Acceptance of smart meter technology increases significantly when users can exercise more control over the technology.
- (Riester, 2017) To increase the acceptance of the technology, industry or corporate customers should be involved in further research work.
- (Khadar et al., 2017) There are several barriers, such as higher security risk, especially with respect to privacy for smart meter research.
- (Gerpott and Paukert, 2013) The survey shows that confidence in the protection of personal smart meter data and the intention to change one's electricity consumption behavior after smart meter implementation are the most important.
- (Campbell et al., 2015) Currently, there is a lack of clarity about what data would be useful, in what format, time frame, and level of aggregation.
- (Pillai et al., 2017) A much lower consumption limit of 200 kWh/a electricity consumption for the introduction of smart meters is applied. So almost every consumer can be reached.
- (Janíček et al., 2015) An implementation obligation at an annual electricity consumption of 4000 kWh reaches more customers than if the limit were set higher.
- (Sovacool et al., 2017) The societal issues of technology should also be addressed in further studies.
- (Vassileva and Campillo, 2016) The development of incentives and "premium" packages of value-added services that would encourage consumers to make better use of their electricity could, in the long run, lead to smarter consumers who could adopt energy-efficient technologies and use them in the most efficient way.
- (Zhou and Brown, 2017) Future research may be needed to examine how technology-driven regulations affect the clean technology manufacturing industry.
- (Chawla et al., 2020b) Consumer affinity for technology and the government's ambitious goals are a very productive mix for a nationwide adoption of smart meter in India.
- (Waeresch et al., 2017) The nationwide installation of smart meters in low-voltage (LV) grids prospectively provides information on system parameters relevant to operation.
- (Yesudas, 2015) Smart metering systems have the potential to contribute to smart grids and improved energy management
- (Weck et al., 2017) Barrier research for smart meters should be conducted on a country-specific basis.

Threats

- Evaluation methods are mostly based on subjective assessments of stakeholders. 89% of the data were collected subjectively.
- Data basis and participants is partly low.
- (Batalla-Bejerano et al., 2020) Only about 12% of the studies consider non-residential buildings, although they show higher consumption.
- (Chawla et al., 2020a) Only 50% of respondents knew what a smart meter was.
- (Hellmuth and Jakobs, 2020) Tenants between 24 and 40 years of age with a medium income and academic background were surveyed. This indicates a strong lack of information and need for information on metering systems and rollout.
- (Vine et al., 2013) Feedback can reduce household electricity consumption by 5 to 20 percent, but there are still significant gaps in knowledge about the effectiveness and cost benefits of feedback.
- (Pullinger et al., 2014) As the standards are currently configured, it is unlikely that practice-based forms of feedback devices will be widely used or deployed in the UK in the near future.
- (Vassileva and Campillo, 2016) The results show that the potential for increasing the energy efficiency of residential buildings through the active participation of informed customers from the information provided by the smart metering infrastructure is still very low and more specific feedback should be provided from the collected data. Very few results are available for Europe, almost no results for Germany.

4. Discussion

Starting point of this work and objective

Smart meter technology is regarded as an enabler of the energy transition and a driver of digitization and energy efficiency (Westermann et al., 2013). In Germany, the smart meter rollout for consumers with an annual electricity consumption of more than 6000 kWh has been made mandatory by law.

In companies, there is uncertainty and a lack of information about the technology and its benefits. This is even the case for those companies that have a higher electricity consumption than the 6000 kWh per year and have a legal obligation to install the technology. These companies should also be picked up with regard to the technology. Otherwise, they will be retrofitted but will not actively use the technology.

Furthermore, hardly any studies are known that deal with the acceptance criteria of the technology in the company environment. Rather, a large number of studies can be found in the household sector.

The Technology Acceptance Model (TAM) by Davis (Davis, 1989) was applied several times and could be transferred to smart meter technology in a few studies. All studies, without exception, dealt with residential end users. Transferability of the TAM and its hypotheses to companies is still pending (Chou and Gusti Ayu Novi Yutami, 2014). In addition, the factors that influence the acceptance and use of smart meters in companies are unclear.

There is also insufficient research on the benefits of enterprises in using smart meters.

Section 2.1 established the research questions and presented the hypotheses to be tested and answered or proven in this thesis. To this end, the current state of research was reviewed and it was examined whether an existing research gap could be identified.

