A matter of status? A study on factors influencing the intention to adopt smart electricity meters in German households

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Abstract

Smart meters play a crucial role in the transition of the energy market. In Germany, the installation of smart meters is only obligatory under specific circumstances. A voluntary installation is possible but is connected with higher costs compared to a mandatory installation. The following research question is investigated: To which extent do factors specified by the theory of planned behaviour influence the intention to adopt smart meters in German households? Furthermore, the effect of socioeconomic status is tested as both an independent and moderating variable on the relationship between attitude, subjective norms and perceived behavioural control and behavioural intention. Data is collected with an online questionnaire and the hypotheses are tested with multiple linear regression analysis. Contrary to the expectations, the results do not indicate a significant effect of attitude, perceived behavioural control and socioeconomic status on intention. The results do indicate a significant effect of subjective norms. No evidence for a moderating effect of socioeconomic status on the relation between the psychological predictors and behavioural intention could be found. It can be concluded that the influence of one's social environment is a significant factor in the decision of whether to install a smart meter.

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1. Introduction

The transition of the energy system away from fossil fuels to renewable energy is one of the fundamental challenges for achieving sustainability goals. However, the current design of the energy sector in terms of production and consumption is geared towards a constant, relatively regular flow of electricity through the grids. Some forms of renewable energy such as wind power and photovoltaics cannot guarantee a constant flux of energy as they fluctuate in the course of the day and year. Therefore, it is necessary to build an increasingly decentralised and flexible energy system. A smart grid is designed for fluctuating amounts of electricity depending on the amount of electricity generated and the changing demand during the course of the day. Regarding private households, especially with increasingly widespread use of electric cars which need to be charged and photovoltaic systems on roofs generating electricity, a crucial step in building an energy system that is capable of handling mainly renewable energy is the widespread installation of smart meters. Smart meters are "an electronic system capable of measuring electricity fed into the grid, or electricity consumed from the grid, providing more information than conventional meters" (European Commission, n.d.). In summary, they are internet-enabled meters that can be read remotely via an additional communication unit. In addition to the central role of smart metering technology in building a smart grid that can provide mainly renewable energy, its importance for sustainability purposes also stems from the fact that smart meters enable the accurate measurement of electricity consumption. This offers the benefit of potential savings through increased awareness of electricity use and the improvement of its management (Wunderlich, Veit & Sarker, 2019, 674). For instance, under the condition that it is possible to measure the electricity consumption at a quarter-hourly interval with a smart meter, it is possible to adjust its use according to the price fluctuations throughout the day. Consequently, the second reason for the importance of smart meters for sustainability purposes is a potential reduction of electricity consumption.

When reflecting upon the adoption of technologies in households for sustainable purposes more generally, it is striking that the focus mostly lies on energy-producing technologies. Commonly discussed examples are residential photovoltaic systems. These technologies offer a way of circumventing the high energy prices on the market and increasing self-reliance. However, they also require the status of a homeowner with the necessary financial resources. Therefore, these kinds of technologies are not available to non-homeowners as this group has limited possibilities of decision-making regarding the renovation and modification of their accommodation. In Germany for instance, people living in rental accommodation constitute half of the population (Destatis, WZB, BiB, 2021, 262). Instead, less intrusive changes of the property not intended for generating electricity but for reducing electricity consumption are ways of adapting to the situation of rising prices. Therefore, the third reason for the importance of smart meters as a technology used for sustainability purposes is the accessibility for non-homeowners.

The background of this study is the political aim of a large-scale smart meter rollout. The EU has obliged member states to "ensure the implementation of smart metering technology" providing there is a positive economic assessment of the costs and benefits (European Commission, 2022). The economic assessment of the long-term costs and benefits to be finalised by September 2012 was necessary as the provisions of the Third Energy Package determine that the large-scale rollout of smart meters must be of long-term benefit for the consumers (European Commission, 2014a). For smart electricity meters, in case of a positive cost-benefit-analysis, the target for a large-scale rollout was 80% by 2020. However, as stated on the website of the European Commission (2022), "the overall successful roll-out of smart meters across the EU is dependent on criteria largely decided by Member States".
In the case of Germany, the results of the cost-benefit-analysis regarding the roll-out of smart meters by 2020 was negative. A large-scale roll-out for smart meters was not recommended with the reasoning that "costs of smart metering systems for final users with low levels of annual consumption would far outweigh the average potential of annual energy savings" (European Commission, 2014b). However, it was concluded to be "economically justified for a specific group of customers", namely high-consumption end-users with an annual consumption of over 6000 kWh per year, major generation facilities, and end-users in new or renovated buildings (European Commission, 2014c).

In 2016, the so-called Messstellenbetriebsgesetz (MsbG), metering point operation act, was passed (Deutscher Bundestag, 2021, 1). According to §30 MsbG, the requirement for the start of mandatory installations of smart meters is the availability of at least three independent companies offering such technology on the market. These must meet the technical requirements determined by the MsbG and be approved by the Federal Office for Information Security (BSI). In case of a positive assessment, it issues a market availability declaration. The market availability declaration was effective February 24, 2020. However, in March 2021, the Higher Administrative Court of North Rhine-Westphalia in Münster ruled that this order was likely to be unlawful as it was unclear whether smart meters sufficiently fulfilled the legally prescribed scope of functions. On May 20, 2022, shortly before the hearing in the main proceedings, the BSI withdrew the market availability declaration on the rollout of smart metering systems. Instead, it issued a transitional regulation making the continued use of already installed smart meters and the installation of new smart metering systems still possible.
Before the declaration of the transitional regulation, the installation of smart meters could occur in three different scenarios. The first one is the legal obligation (§29 I MsbG). This was the case when at least one of the following conditions was met: a household electricity consumption exceeding 6.000 kWh per year or the operation of electricity-generating systems with more than 7 kW of installed capacity. It was obligatory for the so-called 'Messstellenbetreiber', the metering point operators, to install a smart meter and such consumers were obliged to have a smart meter installed and pay for it. According to the transitional regulation, the installation of smart meters does not occur due to legal requirements anymore, the

“metering point operators are not obliged (…) to continue the rollout against their will” (BSI, 2022, 5).
In the second and third scenario, the installation of a smart meter is not prescribed by law. The metering point operator may decide on its own initiative to equip a household with a smart meter, even when the three mentioned conditions are not met (§ 29 II MsbG). In this case, it is optional for the metering point operator to install a smart meter. Although the installation of a smart meter is not obligatory by law, households still have to obey the decision of the metering point operator. In the third scenario, the installation is not obliged by law and not decided so by the metering point operator. Instead, households voluntarily decide on the optional installation of a smart meter, when the conditions otherwise determining a mandatory installation are not met.
In case households are obliged to have a smart meter installed, either previously by law or by the decision of the metering point operator, the annual fees for installation and operation are limited by a statutory price ceiling. These, however, do not apply in the case of a voluntary installation meaning the metering point operators are not bound by the legal limits and can charge more.

Because the installation and operation of smart meters cause higher costs compared to the otherwise installed digital meters, the question arises why households have them installed voluntarily. The influences on the decision to or not to adopt such technology in one’s household are to be explored. To this end, in alignment with previous research on the intention of technology adoption, the theory of planned behaviour is tested. Hence, the research question to be answered is the following:

To which extent do the factors specified by the theory of planned behaviour influence the intention to voluntarily adopt smart meters in German households?

The independent variables are the intrinsic attitudes, subjective norms, and behavioural control as defined by the theory of planned behaviour. The dependent variable is the intention to voluntarily install a smart meter in one’s household. In the following, the installation of smart meters always refers to the voluntary installation of smart meters, even when not explicitly mentioned as such.

