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A Comparative Analysis of House Owners in Need of Energy Efficiency Measures but with Different Intentions

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Abstract: Existing private homes in Germany and throughout Europe often are in need of energy efficient refurbishment measures (EERMs). However, these EERMs are not realized on the required level in order to achieve environment-related political targets. Therefore we investigate, based on an online survey of 1085 German owner-occupiers, the factors that differentiate two groups of single- and two-family house owners in need of EERM. Using an extended version of the Theory of Planned Behavior as a research framework, the performed logistic regression analysis shows that e.g., behavioral beliefs are significant factors for differentiating "Future-Refurbishers" from "Non-Refurbishers". Based on our results we suggest an enhancement of practice-orientated initiatives, e.g., refurbishment workshops or best-practice presentations. By presenting the aesthetic appearance of refurbished buildings or providing knowledge, other owner-occupiers could be motivated to engage in EERM. In addition to funding programs, initiatives like this can be used to increase the general energy efficiency of buildings and specifically of those in cities and urban districts, where a high share of the mentioned houses is located and greenhouse gas emissions are caused to a great extent.

Keywords: energy efficient refurbishment measures; residential buildings; decision-making; Theory of Planned Behavior

1. Introduction

Energy efficiency in the building sector plays a crucial role in Germany and in other European countries. Both Germany and the EU have passed several laws and regulations to improve the energy efficiency of buildings. As examples the 2010 Energy Performance of Buildings Directive [1], the 2012 Energy Efficiency Directive [2] of the European Union, the German National Action Plan on Energy Efficiency [3] and the German Federal Government's energy concept [4] can be mentioned. The stipulations and objectives in these frameworks deal with the high energy demand of the existing building stock and consequently its negative effects on the climate as well as the environment. In total, the European building stock accounts for 40% of the European final energy consumption as well as 36% of the overall European greenhouse gas emissions (GHGE) [5]. For Germany, these figures are similar, with the total building stock accounting for 38% of the final energy consumption and 30% of the overall GHGE [6]. In order to achieve significant reductions in consumption and emissions, the stock of owner-occupied single- and two-family houses is of special importance in Germany. Compared to the more complex ownership structure associated with multi-family houses, owner-occupiers of single- and two-family houses are more independent in their decision-making related to energy efficient refurbishment measures (EERM) [7]. Additionally, these house owners are responsible for 11% of the

total final energy consumption in Germany what also suggests a high energy saving potential [8]. Based on an average energy consumption of 177 kWh/m^2·a, the estimated potential savings could range between 50% and 70% by 2050 [6].

However, despite several governmental actions such as setting legal requirements, grants or low interest loans [9], the refurbishment rate in Germany has currently not yet reached the politically focused target value of 2% p. a. [4,8]. With regard to residential buildings, Rein and Schmidt [10] actually point out a decline of more than 6 billion Euros between 2010 (EUR 40.9 billion) and 2014 (EUR 34.8 billion) in the financial investment in EERM.

In order to achieve an almost climate-neutral building stock by 2050, as determined in the existing German regulations, and moreover benefitting from multiple societal benefits (e.g., decreased energy import dependency, lower residential energy bills and increased residential comfort [11–13]), a better understanding of house owners' reluctance towards EERM is essential. Against this background, the present study considers owner-occupiers of single- and two-family houses in Germany with a specific focus on two groups of owner-occupiers. Next to owner-occupiers who stated their intention to conduct specific EERM in the next years, hereinafter called "Future-Refurbishers," the second group consists of "Non-Refurbishers", who stated a need for EERM but also a lack of intention to take action. For the comparative analysis of these groups we analyze data gained from an online survey. Within this survey we considered influencing factors derived from the scientific literature which are related to the Theory of Planned Behavior [14], Building conditions and individuals' Environmental awareness.

Based on this research framework, our research target is the identification of those factors allowing for a differentiation and consequently a better understanding of "Future-Refurbishers" and "Non-Refurbishers" (research target 1). Furthermore, we intend to provide ideas on how relevant identified factors can be utilized to trigger increased energy-related refurbishment activities among owner-occupiers of single- and two-family houses in Germany and beyond (research target 2). This is of special relevance for cities and urban districts where globally 70% of all GHG originate from [15] and where 57% of all single-family houses are located in Germany [16].

By focusing on willing house owners pre-refurbishment ("Future-Refurbishers") and house owners who do not intend to take actions despite a perceived need ("Non-Refurbishers"), this study is a contribution to the still lacking understanding of decisions regarding EERM [17]. In contrast to our study, which is focused on future refurbishment activities, the existing decision-making literature focused on EERM is, as pointed out in the review of Kastner and Stern [18], primarily characterized by studies considering past decisions (retrospective studies) or experimental/hypothetical approaches. As examples the retrospective studies of Zundel and Stieß [19], Stieß and Dunkelberg [20], Michelsen and Madlener [21] or Black et al. [22] can be mentioned. Experimental/hypothetical approaches are followed in the studies of Achtnicht [23], Achtnicht and Madlener [24], Grösche and Vance [25] or e.g., Alberini et al. [26].