The following research questions should be examined:

What factors influence the acceptance and use of smart meters in organizations?

What are the advantages of smart meter technology for organizations?

The research questions described were investigated in the literature review, but were only inadequately answered.

The basic hypotheses from Davis' technology acceptance model were not applied to companies and empirically proven in any of the literature considered.

H (1): The higher the perceived benefit, the more positive the attitude towards the technology.

H (2): The higher the perceived benefit, the higher the intention to use the technology.

H (3): The higher the perceived ease of use, the more positive the attitude towards the technology.

The hypotheses can be expanded to include additional correlations as desired and are not conclusive.

Thus, the research questions and the hypotheses are still valid because the researched papers could not answer the research question and the hypotheses.

Origin and publication of the paper

The 47 papers from the literature search were considered and evaluated using eight different evaluation criteria and a SWOT analysis. The evaluation showed that most of the studies were published in Germany, the USA and the Netherlands. Nevertheless, this is a topic that is being studied worldwide. A general trend can be observed that smart meter technology is gradually arriving in company practice. Unfortunately, hardly any scientific work is available on this subject.

Identification of trends with Big Data and AI (google trends)

The increasing trend of smart meter technology is also confirmed with the results from google trends search query. Search queries in Germany have achieved the greatest interest in 2012–2015 and 2017. A continuous increase in search queries can be seen in the search queries recorded worldwide.

Type of organization

In Germany, only consumer groups with electricity consumption of 6000 kWh or more are required to install a smart meter; consumers below this level can upgrade voluntarily. Voluntary retrofitting requires a perceived benefit. However, consumer groups with such high electricity consumption are not private households, but companies from the commercial, trade and service sectors.

All the papers examined consider the end consumer and thus mean private households. This is difficult to understand in that most households have an annual consumption of around 4000 kWh. The consumer group between 4000–6000 kWh annual consumption has a greater benefit from the implementation of smart meter technology and could actively contribute to an increase in energy efficiency through digitalization. These consumers are small businesses and not households.

Businesses are diametrically different from households in terms of decision and acceptance criteria. Increasing the implementation of the technology for this consumer group, which can also decide voluntarily whether it wants to switch over, should focus more on their needs and not just on technical feasibility.

Type of data and collection method

The studies used significantly more secondary data (40%) than primary data (21%). The data collection method was mainly through literature review and questionnaires.

The questionnaires were conducted online or by telephone. This favors subjective perception and data collection by the stakeholder. Similar assessments can be evaluated completely differently. Although this uncertainty is minimized by the scientific questionnaire design, it can lead to a large variation in the assessment. Only a few studies (11%) have made use of the option of sending an expert directly to the stakeholders and collecting the data directly on site. While this is costly and time-consuming, it ensures that the data collected are collected with the same consistency. This does not mean that the data is more correct or accurate than that collected via questionnaires, but it does ensure consistency throughout.

Main conclusion from the SWOT analysis of the peer-reviewed papers

So far, only a few research studies have looked specifically at the acceptance of smart meters in Germany. Moreover, these studies only consider private households as end users and not companies. Against the background of the legally regulated introduction in Germany, the studies to date are of little topicality, refer in part to other countries within and outside Europe, and often examine the factors influencing acceptance only one-sidedly (mostly technical). The lack of implementation in Germany is sought to the detriment of the technology in the technical implementation.

This is a misinterpretation, as the end user factor and its benefits are mostly disregarded.

Half of the stakeholders surveyed do not know what a smart meter is, so how can they discuss the technical aspects of the technology and reject it for this reason. More awareness should be raised among the stakeholders. The greater the benefit, the greater the acceptance and, consequently, the greater the implementation of this technology. This is all the more important in Germany because many consumer groups (households and small businesses) are not obliged to install the technology, but have the option of doing so. However, the companies that are obliged to install the technology should also be educated so that they actively use it.

Specifically, industry and commerce should be studied more specifically and more frequently in the context of technology adoption. The studies show, for example, that hypotheses from the Technology Acceptance Model (TAM) could already be applied and answered to technology on the one hand and to private households on the other. This has not yet been scientifically proven for the company sector.

Limitations of own work

Only 47 papers on this topic were examined. The majority of the papers originate from the European Union and are therefore not easily transferable to all countries and their resident companies.