The relevance of investigating the installation of smart metering technology lies in the importance of considering large parts of society which do not have another choice than to obtain electricity through the market. Investigating the factors influencing the intention to install smart meters offers a possibility of better understanding its adoption and the conditions influencing the extent of its adoption. Furthermore, the importance of this issue stems from the fact that households with low socioeconomic status are especially vulnerable to price rises. Technology which is also available to these households might help achieve electricity savings. Also, it is particularly interesting to investigate the willingness of installing smart

meters under the condition of non-compulsion. Since the installation of smart meters is only compulsory under specific circumstances, it is necessary to understand the motivations behind voluntarily installing smart meters. Only on this basis is it possible to convince consumers of smart meters and further enhance the building of an energy grid that is capable of handling mainly renewable energy.

In this study, additional to the factors specified by the theory of planned behaviour, the influence of socioeconomic status is examined. The financial situation of individuals is an important factor in forming pro-environmental behaviour. For instance, a low socioeconomic status may on the one hand limit consumption but on the other hand may also act as a "barrier for adopting ecological substitutes" (Macovei, 2015). Regarding smart meters, it may mean that this technology offers the possibility of saving electricity and therefore money, but it also causes additional costs which might hinder households with low socioeconomic status from having a smart meter installed. Consequently, the following question is posed:

To which extent does socioeconomic status influence the intention to voluntarily adopt smart meters in German households?

Testing the relationship between socioeconomic status and psychological variables defined by the theory of planned behaviour contributes to the literature by adding more knowledge about the relationship between theory-external factors, in this study specifically the socioeconomic status and psychological factors shaping the intention to a behaviour.
Furthermore, this study adds to the existing body of knowledge about sustainable behaviour by addressing the existing knowledge gap in the adoption of sustainable technologies in households by non-homeowners. The factors influencing the intention to employ sustainable technologies in households have mostly been investigated concerning technologies requiring extensive modifications. Given a lack of possibilities to take such decisions regarding one's living space as a non-homeowner, the possibility of using sustainable technology in households remains limited. The study advances into this subject area by delving deeper into a technology that can also be employed by non-homeowners.

In the following chapter, the theory of planned behaviour is described. Deriving from this theory and findings in the literature, hypotheses are developed. Then, in the chapter on research methodology the data-collection procedure, the sample of respondents, the questionnaire construction, and the items used to measure the theoretical constructs are discussed. In the subsequent analyses chapter, the results of the statistical analyses are presented to test the formulated hypotheses. Finally, in the concluding chapter, the results are summarised and the implications and limitations of the study are discussed.

2. Theory

2.1 Literature on smart meter adoption

In this section, the literature on smart meter adoption is discussed. Previous studies on the adoption of smart meters by households typically draw on the theory of planned behaviour, technology acceptance models or the more specific sustainable energy technology acceptance model. These theoretical models show similarities in the determinants hypothesised to influence the adoption of smart meters. Also, extensions for each of the theories are developed. Consequently, a variety of factors and their relationship to the intention and behaviour of adopting smart meters have been studied.
However, the results of the studies differ. For instance, a study investigating the direct and indirect mediating effects of the perception of the smart metering technology on adoption intention (Chen, Xu & Arpan, 2017) has shown that perceived usefulness and perceived costs have a significant effect in contrast to perceived privacy risks and prior electricity curtailment habits. Corroborating the finding that perceived usefulness predicts behavioural intention, Kranz and Picot (2012) however observe that this relationship is indirect. Instead, attitude is found to be the major determinant for predicting intention. Attitude itself is influenced by the antecedents of perceived usefulness, energy price consciousness, and perceived ease of use. No evidence is found for the hypothesised effect of perceived behavioural control on behavioural intention. This finding contradicts the results of another study (Shubaiber, 2018). Perceived control is identified as the main predictor of behavioural intention next to perceived enjoyment, sustainability and trust. Perceived cost is also tested as a possible determinant but does not have a significant influence. However, another study conducted by Shubaiber & Adam (2022) observes that the perceived costs do significantly predict the intention to adopt smart meters. Other predictors shown to be significant are awareness of smart meters, perceived values and trust in the technology.

The differing results can be partly explained by the fact that the setting of the studies differs. According to Chou et al. (2015, 196), “perceptions, preferences, and values that affect the intention to adopt an innovation differ by country”. The factors influencing household adoption of technology differ according to the geographic, political and cultural background (Horis et al., 2013; Wunderlich, Veit & Sarker, 2019, 688). Therefore, in the following, studies conducted specifically in the German context are reviewed as it is the context of the current study. The majority of studies on the topic of the adoption of smart metering technology by private households are placed in a different setting and therefore investigate the adoption of smart meters in different jurisdictions and political contexts. Although most studies are situated in the European context, only few studies have been conducted specifically regarding the German context (Große-Kreul, 2022; Berger et al., 2022; Wunderlich,Veit & Sarker, 2019). Further studies (Kranz, Gallenkamp & Picot, 2011; Kranz & Picot, 2011; Balta-Ozkan, Boteler & Amerighi, 2014) were conducted, however at a time when different legis-

lation was applied for the installation of smart meters. Consequently, it can be stated that research on adoption of smart metering technology adoption in Germany is underdeveloped. Therefore, further research on this topic can offer new insights for the context of Germany.

2.2 Theory of planned behaviour

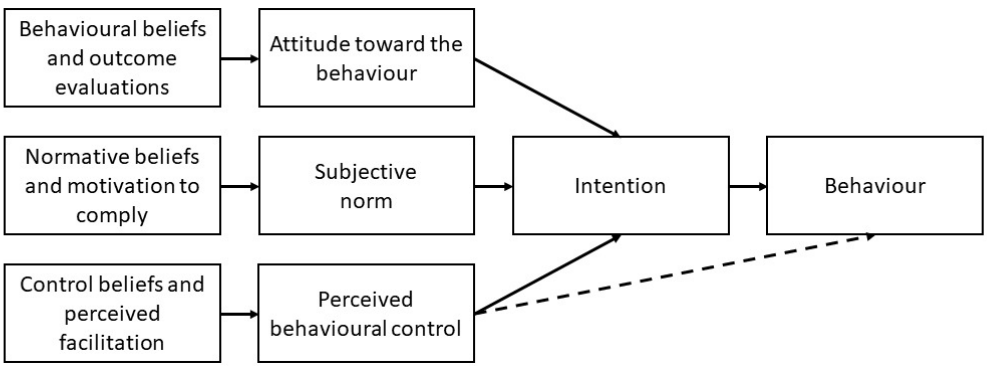
In accordance with previous research, the theory of planned behaviour is tested to investigate factors influencing the intention of German households to adopt smart meters. The theory of planned behaviour is one of the most commonly used psychological theories. It offers an explanation and prediction of human behaviour outlining human behaviour as goal-directed (Ajzen, 1985, 11). The condition for humans to act out a certain behaviour is the intention to do so. The theory postulates three factors determining the behaviour intention: attitude towards a behaviour, subjective norm and perceived behavioural control (Bosnjak, Aizen & Schmidt, 2020, 353). Attitude refers to the "degree to which the person has a favourable or unfavourable evaluation of the behaviour in question" (Ajzen, 1989, 251). The second factor, subjective norm, refers to the social pressure a person perceives in whether to perform the behaviour in question. Thirdly, perceived behavioural control refers to the perceived difficulty of performing the behaviour in question.

