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Promoting Decentralized Sustainable Energy Systems in Different Supply Scenarios: The Role of Autarky Aspiration

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The development of decentralized renewable energy systems is of crucial importance for the decarbonization of energy generation worldwide. Purchase decisions regarding innovative energy systems depend to some extent on consumers' perception of the systems' degree of autarky. We assumed that, in addition to the energetic perspective, consumers associate other non-energetic facets such as independence, autonomy, self-sufficiency, or control with the concept of autarky. These psychological facets of autarky were expected to contribute to purchase decisions. In Study 1, participants ($N = 168$) evaluated three future energy supply scenarios. The scenarios varied regarding their range of autarky (household/neighborhood/small town), but the individually realized degree of energetic autarky did not vary. Participants reported a higher willingness to pay in connection with a higher perceived psychological autarky for the Household Scenario. Study 1's findings were confirmed by Study 2, in which qualitative interviews ($N = 13$) also revealed that participants favored the Household Scenario on several points. These evaluations were driven by the anticipated psychological facets of autarky that is the subjective perception of being independent, autonomous, self-sufficient, energy secure, and of control. To promote an adoption of renewable energy systems, these psychological autarky facets need to be addressed. Enabling the people to self-determine, control, and secure their energy provision even in complex organizational settings in such a manner is likely to increase their acceptance and therefore foster the required social transition as a whole.

Keywords: renewable energy innovations, energy storage systems, autarky aspiration, psychological factors, self-determination, control

1. INTRODUCTION

At the World Climate Summit in Paris in December 2015, the international community agreed on a reduction of CO_2-emmissions in order to keep the global temperature below an increase of 2° (UNFCCC, 2015). To ensure this ambitious goal, the need for a transformation of the current, fossil fuel-based energy system is widely recognized. Decentralized renewable energy systems are considered to play an important role for the decarbonization of energy generation worldwide (IPCC, 2007, 2011). Over the last two decades, the share of renewable energy systems among the energy and electricity production increased enormously. In 2015, renewable energy power capacity constituted 30% of all power capacities worldwide (IRENA, 2016). Apart from the already existing hydro energy systems, especially the electricity production of solar or wind powered systems were favored by many countries around the world (REN21, 2016).

The integration of renewable energy into electrical power systems poses a number of challenges. For energy systems based on a high share of renewable decentralized technologies, matching demand and supply is more difficult due to the high fluctuation of photovoltaic and wind power-based electricity production across day and year. Hydroelectric, geothermal, and biomass-based power production, on the contrary, has the ability to provide base load capacity and substitute centralized options. Using the complete variety of decentralized renewable energy technologies is a first step to ensure system stability. The main task of the grid operator is to match demand and supply, which is ensured by integrating decentralized, produced electricity into "classic" centralized energy systems. Especially, the daily peak of solar power in summer days needs to be adjusted in order to maintain the balance of the grid infrastructure. To distribute electricity to the final locations of consumption, a further extension of the grid is needed (Sims et al., 2011). As the political process to build new transmission lines is complicated and therefore often long-winded, an increasing emphasis has been put on the development of smart grids and buildings with intelligent demand side management (Torriti, 2012). The diffusion of electricity storage systems is an additional means to increase the match between supply and demand in decentralized energy systems. Large pump-fed hydroelectricity power stations are the cheapest technology to store electricity. Located in mountainous regions, the need to transport the stored electricity *via* the power grid remains. Power-to-gas technology, which converts electrical power to transportable gas fuel by splitting up water into oxygen and hydrogen, is another possibility to use the electricity surplus from wind or solar generation. An additional option to store energy is the use of compressed air energy storage systems. The idea is to store the compressed air in large underground caverns. Both the power-to-gas and the compressed air technologies are still in their research stage and not yet ready for the market (Lund and Salgi, 2009; Jülch, 2016). Next to these technologies, the use of small-scale electrochemical storage facilities located in private homes is expected to play a major role in keeping grid stability (Denholm et al., 2010). While in previous years electrochemical storage systems were not affordable for the average homeowner, the technological progress and increasing returns to scale have led to a decrease of the systems' prices. Since 2014, the average price for such battery storage systems decreased by over 30% (BSW-Solar, 2016).

Considering increasing electricity prices, soon the point will be reached where it becomes more profitable for private homeowners to directly consume their self-produced solar electricity instead of feeding it into the grid (Weniger et al., 2015; Kairies et al., 2016; Zapf, 2017). Recent research by Korcaj et al. (2015) has shown that the intention to adopt photovoltaic systems (partially) depends on the perceived autarky benefit provided by the system. They conceptualized autarky as the individual possibility to secure and control part of the energy provision and to become independent of energy providers (Korcaj et al., 2015). The use of electricity storage systems could increase the degree of homeowners' energy autarky as it enables them to increase the amount of self-produced electricity they can use for themselves. In addition to the increased degree of energy autarky, we expect that the use of electricity storage systems provides several psychological benefits, which goes beyond the mere energetic advantage. Research has indicated that the individual consumers associate other non-energetic facets with the concept of autarky such as independence, autonomy, self-sufficiency, supply security, and control (Fischer, 2004; Rae and Bradley, 2012; Valkering et al., 2014; Römer et al., 2015). Considering psychological aspects of human motivation, issues of self-determination (Deci and Ryan, 1985, 1991) and control (White, 1959; Bandura, 2001) are likely to play a major role. Therefore, we expected the individuals' aspiration of autarky to be a decisive factor for the adoption of energy systems with electricity storage.

In the present research (see **Figure 1**), a quantitative online study (Study 1) was combined with qualitative problem-centered interviews (Study 2) to reveal the psychological facets of autarky aspiration and their relevance for purchase decision regarding innovative energy systems. Our chosen approach of analysis in this new field of research is promising, as it ensures the following advantages of both methodological paradigms. The online survey allowed us to quantify participants' willingness to pay, their perceived autarky, feasibility, and desirability in different supply scenarios, assuring 80% of energy autarky. While the technical configuration of the scenarios and thus the degree of autarky were identical, the range of autarky varied across scenarios: energy autarky on a (1) household, (2) neighborhood, and (3) small town level. The aim of the problem-centered interviews was to examine the multiple psychological facets of autarky aspiration indicated in Study 1 more deeply. The applied semi-structured interview technique allowed us to ask predetermined questions as well as allowing us to inquire about individual aspects beyond the predefined questions. Hence, the interviewees were interrogated about their perception of the three supply scenarios first, followed by general questions on their subjective view about the self-supply of electricity and energy. The methodological workflow is represented in a schematic overview in **Figure 1**.

2. THEORETICAL BACKGROUND

2.1. The Psychological Facets of Autarky Aspiration

The way personal energy provision is organized depends to a large extent on individual or subjective considerations. In case of the aspiration of autarky, such personal reflections on the advantages and disadvantages of achieving a high degree of energy autarky are likely to influence the decision-making. As with every other desirable goal, the aspiration of autarky is driven by various motives, personal values, individual opinions, habits, and social norms. Previous studies on decentralized sustainable energy systems showed that purchase decisions are not merely based on financial considerations alone (Fischer, 2004; Jager,

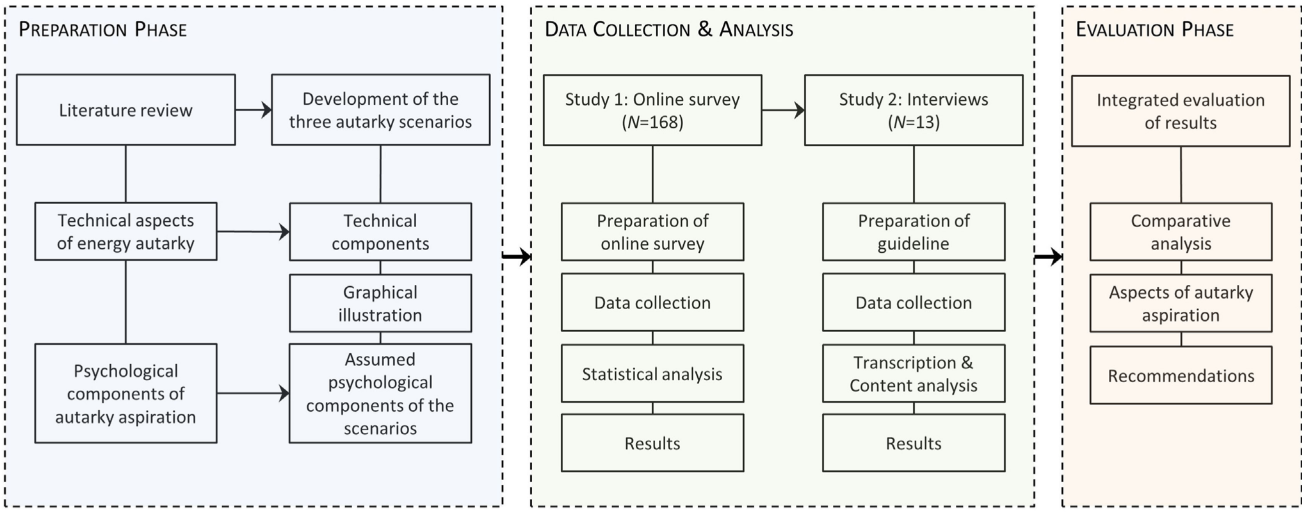

FIGURE 1 | Schematic overview over methodological workflow.