The method chosen to select the search terms and synonyms is partly subjective. Even if the method later follows a clear framework, this cannot be completely excluded. Also, the cleaning process in selecting the papers to be studied is a weakness of the paper. One reason for this could be the excessive focus on smart meter technologies in companies. While this should be explicitly explored in the study, it is this strict focus that may also exclude studies that have explored other technology-level opportunities and measures as side effects in their studies, but have not contextualized them directly through the titles and summaries.

Further Research and contribution

The research questions and hypotheses from Section 2.1 are still valid, as the reviewed work cannot fully answer the research questions. It was shown that there is a research gap in the area of smart meter technology adoption that could be identified through an empirical study in companies.

From the developed literature review, some possible research approaches related to the research questions emerge.

This thesis proposes to fill the identified research gap and thereby contribute to a better understanding of the acceptance research for this technology.

The results of this thesis have also shown that more research on smaller and non-manufacturing companies in this field is useful and necessary. This is simply because there are many small businesses and the acceptance of these businesses is an important factor in the successful adoption of this technology.

More studies should be conducted that look at the decision-making and acceptance criteria of companies. So far, there has been too much focus on households as end users. This can only work in countries where the introduction is required by law for all consumers anyway, in order to verify the technical feasibility. However, if one wants to bring about a voluntary introduction of a technology, it is essential to get those affected on board and to know and meet their needs. This is currently not the case, especially in Germany.

The researched technology acceptance of smart meter technology, which has so far only been aimed at households, can also be extended to companies through the research design. Scientific knowledge and findings from this can be starting points for further research at the company level.

In particular, industry and commerce should be studied more specifically and more frequently in the context of technology acceptance of smart meters.

In addition, future work should extend the technology acceptance model (TAM) to the corporate sector as a user of the technology and provide scientific evidence of its transferability to this user group.

The results can help predict and increase the adoption rate of the technology. Dissemination of the technology in enterprises will lead to an increase in digitization and energy efficiency in enterprises. It will also support strategies for market penetration of smart grids and virtual power plants (Ghasempour, 2017). Smart meter technologies have the potential to connect the energy industry, companies, public properties and private households and to bring about a paradigm shift in generation and consumer structures.

Energy and digital transition

Digitization and the energy transition are two highly interdependent topics. Both must develop in equal measure so that there is no delay. Digitization means that successively more energy is needed. The new digital business models are contributing their energy consumption to this. At the same time, the energy turnaround means that fewer large-scale power plants based on fossil fuels will be operated; volatile energy power plants such as photovoltaics or wind turbines will take over these supply tasks. The market conditions are thus changing from centralized fossil generation plants to decentralized renewable energy plants. This fact makes it clear that the control options for grid operators must be significantly increased so that power generation and power consumption remain at a frequency that is not critical to the grid. Nevertheless, the much needed control capability, the smart meter, is to be installed largely on a voluntary basis. In Germany, for example, the obligation to retrofit the control option exists for electricity consumption greater than 6000 kWh per year. Nevertheless, a successful energy transition requires the digitization of the infrastructure immediately, because the number of small decentralized generators (e.g., photovoltaics) and the development of electricity-based consumers (e.g., heat pumps and charging stations) are increasing rapidly. This is in direct contradiction to the implementation strategy of some EU countries, which have planned implementation until 2030 or later.

Increasing the benefits can contribute to greater acceptance, even if the benefits do not have a direct and immediate monetary impact on every stakeholder. The players must understand the importance of these control options for the overall supply task, which must be accompanied by communication, by energy supply companies as well as politics. If the grid operators' expenses for operating the grids are reduced, this will be passed on to the grid customers. In addition, smart metering can create a completely new network charging system for small consumers. The estimation of consumption and loads, which has so far been based on standard load profiles (SLP), can be changed to a system based on real data. This forecasting accuracy will make a major contribution to reducing the cost of operating the grids and increasing security of supply. A model for billing power prices for smaller consumers is already being considered in Belgium, for example.

A direct and implicit increase in benefits can be created by electricity flexibilities, for example. The related dynamic and flexible tariffs were addressed in the paper. The tariffs can be used for various topics such as e-mobility, virtual power plants, storage solutions, and heat pump technology for heating and cooling purposes. For example, players are required by law to use a smart meter when using heat pumps. This enables the control of these systems, nevertheless other actors have an e-car and charge it via a normal power socket, which remains without control possibility and knowledge for the grid operator.