Respectively, these factors are underlined by considerations about the person's behavioural beliefs, normative beliefs and control beliefs. Behavioural beliefs refer to the considerations about the likely consequences of a behaviour, so-called outcome evaluations. Normative beliefs refer to evaluations of the normative expectations of the social milieu. This includes considerations about the approval of the social milieu and the degree of influence of the social milieu on the individual (Botetzagias, Dima & Malesios, 2015, 59) as well as the motivation to comply (Ajzen, 1989, 252). The third type of consideration is control beliefs and the perceived facilitation or inhibition. These refer to consideration about the ability to perform a certain behaviour. Also, past experiences and possible obstacles are reflected in control beliefs.

Figure 1 depicts the theoretical concepts and their relations.

Figure 1

Theory of planned behaviour



Adapted from Attitude Structure and Behaviour, by I. Ajzen, 1989, 252.

The intention to exercise the behaviour in question becomes more probable the more the attitude toward the behaviour and the subjective norms correspond with the potential behaviour and the greater the extent of perceived behavioural control (Ajzen, 1989, 251). In the following, the intention of the behaviour 'adoption of smart meter' will be investigated.

The variable attitude refers to the favourable or unfavourable judgment about the adoption of smart meters. The findings regarding the relationship between attitude and the behavioural intention to install a smart meter indicate a positive relationship. For instance, attitude has been shown to be positively correlated to the intention to check the possibility of having a smart meter installed (Kowalska-Pyzalska & Byrka, 2019). Other studies indicate that attitude is not only a predictor of interest in smart meters but also of adoption intention (Kranz & Picot, 2012; Idoko et al., 2021, Yang, Lee & Zo, 2017; Wunderlich, Veit & Sarker, 2019; Chawla, Kowalska-Pyzalska & Widayat, 2019; Kranz, Gallenkamp & Picot, 2010). Therefore, following the findings of previous studies, the following hypothesis is developed:

H1: A favourable attitude towards smart meters positively influences the intention to adopt smart meters.

The variable subjective norm comprises the perceived social pressures in whether to perform a certain behaviour; here the adoption of a smart meter. It has been confirmed to be a positive statistically significant predictor (Guerreiro et al., 2015, 1156). Even under the specific condition that one has to pay for the installation of a smart meter, it has been shown that social influences significantly affect this decision (Chawla & Kowalska-Pyzalska, 2019, 16). Positive preferences of peers towards the installation of smart meters and their support is essential in developing the willingness to install a smart meter. Consequently, it is hypothesised that perceived social pressures increase the intention to adopt smart meters.

H2: Favourable subjective norms towards smart meters positively influence the intention to adopt smart meters.

The factor of perceived behavioural control refers to the perceived difficulty or ease of performing the behaviour of adopting smart meters. Residential consumers with the self-perceived capacity to install smart meters are more willing to learn about the smart metering technology, install it and use it regularly (Kowalska-Pyzalska & Byrka, 2019). Therefore, it is hypothesised that the higher one's subjectively perceived level of control, the greater the intention to adopt smart meters.

H3: A higher perceived behavioural control over the choice of adopting smart meters positively influences the intention to adopt this technology.

It must be kept in mind that the three described factors determine the intention preceding the actual behaviour and not the actual behaviour as such. It is expected that people act according to their intentions given the opportunity (Bosnjak, Aizen & Schmidt, 2020, 353). The actual behaviour only emerges from the intention under the assumption of a sufficient degree of actual behavioural control. However, apart from one's intention, other non-motivational theory-external factors can also influence the actual behaviour. These factors may be the availability of resources such as time and money, the opportunity to act upon the intention or more generally economic, environmental and cultural influences (Ajzen, 1989, 251).
Theory-external factors not only influence the actual behaviour but also the behavioural intention (Ajzen & Fishbein, 1980). This is theorised to occur indirectly as the effect is moderated through the psychological variables. As Stern et al. (1999, 83) have stated regarding the influence on the actual behaviour and behavioural intention, "capabilities and constraints determine the efficacy, real and perceived, of an individual's taking particular actions". Therefore, in this study, additionally to the psychological variables, the effect of the variable socioeconomic status on the intention to adopt smart meters is examined. Socioeconomic status is chosen specifically as it, depending on the chosen operationalisation, encompasses different aspects which determine one's capabilities and constraints. In this study, income, education and occupational status are used to measure socioeconomic status.

Firstly, the direct effect of socioeconomic status on the intention to adopt smart meters is examined. It is argued that in addition to the psychological variables defined by the theory of planned behaviour, the intention to adopt smart meters may also be related to the real constraints and opportunities posed and offered by socioeconomic circumstances. Therefore, it is necessary to test the effects of both psychological and socioeconomic factors on behavioural intention. It is hypothesised that the relation between socioeconomic status and the intention to adopt smart meters is positive, meaning that a higher socioeconomic status leads to a stronger intention. This hypothesis is based on the literature on pro-environmentalism which has established an association between socioeconomic status and pro-environmental behaviour (Grandin et al., 2022, 2). As many pro-environmental technologies entail higher expenditures and require the investment of financial resources, the capacities in this regard influence or even determine the decision of whether to adopt environmentally beneficial technologies. Considering that the installation of smart meters causes additional costs, which are even higher in the case of a voluntary installation, it is assumed that households with a lower socioeconomic status develop a lower intention of adopting smart meters compared to households with a higher socioeconomic status due to the different availability of resources. This is supported by findings that higher incomes are more likely to decide in favour of the installation of smart meters (Chawla & Kowalska-Pyzalska, 2019, 18). Thus, the following hypothesis is proposed:

H4: Having a higher socioeconomic status positively influences the intention to adopt smart meters.

Secondly, the effect of theory-external factors being mediated through the psychological variables, the so-called sufficiency assumption, is further examined. The role of the variable socioeconomic status as a moderator of the effects of the psychological constructs attitude, subjective norms and perceived behavioural control on the intention to adopt smart meters is tested. More specifically, it is argued that a higher socioeconomic status strengthens the effect of attitude and weakens the effect of subjective norms and perceived behavioural control.

The hypothesised strengthening effect of a higher socioeconomic status on the effect of attitude is based on findings that favourable attitudes towards the installation of smart meters have a stronger effect on the intention for high-income households compared to low-income households (Chawla, Kowalska-Pyzalska & Widayat, 2019, 18). Applying this finding about income to the socioeconomic status in generating the hypothesis, presupposes that the effect of income is similar to the effect of a variable encompassing other socioeconomic factors such as education or occupational status as these variables frequently correlate. For instance, a positive relationship between attitude towards the adoption of smart meters and education has been recognised. The reason lies in the fact that "higher education reduces the costs associated with information acquisition". In other words, higher education enables one to appreciate the features of new technology more easily (Wunderlich, Veit & Sarker, 2019, 679).

H5: Having a higher socioeconomic status strengthens the effect of attitude on the intention of adopting smart meters.

Regarding the moderating influence of socioeconomic status on the effect of subjective norms on the intention to adopt smart meters, it is argued that this relationship is weakened by a higher socioeconomic status. This hypothesis builds on findings that a higher income reduces the likelihood of being influenced by social recommendations in the decision of adopting the technology of smart meters (Chawla, Kowalska-Pyzalska & Widayat, 2019, 18). Vice versa, when individuals have a lower ability to exercise a certain behaviour, which is argued to be the case with a lower socioeconomic status regarding the installation of costly technology, the expectations of one's social environment are more important than when an individual has a higher ability to exercise a certain behaviour (La Barbera & Ajzen, 2020).

H6: Having a higher socioeconomic status weakens the effect of subjective norms on the intention of adopting smart meters.