In [19,20], the authors pursued a comparative concept by comparing German homeowners with different refurbishment activities, i.e., energy-efficient and standard refurbishment activities. Michelsen and Madlener [21] also conducted an analysis among German homeowners but with a focus on motivational factors that influence the decision-making in the context of residential heating systems. In the study of Black et al. [22] various energy-related efficiency measures were considered in order to investigate relevant factors that determine the decisions of the analyzed US citizens. Next to insulation activities also activities referring to the heating system were considered.

As a prominent experimental/hypothetical approach, the analysis of Achtnicht [23], who conducted a choice experiment among German house owners, can be mentioned. Besides the role of environmental benefits, this study also analyzed the willingness-to-pay for CO2 savings. The study of Achtnicht and Madlener [24] is a continuation of Achtnicht [23] and differs with regard to the considered choice sets. Grösche and Vance [25] analyzed data of German homeowners who conducted one or more EERM (e.g., roof insulation, façade insulation, replacement of the heating system or replacement of windows). Based on this measures and further details, the authors elicited the households' willingness to pay per

kWh saved. Alberini et al. [26] surveyed Swiss owner-occupiers of houses that haven't been renovated in the past years. The considered owner-occupiers had to choose between hypothetical refurbishments during the conducted conjoint choice experiments. These refurbishments were defined by different attributes such as upfront cost, rebate offered by the government or savings on the energy bills per year.

While there is a number of retrospective and hypothetical/experimental studies, only a few studies considering future refurbishment activities can be identified in the existing literature. As examples, the studies of Klöckner and Nayum [27] and Friege [28] can be mentioned. In their study of 3787 Norwegian households, Klöckner and Nayum [27] considered drivers and barriers (in different stages of the decision-making process) referring to planned EERM such as e.g., insulation activities or the replacement of windows. Insulation activities were also regarded in the study of Friege [28] who considered planned refurbishment activities as well as past refurbishment activities in his study among 275 private German homeowners. On the one hand, we want to contribute to the limited understanding of decisions regarding EERM [17] by adding a study using a future-orientated approach in a research field that so far was predominantly analyzed with retrospective and experimental/hypothetical studies. On the other hand, the present study aims to enhance the insights related to the current political activities focused on increasing the refurbishment activities in Germany.

The study is structured as follows: the theoretical and methodological background is outlined in the Sections 2 and 3. Our results related to research target 1 are presented and discussed in Section 4. Finally, we provide conclusions and implications in Section 5 based on our results to meet research target 2.

2. Research Framework of the Study

This section conveys the theoretical research framework of our analysis, including an introduction of the Theory of Planned Behavior (TPB) which is the main guideline for the identification of relevant factors within the scientific literature. This section also introduces additionally considered predictors which were identified when screening relevant literature.

Built upon the Theory of Reasoned Action (TRA) [29], the Theory of Planned Behavior was developed by Icek Ajzen [30]. This was done by adding the predictor 'Perceived behavioral control' to the TRA predictors 'Attitude toward the behavior' and 'Subjective norms' [14]. With these predictors, the TPB is intended to deal with behaviors over which people have incomplete control. In the context of the TPB, the predictor 'Attitude toward the behavior' refers to the extent of which a person has a favorable or unfavorable evaluation or appraisal of the behavior in question. The second predictor is named 'Subjective norm'. This predictor refers to the perceived social pressure to perform or not perform the behavior. The third factor is the degree of 'Perceived behavioral control' and refers to the perceived ease or difficulty of performing the behavior and it is assumed to reflect past experience, individuals' resources and related anticipated barriers. In general, the greater the 'Perceived behavioral control' and the more favorable the 'Attitude' and 'Subjective norm' with respect to a behavior, the stronger is an individual's intention to perform the behavior in question [14]. Thereby, the individual contributions of the three predictors are expected to vary across situations and behaviors [14].

However, according to Ajzen, the developer of the TPB, and Driver [31], the TPB postulates–at the most basic level of explanation–that performance or non-performance of behaviors depends on the beliefs behind the introduced TPB predictors. In addition to *Behavioral beliefs*, which are assumed to affect the predictor 'Attitudes toward the behavior,' these are *Normative beliefs* and *Control beliefs*. While *Normative beliefs* constitute the underlying determinants of 'Subjective norms,' *Control beliefs* refer to the predictor 'Behavioral control' [31].

Based on the TPB we utilized factors associated to these beliefs for the differentiation of "Future-Refurbishers" and "Non-Refurbishers". These factors as well as additional contextual aspects were identified by a screening of the existing scientific literature. The identified additional aspects refer to individuals' *Environmental awareness* and *Building conditions*. The latter were also considered by Organ et al. [32] as important for understanding house owners' motivation in the context of EERM.

