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Investments in renewable energies by German households: A matter of economics, social influences and ecological concern?

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ABSTRACT

We analyzed how internal factors (e.g., value orientations or attitudes) and external factors (e.g., incentives or social influences) affect households' decisions to make an investment in solar thermal energy, and how these factors interact in the decision process. 232 German home owners were questioned using an online survey. Internal factors were measured in the form of value orientations. The influence of external factors was measured in a discrete choice experiment, which covered economic consequences, social influences and ecologic consequences. The data was analyzed using mixed logit models. We found decision makers with strong eco-social value orientations to be more likely to make an investment while strong conservative and strong hedonistic value orientations both reduced investment likelihood. Among the external factors, economic consequences and investment recommendations by trustworthy sources were found highly important. Ultimately, we found several interactions between value orientations and external factors: decision makers with strong conservative or strong hedonistic value orientations are more sensitive towards economic consequences; decision makers with strong eco-social value orientations, however, are more sensitive towards recommendations and ecological consequences of an investment. Our results propose that strategies fostering households' investments in renewable energies should be appropriately adjusted for different groups of decision makers.

1. Introduction

1.1. The share of renewable energies in heat production is still low

Current energy production and consumption have led to severe global problems (e.g., climate change, permanent disposal of nuclear waste). Coping with these problems is one of the most pressing tasks society faces today and in the future [1]. To restrict the global temperature increase to the agreed limit of two degrees Celsius, worldwide decarbonization has to be accomplished by 2070 at the latest.

Some positive developments have taken place already: during the last decades, the use of renewable energies has increased substantially. This increase, however, mainly concerns electricity rather than heat generation. In 2014, about 20% of worldwide electricity generation was based on renewable energy sources. In contrast, the share of renewable heat generation was not even 4% [2]. Consequently, the worldwide energy generation is still mainly based on gas (47%), (non-renewable) solid fuels (39%) and petroleum (5%; [2]). Thus, increasing the share of renewable energies in heat generation should be one main goal in energy policies.

Especially in Western Societies, a large amount of final energy is used in households [2,3]. In this sector, most energy is used for space heating (53%) and water heating (16%)—what results in substantial CO_2 emissions [3]. These emissions could be reduced considerably if households decided to install systems producing heat from renewable energy sources (e.g., Ref. [4]). Solar thermal energy systems are one promising technology households can purchase for that matter. These systems can be used for both, water heating and space heating—in case the house's heating system is based on water circulation which is most common in Western Countries (see e.g., Refs. [5,6] for more information on heating systems in Germany). The residential use of solar thermal energy systems holds substantial CO_2 (and energy cost) saving potentials—especially if they are used for both water and space heating (e.g., Refs. [4,7]). Calculations for German households show that, for instance, in single- and two-family houses more than 25% of the heat energy demand could be covered by solar thermal power

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[4]. Currently, solar thermal energy systems are installed in only about 10% of these houses, though [8]. If the use of solar thermal energies was expanded to all single- and two family houses in Germany, an additional 108 TWh of heat energy and 25 Gt of CO_2 emissions could be saved per year (energy saving potentials were calculated from average consumption data [5,6,9]).

The present study aims at investigating how household decision makers get motivated to make – or not to make – investments in solar thermal energy systems and how different factors interact within the decision process. Our main goal is to provide insights that could help fostering such investments. We focus on owner-occupied residential buildings where investors are directly affected by their decisions [10]. Our study was conducted in Germany but the findings are likely applicable to other Western countries where circumstances are similar and comparable measures are taken to further household investments in renewable energies. In fact, the findings may be even more relevant for other countries: for one thing, the share of renewable sources used for German heat production is approximately 10% [11]—which is a rather high percentage compared to other countries (see above [2]). For another thing, even though owner occupation is high in Germany (53.3%; [12]) it is still low as compared to other Western Countries (e.g., 70.1% in the European Union on average or 64.5% in the United States [12,13]).

1.2. How home owners decide to make investments in renewable energies

As any other behavior, making investments in solar thermal energy systems is based on various factors. According to the ABC theory by Guagnano et al. [14] behavior (B) is a function of internal factors (A) and external factors (C). *Internal factors* involve any kind of *dispositions* (e.g., attitudes, value orientations or personal norms) motivating an individual to act in a certain way. For instance, these dispositions are egoistic (e.g., as one seeks for wealth or influence), eco-social (e.g., as one seeks to protect the natural environment and society in general) or hedonistic (e.g., as one seeks for immediate satisfaction; see e.g., Refs. [15–18] for more detailed information on dispositions). Sometimes different dispositions suggest the same behavior [19]. A decision maker may, for example, make an investment in solar thermal energy systems due to both eco-social (e.g., to protect the natural environment) and egoistic dispositions (e.g., to save money). Other times, different dispositions can be in conflict with each other suggesting different behaviors: One may consider making an investment due to eco-social dispositions, while hedonistic dispositions may suggest spending the money otherwise (e.g., for immediate satisfaction).