The reasoning behind the hypothesis that a higher socioeconomic status negatively influences the effect of perceived behavioural control on the intention to adopt a smart meter is that socioeconomic status determines one's available capacities and resources. It is assumed that with a low income, the resources necessary for the installation of a smart meter influence this decision negatively. However, with a high income, the need to take one's available

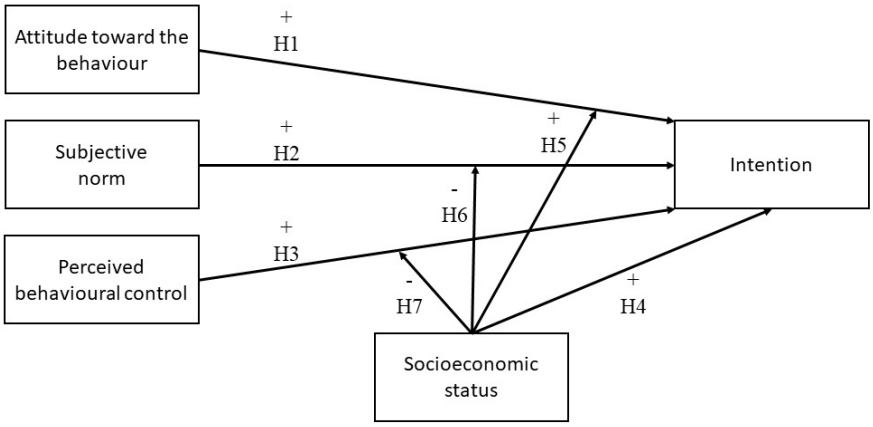
resources into account in the decision for or against the installation of a smart meter is less important as individuals can “focus on less immediate needs” (Wunderlich, Veit & Sarker, 2019, 679). If the necessary resources are given, their consideration might be less dominant in the decision-making process. The consideration of available resources and the perceived possibility of being able to install a smart meter are summarised in the variable perceived behavioural control. The effect of the perceived behavioural control is hypothesised to be different according to socioeconomic status.

H7: Having a higher socioeconomic status weakens the effect of perceived behavioural control on the intention of adopting smart meters.

The seven hypotheses are depicted in figure 2.

Figure 2

Depiction of hypotheses



3. Research method

The research question to be answered is explanatory, namely to which extent the factors as specified by the theory of planned behaviour influence the intention to adopt smart meters in German households. To answer this question, a quantitative research design is employed. It is best suited because it offers the possibility to test the strength of the relations between variables which have been theoretically established. Furthermore, since the theory of planned behaviour has already been discussed in depth and applied in various (extended) versions to a broad spectrum of topics, an exploratory approach is not appropriate. Testing the relations between the psychological variables and the additional variable of socioeconomic status regarding the use of smart meters adds new detail to an already widely discussed theory. To this end, linear multiple regression analysis will be conducted.

3.1 Data collection procedure

The method of data collection is an online survey. The cross-sectional research design entails that all variables are measured at the same time. The data is collected as a joint effort together with two other students who investigate the influence of factors on the intention to adopt other sustainable technology, namely green heating systems and photovoltaic systems. However, respondents are asked to only fill out the questions on two topics to reduce the burden in terms of time needed to complete the questionnaire. Also, the data is collected in a joint survey but the statistical analysis is performed separately accordingly to the individual research topic. An online survey is considered the best choice because respondents can access and perform the survey easily. The time approximately needed to complete the survey is five to fifteen minutes. It is conducted in German in accordance with the setting of this study. The period in which the data was collected lasted from December 14, 2022, until January 15, 2023. The homeowner association Haus & Grund and its regional and local sub organisations were contacted via email requesting them to spread the survey among their members. However, no responses were collected in this way. Data was also collected via snowball sampling among friends and family members. To be able to identify the source of the responses, the contact persons at the homeowner associations and personal contacts were given different links to the questionnaire. The research participants are individuals who are selected via a voluntary-response sample. The selection criteria are a minimum age of at least 18 years and, specifically for this study, that no smart meter has already been installed and no legal obligation applies to have them installed.

3.2 Questionnaire construction

The questionnaire is constructed as described in the following.

First, respondents will be presented with an introduction to the study including information on the aim of the research, the further procedure, voluntariness of participation and the possibility of withdrawing, contact options, potential risks and burdens of participation as well as data protection regulations. Furthermore, informed consent is given by clicking on the corresponding box.

Then, three questions are posed regarding the living situation of respondents eg. whether they live for rent or in their property to be able to investigate possible differences between homeowners and non-homeowners. As it cannot be assumed that every participant has sufficient information on the smart metering technology, basic information is given before answering a block of questions in the form of a short text.

A set of questions is asked respectively regarding the intention to install sustainable heating systems and photovoltaic systems. The item addressing whether respondents already have a smart meter installed serves as a filter question. If this is the case, the respondents will not be integrated into the research. The same is the case if respondents answer that they are obliged

to have a smart meter installed. Next, a set of questions is asked dedicated to the intention of having a smart meter installed.
The last part of the survey contains items regarding respondents' sociodemographic data. These serve as control variables for the other two students and will provide the information to measure the variable of socioeconomic status for this study. No personal information which may be used to identify the respondents will be asked or saved such as names, place of residence, IP or email addresses.

3.3 Operationalisation of the variables

In the following, the operationalisation of the variables is discussed in more detail.
The psychological constructs of attitude, subjective norms, perceived behavioural control and behavioural intention are measured with a catalogue of close-ended items. Each is measured with several items on a six-point Likert scale ranging between strong disagreement (1) and strong agreement (6). Following the argumentation by Nemoto & Beglar (2014, 5), an even-scaled force-number Likert scale was chosen in contrast to an uneven-scaled one without a neutral category. It is suspected that since the technology of smart meters is still relatively unknown, participants might feel less secure regarding their own opinions and might therefore increasingly so select the neutral response option. To prevent this behaviour from skewing the results and forcing respondents to ponder, the option of six possible answers without a middle category was chosen. For instance, the dependent variable, the respondent's intention to adopt smart meters, is measured with the item 'I intend to have a smart electricity meter installed in my household over the next year'. The possible answers range from 'I strongly disagree' (1), to 'I strongly agree' (6).

The psychological attributes, except for behavioural intention, are measured with multiple items to average out measurement errors and to represent the complexity of the theoretical concepts more appropriately (Gliem & Gliem, 2003, 83). A more detailed overview of the items used to measure the variables attitude, subjective norms, perceived behavioural control and intention to behaviour is given in the Appendix (Table 1). To measure the variables attitude, subjective norms and perceived behavioural control, a new scale has to be constructed with the respective items. Regarding attitude, items Q312_2 to Q312_5 have to be reversed before conducting further analyses. The items Q312_1_inverse (A smart electricity meter would be useful for me) and Q311_1 (The installation of a smart electricity meter is unnecessary) were initially also measured but are not included in the scale as they do not measure a specific dimension of attitude towards smart meters, thereby not offering added value in terms of content. The type of scale chosen is a mean scale. The format of the Likert scale is maintained to ensure the descriptive statistics are easier to comprehend as the variables are measured with a different number of items.

Next, the construction of the variable socioeconomic status is described. The scale is created by combining items measuring net equivalent income, education and occupational status. Operationalisations only focusing on one dimension, eg. one's self-perceived status in society or income, fall short of the complexities of this topic. However, too extensive operationalisations constitute a disproportionate burden on the respondents. The approach combining income, education and occupational status was chosen as it satisfies both the interest in detailed and precise information as well as keeps the burden on respondents low. The operationalisation, measurement items and coding are based on Lampert et al. (2018), although slightly altered.