In addition, Black et al. [22] also pointed out a building's physical structure as relevant in the context of capital investments in residential energy efficiency. Considering of house owners' *Environmental awareness* in the analysis is supported by two reasons. The first relates to the interaction of energy consumption and environmental damages and the perceived high relevance of environmental and climate protection in Germany but also other European countries [33]. The second and more important reason is the identified relationship between environmental awareness and related attitudes in previous empirical research considering the adoption of measures to reduce the environmental impact of buildings [34,35]. Thus Rajaie et al. [36] explicitly suggest that environmental awareness should be addressed in research that considers technological advancements for the reduction of the energy demands of buildings and consequently their impact on the environment.

Finally, a legitimization for the utilization of the TPB as a basis framework can be found in the studies of Wang et al. [37], Wu et al. [38] or Abrahamse and Steg [39], in which the TPB was already used successfully in similar contexts (energy efficiency and buildings).

3. Data Collection and Analysis

To analyze our research questions an online survey was conducted using a questionnaire with statements considering *Environmental awareness aspects*, *Building conditions* as well as *Behavioral*, *Normative* and *Control beliefs* of the TPB model. Finally, this extended form of the TPB served as a guideline for the identification of relevant influencing factors within the existing literature. In the following we introduce the precise statements and questions asked based upon the identified influencing factors. Moreover we provide information on the procedure of data acquisition and the method used to statistically analyze the collected data.

3.1. Survey Content

The factors and statements used in this study were either drawn directly from the available scientific literature in the context of energy efficiency and residential buildings (such as e.g., [19,20,24]) or were specifically created based on factors identified as relevant. Moreover, we utilized statements from Bearden et al. [40] to assess the potential influence of individuals' *Environmental awareness*. The *Building conditions* [22,32] were examined using self-developed statements related to the structural condition, the energy efficiency as well as a variable representing the comfort in the building and its visual appearance.

The wording of the statements used in our questionnaire can be derived from Table 1. While "Non-Refurbishers" were asked to refer their answers to hypothetical energy-related refurbishment activities on their buildings, "Future-Refurbishers" were asked to refer their answers to those measures stated as intended for the near future.

Table 1. Statements used in the questionnaire of this study (wording for "Non-Refurbishers").

Factors	Predictor and Statements
	Behavioral Beliefs
	The expenditure for EERM is justified . . .
All in all reasonable *	all in all.
Indoor comfort *	because of an associated enhancement of the indoor comfort.
Energy bills *	because of the cost savings afterwards.
Reasonable for environment *	because of the resulting benefits for the environment.
Doubts about desired effects	I would have doubts regarding the desired effects of EERM.
Susceptibility repairs	Energy-related refurbishment projects make a house less susceptible to repairs.
	Normative Beliefs
Esteem friends/family	Among my friends and my family refurbishments are seen as useful.
Social esteem	Energy-related refurbishments raise the social esteem.
Esteem neighborhood	In my neighborhood refurbishments are seen as useful.

Table 1. *Cont.*

Factors	Predictor and Statements
	Control Beliefs
Experience	I have experience with energy-related refurbishment projects.
Time planning	I would have enough time for planning the refurbishment.
Time conduction	I would have enough time for conducting the refurbishment measures.
Own capabilities	I could renounce on professional help regarding EERM due to my own capabilities.
Support family	My family would support me during an energy-related refurbishment project.
Financing problems	I would have problems financing the EERM.
No loan	I wouldn't want to take up a loan.
Appropriate craftsmen	It surely would be hard to find appropriate craftsmen.
Complex promotion	The governmental promotions for EERM are onerous and bureaucratic.
Legal requirements	Complying with the legal regulations would be difficult.
Dust / dirt no problem	Dust and dirt are no problem for me.
Objective information	Getting objective information in the context of EERM would be difficult.
Complex case	My house would be a complex refurbishment case.
Consulting during conduction	I would use professional help during the conduction of EERM.
Consulting during planning	I would use professional help for the planning of EERM.
Insecurity during refurbishment	I would often be insecure during the planning and conducting of EERM.
	Environmental Awareness
Environmental harm products	It is important to me that the products I use do not harm the environment.
Impacts of decisions	I consider the environmental impact of my actions when making many of my decisions.
Purchase habits	My purchase habits are affected by my concern for our planet.
Waste of resources	I am concerned about the resource wastage on our planet.
Environmental responsibility	I would describe myself as environmentally responsible.
Discomfort Eco-friendliness	I would accept discomfort in exchange for more environmental friendliness.
	Building Conditions
	In terms of the . . .
Energy efficiency **	. . . energy efficiency of the building I ought to take actions . . .
Comfort and appearance **	. . . comfort in the building and its visual appearance I ought to take actions . . .
Building fabric **	. . . structural condition I ought to take actions . . .

