Striving for Energy Autonomy? An Empirical Investigation of Homeowners' Drivers and Barriers to Participate in Community Energy Systems in Germany

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Abstract
Despite extensive political funding programs, the energy consumption in Germany for space heating and hot water stagnated on a high level of 870 TWh over the past few years and even exceeded the level of 2010. To reduce consumption and meeting the energy-efficiency goals set by the German federal government, an option for private homeowners is to participate in community energy systems (CES). However, homeowners' reluctance to join CES constitutes a major issue. Recent research has not provided deeper insights into reasons for this hesitation. Focusing primarily on local district heating systems, we use two theoretical approaches, motivation and attribution theory, to shed light on drivers and barriers in the decision-making process of homeowners. To gain insights, an explorative research design was chosen, and 22 problem-centered interviews were conducted with homeowners as well as experts.Our results show that subjectively perceived energy autonomy can be a barrier for private homeowners to participate in CES. Furthermore, we find a discrepancy between objective energy autonomy, as defined from a technical perspective, and homeowners' perception. Regarding this, the two major aspects shaping homeowners' perception of energy autonomy are (1) perceived independence from third parties as well as other external influences, and (2) a sense of control over the home energy system and its costs. Our study provides new insights into the decision-making process of homeowners to participate in CES. Additionally, we identified several implications in how far practitioners can address subjectively perceived energy autonomy issues to reduce inertia to join CES.

Keywords: Energy Autonomy, Community Energy Systems, District Heating, Private Homeowners, Decision-Making Process, Consumer Research

Introduction

Climate protection represents one of the main challenges of the 21st century. To reduce harmful carbon emissions, a restructuring of the German energy sector is required. Although considerable achievements have increased the share of renewable energies in the power supply sector, the transition to more energy saving in the heating sector lacks severely behind (Schubert, 2016). The energy consumption for space heating and hot water stagnated on a high level of 870 TWh over the past few years and even exceeded the level of 2010 (Dena, 2019). In this context, private households account for approximately two thirds of the total energy used in Germany. To reduce consumption and meet the energy-efficiency goals set by the German federal government (BMU, 2018), a need for sustainable heating solutions for communities and neighborhoods has emerged (Riechel, 2016).

By implementing cogeneration technologies (characterized by generating power and heat), decentralized solutions are capable of providing cross-sectoral energy supply to local communities. These so-called community energy systems (CES) do not only include production and distribution of energy but also consumption and prosumption (Koirala et al., 2018). In the specific context of heat supply for local communities, a shift from individual, fossil-fueled heating to district heating contributes to energy efficiency as well as sustainable energy supply (Werner, 2017; Lund, Möller, Mathiesen, & Dyrelund, 2010). Local district heating systems (in the following referred to as district heating) distribute heat from local energy sources through pre-insulated pipes for (space) heating and domestic hot water (preparation) in urban and rural neighborhoods (Frederiksen & Werner, 2013). To provide future communities with these viable heating services, an integration of (low temperature) heat sources is necessary, e.g. industrial waste heat or renewable heat such as solar thermal (Lund et al., 2014). Therefore, CES inevitably move closer to citizens (Local Energy Consulting, 2020).

However, residents' resistance and lack of willingness to participate in CES still constitute major challenges (Büscher & Sumpf, 2018; van Veelen & Haggett, 2016; Raven, Mourik, Feenstra, & Heiskanen, 2009). This is especially the case for district heating, as it requires a minimum number of consumers to operate profitably. In Germany, only 6.6% of the residential building stock is connected to district heating, with individual fossil-fueled heating like gas and oil still leading clearly (BDEW, 2019). In the literature approaches to explain the drivers and barriers are often derived from a sociological perspective, concentrating on community issues (Koirala et al., 2018; Li, Birmele, Schaich, & Konold, 2013) and applying theories on social movements (Bomberg & McEwen, 2012). Although these studies reveal several important drivers of residents' participation in CES, i.e. bottom-up planning processes (Young & Brans, 2017; Li et al., 2013; Allen, Sheate, & Diaz-Chavez, 2012) and community trust (Kalkbrenner & Roosen, 2016; Walker, Devine-Wright, Hunter, High, & Evans, 2010), the underlying reluctancy to connect to district heating has not been clarified in more detail so far.