The level of education is measured with two items regarding the highest school qualification and the highest vocational qualification. The items are based on the CASMIN Educational Classification, short for Comparative Analysis of Social Mobility in Industrial Nations. It was developed as an instrument for internally comparing educational levels (Hoffmeyer-Zlotnik & Warner, 2012b, 155). Due to the differentiation between school and vocational education, it is suitable for the German context as operationalisations of education only considering the highest school-leaving qualification do not take into account that Germany's education system has a strong focus on apprenticeships (Hoffmeyer-Zlotnik & Warner, 2005, 225f.; Hoffmeyer-Zlotnik & Warner, 2012a, 95). The measured general and vocational education are ordered in a matrix assigning each combination a value between one and seven according to the wages earned on average with the corresponding educational qualification (Lampert et al., 2018, 117).

Although the original operationalisation by Lampert et al. (2018) does not include those still in school or vocational training, the latter responses were not discarded. In case a respondent answered that they were still in vocational training and no other qualification was indicated, this response was handled as if no vocational qualification has been achieved. The value is assigned according to the highest school-leaving qualification. However, respondents still going to school were not included in the analysis as it could not be ensured at which level they are studying. Those studying for their Abitur have already achieved qualifications but might not indicate so. This approach is further justified by the fact that none of the respondents reported still going to school. Also, the so-called 'duale Ausbildung' is not considered by Lampert et al. It is a combination of both an apprenticeship and a university degree. Therefore, the higher qualification, the university degree, is taken into regard in assigning a value.

Occupational status is based on two items measuring the dimensions 'general type of employment' and 'management or supervisory role'. Based on the International Socio-Economic Index of Occupational Status the points are distributed depending on the average wages and necessary qualifications (Lampert et al., 2018, 117). This approach was chosen in comparison to operationalisations measuring the occupational status in more depth with items regarding not only the general type of employment but more specifically the professional

status (eg. Lampert et al., 2012). The reason is that such operationalisation is deemed too demanding on the respondents posing the risk of them terminating the survey.

Income is measured with five items in total. The first one measures whether the respondents' households' total net monthly income is under 2500 Euro, between 2500 and 5000 Euro or over 5000 Euro. The household total net monthly income is the monthly income of all household members including parental allowance, child benefit after the deduction of taxes and social security contributions. The following three items measure the income in more detailed steps of 500 or 1000 Euro, depending on the level of income. Based on the given answer in the previous question, only one of these three items is shown. Finally, the fifth item measures the number of persons living in the respondents' households. The net equivalent income is then calculated by dividing the household's total net monthly income by the number of household members. Shortly, the net household income is calculated as the net income of the entire household divided by the number of household members.
However, as income is measured as an ordinal and not as a continuous variable, the difficulty arises as to how to divide the measured income category by the number of household members. To this end, in accordance with the procedure by Lampert et al. (2012) slightly deviating from the procedure undertaken by Lampert et al. in 2018, the mean value of a category is taken for this equation. This approach offers less detail and bears a greater risk for inaccuracies compared to measuring income as a continuous variable by letting respondents report their income as a number. However, the approach of measuring income as an ordinal variable by providing pre-formulated categories as an answer option instead of an open-ended version is chosen to lower respondents' unwillingness to answer this sensitive question. Also, for this reason, one filter question with three following items of which only one respectively is shown to the respondent, is chosen as the approach to keep the questionnaire concise and to not overwhelm respondents with a vast array of possible response categories. The items have to be compiled in a new variable, total household income.

Then, following the operationalisation and coding by Lampert et al. (2018), the different values of the variables education, occupational status and net equivalent income are assigned points between one and seven. A more detailed overview of the indicators and the assigned points is provided in the appendix (Table 2). The final variable socioeconomic status is constructed as a sum score by adding these. Therefore, the variable can have a value between three and 21.

3.4 Sample

The questionnaire has been filled out by 108 respondents. However, only those who have filled out the part on smart meters are considered. Therefore, the sample consists of 51 respondents. The majority of respondents are male (54.9%) compared to female respondents who are less represented in the sample (39.2%). The remaining (5.9%) did not respond to the

question. None reported being non-binary. Regarding age, the responses range between 22 and 76. The average age of respondents is 47.09 years (SD = 15.41). The majority of respondents are homeowners (56.9%) compared to non-homeowners (43.1%).

3.5 Descriptive statistics

In the following, the descriptive statistics on the measured variables are presented. Table 1 presents the descriptive statistics for the independent and dependent variables. The psychological variables are measured on a scale from 1 to 6. The variable socioeconomic status is measured on a scale from 3 to 21. Therefore, the range of values is higher.

Table 1

Descriptive statistics for independent and dependent variables

Variable	N	Min	Max	Mean	SD
Intention	47	1.00	5.00	2.40	1.28
Attitude	49	1.10	6.00	3.96	1.02
Subjective norms scale	47	1.00	4.83	2.15	1.09
Perceived Behavioural Control	47	1.00	6.00	3.56	1.30
Socioeconomic status	35	9.00	20.10	15.13	3.31

4. Analyses

In the following, to explore the determinants of the intention to install a smart meter, the results of the statistical analyses are presented. All calculations are performed with the SPSS statistical program.

4.1 Internal consistency of the scales and multicollinearity

The internal consistency of the scales is discussed. To this end, the alpha coefficient is measured. It indicates the "extent to which all the items in a test measure the same concept or construct" (Tavakol & Dennick, 2011), in other words, whether responses are consistent between different items of a scale. The alpha coefficient is expressed with a value between 0 and positive or negative 1. Great internal consistency of the items in the scale is indicated by a value close to 1.0 (Gliem & Gliem, 2003, 87). Generally, as a rule of thumb, a coefficient above 0.7 is regarded as good and a coefficient above 0.8 as very good (Taber, 2017, 1278). However, an alpha coefficient above 0.9 might not be desirable. The alpha coefficient of a

long, multidimensional scale might be caused by the large number of items used for measuring a single construct (Streiner, 2003, 102). Also, an alpha coefficient above 0.9 can indicate redundancy or construct underrepresentation by measuring the theoretical construct too narrowly with items that are heavily correlated (Taber, 2017, 1288; Streiner, 2003, 102).

Table 2

Alpha coefficient for scales measuring psychological variables

Variable	No. of items	Cronbach's Alpha
Attitude	10	.901
Subjective norms	6	.906
Perceived Behavioural Control	3	.841

As depicted in table 2, the alpha coefficient for the scale measuring the variable attitude amounts to 0.901 which is slightly over but still close enough to the value of 0.9 to not cause concern. The alpha coefficient for the scale measuring the variable subjective norms amounts to 0.906 and the alpha coefficient for the scale measuring the variable perceived behavioural control is 0.841. All values reflect a high internal consistency but the values are not too high to cause concerns about redundancies or the use of too heavily correlated items.

Before conducting regression analysis, the data has to be tested for multicollinearity. A prerequisite for conducting a regression analysis with multiple independent variables is that these predictors do not highly correlate. Otherwise, when included simultaneously in a regression model, it is not possible to specify the respective proportions of the individual independent variables in determining the variance of the dependent variable (Fromm, 2010, 89, 98). Furthermore, multicollinearity can cause biased standard errors and unreliable p-values, thereby impeding accurate interpretation (Vatcheva et al., 2016; Rudolf & Müller, 2004, 45).