Answer-scales: I totally agree/I agree/Neither agree nor disagree/I don't agree/I don't agree at all. * Yes/Not sure/No. ** I should take actions . . . as soon as possible (asap)/ . . . in the next years/there is no need. Source: Content adapted and adopted from Zundel and Stieß [19], Stieß and Dunkelberg [20], Achtnicht and Madlener [24], Bearden et al. [40], Black et al. [22] and Organ et al. [32].

3.2. Data Collection

For the purpose of our study, a Germany-wide online survey was conducted during June and July 2016 using an online panel provided by a market research institute. Our target group were house owners of single- and two-family houses in Germany who lived in these houses at the time of data collection. By asking the house owners whether a refurbishment project was planned or not, the group of "Future-Refurbishers" and "Non-Refurbishers" were identified. Subsequently, "Future-Refurbishers" were asked whether they plan to undertake EERM on the upper or lower building envelope, the façade, windows and/or doors. Only those house owners who stated their intention to realize at least one EERM related to these building components or intended to modernize the heating system (e.g., via solar thermal systems, installation of a ventilation system with heat recovery) were considered as "Future Refurbishers" for the present study. "Future-Refurbishers" without energy-related measures were not considered for this study.

Those individuals who stated to have no refurbishment intentions were considered for this study when a need for EERM was indicated. This need was identified by asking a question considering the perceived energy-related status of those building components.

Only those owner-occupiers (without refurbishment intentions) who stated a "need" or an "immediate need" for improving the energy efficiency of the heating system or of at least one of the mentioned building components were considered for the group of "Non-Refurbishers".

Finally, after data cleaning and sorting out owner-occupiers without energy-related refurbishment intentions (75 respondents) or needs (627 respondents) 351 "Non-Refurbishers" and 734 "Future-Refurbishers" were available for statistical data analysis. The data cleaning procedure followed a combined approach characterized by an analysis of the respondents' answers to the individual question sets as well as the time respondents devoted for answering the questions. After marking questionnaires in which mainly identical answers and/or short processing times were evident, an individual case-by-case examination of suspicious but also incomplete data sets finally led to the exclusion of questionnaires of 320 "Future-Refurbishers" and 345 "Non-Refurbishers".

The characteristics of the respondents of both groups are presented in the Figures 1–4 indicating statistically significant differences between the two groups in terms of age (Figure 1), education (Figure 2), average monthly net household income (Figure 3) and in terms of the construction periods (Figure 4) of the participants' buildings.

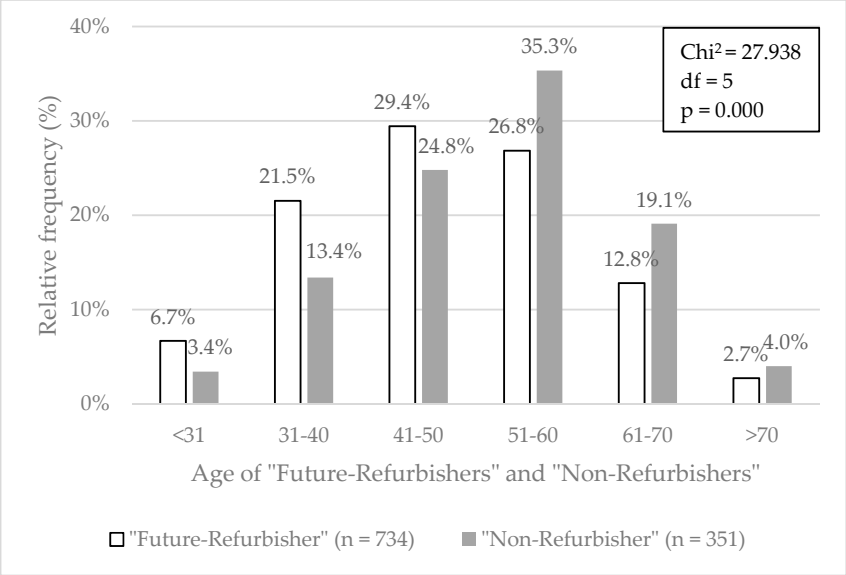

Figure 1. Age groups of "Future-Refurbishers" and "Non-Refurbishers".