2006; Korcaj et al., 2015; Römer et al., 2015). The decisions to behave environmental friendly are also strongly influenced by individuals' values, motives, and norms (Hansla et al., 2008; Lindenberg and Steg, 2013). Thus, for example, consumers favor green innovations such as electric vehicles that reflect their environmental values as well as their perceived demand in daily life (Hahnel et al., 2014a,b). In terms of purchase decisions regarding photovoltaic systems (PV), it is indicated that the aspiration of autarky serves as an additional strong predictor of homeowners' attitude toward the systems, which in turn affects homeowners' purchase intentions (Korcaj et al., 2015). The desire to generate energy in an independent, self-determinant, and self-sufficient way appears to be a crucial factor in achieving acceptance and commitment. Autarky has been conceptually linked to a variety of psychological constructs such as individuals pursuit of independence (Jager, 2006; Leenheer et al., 2011; Müller et al., 2011; Schmidt et al., 2012; Valkering et al., 2014; Römer et al., 2015; Engelken et al., 2016), autonomy (Fischer, 2004; Späth and Rohracher, 2010; Rae and Bradley, 2012), self-sufficiency (Fischer, 2004; Späth and Rohracher, 2010; Leenheer et al., 2011; Müller et al., 2011; Rae and Bradley, 2012; Schmidt et al., 2012; Römer et al., 2015; Brosig and Waffenschmidt, 2016; Engelken et al., 2016), security of supply (Rae and Bradley, 2012; Römer et al., 2015), and power of control (Fischer, 2004; Valkering et al., 2014).

Römer et al. (2015) revealed that the affinity toward autarky and the customers' concern about the security of supply are strong factors influencing the intention to purchase small-scale electricity storage systems. Their conception of autarky consists of the independence from utility companies, the possibility of autonomous choices, and the opportunity to be self-sufficient (Römer et al., 2015). According to Brosig and Waffenschmidt (2016), (some) individuals possess the personal wish of being autarkic. They showed that some users are willing to increase their level of self-sufficiency by renouncing the use of electric household devices (Brosig and Waffenschmidt, 2016). Research on the acceptance of small combined heat and power plants highlighted that the desire for independence, the wish for autonomy, the vision of self-sufficient home systems, and the desire for personal control were reported to be the most important motives to adopt these systems (Fischer, 2004). Further, the engagement in smart grid projects depends partially on the perceived availability of controlling appliances and the possibility of becoming more energy independent (Valkering et al., 2014). The desire to become independent from electricity suppliers was identified as an important aspect of purchasing a PV-system among Dutch homeowners (Jager, 2006). A consumer survey among Dutch households focused on the analysis of autarkic behavior itself and revealed that the intention to generate its own power is influenced by consumers' environmental concern, their affinity toward technologies, and the reputation of the electricity companies (Leenheer et al., 2011). The idea of energy autarky, self-sufficiency, and of energy autonomy could be identified in a case study of an Austrian alpine district, in which a strong actor network has established a shared vision to promote the necessary socio-technological transformation toward a sustainable low-carbon energy system (Späth and Rohracher, 2010). Sustainable communities are often related to energy autonomy, which is characterized by a high degree of self-governance, the possibility to store and use energy self-sufficiently, and the capability to function independently. Local residents value the resulting benefits of an increased security of supply and the potential to reduce costs and carbon emissions (Rae and Bradley, 2012). Several regions in Germany, Switzerland, and Austria promote the idea of regional energy autarky, which is conceptualized as fully relying on internal resources to satisfy their energy demands. The comparison of these cases revealed that a strong motive of the initiators has been to strengthen the local economy and to reduce the dependencies on external imports of resources (Müller et al., 2011; Schmidt et al., 2012). Engelken et al. (2016) came to a similar conclusion. In order to analyze why municipalities strive for energy self-sufficiency, they conducted a survey among 109 majors of German municipalities. Results confirmed that the expected tax revenues, environmental awareness, and independence from private utility companies influenced the majors striving for energy self-sufficiency (Engelken et al., 2016).

Next to the individual aspects related to the concept of autarky, social aspects need to be considered as well. Decentralized renewable energy systems often require a high level of communication among the participating individuals. This involves a well-functioning cooperation between neighbors, tenants, or homeowners. Energy cooperatives, a promising way to foster the diffusion of renewable energies at a regional level, can be considered as a societal network of actors, committed to achieve high rates of autarky and self-sufficiency (Yildiz, 2014; Yildiz et al., 2015). Aspects of participation, engagement, and trust are especially relevant to the social relationships in organizations, such as energy cooperatives (Yildiz et al., 2015). For example, bottom-up community-based renewable energy projects developed by citizens are more likely to be accepted by the public than top-down projects developed by large companies (Rogers et al., 2008). Financial citizen participation showed to be successful in reducing opposition and increasing acceptance toward renewable energy projects (Yildiz, 2014). The comparison of a community-owned windfarm and several windfarms, developed and owned by a large company in Scotland, revealed that public attitudes toward windfarm developments are more positive in areas where the local community is directly involved (Warren and McFadyen, 2010). Even for such large developer-owned projects, the provision of community benefits such as jobs or investment opportunities to the local citizens is seen as an effective strategy to reduce resistance and raise acceptance (Cass et al., 2010). Holstenkamp and Kahla (2016) conducted a survey among shareholders and members of community energy companies to analyze their investment motives. The results revealed that for members of energy cooperatives the economic consideration of achieving returns is less important than for members of limited partnerships (Holstenkamp and Kahla, 2016). Research on community-based renewable energy initiatives revealed that interpersonal and social trust between local people and groups is advantageous for the realization of the projects, as the people feel positive about getting involved and about the development process in general (Walker et al., 2010). The identification with the local community is seen as an important determinant for citizens to actively participate and support cooperative behaviors (Stürmer et al., 2008).

Despite the variety of research dealing with different autarky aspects, an empirical conceptualization and definition of the concept autarky and its facets is still missing. In terms of renewable energy technologies that impact objective autarky, the different psychological facets of autarky aspiration need to be explored to yield more accurate predictions of homeowners' purchase decisions and to support the adoption of the systems.

2.2. Psychological Theories Explaining Autarky Aspiration

Psychological theories allow an enhanced understanding of the underlying psychological mechanisms of autarky aspiration. More specifically, aspects of human motivation, issues of self-determination and control should be taken into account when examining the impact of autarky aspiration on purchase decisions.

2.2.1. Control Theories

The idea of a fundamental need to exert control over the environment has been widely discussed in psychological research (White, 1959; DeCharms, 1968; Seligman, 1975; Thompson, 1981; Bandura, 1996). Individuals seek to influence their surrounding situations, control ongoing processes, and anticipate unfolding events (White, 1959). White (1959) developed and defined the concept of competence, which can be defined as the capability to interact effectively with one's environment. Individuals tend to consider themselves to be the cause of actions and changing environments (DeCharms, 1968). In order to be effective, control does not need to be exercised. Instead, it is sufficient if a situation is perceived as controllable (Seligman, 1975; Thompson, 1981). According to Bandura (2001), "the capacity to exercise control over the nature and quality of one's life is the essence of humanness." (p. 1). Therefore, Bandura (1977, 1982, 1996) developed the concept of self-efficacy, the individual's perception or belief in his or her capabilities to execute an intended behavior. Within the theory of planned behavior (Ajzen, 1985, 1991), the concept of perceived behavioral control is compatible with the construct of self-efficacy.

When these aspects of control are taken into account in the operation of energy systems, it is likely that the adoption and diffusion of technological innovations is enhanced. For example, the involvement of users in the implementation processes revealed that the users' perception of control is restored, which facilitates the acceptance of the used technologies (Baronas and Louis, 1988). Control, conceptualized by internal self-efficacy and by external facilitation conditions, proved to be one of the main determinants of the perceptions about the ease of use of a new introduced technology (Venkatesh, 2000).

2.2.2. Self-Determination Theory

Self-Determination Theory (Deci and Ryan, 1985, 1991) emphasizes that human beings pursue goals to fulfill the three innate psychological needs for autonomy, competence, and relatedness. Autonomy is described as the desire to self-organize and self-initiate one's own behavior, while competence refers to the desire to feel effective in interactions with the environment and in performing actions. Relatedness, on the contrary, implies that individuals have the desire to feel connected with others and to be supported by important others around them (Ryan and Deci, 2000, 2006). Further, Deci and Ryan (2000) differentiated between the content of goals and the regulatory processes through which these goals are pursued. Individuals perceive the importance of goals for themselves in accordance with their personal aspirations. Some goals provide greater potential to satisfy the three psychological needs than others. Beside the content of goals, the regulatory processes of goal pursuits determine the outcomes of the goal-directed behavior. Experienced autonomy, competence, and relatedness during the execution of action lead to a better performance and improved persistence of behavioral change (Deci and Ryan, 2000).