External factors are related to the behavior context determining *behavior difficulty*. Among others, these factors cover the degree of financial, social or structural support decision makers' experience. A certain behavior is perceived as difficult (or "costly") if it, for instance, requires a lot of money and effort or if it is rejected by the social environment. Behavior difficulty can be alleviated if financial incentives or social support are provided. The easier a behavior is perceived to be the more likely it is to be shown.

Empirical findings by Guagnano et al. [14] and other research groups suggest that internal and external factors interact (see Ref. [20] for an overview). A common finding is that perceived behavioral difficulty moderates the influence a person's dispositions have on behavior. Diekmann and Preisendörfer [21] investigated such moderation effects by analyzing the influence of eco-social dispositions on several environmentally relevant behaviors at varying difficulties. In their study, they defined seldom performed behavior as difficult. For instance, recycling behavior was found to be carried out frequently and thus classified as easy, while curtailing car use was a comparatively rare behavior which was classified as difficult. Diekmann and Preisendörfer's findings clearly suggest that internal factors have the greatest influence on behavior if said behavior is perceived to be easy; for more difficult behaviors their influence decreased (*low cost hypothesis*). However, it should be pointed out again that – in line with several other studies – Diekmann and Preisendörfer only accounted for internal factors in terms of eco-social dispositions while other potentially relevant dispositions (e.g., egoistic or hedonistic ones) were not included.

Interaction effects between internal and external factors were also investigated in a similar study by Guagnano et al. [14]. Here it was analyzed how the influence of eco-social dispositions on (environmentally relevant) behavior was moderated by behavioral difficulty. Here, the authors found a reversed U shaped moderation. Thus, their findings suggest that internal factors have the greatest influence on behavior if behavioral difficulty is in the middle range: The influence of internal factors was found to be lower if behavioral difficulty was relatively high – which is in line with the low cost hypothesis – but also if behavioral difficulty was relatively low (see also Ref. [19]).

Installing a solar thermal energy system to a residential building goes hand in hand with several consequences: among others, the installation costs several thousand euros, brings about changes to the heating system as well as to the house's appearance (e.g., Refs. [4,22]). Thus, making investments in solar thermal energy systems can be classified as difficult behaviors. According to the low cost hypothesis and the ABC theory, external factors should be more relevant for these behaviors than internal ones [14,21]. Empirical research on household investments in solar power and heating systems supports this assumption: even though a large number of internal factors was considered across these studies, only a fraction of them has shown to be decision-relevant ([23–27]; see Table 1 for an overview of decision-relevant internal factors). External factors, on the other hand, were found to be more relevant in the decision process [26–33]. In most empirical studies external factors were measured in terms of perceived investment circumstances and consequences. As theory suggests, making investments was found to be more likely if decision makers perceived behavior difficulty to be reduced by certain external factors. Highly relevant external factors involved expected financial costs and benefits, expected reliability and operation security of the new system, perceived social support and recommendations by others to make an investment, and expected environmental benefits arising from the investment (see Table 1 for an overview).

It should be noted, though, that the total amount of empirical research on energy-relevant investment decisions in households is fairly limited up to now [34]. The available investigations frequently suffer from some shortcomings: for one thing, most of the available studies focus either on internal or on external factors while they do not take the interaction of these factors into account [34]. For another thing, studies accounting for internal factors mostly focus on eco-social dispositions while other potentially relevant (e.g., egoistic or hedonistic) dispositions are hardly considered (e.g., Refs. [19,35]). Thus, there are still uncertainties on how any other of these other dispositions influence energy-relevant investment decisions and how they interact with external factors [34].

Analyzing such interactions could be most useful for identifying different target groups of households—and for tailoring policy measures accordingly [19,36]. It can be argued that home owners with, for instance, strong egoistic dispositions are particularly sensitive towards financial consequences (and thus financial incentives) when it comes to solar thermal energy investments, while others with high eco-social dispositions could be more interested in environment-related investment consequences (and, for instance, environmental certifications).