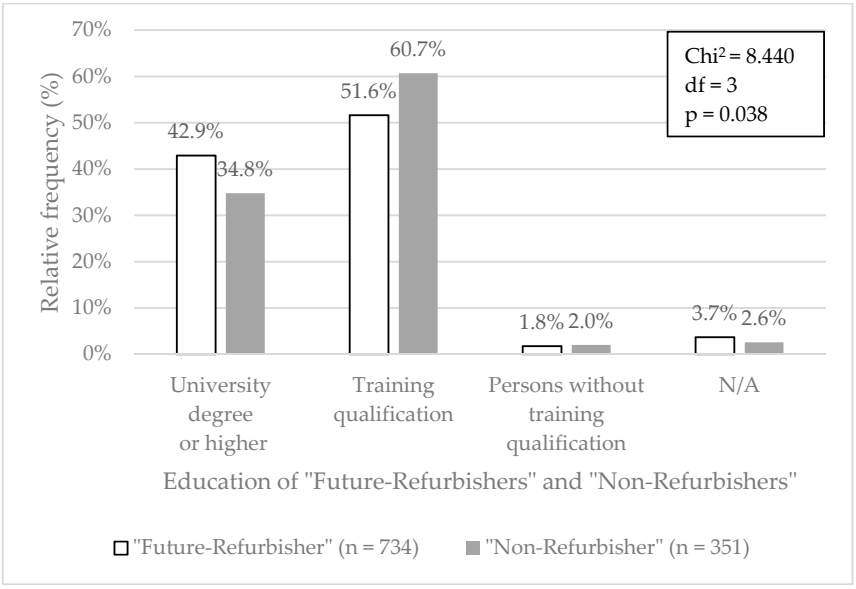

Figure 2. Education levels of "Future-Refurbishers" and "Non-Refurbishers".

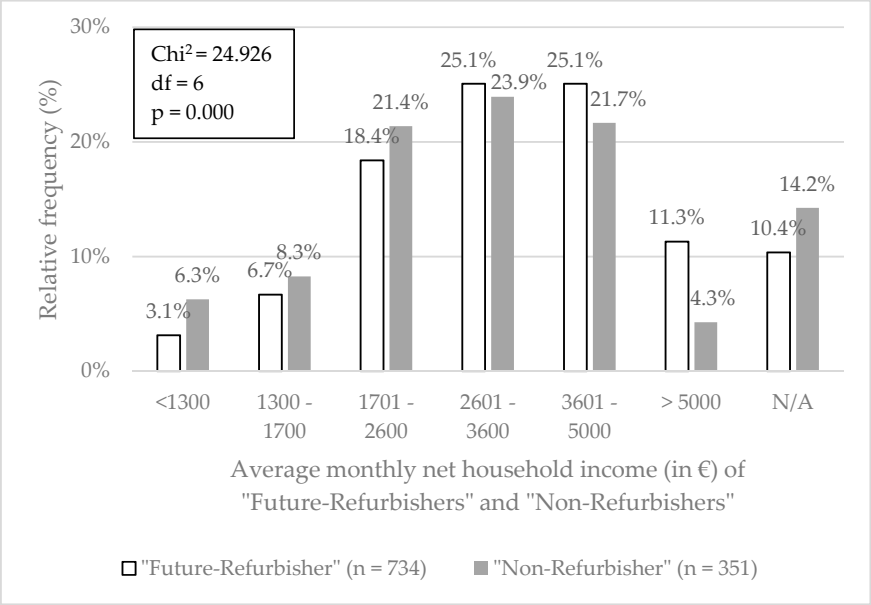

Figure 3. Average monthly net household income (in €) for "Future-Refurbishers" and "Non-Refurbishers".

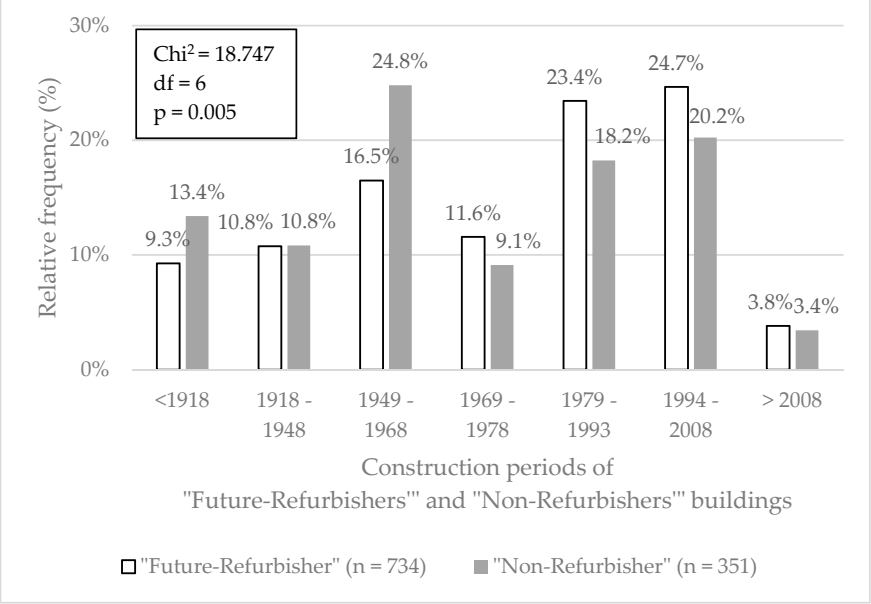

Figure 4. Construction periods of "Future-Refurbishers" and "Non-Refurbishers" buildings.