Taking these individual tendencies for self-determination into account in the process of the implementation and operation of energy systems, it is likely that the acceptance of technological innovations is improved. For example, previous research (Roca and Gagné, 2008; Yoo et al., 2012; Nikou and Economides, 2014) combined the Self-Determination Theory with the Technology Acceptance Model (Davis, 1989), which has proven to be one of the major models in explaining technology acceptance. The two factors, perceived usefulness and perceived ease of use are expected to be the core determinants of usage behavior. The first, perceived usefulness, refers to a person's belief that the use of a particular technology enhances her/his performance. The second, perceived ease of use, is defined as the person's belief that the use of the particular technology is effortless (Davis, 1989). In case of web-based e-learning facilities, the willingness to continue using information technologies increases if the users perceive themselves as autonomous and competent, and when they feel connected and supported by colleagues (Roca and Gagné, 2008). Individuals developed a higher motivation to use e-learning in the workplace, when they independently decided whether to show a certain behavior and when they could act autonomously (Yoo et al., 2012). Attitudes toward the use of mobile-based assessment are significantly influenced by the perceived autonomy, competence, and relatedness (Nikou and Economides, 2014). Concerning environmental behavior, self-determined individuals tend to be dissatisfied with the environmental state and, as a result, to engage more willingly in behavior to protect it (Pelletier et al., 1998). Further it was revealed that autonomous individuals are more consistent in their pro-environmental attitudes and behavior across time (Villacorta et al., 2003). Participants internalized motivation regarding self-selected environmental goals to a larger extent when they perceive the situation as autonomy-supportive and when their right to choose is respected (Osbaldiston and Sheldon, 2003). In the case of household energy consumption, autonomous motivation significantly effects the consumers' energy-saving behaviors (Webb et al., 2013).

2.2.3. Assumptions

We assumed that the degree of energetic autarky, which is determined by the amount of energy generated by the renewable energy system(s) of a given person, her neighborhood, or her community, is only one of multiple facets of the psychological autarky concept relevant for the assessment of such systems. In accordance with this assumption and the presented theories of self-determination and control, non-energetic facets of autarky aspirations need to be considered in an examination of the adoption of technological innovations affecting autarky. Examples for such non-energetic facets are the desire for independence, autonomy, self-sufficiency, security of supply, and power of control. The assumed psychological components of the presented scenarios are depicted in **Table 1**.

In the case of purchase decisions of decentralized sustainable energy systems, we expected that people favor technological systems, which support their independence, autonomy, self-sufficiency, security of supply, and control over their energy provision. Thus, purchasing decisions regarding decentralized sustainable energy innovations should be impacted by home-owners' perceived autarky aspiration and its multiple facets that extend beyond a mere energy autarky.

TABLE 1 | Assumed psychological components of the presented scenarios.

Range of autarky	Assumed psychological components
Household	Only a few people involved (family members) High sense of independence Individuals feel autonomous and self-sufficient Easy decision-making process Control of the ongoing process Energy supply is secured
Neighborhood	Increased number of involved people Dependencies on others Individuals feel less autonomous and self-sufficient Need for communication and interpersonal trust Decision-making is complicated Less control of the ongoing process Energy supply is secured
Small town	High number of involved people Dependencies on others Individuals feel less autonomous and self-sufficient Need for advanced communication and collaboration Need for organized decision-making process Need for organized control process Energy supply is secured

3. STUDY 1: ONLINE SURVEY

3.1. Method

3.1.1. Participants

In total, 168 participants (100 females) completed the online study. Participants' mean age was 32.5 years (SD = 13.3). Aiming for a convenient sample, student and non-student acquaintances were contacted by means of email, social media, or were directly approached. We asked participants to forward the email containing the link to the online survey to additional potential participants. The participants completed the survey online and received no compensation. All participants were living in Germany. Participation took about 15 min. As the participants voluntarily agreed to complete the online survey, it is likely that our sample contains a self-selection bias, which could lead to a sample not being fully representative of the population.

According to the ethical standards described by the German Science Foundation (DFG, 2016), psychological research on healthy humans is exempt from an ethical approval when the research neither involves personal risks nor high physical or emotional stress and when the participants are fully aware of the objectives and procedures of the study. Concerning our study, the participants voluntarily agreed to complete the survey online and had the opportunity to withdraw from participation at any point of the survey. The participants were fully informed about the objectives and procedure of the survey. An informed consent was obtained from all participants before starting the survey. The answers were anonymized and coded in a way, which makes it impossible to link the statements back to the individual subject. As the online survey entirely meets the ethical requirements of the German Science Foundation (DFG, 2016), an ethics approval of the responsible ethics committee was not required.

3.1.2. Design

The study was based on a within-subjects design with the factor scenario (household/neighborhood/small town) and the dependent variables willingness to pay, perceived autarky, perceived feasibility, and perceived desirability.

3.1.3. Development and Characterization of the Three Scenarios

The aim of the scenario development was to vary the different assumed psychological components of autarky aspiration while keeping the energetic autarky constant (see **Table 1**). As participants indicated their willingness to pay for the realization of the described scenarios, it was important that the scenarios were realistic in that they represented possible future conditions. The scenarios consisted of a wide range of decentralized renewable energy systems, such as photovoltaic and solar thermal modules, electrochemical storages, and small combined heat and power stations (Schmidt et al., 2012). In all three scenarios, a degree of energy autarky of 80% was postulated, implying that 80% of the energy demand is covered by internal resources. In addition, it was highlighted that electricity will be derived from 100% renewable resources (Leukefeld and Prutti, 2014; Weniger et al., 2015; KfW, 2016). The main difference between the three depicted scenarios was the range of autarky: (1) household, (2) neighborhood, or (3) small town level. In all three scenarios, participants were asked to imagine they were living in their own house. The use of illustrations in experimental research should be carefully executed in order to avoid distorting effects on the participants' perception. Previous research has pointed out that the use of deficient illustrations can lead to misinterpretations of the intended content (Feenstra, 2012). For this reason, we paired the illustration of the three scenarios with adequate text materials (L'Orange Seigo et al., 2013). The design of the graphics (see **Figures 2–4**) and the length of the descriptions were held as similar as possible across the three scenarios, only varying in terms of the range of autarky. Different keywords were used to trigger and frame the presented setting and the varied range of autarky across scenarios. We assume that the supposed psychological facets of autarky aspiration, such as independence, autonomy, self-sufficiency, security of supply, and control, will differ between the three scenarios. Thus, the participants' perception and evaluation of each scenario should differ as a result of the varied range of autarky.

3.1.3.1. Household Scenario

In the Household Scenario, participants were asked to imagine that they were living in their own house in a small town in a rural area. In this scenario, photovoltaic and solar thermal modules on the roof generate electricity and warm water. A small combined heat and power unit in the cellar of the house provides additional electricity and energy. An electrochemical storage system stores the electricity surplus produced in the house, providing it during times of low or none energy generation, such as during night hours or cloudy weather conditions. The production and consumption in the household is optimized by means of a computer-based energy manager (see **Figure 2**).

3.1.3.2. Neighborhood Scenario

In the Neighborhood Scenario, the house is connected to several houses in the proximate neighborhood. The technical configuration consists of the same technologies as in the Household Scenario. The only difference is that the technological systems are shared and collectively used by the participating homeowners in

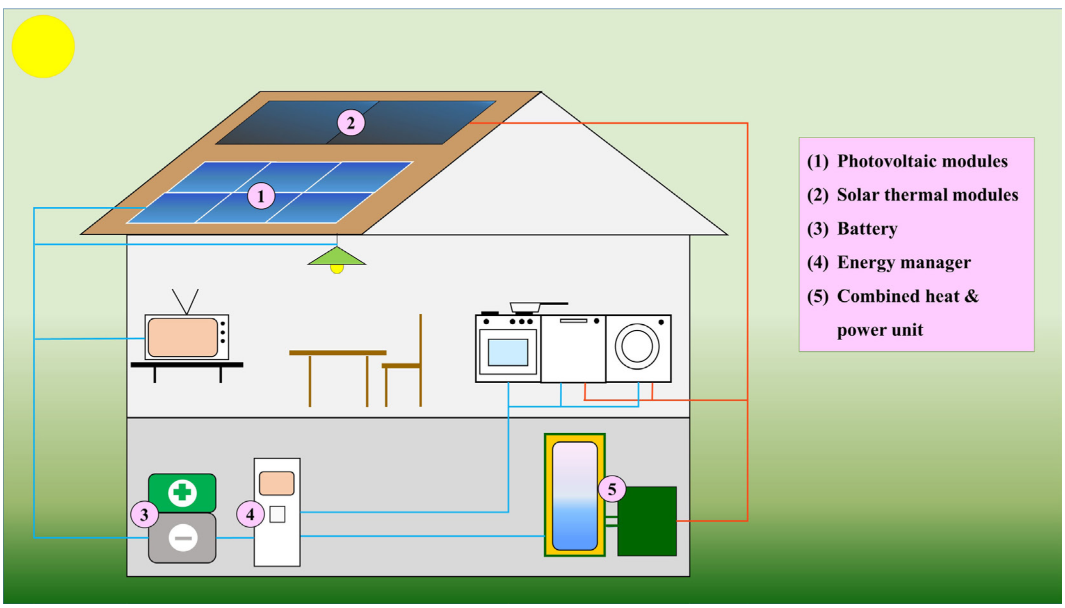

FIGURE 2 | Household Scenario: energy autarky on the household level.