Recent research focuses mainly on economic aspects and financial incentives to motivate homeowners to connect to district heating (Østergaard & Svendsen, 2019; Burlinson, Giulietti, & Battisti, 2018). Despite extensive political funding programs by the German federal government, the willingness to connect remains low, even though district heating can present a more cost-efficient and comfortable alternative for private homeowners. Therefore, the questions arise why private homeowners refuse to connect to district heating and how they can be activated to participate in CES.

As a possible explanation, we aim to investigate a rather unexplored construct in the context of CES, namely the concept of perceived energy autonomy. Derived from research in the field of residential heating systems, studies show that homeowners' preference for independence, e.g. from fossil fuels and energy suppliers, plays a significant role in the decision-making process, besides factors like costs and comfort (Karytsas & Theodoropoulou, 2014; Michelsen & Madlener, 2013). A study conducted by Koirala et al. (2018) shows that energy autonomy can also have a significant effect on citizens' willingness to participate in CES. In this instance, it is defined as the idea of being independent from a national grid and big energy suppliers. We refer to it as energy autonomy at a community level. Nonetheless, when it comes to individual homeowners' perception, we assume that autonomy may constitute a barrier for participation. Following two theoretical approaches, motivation and attribution theory, we aim to shed light on this construct and provide new insights in homeowners' decision-making to connect to district heating.

Conceptual Background

In the context of energy transition, the term autonomy is predominantly examined from a technical perspective (Gawali & Deshmukh, 2019; Fedak, Anweiler, Ulbrich, & Jarosz, 2017). Rae and Bradley defined energy autonomy as "the ability of an energy system to function fully without the need of external support" (Rae & Bradley, 2012, p. 6499). Yet most studies do not define the label autonomy clearly, so that it is often used synonymously with the term autarky (Deutschle et al., 2015). Regarding CES, degrees of autonomy can be calculated in order to estimate the coverage of local energy demands by local supply options (Rae & Bradley, 2012). In technical literature, there are traditional methods to determine a technology mix (e.g. on individual building-scale) that fulfils the autonomy demand, such as storage systems in order to bridge time gaps between (renewable) supply and consumption (Köthe, 1982). These multi-technology energy systems require large investments as well as space which is limited in urban areas. In general, self-sufficiency for single buildings is often neither technically expedient nor economically profitable (Bracke, Tomaschek, Brodecki, & Fahl, 2016). In addition, autonomy does not represent a main goal, particularly in CES when implementing improved (renewable) energy systems in neighborhoods (Protogeropoulos, Brinkworth, & Marschall, 1997). Nevertheless, several studies exist researching ways to develop completely energy-autonomous houses (Brosig & Waffenschmidt, 2016; Storch, Leukefeld, Fieback, & Gross, 2016) or (on a larger-scale) islands (Kaldellis, Gkikaki, Kaldelli, & Kapsali, 2012). Although being completely autonomous is a technical challenge and trying to be independent from common supply system can oftentimes be economically inefficient, a general propensity towards autonomy can be identified among homeowners (Bracke et al., 2016; Klein, 1983).

Motivational Perspective

In the context of energy saving investments, independence/autonomy is defined as a consumer motive that shapes private homeowners' decision-making to invest in energy saving measures (vom Hofe, Frensemeier, & Holzmüller, 2016; Jager, 2006). In studies analyzing homeowners' decision between different residential heating systems, it is described as homeowners' preference to be independent from fossil fuels, politically motivated supply crises and fluctuating energy prices (Michelsen & Madlener, 2013; Claudy, Michelsen, & O'Driscoll, 2011; Decker, Zapilko, & Menrad, 2010). Further investigations show that homeowners with a preference for being independent from fossil energy sources are more likely to choose an individual heating system, e.g. a heat pump (Karytsas & Theodoropoulou, 2014; Michelsen & Madlener, 2012). Considering different small-scale cogeneration technologies, independence is considered as a relative advantage increasing homeowners' willingness to pay for wood pellet boilers and solar panels. Homeowners believe that these heating systems will make them more independent from energy providers and their houses more self-sufficient, while also reducing the dependence on fossils like gas or oil (Claudy et al., 2011).

Another finding is that there seems to be a discrepancy between perceived and objectively existing energy autonomy. In a qualitative study examining private homeowners' motives to purchase photovoltaic, Sonnberger (2015) found out that homeowners acknowledge the misperception that the installation of solar panels fosters their independence. However, the "feeling" of being self-sufficient is deemed to be satisfying. Regarding this misperception of autonomy and its potential role as a barrier in the context of CES, we use a second theoretical approach to examine perceptual differences between subjective and objective autonomy.