Figures 2 and 3 show that "Future-Refurbishers" are not only more likely to have a university degree, but also a higher income than "Non-Refurbishers." Since EERM often result in substantial costs, it seems that people with a higher income are more capable of realizing EERM in the future. Moreover, the group of "Non-Refurbishers" is older than the group of "Future-Refurbishers." Further, there are significant differences between the two groups related to the age of their houses with the average construction year of "Future-Refurbishers" buildings being 1968 compared to 1963 for houses of "Non-Refurbishers". This implies that a higher share of "Non-Refurbishers" buildings were built before the 'Thermal Insulation Ordinance' came in place in 1977 in order to enhance the energy efficiency of new buildings in Germany.

The answers of the "Future-Refurbishers" and "Non-Refurbishers" to the statements presented in Section 3.1 were analyzed using binary logistic regression. This method is intended to reveal factors—beyond socio-demographic aspects—that allow for a differentiation of both analyzed groups and

potentially for deriving recommendations for overcoming the reluctance concerning residential EERM in Germany.

3.3. Mathematical Approach for Data Analysis

In general, logistic regression is a form of multiple regression with a categorical outcome variable and categorical or continuous predictor variables. In its simplest form it is possible to forecast which of two categories a person is likely to belong to given some other details [41]. In this study, the two outcome categories are represented by "Future-Refurbishers" and "Non-Refurbishers." The predictor variables, in turn, are represented by the underlying factors of the questions and statements presented in Section 3.1.

In multiple linear regression, Y is, as presented in Equation (1), predicted by a combination of predictor variables multiplied by their respective regression coefficients:

$$Y_i = b_0 + b_1X_{1i} + b_2X_{2i} + \ldots + b_nX_{ni} + \varepsilon_i \quad (1)$$

Instead of predicting the value of a variable Y from several predictor variables X_n, in binary logistic regression a probability P(Y) of Y occurring given known values of X_n is determined with Equation (2):

$$P(Y) = \frac{1}{1 + e^{-(\,b_0 + b_1X_{1i} + b_2X_{2i} + \ldots + b_nX_{ni} + \varepsilon)}} \quad (2)$$

In this equation e is the base of the natural logarithm and the other coefficients form a linear combination. By expressing the multiple linear regression equation in logarithmic terms (called the logit) the results of the equation vary between 0 and 1. Thus, a value close to 1 means that Y is very likely to have occurred while a value close to 0 expresses the opposite [41]. The coefficients of the predictor variables are determined by using maximum-likelihood estimation. This estimation method selects coefficients that make the observed values most likely to have occurred [41]. Based on these values so-called "odds" and "odds ratios" (the proportionate change in odds due to a unit change in the predictor variable) can be calculated [41]. These odds ratios and the regression coefficients are presented hereinafter in Section 4.

For identifying relevant factors behind the introduced statements, we used the IBM SPSS Statistics 23 analysis program. Due to the high amount of initially considered influencing factors, a stepwise logistic regression was used for identifying the most important factors capable of distinguishing the survey participants into "Future-Refurbishers" and "Non-Refurbishers." Due to potential suppressor effects (those effects occur when a predictor has a significant effect but only when another variable is held constant) we used the stepwise backward method. In [42], this method is described as follows: "With this method, the initial model contains all of the terms as predictors. At each step, terms in the model are evaluated, and any terms that can be removed without significantly detracting from the model are removed. In addition, previously removed terms are reevaluated to determine if the best of those terms adds significantly to the predictive power of the model. If so, it is added back into the model. When no more terms can be removed without significantly detracting from the model, and no more terms can be added to improve the model, the final model is generated." The thresholds for this procedure were P_{IN} = 0.05 and P_{OUT}= 0.10. The stepwise backward method was used in order to reduce the risk of a Type II error (i.e., missing a predictor that does in fact predict the outcome) which would be more likely with the alternative method of stepwise forward selection [41]. This method in essence follows an opposite procedure than the stepwise backward method but starts with no model terms (except the constant) in the equation. The third general method available in SPSS when conducting a binomial logistic regression is the default mode called 'enter'. This method simply adds all terms into the equation [42].

4. Results and Discussion

In order to gain a better understanding of the differences between house owners who are aware of their need to conduct EERM but differ with regard to their intention to take action, we compared reluctant "Non-Refurbishers" with house owners who plan to take action, i.e., "Future-Refurbishers." The results of the applied binary logistic regression analysis as well as a discussion are presented in the following subsections.

4.1. Differentiating Influencing Factors

The results of the binary logistic regression analysis are provided in Table 2. For all significant influencing factors not excluded via the stepwise regression, the odds ratios (Exp(B)), the regression coefficients (β) and p-values are presented. A significant Exp(B) value (p-value ≤ 0.05) greater (less) than 1.0 indicates that, as the predictor increases, the odds of the outcome occurring (being a "Future-Refurbisher") increase (decrease). Statistically insignificant results are printed in non-bold letters.