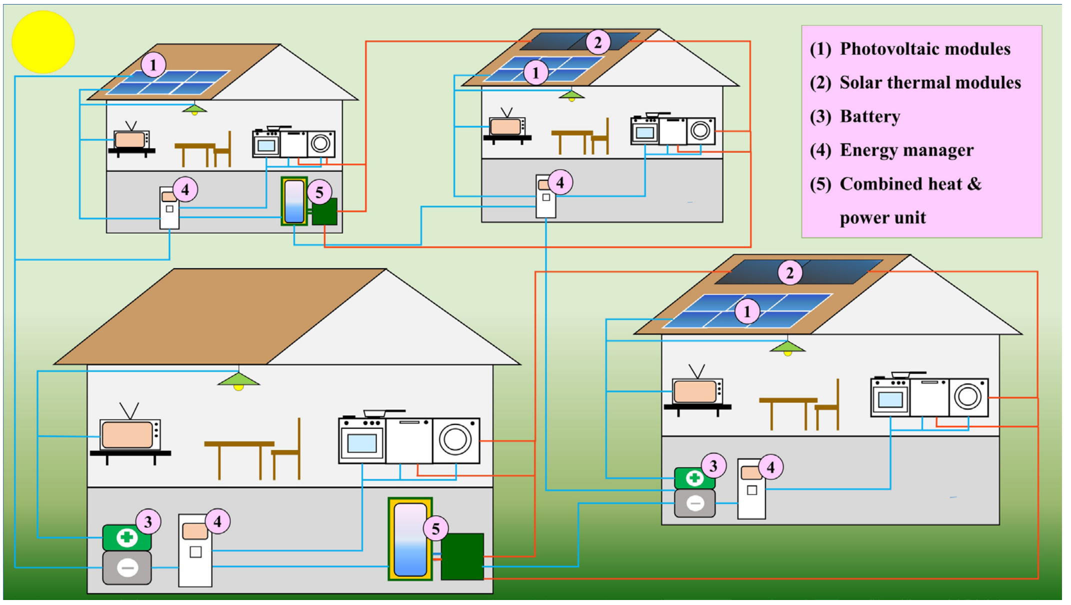

FIGURE 3 | Neighborhood Scenario: energy autarky on the neighborhood level.

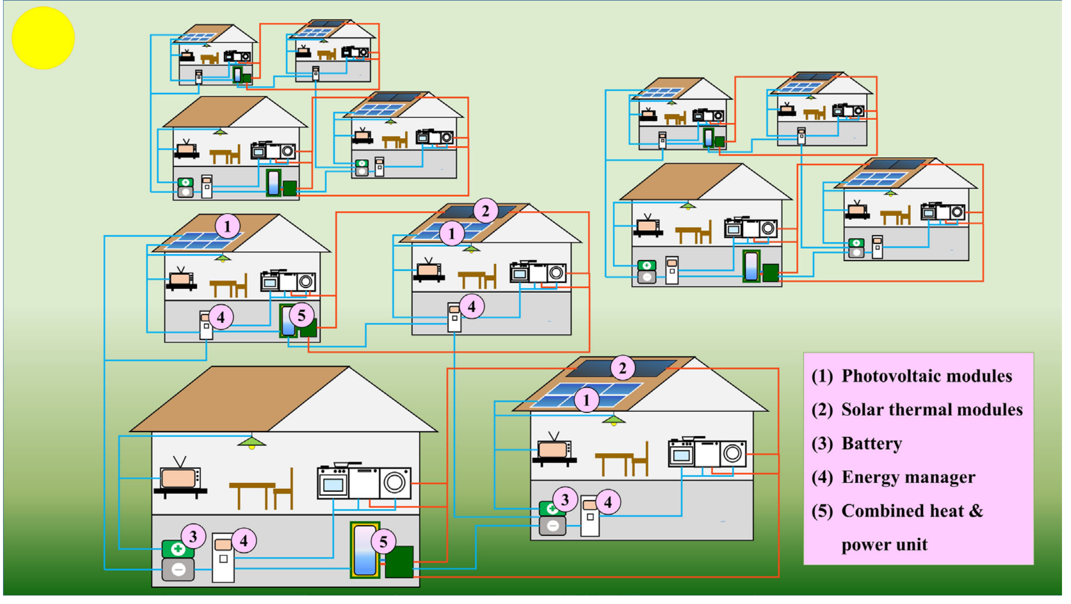

FIGURE 4 | Small Town Scenario: energy autarky on the small town level.

the neighborhood. Again, there are photovoltaic and solar thermal modules on most of the roofs. In some of the cellars, small combined heat and power units provide the neighborhood with additional power and energy, and batteries store the electricity for consequent energy demand. A computer-based energy manager connects the houses in the neighborhood and optimizes the generation and consumption of energy in the neighborhood (see **Figure 3**).

3.1.3.3. Small Town Scenario

In the Small Town Scenario, the house is connected to several other houses located within the area of a small town (thus beyond the proximate neighborhood). The technical configuration consists of the same technologies as in the other two scenarios. The main difference to the Household and Neighborhood Scenario is that the technological systems, while still located in each of the private houses, are collectively used by the participating homeowners located in the small town. Technological appliances to generate and store energy are identical to the first two scenarios. Computer-based energy managers connect the houses in the small town and optimize the generation and consumption of energy in the small town (see **Figure 4**).

3.1.4. Dependent Variables

3.1.4.1. Willingness to Pay

For assessing the willingness to pay for the realization of the described scenario, the participants were asked to imagine that the additional costs would be added to the electricity price. We used a direct approach (Le Gall-Ely, 2009; Miller et al., 2011), asking the participants directly to state their willingness to pay for the realization by the following item: "How much are you willing to pay more for the realization of the described scenario?" For further illustration, information was provided indicating that the average electricity price was around 28 cent per kWh (BDEW, 2016). Considering a consumption of a small family of 5,000 kWh per year, the annual electricity bill approximates 1,400 EUR. Additionally, a small table informed them that a price increase of 1/5/10 cent per kWh will result in an additional cost of 50/250/500 EUR per year. Participants reported their willingness to pay for each scenario by indicating the sum they were willing to add to the fixed electricity price of 28 cent per kWh. We are well aware of the methodological imprecision to ask subjects in a hypothetical way to indicate their willingness to pay for the realization of a scenario. We explicitly left open the question, whether the used system is owned or not, avoiding possible confounding effects on the given answers. Our main goal was to evaluate relative interpersonal differences concerning the perception of the three scenarios, rather than identifying absolute values.

3.1.4.2. Perceived Autarky

The perceived autarky of the scenarios was measured by one item: "How do you perceive the autarky of the described scenario?" Participants indicated their perception on a 6-point Likert scale ranging Participants indicated their perception on a 6-point Likert scale ranging from *1* (*definitely not autarkic*) to *6* (*completely autarkic*). The Likert-type scale is one of the most commonly used survey tools to measure attitudes and opinions toward a certain statement or question (Likert, 1932; Carifio and Perla, 2007).

3.1.4.3. Perceived Feasibility

The perceived feasibility of the scenarios was measured by one item: "How do you perceive the feasibility of the described scenario?" Participants indicated their perceived feasibility on a 6-point Likert scale ranging Participants indicated their perceived feasibility on a 6-point Likert scale ranging from *1* (*definitely not feasible*) to *6* (*completely feasible*).

3.1.4.4. Perceived Desirability

The perceived desirability of the scenarios was measured by one item: "How do you perceive the desirability of the described scenario?" Participants indicated their perception on a 6-point Likert scale ranging Participants indicated their perception on a 6-point Likert scale ranging from *1* (*definitely not desirable*) to *6* (*completely desirable*).

3.1.5. Procedure

The online study started with an introduction page mentioning the overall topic of the scientific project. Before the three autarky scenarios were presented, participants reported their demographics. Subsequently, each of the three autarky scenarios was presented in a randomized order. Participants reported their willingness to pay, their perceived autarky, their perceived feasibility, and their perceived desirability for each scenario. Finally, participants had the opportunity to report general comments and were thanked for their participation.

3.2. Results

In our experimental design, each participant was asked to rate all three scenarios. This repeated measure design, comparing differences within a subject, seemed most suitable for our statistical analysis (Field, 2014). As we wanted to measure the perception of three distinct scenarios rather than identifying an optimal product profile, we decided against applying a conjoint analysis (Green et al., 2001). For each of the dependent variables, a one-way repeated measures analysis of variance (rmANOVA) was applied to test the effect of the factor scenario. When Mauchly's test indicated that the assumption of sphericity had been violated, the degrees of freedom were corrected using Huynh–Feldt estimates. To account for alpha error accumulation due to multiple testing, we applied a Bonferroni correction for each of the conducted analyses, adjusting the level of significance from $p = 0.05$ to 0.0125.

3.2.1. Willingness to Pay

The results showed that there was a significant effect of the factor scenario on the willingness to pay, $F\ (2, 334) = 8.97$, $p < 0.001$, $\eta_p^2 = 0.051$; *Huynh–Feldt corrected* ($\epsilon = 0.94$). The results of the *post hoc* comparisons, using the Bonferroni correction, confirmed that there were also significant differences between pairs of the scenario's means. The mean value of the willingness to pay in the Household Scenario was significantly different from the Neighborhood ($p = 0.003$) and Small Town Scenario ($p = 0.002$). Between the Neighborhood and Small Town Scenario the difference was statistically insignificant ($p = 1$). The mean values of the scenarios are depicted in **Figure 5**.