The energy transition also requires a digital transition, as the new business models, which have approximately double-digit percentage growth per year, make this necessary. The more players adapt, the more efficiently the distribution network can be intelligently controlled. This means that all players, whether households, small or large companies, should be involved by politics and science.

This study has raised awareness of the fact that households are the focus of scientific research, but politically there is often no obligation to install smart meters. In addition to households, small companies with an electricity consumption of less than 6000 kWh per year are not included.

One possibility for Germany could be to lower the implementation requirement from 6000 kWh per year to, for example, 4000 kWh per year. On the one hand, this would directly oblige many households, but also a large number of small companies, and installation would no longer be voluntary for the consumer groups. The additional costs of the technology during installation and operation, which led to the decision in favor of this 6000 kWh limit, could be reflected via a subsidy program. Delaying the new digital business models due to possible power outages would probably be much more expensive economically.

Another possibility is the rapid expansion of digital business models, even for micro-consumers, which allows voluntary players to quickly amortize the additional costs of a smart meter or increase the added value. In this context, vehicle-to-grid (VtG) and vehicle-to-home (VtH) technology may become important as a way of sector integration. Consumers and grid operators can benefit. From the consumer's perspective, the electricity from the electric car can be used for the consumer's own home or as reserve power for the grid operator in return for a fee. At the same time, the electric car can be made available as storage when there is too much electricity in the grid. The grid operator can thus manage flexibilities in its grid more efficiently and possibly avoid grid expansion measures and expensive peak load electricity.

The idea that the cost of upgrading to smart meter technology should be paid for by the network operators may also be useful. If the costs for retrofitting are lower than the costs for controlling the grid and procuring additional loads, then this would be a viable option. Furthermore, based on this consideration, a special tariff could also be created for players who voluntarily retrofit a smart meter. This would be a new business model for the grid operators. The considerations must be approved by the regulatory authorities, with the goal being the most secure, affordable, consumer-friendly, efficient and environmentally compatible grid-based supply of electricity to the general public. There is initially no contradiction in this.

5. Conclusions

The aim of this work was to answer the research questions of what factors influence the acceptance and use of smart electricity meters in companies and what benefits the technology brings. An extensive literature review was conducted and 47 papers were considered in detail. To answer the research questions, the papers were examined using a literature review and SWOT analysis. The research questions and the hypotheses could not be fully answered and the research gap in the field of acceptance research in organizations (mainly in companies) could be identified.

Initially, the results indicate a need for research in acceptance research in the corporate environment, as no studies on it could be found and verified in the literature review.

Above all, the results of further research can contribute to a better understanding of the acceptance of technology in organizations. This will ultimately enable both smart meter manufacturers and policymakers to launch more targeted value-added services and support programs, thereby achieving greater adoption among the stakeholders who are likely to use the technology.

Knowing stakeholders' needs and fears about smart meter technology and its implementation enables robust predictions that support more accurate costing scenarios.

The technology is still considered a game changer for the energy transition. Therefore, the acceptance of this technology by users is enormously important to better communicate topics such as Big Data, Industry 4.0 and Artificial Intelligence.

Nevertheless, as with other technologies, it must be understood whether and how this technology will be accepted by users in order to actively influence decision-making. In Germany, for example, the implementation of smart meters is mandatory for consumers with an annual electricity consumption of 6000 kWh or more. However, many consumers such as households and small businesses often have annual consumption of less than 6000 kWh, so there is no legally binding nationwide rollout. In addition, the courts are currently examining whether mandatory rollout is permissible at all.

This challenge, as well as the fact that information deficits exist and value-added services are still in their infancy, already point to a need for research that is not only technical.

The open research questions are to be answered with the help of a case study in the corporate environment. For this purpose, extensive research data has already been collected from around 400 companies. The survey was carried out in a mixed methods approach using interviews, questionnaires and expert visits. In the process, the transferability of the TAM can be demonstrated and the question of what increases the acceptance and benefits of the technology among small companies can be investigated. Considering the fact that especially in Germany the implementation of the smart meter rollout will continue until 2032 and no change in the law is in sight which will tighten the implementation, other ways have to be found to pick up the consumers. This can be done by increasing consumer acceptance and benefits as well as by benefit-driven digital business models.