Table 2. Results for the numeric and categorical variables of being a "Future-Refurbisher".

Factors	Predictors and Statements		Exp (B)/β (p-value)
Behavioral beliefs			
	The expenditure for EERM is justified ...		
All in all reasonable	all in all.	YES vs. NO	1.62/0.48 (0.411)
		DON'T KNOW vs. NO	0.92/−0.086 (0.881)
Indoor comfort	because of an associated enhancement of the indoor comfort.	YES vs. NO	**5.37/1.68 (0.000)**
		DON'T KNOW vs. NO	**3.33/1.20 (0.013)**
Energy bills	because of the cost savings afterwards.	YES vs. NO	**2.09 /0.74 (0.043)**
		DON'T KNOW vs. NO	1.13/0.125 (0.722)
Reasonable for environment	because of the resulting benefits for the environment.	YES vs. NO	**0.15/−1.92 (0.000)**
		DON'T KNOW vs. NO	**0.29/−1.26 (0.013)**
Doubts about desired effects	I would have doubts regarding the desired effects of EERM.		**2.06/0.723 (0.000)**
Normative beliefs			
Esteem friends/family	Among my friends and my family refurbishments are seen as useful.		**0.64/−0.439 (0.004)**
Social esteem	Energy-related refurbishments raise the social esteem.		0.81/−0.212 (0.089)
Esteem neighborhood	In my neighborhood refurbishments are seen as useful.		0.79/−0.240 (0.089)
Control beliefs			
Experience	I have experience with energy-related refurbishment projects.		1.22/0.202 (0.060)
Time planning	I would have enough time for planning the refurbishment.		**0.74/−0.302 (0.028)**
Time conduction	I would have enough time for conducting the refurbishment measures.		**0.66/−0.422 (0.001)**
Own capabilities	I could renounce on professional help regarding EERM due to my own capabilities.		**0.74/−0.305 (0.015)**
Financing problems	I would have problems financing the EERM.		**2.43/0.888 (0.000)**

Table 2. *Cont.*

Factors	Predictors and Statements		Exp (B)/β (*p*-value)
Appropriate craftsmen	It surely would be hard to find appropriate craftsmen.		**0.58/−0.545 (0.000)**
Complex promotion	The governmental promotions for EERM are onerous and bureaucratic.		**0.67/−0.399 (0.000)**
Legal requirements	Complying with the legal regulations would be difficult.		**1.36/0.310 (0.008)**
Complex case	My house would be a complex refurbishment case.		**1.24/0.218 (0.044)**
Consulting during conduction	I would use professional help during the conduction of EERM.		**1.43/0.357 (0.011)**
Consulting during planning	I would use professional help for the planning of EERM.		**1.34/0.295 (0.025)**
Environmental awareness			
Impacts of decisions	I consider the environmental impact of my actions when making many of my decisions.		**0.64/−0.453 (0.001)**
Discomfort Eco-friendliness	I would accept discomfort in exchange for more environmental friendliness.		1.30/0.261 (0.069)
Building conditions			
	In terms of the ...		
Energy efficiency	energy efficiency of the building I ought to take actions ...	ASAP vs. NO NEED	**10.60/2.36 (0.000)**
		NEXT YEARS vs. NO NEED	**4.09/1.41 (0.000)**
Comfort and appearance	comfort in the building and its visual appearance I ought to take actions ...	ASAP vs. NO NEED	**7.25/1.98 (0.000)**
		NEXT YEARS vs. NO NEED	**3.50/1.25 (0.000)**
Building fabric	structural condition I ought to take actions ...	ASAP vs. NO NEED	1.49/0.398 (0.455)
		NEXT YEARS vs. NO NEED	**1.91/0.647 (0.012)**
Constant term			*N/A/−1.61 0.143*

Reference-category: "Non-Refurbishers"; Source: own calculation.

Regarding *Behavioral beliefs*, the factors *Indoor comfort*, *Reasonable for environment*, *Energy bills* and *Doubts about desired effects* were significant and thus included in the regression model. The affiliated Exp(B) values for these factors suggest that it is more likely to be in the group of "Future-Refurbishers," given house owners assume that EERM enhance the housing comfort and that EERM lead to a reduction of the energy bill. Belonging to this group is also more likely for individuals, who are not or less skeptical regarding the doubts about the pursued effects of EERM. The Exp(B) value associated with the factor *Reasonable for environment* is smaller than 1.0. This indicates that house owners who think that EERM are good for the environment are less likely to be part of the group of "Future-Refurbishers."

When considering *Normative beliefs*, only the factor *Esteem friends/family* is significant and included in the regression model. The calculated Exp(B) value suggests that belonging to the group of "Non-Refurbishers" is more likely with a decreased appreciation of EERM by house owners' friends and family.