3.2.2. Perceived Autarky

The results showed that there was a significant effect of the factor scenario on the perceived autarky, $F\ (2, 334) = 58.16$, $p < 0.001$, $\eta_p^2 = 0.258$; *Huynh–Feldt corrected* ($\epsilon = 0.94$). The results of the *post hoc* comparisons, using the Bonferroni correction, confirmed that there were also significant differences between pairs of the scenario's means. The mean value of the perceived autarky in the Household Scenario was significantly different from the Neighborhood ($p < 0.001$) and the Small Town Scenario ($p < 0.001$). Between the Neighborhood and the Small Town Scenario the difference was statistically not significant ($p = 0.014$). The mean values of the scenarios are shown in **Figure 6**.

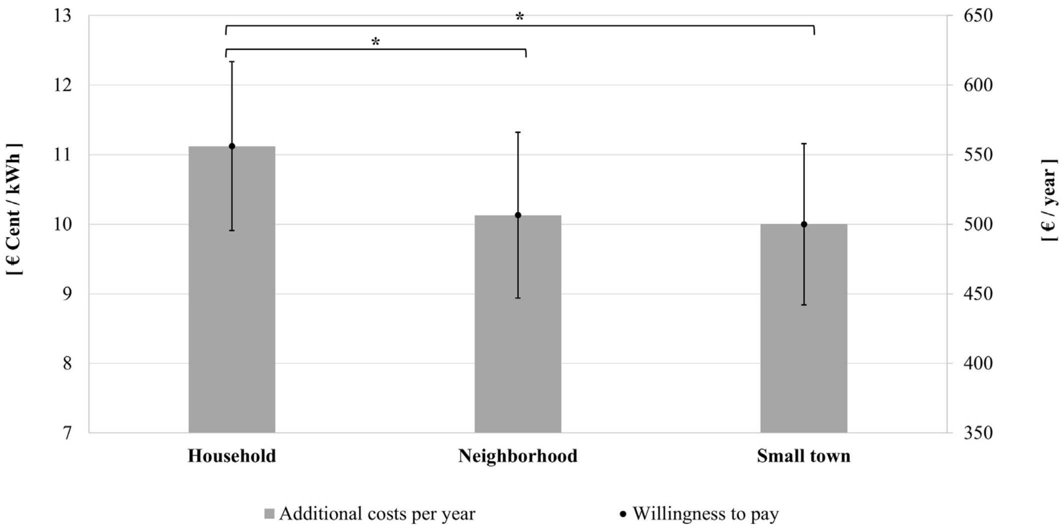

FIGURE 5 | Mean values in EUR cent per kWh and EUR per year for the three supply scenarios; left y-axis: additional costs per kWh; right y-axis: resulting additional costs per year for an annual consumption of 5,000 kWh. A repeated measures ANOVA revealed a significant main effect, F (2, 334) = 8.97, p < 0.001, $\eta_p^2 = 0.051$. Pairwise comparison revealed that the willingness to pay more were higher in the Household Scenario than in the Neighborhood Scenario (p = 0.003) and than in the Small Town Scenario (p = 0.002), but the difference between the two latter scenarios was not significant (p = 1). Error bars depict the 95% confidence intervals. N = 168 (100 females). *$p \leq 0.0125$.

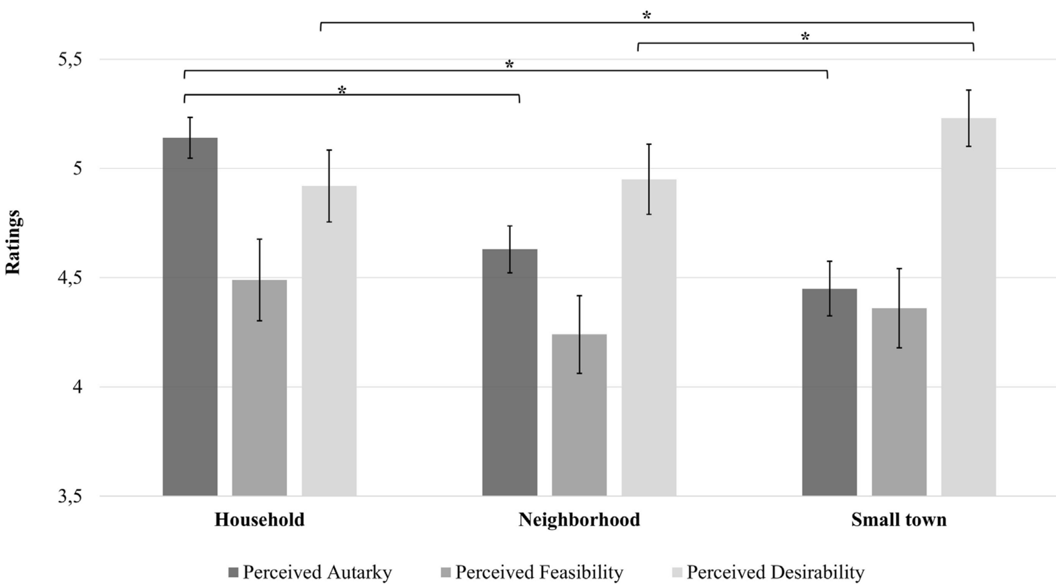

FIGURE 6 | Mean values of perceived autarky, perceived feasibility, and perceived desirability for the three supply scenarios. Repeated measures ANOVAs revealed only a significant main effect for the perceived autarky, F (2, 334) = 58.16, p < 0.001, $\eta_p^2 = 0.258$, and a significant main effect for the perceived desirability, F (2, 334) = 7.14, p < 0.001, $\eta_p^2 = 0.041$. Pairwise comparison revealed that the perceived autarky was higher in the Household Scenario than in the Neighborhood Scenario (p < 0.001) and than in the Small Town Scenario (p < 0.001). Pairwise comparison revealed that the perceived desirability was higher in the Small Town Scenario than in the Household Scenario (p = 0.003) and than in the Neighborhood Scenario (p = 0.006). Error bars depict the 95% confidence intervals. N = 168 (100 females). *$p \leq 0.0125$.

3.2.3. Perceived Feasibility

The results showed that there was no significant effect of the factor scenario on the perceived feasibility, F (2, 334) = 2.84, $p < 0.062$, $\eta_p^2 = 0.017$; *Huynh–Feldt corrected* ($\epsilon = 0.96$). The mean values of the scenarios are portrayed in **Figure 6**.

3.2.4. Perceived Desirability

The results showed that there was a significant effect of the factor scenario on the perceived desirability, F (2, 334) = 7.14, $p < 0.001$, $\eta_p^2 = 0.041$. The results of the *post hoc* comparisons, using the Bonferroni correction, confirmed that there were also significant differences between pairs of the scenario's means. The mean value of the perceived desirability in the Small Town Scenario was significantly different from the Household ($p = 0.003$) and the Neighborhood Scenario ($p = 0.006$). Between the Household and the Neighborhood Scenario the difference was statistically insignificant ($p = 1$). The mean values of the scenarios are illustrated in **Figure 6**.

3.3. Discussion

Findings showed that the highest willingness to pay (see **Figure 5**) was found for the Household Scenario. Comparing the results with the levelized cost of electricity (LCOE) of photovoltaics (PV) in Germany (ISE, 2013), an interesting observation could be made. According to the Fraunhofer ISE (2013), the levelized cost of electricity (LCOE) of photovoltaics (PV) plants in Germany in 2013 was between 7.8 and 14.2 cent per kWh. With additional costs of 11 cent per kWh and resulting additional costs per year of 550 EUR, the willingness to pay (see **Figure 5**) for the Household Scenario is within the LCOE for PV power plants. For the future, even further cost decreases are expected (ISE, 2013). Regarding the perceived autarky (see **Figure 6**), findings showed that it was also the highest in the Household Scenario. We assume that the perception of the Household Scenario is in particular influenced by the psychological facets of autarky aspiration, while for the other two scenarios these aspects are presumably less influential. Due to the fact that the range of autarky is varied, the number of involved people differs from scenario to scenario and so does the resulting communication and decision-making processes. The Household Scenario is characterized by the hypothetical situation of the subjects living in their own houses with only their family members. They are in control of the ongoing processes and are not responsible for other people during the decision-making process. They are probably convinced to secure their energy supply by themselves (Brosig and Waffenschmidt, 2016), without relying on external support. In consequence, they may consider themselves as autonomous and self-sufficient subjects (Fischer, 2004; Römer et al., 2015). In contrast to that, the number of involved persons increases in the Neighborhood and Small Town Scenario. The subjects are dependent on others and are forced to respond not only to their family members but also to the people in their neighborhood and their small town. Some of the decisions have to be made together in order to be effective. The cooperative use of the technologies makes a clear and effective communication necessary, in which interpersonal and social trust represents a key element (Walker et al., 2010; Yildiz et al., 2015). Hence, the subjects may consider themselves as less self-determinant and less autonomous in these scenarios than they do in the Household Scenario. Some of them may not be convinced anymore that they are pulling the strings and thus not able to influence the ongoing processes. Interestingly, the perceived desirability (**Figure 6**) was the highest in the Small Town Scenario on the contrary. In contrast to the willingness to pay, we assume that the perception of desirability is rather influenced by social and political consideration than by the psychological facets of autarky aspiration. With a realized degree of energy autarky of 80% and an electricity supply comprising 100% renewable energies in each scenario, it is likely that the subjects perceive all scenarios as promising to reduce dependency from fossil fuels and to foster the necessary CO_2-reduction (Engelken et al., 2016). The fact that in the Small Town Scenario more houses and people are taking part in the decarbonization and sustainable transformation of the energy and electricity generation was maybe the reason for the identified preference for the Small Town Scenario (Rae and Bradley, 2012). Regarding the feasibility, all scenarios were perceived as rather feasible (see **Figure 6**). It seems that the participants based their decision mainly on the technical configurations, which were identical in all three scenarios.