The independent variables are examined for possible correlations. Table 3 depicts the results for Pearson's correlation coefficient. These can range from 0 to either positive or negative 1. The closer the value is to 1, the stronger the correlation. The threshold of .8 is commonly used as a cut-off value above which problematic pairwise correlation is indicated. A stricter alternative is the use of .5 as a cut-off value (Vatcheva et al., 2016). The results show that the variable subjective norms correlates significantly with both attitude and perceived behavioural control. Furthermore, attitude also correlates with socioeconomic status. The correlation coefficients are under both proposed thresholds.

Table 3

Pearson correlation among independent variables and behavioural intention

Variable	1	2	3	4	5
1. Attitude	-				
2. Subjective norms	.328* (47)	-			
3. Perceived behavioural control	.149 (47)	.418** (45)	-		
4. Socioeconomic status	.356* (34)	.103 (32)	.326 (34)	-	
5. Intention	.313* (47)	.795** (45)	.479** (47)	.256 (34)	-

Note. * p < .05; ** p < .01; *** p < .001 (two-tailed).
N is given in parentheses.

The dependent variable intention displays a significant correlation with all psychological variables attitude, subjective norms and perceived behavioural control. Especially the correlation with the variable subjective norms is strong and highly significant. In contrast, no significant correlation exists with socioeconomic status.

Although all values are below the threshold and therefore no problematic correlation is visible, this test is not enough to detect and rule out multicollinearity (Berry & Feldman, 1985, 42). Therefore, also the variance inflation factor (VIF) and tolerance values are evaluated to check for multicollinearity. The results are summarised in table 4.

Regarding the variance inflation factor, no universal rule exists as to which threshold is most suitable. The proposed thresholds for detecting multicollinearity range from a VIF above 10, above 5, or even 2.5 being problematic (Jonston, Jones & Manley, 2018, 1958f.). Considering that the sample is comparatively small with only 51 respondents, out of which the socioeconomic status could be calculated for only 35 respondents, and multicollinearity causes more problems for smaller than for larger samples (de Jongh et al., 2015), a conservative approach is chosen. Due to the fact that the VIF values range between and 1.27 and 1.32 and are therefore all under the threshold of 2.5, one cannot conclude a problem with multicollinearity.

Also evaluating the VIF in relation to the overall fit of the model, revealed no indication of multicollinearity. A VIF value larger than the ratio of 1/(1-R2) indicates that the “correlation between the predictors is stronger than the regression relationship” (Vatcheva et al., 2016). However, this is not the case (VIF < 3.937).

The reciprocal of the VIF is the tolerance value. Commonly used thresholds are below 0.1 (Hair, Black & Babin, 2010), or when applying a more conservative approach 0.4 (Allison, 1998), below which multicollinearity is indicated as problematic. The results show that the

tolerance values range between .758 and .789 and are therefore significantly above the threshold. Consequently, no indication of multicollinearity can be found.
Altogether, after checking the internal consistency of the scales and the independent variables for collinearity, it can be concluded that no problems are to be detected and further statistical analysis can be conducted.

Table 4

Collinearity statisticsa

Variable	Collinearity Statistics	
	Tolerance	VIF
Attitude	.789	1.268
Subjective Norms	.773	1.294
Perceived Behavioural Control	.758	1.320
Socioeconomic Status	.782	1.280

a Dependent Variable: Intention

4.2 Hypotheses testing

Multiple linear regression models are tested to explore the predictors of the intention to adopt smart meters and investigate a possible moderating effect of socioeconomic status. This type of regression analysis is performed in case the independent and dependent variables are scale-level variables. It can also be conducted with ordinal-level variables if the response categories of the scale measuring the dependent variable can be ordered and can therefore be given an additional numerical attribution (Bugden & Stegeman, 2018, 141). Linear regression was chosen instead of ordinal logistic regression due to its comprehensibility (Gelhan & Hill, 2007, 119). However, when conducting linear regression analysis with a dependent variable that is operationalised as an ordered, categorical variable measured with a Likert scale and not as an interval-level variable, one cannot conclude the distances between the different categories of the dependent variable. This does not pose a problem for the interpretation of the results in this study as the distance between the categories is not relevant for testing the hypotheses. Instead, only the existence and direction of a relationship shall be investigated.

A regression analysis was conducted to evaluate the prediction quality of the variables attitude, subjective norms, perceived behavioural control and socioeconomic status on the dependent variable behavioural intention. The results are summarised in table 5. The overall regression was statistically significant ($R^2 = .746$, $F(4, 27) = 19.856$, $p < .001$). The variables explain 74.6% of the variance in the dependent variable intention. However, of the proposed seven hypotheses, the results show that only one hypothesis is supported.

Table 5

Regression coefficients (N=35)a

Model		B	SE	β	t	Sig.
1	(Constant)	-.653	.702		-.930	.361
	Attitude	.013	.154	.009	.081	.936
	Subjective norms	.859	.121	.780	7.075	<.001***
	Perceived behavioural control	.104	.104	.111	.997	.328
	Socioeconomic status	.050	.041	.134	1.219	.233

aDependent variable: Intention
Note. * p < .05; ** p < .01; *** p < .001 (two-tailed).

The first hypothesis states that a favourable attitude towards smart meters, measured by a higher value on the attitude scale, positively influences the dependent variable intention to adopt smart meters. The analysis yielded a weak non-significant effect of attitude on intention. Therefore, the first hypothesis cannot be supported.

Next, the second hypothesis is tested according to which favourable subjective norms positively influence behavioural intention. The results show that the variable subjective norms significantly predicts the intention to adopt a smart meter. Also taking into regard that the coefficient is a positive value, it can be concluded that this hypothesis is supported by the results.

According to the third hypothesis, a higher perceived behavioural control positively influences behavioural intention to adopt a smart meter. However, due to the non-significant results of the regression analysis, this hypothesis has to be rejected.

Next, the effect of socioeconomic status on the intention to adopt smart meters is tested. The fourth hypothesis states that a higher socioeconomic status positively influences behavioural intention. This hypothesis is not supported by the results and must therefore be rejected.

Finally, the effect of socioeconomic status as a moderating variable on attitude, subjective norms and perceived behavioural control are tested. Higher socioeconomic status is hypothesised to strengthen the effect of attitude (H5) and weaken the effect of subjective norms (H6) and perceived behavioural control (H7) on the intention to adopt smart meters. Three requirements have to be met in order to prove an interaction effect. Only if all three conditions are met, can a moderation effect be proven.

Firstly, a significant effect of the predictors attitude, subjective norms and perceived behavioural control on the dependent variable needs to be indicated by the regression coefficients. Only the variable subjective norms can be proven to have a significant effect and therefore only a moderating influence of socioeconomic status on the effect of this variable is plausible. Secondly, an interaction effect is indicated by a higher coefficient of determination when including the interaction term in the regression model in comparison to a model without the interaction term. If no significant difference can be observed, a moderating effect cannot be proven. The results show that for the second model, a statistically significant increase in R^2 cannot be seen. The explained variance increases by .025 but this change is not statistically significant ($p = .475$). The adjusted R^2 which accounts for the number of variables included in the regression model even slightly decreases from .709 to .704. Therefore, it can be concluded that including the interaction terms in the regression model as new variables does not increase its explanatory power. Thirdly, for completeness, an interaction term for each of the three variables is generated. To this end, three new variables are created by multiplying socioeconomic status with the variables attitude, subjective norms and perceived behavioural control respectively. These interaction terms are added to the regression analysis. Results signalling a significant effect of the interaction term are considered an indication of a moderating effect (Chou & Yutami, 2014, 346). The results of the regression analysis including the interaction terms are listed in table 6.