Attributional perspective

Based on Heider (1958), attribution theory describes how individuals make sense as well as predict other peoples' behavior and events by attributing causes to them. The theory was expanded by Weiner (1985) who classified causal attributions according to three dimensions: (1) locus (internal vs. external), (2) stability (stable vs. variable), and (3) controllability (controllable vs. uncontrollable). In the cause of this investigation, we concentrate mainly on the locus and controllability dimensions. First established by Rotter (1966), the concept *locus of control* describes the degree to which a person perceives a certain event as a consequence of his own behavior or the result of external forces. Furthermore, individuals with an internal locus of control believe that their actions have an influence on their environment, and they can exert control over it (Weiner, 1985). If individuals tend to perceive themselves as controlled by external forces, they are less convinced to have certain degrees of freedom regarding their choices for action and would choose a lower level of action identification (Förster, 2014). Action identification is related to the same called theory by Vallacher and Wegner (2014), in which different levels of personal agency have been determined. According to these levels, one has to differentiate between high-level agents assigning their acts to larger meanings of action and low-level agents thinking of their acts in regard to details as wells as means of action (Vallacher & Wegner, 1989).

Although attribution theory was mostly used to investigate interpersonal relationships (human – human), recent studies began to apply this theoretical approach to examine non-interpersonal relationships (human – non-human), like human's adoption of technical systems (Alony, Hasan, & Paris, 2014). An application to CES and private homeowners' adoption of district heating, has – to the best of our knowledge – not been studied so far.

Methodology

Since the construct of subjectively perceived energy autonomy remains largely unexplored so far, we used an explorative research design to gain deeper understanding of the underlying structure of dimensions and factors of the construct (Homburg & Giering, 1996). Hence, qualitative techniques are deemed as suitable, since they provide information about individual attitudes and underlying motives (Misoch, 2015).

In a first step, problem-centered interviews (Witzel, 1982) with 14 homeowners were conducted. The number of interviews was determined according to the principle of theoretical saturation (Strauss, 1991). To gain different insights and ensure heterogeneity amongst the interviewees, purposive sampling was performed (Patton, 2009). Private homeowners were selected for interviews, who (1) live in an urban neighborhood and are/were already connected to district heating or (2) plan to replace/have already replaced their heating system within the future/last years. These two categories of interview partners are used to examine various aspects of energy autonomy with regard to different heating systems and decision-making situations. For the first category, we selected three urban neighborhoods in the Ruhr area in Western Germany. The interviewees were personally contacted. The examination area in terms of CES is of particular interest due to the influence of an extinct mining industry. Therefore, former collieries' houses still exist in this area with homeowners who are still using coal heating because they receive concessionary coal. Participants of the second category were acquired by posting in discussion groups on social media. The interviews were conducted personally or via telephone with an average duration of 37 minutes. The sample contained six female and nine male participants with an age variation between 37 and 69. A semi-standardized guideline was used (Hopf, 2010) and improved iteratively after each interview as well as slightly adjusted to the different circumstances.

In addition, eight semi-standardized interviews with experts were conducted. Interview partners we selected had long-term experience in customer service and operated in locations concerned with the implementation of heating systems. Interviews were carried out with energy consultants (who focused on heating systems), energy suppliers (with business projects concerning district heating), heating engineers, consultants for finance and business models for community energy projects and an architectural advisor. The average interview duration was 55 minutes.

Next, we recorded, transcribed, and analyzed all interviews using the commercial software tool MAXQDA. To interpret the findings, qualitative content analysis was applied (Mayring, 2015), and a category system was developed following inductive coding (Kuckartz, 2009). To meet high quality standards of qualitative research, several measures were taken. Credibility was increased by using multiple method triangulations (Flick, 2004). Interview material as well as the coding system was reviewed several times to fulfill intracoder-reliability (Mayring, 2015). A detailed description of the investigation process was used to ensure transferability.