To summarize, we assume that the subjects are favoring a scenario, which enables them to achieve independence from energy providers and to secure their energy supply, and which allows them to become autonomous, self-sufficient, and in control of the ongoing processes. Our assumption is based on the specific configuration of the three supply scenarios and how they were perceived by the participating subjects. For a robust interpretation of the identified results, we carried out 13 semi-structured interviews in Study 2 to foster our assumption and to examine the multiple psychological facets of autarky aspiration indicated in Study 1 more deeply.

4. STUDY 2: SEMI-STRUCTURED INTERVIEWS

4.1. Method

4.1.1. Participants

In total, 13 subjects (6 females) were interviewed in autumn 2015. Their mean age was 44 years, ranging from 21 to 80 years. The sample consisted of 10 laypersons and three experts working in the field of renewable energies. Experts were a constructor of PV-modules and solar batteries, a consulting engineer and energy adviser, specialized on decentralized renewable energy solutions for small communities, and a representative of the regional cooperative union, responsible for citizen-owned energy projects (see **Table 2**). The combination of laypersons and experts is promising to reproduce the variety of different conceivable perspectives. The interviewees were selected by using personal and professional university contacts. Two interviewers conducted the interviews separately. The duration was ranging from 25 to 60 min. All interviews were audio recorded and held in German. It is important to keep in mind that the experts' opinion might suffer from possible overconfidence effects, such as the overestimation of one's own ability or the overprecision of one's own beliefs (Moore and Healy, 2008).

According to the ethical standards described by the German Science Foundation (DFG, 2016) psychological research on healthy humans is exempt from an ethical approval when the research neither involves personal risks nor high physical or emotional stress and when the participants are fully aware of the objectives and procedures of the study. Concerning our study, the interviewees voluntarily agreed to take part in the interviews and had the opportunity to withdraw from participation at any stage of the interview. The interviewees were fully informed about the objectives and procedure of the interview. An oral informed consent

TABLE 2 | Characteristics of interviewed laypersons and experts.

Interview number	Age	Sex	Living situation	Employment/profession
Laypersons				
L01	24	Male	Tenant	Student
L02	21	Female	Tenant	Student
L03	52	Female	Homeowner	Full-time
L04	24	Female	Tenant	Student
L05	55	Male	Homeowner	Full-time
L06	48	Female	Tenant	Part-time
L07	47	Male	Tenant	Full-time
L08	80	Female	Tenant	Retired
L09	47	Female	Homeowner	Part-time
L10	51	Male	Homeowner	Full-time
Experts				
E01	60	Male	Homeowner	Consulting engineer and energy adviser
E02	29	Male	Tenant	Constructor of PV-modules and solar batteries
E03	32	Male	Tenant	Representative of the regional cooperative union

was obtained from all interviewees before starting the interview. The answers were anonymized and coded in a way, which makes it impossible to link the statements back to the individual subject. As the conducted interviews entirely meet the ethical requirements of the German Science Foundation (DFG, 2016), an ethics approval of the responsible ethics committee was not required.

4.1.2. Development of the Interview Guideline

The problem-centered interviews (PCI) followed the guidelines of Witzel (1985, 2000). The containing questions are supposed to stimulate reflections of the interviewees rather than forcing them into a strict question–answer scheme. The goal of the PCI is to create an open conversation. Interviewees are supposed to talk freely. The task of the interviewer is to guide the conversation. Therefore, the development of the interview guideline is of crucial importance. The guideline provides a framework of orientation ensuring comparability of the interviews. The guideline was split into two parts.

In the first part, the interviewees were asked about their hypothetical willingness to pay and their perception concerning autarky, feasibility, and desirability concerning the three supply scenarios (see **Figures 2–4**) developed in Study 1. Afterward, the interviewees were asked to explain their ratings. The presentation of the scenarios served as a stimulus to initiate the interview and to frame the overall topic of decentralized renewable energy systems.

In the second part, the interviewees were asked to report their general view on issues of decentralized renewable energy systems and on multiple facets of autarky aspiration. We asked the interviewees to report their relationship with their energy and electricity provider. Further, we wanted to know if they could imagine generating their own energy, either individually or collectively with other people, before they should report their intentions regarding an automatic or manual control of the technological system as well as their desire to possess the technology. We also asked them to outline aspects of self-sufficient supply systems that they considered as negative or positive. The last point inquired about personal motives to produce their own energy and electricity.

The aim of the interviews was to yield a better understanding of the underlying argumentation leading to the outcomes observed in Study 1 and to identify the different psychological aspects of autarky aspiration. While Study 1 showed that the degree of energetic autarky is only one of multiple facets of the psychological autarky concept relevant for the assessment of energy systems, the interviews aimed at an in-depth examination of the different non-energetic facets of autarky aspiration, such as the desire for independence, autonomy, self-determination, and control.

4.1.3. Procedure

With regard to methodological issues and in order to familiarize ourselves with the prepared guideline, we conducted a test run. The test run was evaluated in a team in order to minimize interviewer effects as we were two interviewers, conducting the interviews separately.

After a short introduction mentioning the background of the scientific research project, the interviewer briefed the interviewee with regard to the procedure, the transcription of the interview, and the anonymous analysis of the mentioned statements. Before the interview started, a short paper-based questionnaire was handed out to control for sociodemographic variables. The first part, the presentation of the three supply scenarios, was facilitated by posters depicting the scenarios applied in Study 1. The interviewees indicated their willingness to pay and their decisions concerning the perception of the different aspects on a provided chart. In the second part of the interview, subjects stated their opinions concerning decentralized energy systems and the multiple psychological facets of autarky aspiration freely in the second part of the study.

4.1.4. Content Analysis

The interviews were tape recorded and transcribed by the responsible interviewer with the aid of the software program *MAXQDA*. The qualitative content analysis of the transcribed interviews followed the approach of a deductive category application, developed by Mayring (2000, 2015). Central to this procedure is the prior formulation of theoretical aspects, which serve as defining categories. The resulting categories are independence, autonomy, self-sufficiency, security of supply, and power of control. These category definitions serve as the basis of the coding scheme to analyze passages of the transcripts. The content of each interview is explored by scanning each transcript for the assumed theoretical aspects or defined categories that were mentioned, and analyzing in what way they were mentioned. Each interview was coded by the two interviewers separately. To minimize effects of subjectivity, the coding results were compared and discussed to achieve a common agreement.

4.2. Results

4.2.1. Willingness to Pay More for the Realization of the Three Scenarios

Concerning the willingness to pay more, laypersons favoring the Household Scenario argued that they then consider themselves more autonomous and self-reliant. The benefit of being the owner of the house in control over the installed technology systems was mentioned by 8 of the interviewed laypersons as a motive for a higher willingness to pay. Typical statements were "For the own household, I would definitely spend more" (L03) or "I feel somehow safer. Because, I think, we are less dependent on others." (L10). In line with this argumentation, five laypersons explained their decision to pay more for the Household Scenario and less for the Small Town and Neighborhood Scenario by the fact that they consider the higher number of people who are involved in the last two scenarios as a risk for the decision-making process. One layperson formulates his argument as follows: "With an increasing number of involved persons, it is more complicated to find a common line and to realize it in a reasonable way." (L01). One interviewed layperson claimed that due to the shared investments for realizing a scenario with several households, the individual contribution could be smaller (L10). Another layperson willing to pay more for the Neighborhood and the Small Town Scenario argued that because of his superior income and economic status, his contribution for realizing such a collective scenario should be significantly higher (L05). This is in line with the argumentation of another layperson, who claimed that if more people are willing to contribute, her personal share should be higher as well (L04).

Asked for their willingness to pay more, also one of the three experts favored the Household Scenario. He based his decision mainly on issues of control and self-determination, what can be identified in his statement: "It is mine then. So I am able to control it—it is my own investment…. Therefore I am willing to spend more when I am the only one who decides." (E02, solar constructor). The second expert on the contrary favored both the Household and the Neighborhood Scenario over the Small Town Scenario. In his point of view, large-scale solutions are more difficult to realize, because the involved persons are not as close together than in small-scale solutions. He argues as follows: "Because I prefer small-scale over large-scale solutions…. Such a small-scale, neighborly or quarterly organized community, I would rather support than a project where a really large firm is in charge." (E01, energy adviser). The third expert did not make any difference between the scenarios. He is willing to pay the same amount in each scenario for the implementation of the energy transition: "400 EUR more, that's what I would pay for the energy transition." (E03, representative of the regional cooperative union).