Table 6

Regression coefficients for model including interaction terms (N=35)a

Model		B	SE	β	t	Sig.
2	(Constant)	.796	3.721		.214	.832
	Attitude	-.511	.851	-.362	-.601	.554
	Subjective norms	1.864	.651	1.693	2.862	.009**
	Perceived behavioural control	-.394	.498	-.421	-.791	.436
	Socioeconomic status	-.027	.235	-.073	-.116	.908
	Attitude interaction	.027	.053	.505	.513	.613
	Subjective norms interaction	-.066	.042	-1.068	-1.586	.126
	Perceived behavioural control interaction	.035	.035	.729	1.012	.322

aDependent variable: Intention
Note.* $p < .05$; ** $p < .01$; *** $p < .001$ (two-tailed).

The fifth hypothesis states that a higher socioeconomic status strengthens the effect of attitude on behavioural intention. Due to non-significant results of the regression analysis, this hypothesis cannot be proven.

According to the sixth hypothesis, higher socioeconomic status weakens the effect of subjective norms on the intention of adopting a smart meter, in other words, has a negative effect on the relation between subjective norms and behavioural intention. The interaction term is non-significant. Considering that the hypothesis states a negative directional effect which is reflected in the negative β coefficient of -1.068, a one-tailed significance level can be calculated by dividing this value by half. It is worth mentioning that the significance level is close to the threshold of .05 (0.063). The hypothesis is not supported by the results.

Finally, an interaction effect of socioeconomic status on the relation between perceived behavioural control on the intention of adopting smart meters is tested. The seventh hypothesis states that a higher socioeconomic status weakens the predictive strength of perceived behavioural control on behavioural intention. However, this hypothesis is not supported by the results as these are non-significant. The hypothesis must therefor be rejected.

Consequently, only the second hypothesis can be proven. The variable subjective norms has a significant positive effect on the dependent variable intention. The other hypotheses have to be rejected. Regarding the variables attitude, perceived behavioural control and socioeconomic status no significant direct effect can be proven. Also, an interaction effect of socioeconomic status on the prediction quality of attitude, subjective norms and perceived behavioural control respectively on intention cannot be proven.

5. Conclusion

5.1 Results

The objective of this study was to investigate factors influencing the intention to adopt smart meters in German households. For this purpose, the theory of planned behaviour was tested. Furthermore, a possible direct and indirect moderating effect of the socioeconomic status was investigated. The main finding is that only the variable subjective norms has been proven to have a direct effect on the dependent variable behavioural intention whereas for the variables attitude and perceived behavioural control, no significant effect could be confirmed. Neither a direct effect of socioeconomic status on behavioural intention nor an indirect moderating influence on the effect of the variables attitude, subjective norms or perceived behavioural control on intention can be proven due to the fact that the change in the explanatory power of the model as well as the regression coefficients of the interaction terms are non-significant.

The results of this study are surprising as only one variable has been proven to have a direct effect on intention. Therefore, the results are not entirely consistent with previous research on the theory of planned behaviour due to the fact that no significant effect of attitude or perceived behavioural control could be proven. In other studies, attitude (Kranz & Picot, 2012, 5) and perceived behavioural control (Idoko et al., 2021, 12; Yang, Lee & Zo, 2017, 80) did have a significant effect on behavioural intention. The lack of an effect of attitude may be grounded in the fact that the respondents do not have a smart meter installed and therefore have not had enough contact to develop a "clearly favourable or unfavourable position" (Guerreiro et al., 2015, 1157). Also in few other studies, perceived behavioural control did not have a significant effect on intention (Kranz & Picot, 2012, 5; Arya & Chaturvedi, 2020, 524). A possible explanation for the results in this study might be a discrepancy between the perceived control over the behaviour in question and the actual control (Arya & Chaturvedi, 2020). For instance, tenants might perceive their control over the decision to install a smart meter as limited due to the fact that it is unclear that this decision is not exclusive to the landlord (Balta-Ozkan et al., 2014, 73f.). Another possible explanation for the results in this study is the small sample size. As reflected in large confidence intervals, the results are influenced by uncertainties regarding the direction and size of the effect of the variables.

The finding of a strong effect of subjective norms is in line with previous research on predictors influencing the intention to adopt smart meters (Yang, Lee & Zo, 2017, 80; Arya & Chaturvedi, 2020, 524; Idoko et al., 2021; Gumz et al., 2021; Chawla & Kowalska-Pyzalska, 2019, 18; Guerreiro et al., 2015, 1157). The results suggest that the influence from one's social environment is influential in whether someone wants to install a smart meter.

The finding that no direct effect of socioeconomic status on intention could be proven is surprising as the results of prior studies have tended to indicate otherwise. For instance, households with a higher income have been shown to be more likely to decide in favour of installing smart meters (Chawla & Kowalska-Pyzalska, 2019, 18). However, income only forms one-third of the scale on which socioeconomic status is measured. Also, in this study, no significant correlation between socioeconomic status and intention was found.
A moderating influence of socioeconomic status on the relationships of the psychological predictors on the intention to adopt a smart meter was expected. However, no evidence for the hypotheses H5 to H7 could be found. This is surprising considering a positive relationship between income or education and attitude has been found in previous studies (Chawla, Kowalska-Pyzalska & Widayat, 2019, 18; Wunderlich, Veit & Sarker, 2019, 679) which is confirmed in this study with a significant correlation between attitude and socioeconomic status. However, it does not translate in a moderating influence of socioeconomic status on the effect of attitude. Due to the fact that the requirements for proving an interaction effect are not met, the results also do not indicate a moderating effect of socioeconomic status on

the relationship between subjective norms or perceived behavioural control and the intention to adopt a smart meter.

Consequently, the following answer to the central research question, to which extent the factors as specified by the theory of planned behaviour influences the intention to adopt smart meters in their households, can be formulated. Only the positive influence of subjective norms on the intention to adopt smart meters could be proven in this study. The variables attitude and perceived behavioural control displayed a non-significant effect.
Regarding the sub-question, to which extent socioeconomic status influences the intention to adopt smart meters in households, it can be summarised that no direct effect on intention could be proven. Also, the results do not indicate a moderating effect of socioeconomic status on the effect of attitude, subjective norms and perceived behavioural control on intention.

5.2 Discussion

In the following, the limitations and implications of the study are discussed.
The external validity and generalisability of the results are negatively influenced by the fact that the response sample is small. The questionnaire has been filled out by 108 respondents. However, not all respondents were asked to fill out every block but only two out of three to reduce the burden on respondents in terms of time needed to fill out the questionnaire. Also, two filter questions were asked to only include those who do not have a smart meter installed and might not be under an obligation to do so. Consequently, only 51 have filled out the block of items on smart meters. The sample is further limited by the fact that the socioeconomic status could only be calculated for 35 respondents.
To recruit respondents, the homeowner association Haus & Grund and its regional and local sub organisations were contacted. However, all respondents were recruited via snowball sampling among friends and relatives. Homeowners (56.9% in contrast to 43.1% non-homeowners) and men (54.9% in contrast to 39.2% women) are slightly overrepresented in the sample. However, the latter might be a consequence of asking to let the person who is most involved in decisions regarding home and energy technology fill out the survey. Still, the results of this study need to be dealt with carefully and not considered representative of the population.

