Acceptance of decentralized sustainable energy systems: Psychological exploration of the individual pursuit of autarky.

(Akzeptanz dezentraler nachhaltiger Energiesysteme: Psychologische Untersuchungen des individuellen Autarkiestrebens.)

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Background

Decentralized energy storage systems (ESS) are a promising means to more effectively match the supply and demand of fluctuating renewable energies. For policy and industry alike, it is of particular interest to identify factors that drive ESS adoption. Empirically addressing this question, we hypothesized that the factors autarky and autonomy aspirations crucially determine ESS adoption decisions. In four studies, sketching future decentralized energy scenarios, we found evidence for the importance of both factors for homeowners' evaluations of the technology. Results showed that both factors significantly affected homeowners' acceptance and willingness to pay extra for ESS. In accordance with concepts aspiring to optimize energy flow on the low-voltage grid level (e.g. Smart Neighborhoods), we additionally examined the influence of autarky and autonomy aspirations on homeowners' willingness to exchange self-generated energy within a local energy network. Results showed that emphasis on autarky increased the subjective value of self-generated energy, decreasing the likelihood of peer-to-peer energy trading.

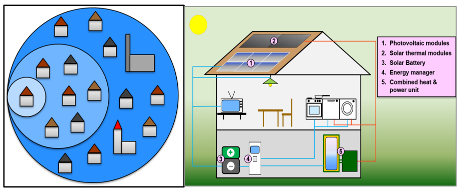

Fig. 2: Energy autarky on the household level

Study 1 & 2: Autarky aspiration in different supply scenarios

Method: 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.

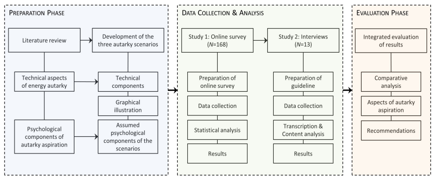

Fig. 1: Schematic overview over methodological workflow of study 1 & 2.

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 (see **Figure 2**).

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.

Results: Participants are willing to pay more for scenario household (see **Figure 3**). The content-analysis of the transcribed interviews revealed that the energetic autarky is only one component of autarky. Other aspects are important as well, such as independence, autonomy, self-sufficiency, power of control, and security of supply. It seems that willingness to invest in decentralized renewable energy systems was, on the one hand, in 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 (see Ecker et al. 2017).

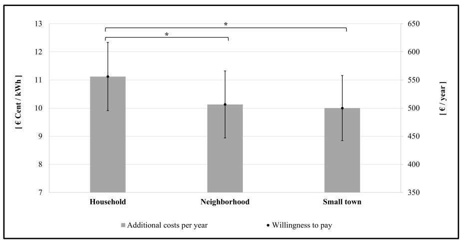

Fig. 3: Mean values in EUR Cent/kWh and EUR/y for the three supply scenarios; $F(2,334) = 8.97$, $p < .001$, $\eta_p^2 = .051$.

Study 3: Homeowners acceptance of electrical storage systems

Method: Experimental variation of autarky & autonomy (Study 3)

In study 3, we followed a 2x2-mixed design and experimental varied the degree of energy autarky (90% vs. 30%) and the level of autonomy (self-determined vs. external controlled), see **Figure 4**.

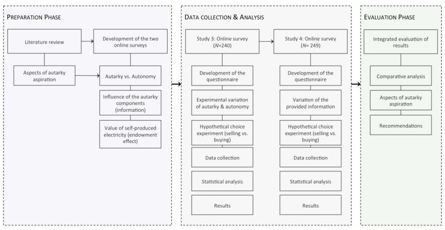

Fig. 4: Schematic overview over methodological workflow of study 3 & 4.

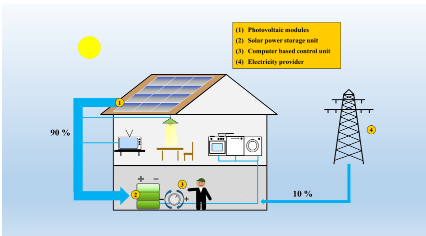

Fig. 5: Household: high degree of energy autarky & self-determined.

Results: Participants (N = 240) are favoring scenarios which enables them to achieve high degree of energy autarky, to secure their supply and to achieve self-sufficiency (see **Figure 6**).

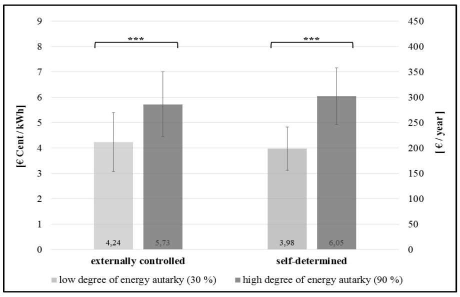

Fig. 5: Mean values in EUR Cent/kWh for the two conditions, $F(1,238) = 50.37$, $p < .001$, $\eta_p^2 = .18$. ***$p < .001$, **$p < .01$, **$p < .05$.