4.2.2. Perceptions of Autarky

As expected, the interviewed laypersons differed in their perception of autarky, despite the fact that the degree of energy autarky was kept constant in all three scenarios. Looking in detail at the mentioned reasons, it becomes obvious that the laypersons associate different aspects with the concept of autarky. For example, laypersons favoring the Household Scenario highlighted that they consider their situation in such a scenario as more independent and self-determined. Typical statements are: "Autarky for me is definitely, that I am always able to influence it." (L03), "Part is the autarky and the self-reliance. That I am partly cut-off from the things around me and not so dependent." (L01) or "Simply less dependent on arbitrary price increase." (L04). They assumed that in the Neighborhood and Small Town Scenario they would have fewer possibilities to intervene and to influence the decision-making process. The ability to decide on your own and to be in charge was associated with the Household Scenario. For example, one layperson claimed that "The absolute advantages are, that I can determine, how much and in which way I produce and how I will use it in the end." (L03). She even mentioned that within the Neighborhood and Small Town Scenario it is even likely, that her own autarky could be severely limited by certain elements of this scenario: "There are more factors, which could possibly disturb the autarky. Could disturb my autarky!" (L03). An interesting observation was that one layperson, who rated the Household Scenario more autarkic than the other scenarios, could not explain his decision in detail. His vague statement was the following: "I cannot explain it precisely. It is more a feeling." (L10).

Contrary to the laypersons, each expert viewed autarky mainly from an energetic perspective. In their view, full autarky is an "absolute illusion" (E01, energy adviser), which is "unbelievable difficult to achieve and extremely cost intensive" (E02, solar constructor). In order to achieve independence and security of supply, they are all favoring small-scale and cooperatively organized communities. The expert, which represents the regional cooperative union made the following statement: "From a realistic point of view, it makes more sense to join forces and looking collectively for solutions." (E03, representative).

4.2.3. Perceptions of Feasibility

In terms of feasibility of the scenarios, laypersons considering the Household Scenario as most feasible highlighted the clear responsibilities, the well-defined decision-making processes, and the manageable amount of involved individuals. Typical statements were "The whole thing is more manageable when it is done on a smaller scale." (L01) or "For me, this scale of a small town is too large." (L03) or "It is very feasible, because I can do, whatever I want." (L05). The feasibility of the Neighborhood Scenario, on the contrary, was perceived lower compared to the other two scenarios. The reason for that was the increase in involved individuals compared to the Household Scenario, which was thought to cause communication difficulties in the group. One layperson stated, for example, "In the neighborhood, I think it is not feasible, because there are a lot of individuals who are forced to team up and solve their problems together." (L09). Interestingly, the laypersons did not mention this argument when evaluating the Small Town Scenario, which contained an even larger number of people. The interviewed laypersons answered that they assume the Small Town Scenario as more feasible because they expect a local authority or municipality to be in charge of the developing process. One of the laypersons articulated his thoughts as follows: "The Small Town Scenario is more likely, because I can imagine when there is the city or a large community behind it, it is possible despite the immense effort." (L02).

Concerning the feasibility, the opinion of the experts slightly differed. The expert, working as an advising engineer, did not make a distinction between the scenarios feasibility. He referred to the technological feasibility, which he considered as high in all three scenarios, and specified his thoughts as follows: "Yes, it is realizable. All of it, is feasible. All of it, can be build, if only there is a will." (E01). The expert, working as a solar constructor, highlighted the beneficial effect of cooperatively organized scenarios: "I think it is easier in a community to take the next step." (E02). He considered therefore the Household Scenario as less feasible than the other two scenarios. On the contrary, the third expert, representing the regional cooperative union, considered the Small Town Scenario as less feasible than the other two scenarios. He argued that the Household and the Neighborhood Scenario are already realized in a similar manner somewhere, while he could not find an equivalent for the Small Town Scenario: "Considering the Small Town, I don't know. No, I don't think it exists today." (E03).

4.2.4. Perceptions of Desirability

Regarding the desirability, the interviewed laypersons favoring the Small Town Scenario argued that the chance to contribute to a substantial environmental benefit is larger when more houses or the whole community is taking part in the project. One layperson exemplified her thoughts as follows: "I prefer the Small Town Scenario, because I think that there are more balancing possibilities. For example some houses receive more sunlight than others and therefore the interaction could be more positive …" (L01). On the contrary, the laypersons rating the Household Scenario as most desirable outlined that they could most likely picture themselves in it, while they perceived the realization of the other two scenarios to be highly uncertain. "I consider it as extremely desirable for the private household…. But otherwise I think it is not necessarily constructive for me." (L03). Some of the laypersons who did not make a distinction between the scenarios and rated them all as very desirable emphasized environmental reasons, "All of it is highly desirable. Especially from the perspective of the environment" (L02) and the necessity to transform the current way of producing energy and electricity, "That is the only way. Otherwise we cannot make the energy transition work." (L05).

Looking at the experts' opinion, a similar diversity could be identified. The solar constructor favored the Small Town Scenario and argued as follows: "In a small town, from an ecological point of view, I can save more CO_2, because I can reach more people with it." (E02). The expert, working as an advising engineer, favored the Neighborhood Scenario: "The situation, in which the sense of community and solidarity is the strongest, I regard as most desirable." (E01). In a similar direction argues the expert, representing the regional cooperative union: "I consider such association as wiser, whether it is in the neighborhood or in the small town …" (E03).

4.2.5. Perceptions of Multiple Facets of Autarky Aspiration

The issue of independence was highly prominent in the statements of the interviewed laypersons. The ability to become independent from energy and electricity provider was a firm motive to pay for energy. Typical statements were "Well, you are dependent on your grid operator…. And I would gladly have changed it" (L03) and "Yes, not being dependent on the big players anymore." (L07). Interestingly, the laypersons favored independence not only in their relationship to their energy providers but also in their relationship to other people. One layperson mentioned "You are still a bit dependent on others, because they are also involved." (L02). This mistrust in collectively organized supply scenarios derives from the view that mutual dependencies increase with the number of involved individuals. Regarding the statements of the interviewed experts, the issue of independence also appeared in various answers: "That's a very old argument: We want to be independent" (E01) and "The opportunity to become economically independent from increasing electricity prices." (E02). Interestingly, they consider the dependency from the electricity provider and the grid operator not as severe as the laypersons do: "The dependency from the electricity-, grid- or energy provider is not that bad, because I am convinced that we need them and urgently so. Sooner or later it will be like this, the grid serves as a puffer, a compensatory measure…. And therefore I need a grid operator." (E02). They highlighted that the connection to the grid will be essential in order to sell to the grid operator, when the electricity surplus can no longer be stored or used otherwise: "When it is connected to the grid, then I can make the surplus available to the community…. What we need is cooperation. We need to produce as much renewable energy locally, but we have to make the surplus available and to supply the others." (E03).

Four of the interviewed laypersons highlighted aspects of autonomy and the advantage to self-determine the way of electricity production. The following statements were typical: "You can determine by yourself, where the electricity is coming from" (L09) and "The absolute advantages are, that I can completely determine by myself, how much and in which way I will produce and how I am going to use it in the end." (L03). Another layperson emphasized the advantage of an unrestricted freedom of choice: "I can decide everything for myself." (L05). Also, two of the experts considered autonomy and self-determination as a beneficial aspect: "And thereby I am willing to spend more money of course, when I am the only decision-maker" (E02) and "At home in the family I am also more autarkic considering the decision-making, because I am able to adapt more quickly." (E03).

Almost all interviewed laypersons expressed their desire to control the conditions of electricity generation: "That is what it is ultimately all about, that I can control it by myself." (L03). The ability to directly influence and intervene is considered as one of the main reasons to install private autarkic energy systems. One layperson put it into words: "And certainly, that I have access to the facility" (L06). Four laypersons even expressed that they would like to individually adjust and modify small parts of their decentralized energy system. One layperson expressed his wish: "That you are able to regulate a little bit of it by yourself." (L10). Six interviewed laypersons explicitly highlighted that they would like to possess the used technologies in order to make sure that the power of control lies in their hands. "When the systems belongs to me, then there is more control. Less people will interfere" (L06) was one typical statement. Also the expert, working as a solar constructor, highlighted these advantages of control: "Then I would like to control the system. I would like to improve it, optimize it, develop my own ideas which system fits the house." (E02).

The vision to achieve partial self-sufficiency was mentioned by four of the interviewed laypersons. The certainty that the energy they use is partially generated by themselves fills them with satisfaction. Typical statements were "With the combination of PV and this heating unit AND the battery. That's an amazing story…. When I am autarkic, I will take care of myself. Then I don't need anything" (L03) and "That I contribute to the energy transition. Because as soon as I will use my own electricity, I do not need the electricity derived from coal or nuclear energy any more" (L04) and "Because I will be able to use the electricity almost without cost and to save it with today's technology and to use it later when I need it." (L01). Among the experts, the benefit of self-sufficiency was also prominent: "I can provide my house with household electricity. I can store the energy." (E02).