Nomenclature

AI	Artificial Intelligence
EU	European Union
HEMS	Home Energy Management System
kWh	kilowatthour
LV	Low Voltage
RTP	Real-Time-Pricing
SLP	Standard Load Profile
SM	Smart Meter
SWOT	Strengths–Weaknesses–Opportunities–Threats
TAM	Technology-Acceptance-Model
ToU	Time-of-Use
VtG	Vehicle-to-Grid
VtH	Vehicle-to-Home

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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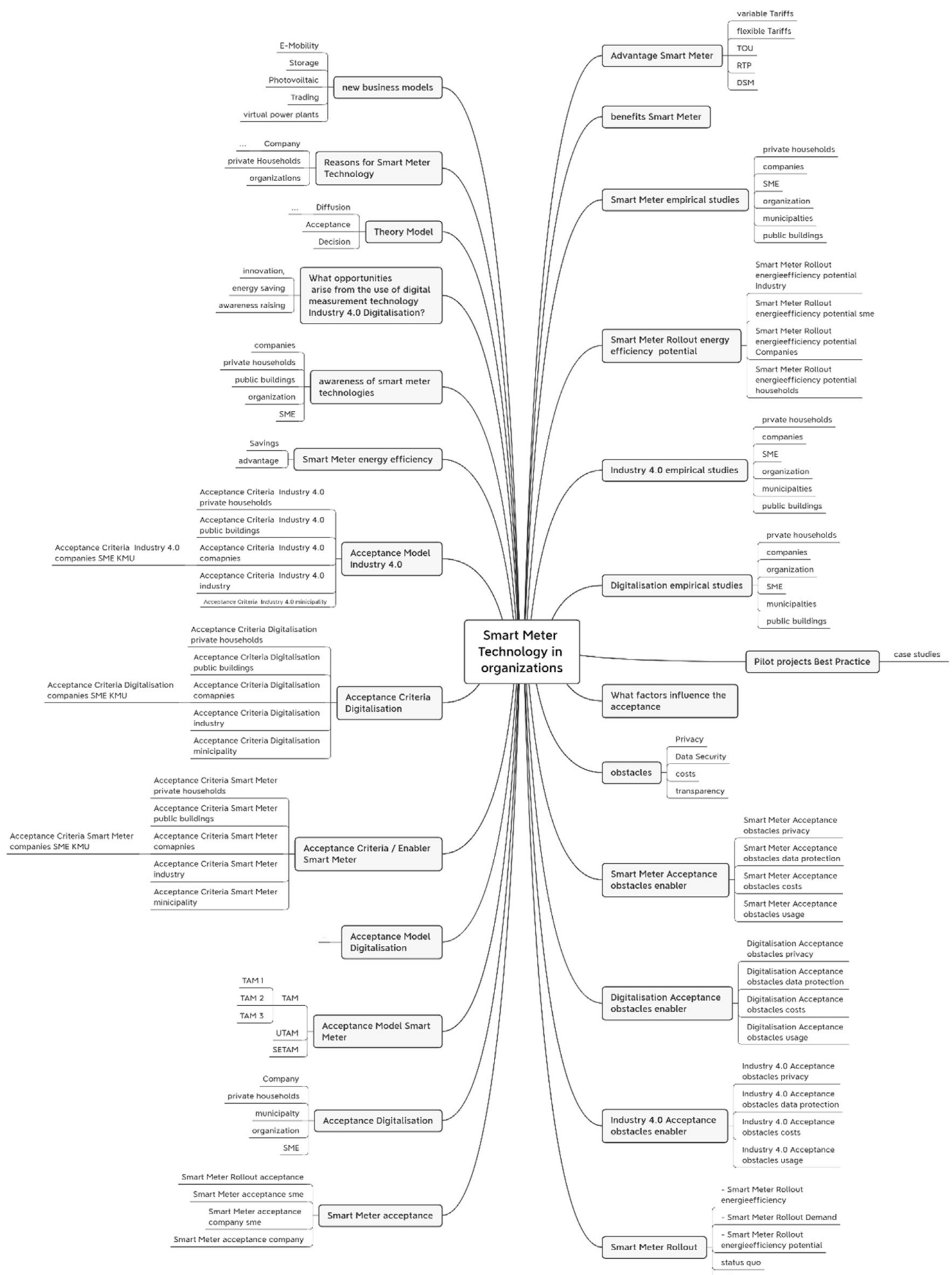
Appendix. Overview mindmapping and keywords



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