Study 4: Influence of information and the value of self-produced electricity

Method: Experimental variation of the provided information (Study 4).

In study 4, we followed a one-way between-subject design and divided the sample (N = 249) into three information condition (neutral, autonomy, autarky framed). The participants were provided with the same graphical illustration (see **Figure 8**), only varying the provided information (see **Table 1**).

Neutral condition	Information which were already written in the description
Autonomy condition	Benefits which are related to autonomy, e.g. self-determination, control, intervention.
Autarky condition	Benefits which are related to energy autarky, e.g. independence, security, self-sufficiency.

Tab. 1: Experimental variation of information according to the group.

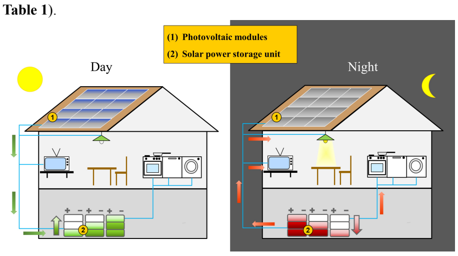

Fig. 8: Household: high degree of energy autarky & self-determined.

We additionally examined the influence of autarky and autonomy aspirations on homeowners' willingness to exchange self-generated energy within a local energy network. They were either in a **selling situation**, asked to indicate the **minimum amount** their neighbor has to offer in order **to sell**, or in a **buying situation**, asked to indicate the **maximum amount** there are prepared **to pay** to their neighbor for the self-produced electricity.

Results: Participants, provided with the autarky framed information (N = 79), are willing to spend more (see **Figure 9**). Autarky related information seems to establish a bonding relationship between the participants and the "product" self-produced electricity (see **Figure 10).**

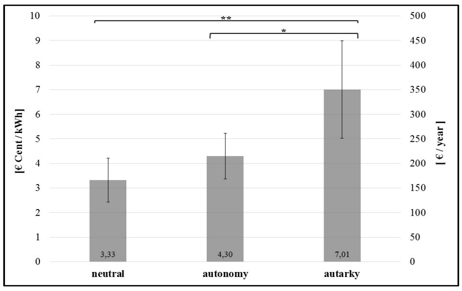

Fig. 9: Mean values in EUR Cent/kWh for the three conditions, $F(2,246) = 7.918$, $p < .001$, $\eta_p^2 = .06$. ***$p < .001$, **$p < .01$, **$p < .05$.

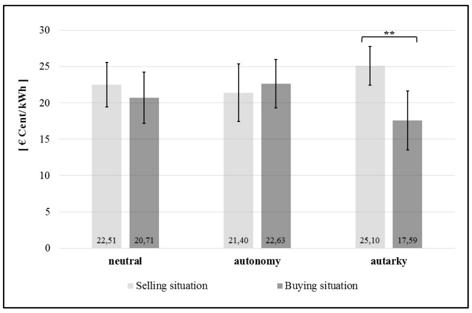

Fig. 10: Mean values in EUR Cent/kWh for the three conditions, $F(1,71) = 10.508$, $p = .002$, $\eta_p^2 = .129$. ***$p < .001$, **$p < .01$, **$p < .05$.

Discussion

The present research illustrates that the autarky attained by ESS constitutes a crucial factor in the adoption of the technology that can be leveraged to accelerate its market share. We demonstrate that this factor goes beyond mere energy-related or financial considerations, encompassing psychological motives such as self-sufficiency and supply security that can be specifically addressed by policy makers and industry. Our results emphasize that autonomy reflected by individual control over the systems is a desired attribute that should be addressed by policy makers and external energy providers that strive to centrally optimize distributed generation and storage units. However, while autarky aspirations are promising in stimulating the adoption of ESS, they can likewise render homeowners more likely to assign higher prices for self-generated energy. In decentralized energy projects that aim at optimizing energy flows within local energy networks, higher assigned energy prices might impede exchange of energy and thus effective optimization. Policy makers and project designers can tackle this drawback by addressing sense of community from the very beginning of local energy projects - eventually expanding the sphere of autarky from the individual to the group level.

Publications

- Ecker, F., Spada, H., and Hahnel, U.J.J. (2018). Independence without control: Autarky outperforms autonomy benefits in the adoption of private energy storage systems. In Energy Policy, 122, 214-228.
- Ecker, F. (2018). Akzeptanz dezentraler nachhaltiger Energiesysteme: Psychologische Untersuchungen des individuellen Autarkiestrebens. Dissertation. Institut für Psychologie, Universität Freiburg.
- Ecker, F., Hahnel, U.J.J. and Spada, H. (2017). Promoting Decentralized Sustainable Energy Systems in Different Supply Scenarios: The Role of Autarky Aspiration. Front. Energy Res. 5:14.