Aspects concerning the security of supply were expressed by four interviewed laypersons. One stated his view as follows: "In my opinion it is desirable to conduct it in order to guarantee your security of supply." (L01). Another layperson highlighted the beneficial effect of the storage facilities: "When these batteries do exist. Then you will be self-reliant in your supply…. For such a situation, you got this battery, right? That you got a certain reserve." (L03). Contrary to the laypersons, two of the experts consider the beneficial effect of gaining security as an illusion: "The autarky, you think you are buying, is an absolute illusion. When there is a BANG somewhere, we are all sitting in the same boat. Even though, I have got some kilowatt-hours left in my battery." (E01). According to them, the aspiration of autarky may serve the individual desire for security, but from a realistic point of view living in a house that guarantees your electricity or even your energy supply will not diminish your dependencies to the outside world. In case of a blackout, you may have a certain reserve for a couple of days, but then you are dependent again. The idea of a fully autarkic house may work in rural areas, but in urban areas it is not feasible and economical desirable. That's why, they are favoring community-based solutions: "When I think about it, that the autarky should provide security and independence, then I am convinced that is not only a question if there is coming electricity out of the socket. Therefore I value the sense of community." (E01) or "For reasons of security, it is better though to realize such a thing in the neighborhood or in the small town than alone…. It makes more sense to join forces and extent it psychologically to 'we take care of ourselves' than to 'I take care of myself'" (E03).

4.3. Discussion

Study 2 provides direct evidence for the different assumed psychological aspects of autarky aspirations and their influence on the perception of decentralized energy supply systems. The overarching psychological components of autarky aspiration are depicted in **Figure 7**. The comparative analysis of the interviewees' perception of the three supply scenarios enabled a deeper exploration of the underlying psychological mechanisms of the autarky concept. Almost all interviewed laypersons highlighted aspects of independence, autonomy, self-sufficiency, supply security, and control as beneficial factors, which lead to a clear preference for the Household Scenario (Jager, 2006; Leenheer et al., 2011). The possession of the used technologies is seen as an adequate measure to ensure controllability (Fischer, 2004). In accordance with this observation, it is not surprising that the cooperatively organized Neighborhood Scenario is perceived to be less suitable, as the number of people who are involved is often perceived as not manageable. The fact that the Small Town Scenario is not assessed negatively, despite the even larger number of people involved, suggests its special position. It seems that the subjects include social and political aspects in their perception of the Small Town Scenario (Rae and Bradley, 2012), but not for the evaluation of the other two scenarios. Interestingly, each of the three experts emphasized the development of small-scale and cooperatively organized solutions. In their view, the promotion of regional energy cooperatives or community-owned energy projects, characterized by a strong sense of community and solidarity, is seen as an important step toward a successful transition of the energy system (Warren and McFadyen, 2010; Yildiz et al., 2015).

5. GENERAL DISCUSSION

5.1. Conclusion

The present research provides empirical evidence that the factor autarky has a firm influence on the acceptance of decentralized renewable energy systems. Both studies presented here confirmed that individuals are willing to pay more for the realization of a scenario, which guarantees them a higher independence, autonomy, self-sufficiency, supply security, and control. The ability to produce one's own energy is seen as a purchase incentive and an appropriate solution to ensure independence from energy or electricity providers. Both studies aimed to analyze the psychological concepts underlying autarky aspiration (see **Figure 7**). The studies provide evidence that the concept of autarky contains more than the energetic aspect of autarky. Based on the repeated measures analysis of variance (rmANOVA) of the three energy supply scenarios, strong support was found

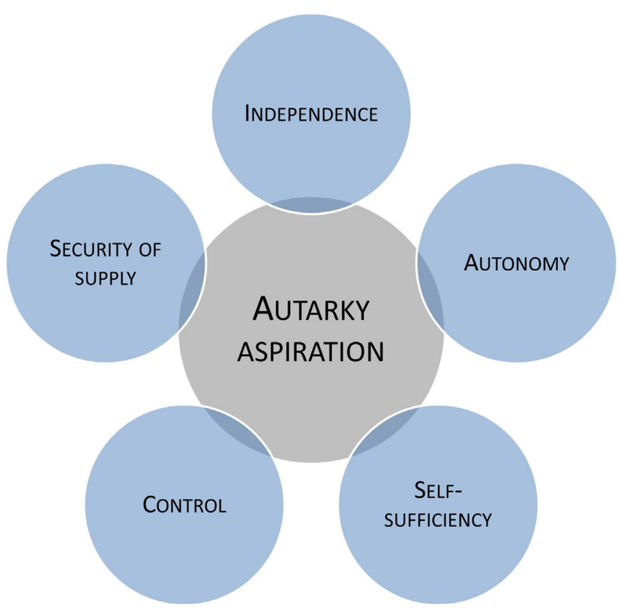

FIGURE 7 | Psychological components of autarky aspiration.

for the preference of the Household Scenario (see **Figure 6**). Participants were willing to pay the highest extra fee in this scenario (see **Figure 5**). Following the motivational distinction of Deci and Ryan (2000) between content-related goals and regulatory processes, we assume a similar pattern for the concept of autarky aspiration. We think that the different aspects of autarky could either be clustered in content-related goals, individuals are pursuing when they are making autarky related investment decisions, or in regulatory processes, containing aspects relevant for pursuing the desired goals. Therefore, we think that the willingness to invest in decentralized renewable energy systems was, on the one hand, influenced by the desired goals, such as independence, self-sufficiency, security of supply, and a high share of renewables, and, on the other hand, affected by the regulatory processes, such as autonomy, and control, leading to the desired outcomes. While the desired goal of a mere energy autarky was met in all three scenarios, the regulatory processes, which allow individuals to achieve autonomy and control, were mainly associated with the Household Scenario. Especially for the adoption of energy storage facilities, such as solar batteries, the identified autarky aspects are likely to play a major role. To promote an adoption of renewable energy systems in innovative supply scenarios beyond the classic household scenario, the psychological autarky facets revealed in the present findings need to be addressed.

5.2. Limitations

Concerning possible limitations of our results, the sample structure and the research design of both studies need to be considered. The demographic variables of both studies indicated that the sample structure is convenient, although the share of students in Study 1 is above average, which could disturb the generalizability of our results. A possible limitation for the interpretation of the results concerning Study 2 and the interviews is the small sample size of laypersons and of experts in particular. Even though the results were not statistically analyzed, they provide nevertheless useful insights at an early stage in the research process. The identified patterns cannot be generalized but can serve to structure and design future research. To strengthen the identified outcomes, future research should especially widen its scope and include a broader variety of experts, which represent larger corporations or are in favor for centralized solutions. Further limitations in terms of self-selection could derive from the recruiting process *via* personal and university contacts due to voluntary participation. Additional limitations could deduce from the fact that the participants were confronted with hypothetical decision situations in which the complexity of the presented supply scenarios was reduced to control for confounding variables. We are well aware that in real life situations, individuals are exposed to a variety of stimuli, and it is impossible to picture all of them in a hypothetical setting. Nevertheless, the individuals' responses could be seen as an approximation of the reality. A few interviewed laypersons expressed the concern that there will be the duty of maintaining decentralized systems by those operating them. On one side, they want to control their energy provision, but on the other side, the effort in doing so should be manageable. A key point is the technical reliability of the system and its components. Otherwise the trade-off between the increased responsibilities and the gained benefits is not acceptable.

5.3. Implications for Practice

In order to increase the purchase of decentralized renewable energy systems, an implication of the present results could be that the design and development of energy solutions for private homeowners need to consider the motivational aspects of autarky aspiration. People are more likely to accept new technologies when their individual need for independence, autonomy, self-sufficiency, supply security, and control is respected. Due to the fact that the energetic degree of autarky in the supply scenarios was held constant, we recommend further research to analyze the effect of different supply rates on acceptance.

Although the vision to achieve supply rates of full autarky is most attractive, at least to laypersons, the realization of partial autarky in only some fields seems to be worthwhile as well. For example, individuals seem to be satisfied if at least their warm water and part of their electricity comes from their own roofs, while the rest of the energy demand is still coming from outside. The individual's preference to be the owner of the technologies needed to produce one's own energy reminds us of the endowment effect, i.e., that individuals ascribe more value to objects only because they own them (Thaler, 1980; Kahneman et al., 1991). In the case of energy or electricity production, it would be interesting to analyze this relationship in regard to an added value for self-produced energy or electricity.

Each of the three future supply scenarios represents different options for a societal transition of the current energy systems. While the Household Scenario mainly suits the circumstances of homeowners in rural areas, the cooperatively organized scenarios of a Neighborhood or a Small Town also provide solutions for tenants in more densely populated areas. The current research has shown that the cooperatively organized scenarios raise skepticism. Laypersons favored the Household Scenarios due to its higher independence, autonomy, self-sufficiency, and control over the ongoing processes. In order to reduce the skepticism, cooperatively organized energy systems should possibly consider the different psychological facets of autarky in their design of the business models. For example, citizen-owned energy cooperatives already provide each member the possibility to influence the decision-making process. Enabling the people to self-determine and control their energy provision even in complex organizational settings in such a manner is likely to increase their acceptance and therefore foster the required social transition as a whole.

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FE is the corresponding author. UH provided assistance and HS supervised the research.

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