Also, the differentiation between the individual and household level which is not entirely consistent needs to be critically discussed. Income is operationalised as net equivalent household income, including the income of all household members divided by the number of household members. However, the other two variables used to construct the variable socioeconomic status, education and occupational status, are measured on the individual level. To address this problem, the respondents were asked at the beginning of the questionnaire to only let the person most involved in decisions regarding energy technology complete the survey. However, this cannot be checked. Still, this approach was considered the most ap-

propriate as the psychological variables are also measured on the individual level. Furthermore, the financial situation of the individual which was argued to influence the decision whether to adopt smart meters also depends on the income of other household members.

Finally, the fact that smart meters are not well-known has to be addressed. This constitutes another weakness of the research design. A short informational text on the technology of smart meters and its costs was provided before the questions about smart electricity meters but this does not substitute time to gather in-depth information and form a differentiated opinion. For instance, the text on the costs of smart meters depicts the average costs and mentions that these may be higher in the case of a voluntary installation but it is not feasible to give specific information regarding the costs for the respondent's individual situation. Depending on the amount, this might influence the respondent's answers. However, due to the limited scope of the questionnaire, only average costs could be given. Furthermore, tenants might be unsure regarding this subject because of perceived limitations regarding the installation of energy efficiency measures (Balta-Ozkan et al., 2014, 73f.). Such conversion work might be seen as the landlord's responsibility. Tenants may not know they can decide about the voluntary installation and therefore report a low intention of adopting a smart meter.

Based on the discussion of the results and the design of this study, following recommendations for further research are suggested.
In most studies, only the proxy of a certain behaviour is measured and not the behaviour as such. Therefore, a crucial part of the theory is not tested. Although the link between behavioural intention as proxy of a behaviour and the actual behaviour is established in the literature, if possible the actual behaviour of respondents should also be measured in order to develop more complete data (Noppers et al., 2016, 13; Kranz, Gallenkamp & Picot, 2010, 7). The limitation of studying the proxy intention and not the behaviour, is that respondents may claim to want to adopt sustainable technologies but may not act accordingly. Therefore, the behaviour should also be measured for a comprehensive study on the theory of planned behaviour as done by Alkawsi, Ali & Baashar (2021) in a cross-sectional study or by Kowalska-Pyzalska, Byrka & Serek (2020) in a longitudinal study with respondents already using smart meters. It is possible to conduct a survey focusing on respondents who have already implemented a smart meter voluntarily, their reasons for this decision and their experiences. These respondents were excluded from this study to only focus on the intention of those respondents who have not implemented a smart meter yet. Also, research could examine the individual difference factors between adopters and non-adopters (Noppers et al., 2016, 14) to reveal insights into factors influencing the behaviour of adopting a smart meter.
Furthermore, it is recommended to investigate Ajzen and Fishbein's sufficiency assumption. The effect of all theory-external influences is theorised to occur indirectly by being moderated through the psychological variables. However, in this study, no moderating influence of socioeconomic status on the relation between psychological predictors and intention could be proven. In further research it might be investigated whether the sufficiency assumption can

be confirmed and how the effect of theory-external variables can be integrated in the theoretical model. To better understand the effect of theory-external variables, it is not sufficient to only test sociodemographic and socioeconomic variables in a regression analysis. Profound qualitative research might offer insights into how the theory-external factors function. Consequently, it is recommended to conduct further research on the moderating effect of socioeconomic variables.

This study has contributed to knowledge on the effect of variables external to the theory of planned behaviour by testing socioeconomic status as both an independent and moderating variable on the relationship between attitude, subjective norms and perceived behavioural control on the intention to adopt smart meters. So far, research on sociodemographic and socioeconomic variables has focused on their direct effect on behavioural intention. In this study, the sufficiency assumption according to which their effect is moderated through the psychological variables has been tested but no supporting evidence could be found.

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Appendix

Table 1

Overview of items used to measure the psychological variables and socioeconomic status

Theoretical construct	No. of items	Items
Behavioural intention	1	I intend to have a smart electricity meter installed in my household over the next year (Q314_4).
Attitude	10	A smart electricity meter is a sound financial investment (Q311_2). I would like to have more detailed information about my electricity consumption (Q311_3). I would like to be able to check my electricity usage with an app (Q311_4). Better information about my energy use would help me save energy (Q311_5). The data measured with a smart electricity meter is secure (Q311_6). I would like to adjust my electricity consumption to a time-of-day rate (Q311_7). I am concerned about my data being transmitted via the internet (Q312_2). Smart electricity meters cause data protection problems (Q312_3). The additional cost of a smart electricity meter is not worth it (Q312_4). I am concerned about possible mismeasurement (Q312_5).
Subjective norms	6	Many people I care about think I should have a smart electricity meter installed (Q313_1). Many people in my surrounding would like it if I had a smart electricity meter installed (Q313_2). I am expected to have a smart electricity meter installed (Q313_3). I feel socially obligated to have a smart electricity meter installed (Q313_4). Many people I care about have a smart electricity meter installed (Q313_5). For people in my situation, it is common to install a smart electricity meter (Q313_6).
Perceived behavioural control	3	I am confident that I can have a smart electricity meter installed when I want (Q314_1). I see myself in a position to have a smart electricity meter installed (Q314_2). I have the resources, time and willingness to have a smart electricity meter installed (Q314_3).
Socioeconomic Status	2	What is the highest school qualification you have achieved (Q911)? What vocational qualification you have achieved (Q921)?
	2	What is your professional position in your main job (Q942)? Do you perform a management function, i.e. are you authorised to give instructions to employees who are not trainees (Q943)?
	5	What is your household's total net monthly income (Q951, Q952a, Q952b, Q952c)? How many people live permanently in your household, including yourself (Q953)?

Table 2

Overview of construction of the scale measuring socioeconomic status

Assigned points	Education		Occupational status		Net equivalent income
	school-leaving qualification	vocational qualification	type of employment	supervisory/ management role	
1	none	none	Farmer in main occupation		78 - 609€
1.5					610 - 821€
1.7	Haupt-/ Volksschule	none			
1.9			Worker	without	
2			Worker	without further specification	822 - 960€
2.5					961 - 1091€
2.7			Worker	management or supervisory role	
2.8	Realschule/ Mittlere Reife/ Mittlerer Schulabschluss/ Polytechnische Oberschule	none			
3	*No* graduation from Realschule/ Mittlere Reife/ Mittlerer Schulabschluss/ Polytechnische Oberschule	apprenticeship, beruflich-betriebliche Ausbildung			1092 - 1221€
3.5					1222 - 1344€
3.6	Realschule/ Mittlere Reife/ Mittlerer Schulab-schluss/ Polytechnische Oberschule	apprenticeship, beruflich-betriebliche Ausbildung			
3.7	Abitur, allgemeine/ fachgebundene Hochschulreife, Erweiterte Oberschule, Fachhochschulreife/ Fachoberschule	none			
4					1345 - 1454€

Assigned points	Education		Occupational status		Net equivalent income
	school-leaving qualification	vocational qualification	type of employment	supervisory/ management role	
4.4			Employee	without	
4.5					1455 - 1600€
4.7			Employee	without further specification	
4.8	Abitur, allg./ fachgebundene Hochschul-reife, Erweiterte Oberschule, Fachhochschulreife/ Fachoberschule	yes	Employee	supervisory role	
5					1601 - 1762€
5.1			Self-employed without employees		
5.5			Self-employed with employees		1763 - 1971€
6					1972 - 2260€
6.1	Graduation from Fachhochschule, Ingenieurschule		Employee	management role	
6.5					2261 - 2833€
7	Graduation from university or Hochschule		Civil servants		≥ 2834€

Adapted from *Messung des sozioökonomischen Status und des subjektiven sozialen Status in KiGGS Welle 2*, by T. Lampert et al., 2018, 131f.