Results

Subjective energy autonomy as a barrier to participate in CES

A major finding of our exploratory study is that subjective energy autonomy can be a reason for the failure of implementing CES. It can lead to homeowners' reluctance to connect to district heating, because they perceive it as becoming dependent, on e.g. neighbors, resulting in a loss of control over the energy system. Energy consultants and heating engineers named several examples of failed projects due to homeowners, perceiving CES as a less autonomous solution compared to their individual fossil-fueled heating. One of the interviewed homeowners described a family member, living in the same neighborhood, who refused to connect to district heating, although subsidies were provided: "I told him, listen to me, do it now, it is never going to be cheaper than now […] But no, I want to regulate the heating myself and all this stuff he has told me." Participants even spoke of the idea to become entirely autonomous by insulating their houses, deploying ground source heat pumps, and installing solar panels on the roof: "If a house is energetically self-sufficient, this is what I think is great. I think this would be a nice asset […] I would definitely pay a premium for it." The idea of being more autonomous can even outweigh rational motives like economic ones, causing irrational decision-making.

Facets of subjective energy autonomy

Based on the various insights given by the participants, we brought up a working definition of the examined construct: *Subjective energy autonomy presents the individual perceived state of self-determination over one self's energy supply, and further on having a sense of control over the energy system, and its costs*. Categorizing the interview material via qualitative content analysis two dimensions of subjective energy autonomy were identified: (1) Independence as an external perspective, and (2) control as an internal perspective (Figure 1).

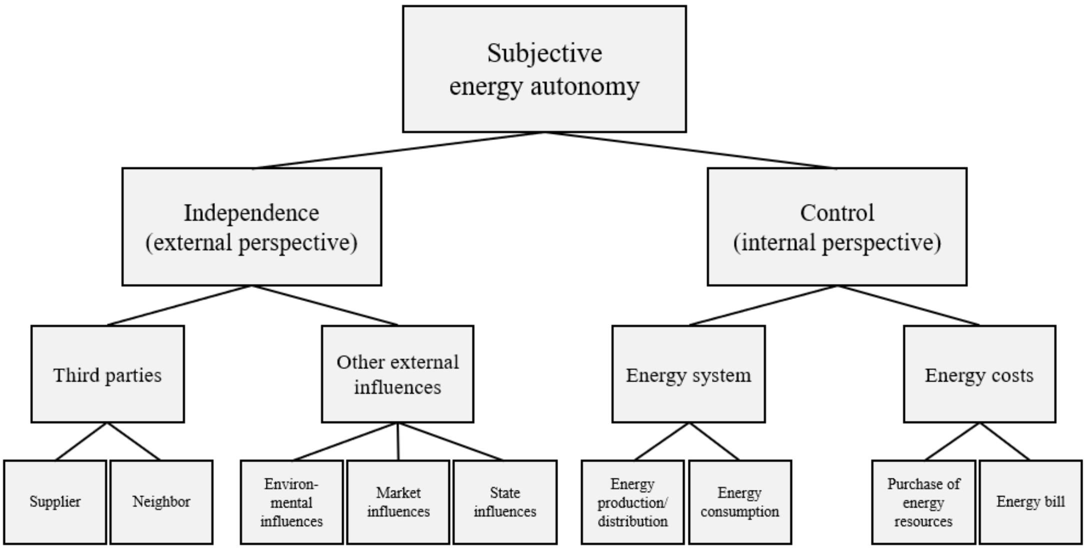

Figure 1: Conceptualization of the construct of subjective energy autonomy (Source: own illustration)

Independence (External perspective)

The aspect of independence was mentioned several times by the interviewees. It depicts the perception of homeowners to make decisions over the energy supply without the influence of third parties (e.g. suppliers, neighbors) as well as other external impacts. When it comes to being independent from suppliers one must differentiate between (1) CES owned by citizen-cooperatives, and (2) CES owned by energy suppliers. In the first case, when the energy production and distribution is in the hand of residents, CES can be seen as becoming more independent from energy suppliers and, thus, present a driver for such projects. In the second case when an energy supplier is involved in the business model, it can become a barrier and individual forms of residential heating would be preferred. In this context, a strong reason against district heating were long-term contracts: "What really bothered us […] was the dependence on one supplier that you have no alternatives to later on and that you are at the mercy of the supplier when it comes to price policy." Owners of district heating systems set up contracts for approximately ten years during which homeowners are required to consume heat, otherwise the connections would not be profitable for the operator. In addition, the operator of district heating often holds the position of a local monopolist, as there are usually no alternative suppliers operating in the distribution network (*supplier-lock-in*). An implementation of several district heating grids in one community would be inefficient.

Another core aspect mentioned was the perceived dependence on neighbors. When starting a cooperation with neighbors to install a CES, trust issues need to be considered. Some of the interviewed homeowners can imagine sharing an energy system with a family member or close friend, but not a neighbor. Even if a district heating system was operated by a professional company, trust issues do play a role: "There was an opportunity that they put the pipelines through the property of our neighbor into our basement connecting it to our heating system, but we did not want that, we wanted our own connection, because what will happen if there is going to be an argument with the neighbor in the future." In the expert interviews it was also mentioned that the perception of being dependent on neighbors, whether it is on a technical level or in form of a contract (case of mutually owned grids), raises difficulties regarding personal conflicts and trust issues.

Another factor that was brought up by the interviewed homeowners was the independence of other various external influences, such as market influences, like fluctuation of oil and gas prices. Some interviewed homeowners said that with fossil heating systems one is less autonomous due to the dependency on fluctuations of market prices as well as other environmental influences. Others perceived this circumstance in the opposite way, thinking they are in the position to determine when they want to buy energy resources like oil and liquid gas. Thus, they believe that they can exert control over prices (shown in Figure 1 as control over purchase of energy resources), causing a higher degree of perceived autonomy for fossil-fired heating compared to district heating. This leads us to another dimension of subjective energy autonomy, which concentrates more on an internal perspective.

Control (Internal perspective)

The aspect of control deals with homeowners' perception in how far they can exert control over the energy system as well as its costs. When it comes to the technical control over the energy system, interviewees argued that the perceived level of energy autonomy of a heating system would be higher if they (a) have a 100% ownership of the system and (b) the system is physically located in the house. The underlying idea is that with an oil or liquid gas tank the energy production as well as distribution is located on the property. An expert working as an energy supplier for district heating in rural areas describes the situation as follows: "I want my oil. It is the generation of 'war children' saying, I own what I sit on." The fact that oil needs to be imported is not taken into consideration. However, when taking different heating systems into account, where purchases of energy resources are needed like oil, liquid gas or even pellets, varying degrees of the perceived level of autonomy can be observed: "Oil heating, assuming that you have a tank, would be kind of more autonomous […] but not like wood-fired heating." The given reason was that the stock of wood resources is located near the house and can be acquired way easier in an emergency.

The last aspect mentioned includes the perceived control over energy costs. Part of the perceived level of energy autonomy was associated with a feeling of financial control over energy costs. One of the energy consultants talked about her longtime experiences with customers concerning energy bills when sharing heating systems: "So, everyone has the fear that they are not able to bill energy costs separately anymore […] I think it is very extreme how strong their need for an own energy bill is." In this context, it was also mentioned that some homeowners are even willing to pay more than to pay for somebody else. In most cases, however, it is an irrational fear since separate heating meters are installed.

"Mismatch" between subjective and objective energy autonomy

Another finding of our study is that there is a clear discrepancy between the objective degree of energy autonomy of a heating system and how it is perceived by the interviewed homeowners. One of the interviewees with a former coal-fired heating system stated: "So, I'd like to tell myself that I want to be self-sufficient. So, I was self-sufficient with my coal heating, because I could fill coal in the oven myself. I could pick a haulage company myself. I could observe the market a little bit." Even though, individual fossil-fired heating is not self-sufficient from a technical perspective due to the dependence on (international) suppliers. Some of the interviewed homeowners with fossil-fired heating systems on individual building-scale perceived such systems as more autonomous than district heating.

In general, the perceptions of autonomy differed across the interviews. Homeowners who stated energy autonomy means to be completely independent of third parties and other external influences rated geothermal solutions as highly self-sufficient, but also said that for example fossil heating systems, like oil and gas, are less autonomous than district heating. Others purported that having the energy system located in their houses (e.g. in the case of oil or liquid gas tanks), increased their control over it and, thus, the degree of autonomy.

Discussion

Our empirical study revealed various new insights into the construct of subjectively perceived energy autonomy. This construct can shape private homeowners' decisions to participate in CES, such as district heating. Delving deeper into the different facets of subjective energy autonomy, we found that it can act as a barrier in the decision-making process to connect to district heating. Prior studies on this topic refer to autonomy as a driver for the participation in CES controlled by residents (Koirala, Koliou, Friege, Hakvoort, & Herder, 2016; Bomberg & McEwen, 2012). In addition to this, we found out that subjective energy autonomy can also be a barrier, due to the emerging perception of becoming dependent (e.g. on neighbors). In this context, homeowners fear losing control over the energy system as well as losing financial control because they assume a collective energy billing. Regarding studies on district heating stating that heating systems should be motivated economically (Østergaard & Svendsen, 2019), our results extend these findings by demonstrating that private homeowners' decision to connect to district heating is not a pure investment decision. Homeowners may assess residential heating systems and district heating based on subjective energy autonomy. Interviews showed that even if a community energy solution presents a more cost-effective alternative, private homeowners may reject it and chose an energy system that is more costly but has a higher degree of perceived energy autonomy instead.

Regarding the different facets of energy autonomy, several results of our study are in good alignment with findings of recent research. In the literature homeowners' preference for independence from suppliers and price fluctuations of fossil fuels plays a significant role when choosing a residential heating system (Michelsen & Madlener, 2013; Claudy et al., 2011). These aspects of independence were also mentioned by our interviewees. An additional finding in our research is the *supplier-lock-in* situation which can act as a barrier for homeowners to connect to district heating. District heating businesses in Germany commonly set up contracts for approximately ten years (e.g. in new-built neighborhoods). This lock-in of consumers by long-term contracts "creating natural monopolies" was also mentioned by Burlinson et al. (2018).

One of the major findings of our investigation is that there is a difference between objectively existing and subjectively perceived energy autonomy. This misperception can also be found in studies focusing on homeowners' decisions to implement solar panels (Sonnberger, 2015). In this context, attribution theory can provide possible explanations. Referring to the concept of *locus of control* (Weiner, 1985; Rotter, 1966), homeowners with an individual fossil-fueled heating, i.e. coal, oil or liquid gas, may have an external locus of control. Following this assumption, they perceive events as controlled by external forces and think that they have no or less control over certain events. Taking the levels of personal agency into account (Vallacher & Wegner, 1989), these homeowners may choose lower levels of action identification, such as residents who depict low-level actions like "filling coal in the oven" themselves and "picking a haulage company" on their own as actions symbolizing autonomy.

Practical Implications

From our findings, several practical implications can be drawn for marketers as well as technicians. Besides well-structured communication strategies that increase transparency and inform private homeowners about a new CES, several other aspects need to be considered. For example, we recommend developing strategies in order to balance negative effects of the *supplier-lock-in* situation. This can be achieved by designing contracts in such a way that prices and their increase are fixed so that homeowners have no fear of an arbitrary price policy by the operator. When it comes to private homeowners' concerns of being dependent on neighbors, following suggestions might work: (a) In communities in which an energy network or plant is owned together with other local residents, contingent liabilities should be clarified. (b) In communities where an energy network is operated by an energy supplier, homeowners should be informed that connections to the grid are technically separated as well as billed separately from neighboring houses (e.g. by offering information events and consultation). Public meetings in the neighborhood such as round tables can not only help to clarify misunderstandings and eliminate incorrect information, they may also help to build trust between neighbors and prevent future conflicts. This implication is also in line with the findings of van der Schoor and Scholtens (2015) that a high level of joint activities as well as a shared vision are crucial to strengthen *local networks*.

Regarding the technical set-up of district heating systems, a recommendation is to provide each homeowner's building with its own pipe connection to the main network instead of attaching pipes that are located on a neighbors' property. Besides using information instruments, promotion could help to position district heating as gateways to become independent from finite resources and price fluctuations of fossil fuels in the long run. Considering the discussion on banning of fossil heating in certain areas, district heating can also guarantee a certain level of independence from future political regulation steps as it already fulfills high energy-efficiency standards. Another opportunity for marketing campaigns would be focusing not primarily on individual energy autonomy, but on autonomy at a community level which covers demand through local sustainable energy production.

Conclusions

Our study represents a novel step in the research field of CES by providing insights into the rather unexplored construct of subjective energy autonomy, its underlying dimensions and factors. In this context, we contribute to recent research by conceptualizing the construct of subjective energy autonomy through qualitative techniques and extend the concept from a motivational and attributional perspective. Furthermore, our findings shed more light on homeowners' drivers and barriers when participating in CES.

Regarding limitations of this investigation, a sample of 22 qualitative interviews provides (individual) in-depth insights. Therefore, our results should not be generalized too much. Further studies should conduct quantitative research in order to analyze the effect of subjective energy autonomy on homeowners' willingness to participate in CES with a larger sample size. The results of our study are a basis for conceptualization and operationalization for those future projects. In addition, several other factors (e.g. comfort, energy safety, ecological motives) should be simultaneously included when investigating homeowners' decision to join CES from a consumer research perspective.

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