A look at the *Control beliefs* shows that there are ten significant factors identified as being relevant for predicting group membership. Among these factors the most differentiating factors with Exp(B) values bigger than 1.0 are *Financing problems*, *Consulting during conduction*, *Legal requirements and Consulting during planning*. These results indicate that being a member of the group of "Future-Refurbishers" is more likely the lower house owners perceive financial problems to be associated with EERM. Implementing EERM is, furthermore, more likely for those house owners who have a lower demand of consultation. Further, the results of the factors *Legal requirements* but also *Complex case* imply that the uptake of EERM is more probable if complying with legal requirements in connection with EERM is perceived as less complex and also when the building does not appear to be hard to treat.

Significant Exp(B) values smaller than 1.0 are calculated for the factors *Appropriate craftsmen*, *Time conduction* as well as *Complex promotion*, *Own capabilities* and *Time planning*. With respect to the wording of our statements and the answer scales used in the questionnaire, this can be interpreted as follows: the more positive a house owner's expectation is to find appropriate craftsmen for conducting EERM, the more likely this person belongs to the group of "Non-Refurbishers." This also applies to the perceived difficulty connected to governmental promotion—if individuals perceive governmental promotion as not complex, their belonging to the group of "Non-Refurbishers" is more likely. In contrast to the latter two rather surprising results, we also find that limited time for conducting and planning EERM and low *Own capabilities* of the house owners in this area increase the odds of belonging to the group of "Non-Refurbishers."

Along with factors associated with the TPB we included *Environmental awareness* factors and *Building conditions* as additional contextual aspects in our study. When considering the results related to the *Environmental awareness* aspects, there is only one significant factor, which is *Impacts of decisions*. The associated Exp(B) value suggests that belonging to the group of "Non-Refurbishers" is more probable if house owners do not or hardly consider the potential environmental impacts of their actions when making decisions.

With respect to *Building conditions,* the factors *Energy efficiency* and *Comfort and appearance* are included, significant and connected to strong Exp(B) values greater than 1.0. These results suggest that being a "Future-Refurbisher" is more likely if house owners perceive an immediate need or a need within the next few years to take actions to improve the energy efficiency, the appearance or the comfort of their buildings. A perceived need to take care of a buildings structural condition in the foreseeable future (*Building fabric*) was also identified as increasing the likeliness of being part of the "Future-Refurbishers."

The factors which have been excluded via stepwise backward algorithm are presented in Table 3. In total 10 factors were excluded by the stepwise regression algorithm in SPSS.

Table 3. Excluded factors/statements.

Factors	Predictors and Statements
	Behavioral beliefs
Susceptibility repairs	Energy-related refurbishment projects make a house less susceptible to repairs.
	Normative beliefs
	—
	Control beliefs
Support family	My family would support me during an energy-related refurbishment project.
No loan	I wouldn't want to take up a loan.
Dust/dirt no problem	Dust and dirt are no problem for me.
Objective information	Getting objective information in the context of EERM would be difficult.
Insecurity during refurbishment	I would often be insecure during the planning and conducting of EERM.
	Environmental awareness
Environmental harm products	It is important to me that the products I use do not harm the environment.
Purchase habits	My purchase habits are affected by my concern for our planet.
Waste of resources	I am concerned about the resource wastage on our planet.
Environmental responsibility	I would describe myself as environmentally responsible.
	Building conditions
	—

Source: own figure.

4.2. Overall Classification

This section is intended to allow a better evaluation of the quality of the analysis results. Next to the actual and predicted group membership via binary logistic regression in Table 4 we furthermore provide additional information on specific quality indicators.

Table 4. Classification table showing the predicted and actual groups from the sample.

Actual Membership	Predicted Membership		
	Future-Refurbishers	**Non-Refurbishers**	**Correctly Classified**
Future-Refurbishers (N = 734)	671	63	91.4%
Non-Refurbishers (N = 351)	93	258	73.5%
Overall:			85.6%

Source: own figure.

From 734 respondents who stated their willingness to conduct relevant refurbishment measures in the future, 91.4% were assigned to the correct group. In the case of the "Non-Refurbishers," this value is 73.5%. In total, the binary logistic regression function assigned 85.6% of the sample participants correctly. By comparing this proportion of correctly classified observations with the proportion expected by chance, known as proportional chance criterion (56.2%) [43], our model improves this indicator by almost 30%.

The pseudo R^2 value that determines the amount of variance in the dependent variable explained by the independent variables of 0.649 (Nagelkerke) also indicates a very good quality of the analysis [44]. The finally computed significance levels associated with the model chi-square value (678.8) of $p = 0.000$ and the Hosmer and Lemeshow test with $p = 0.960$ (>0.05) also suggest a good model fit. For the assessment of multicollinearity among the considered variables, the variance inflation factors (VIF; details on VIFs can be derived from [44]) were calculated. None of these VIFs was higher than 3, which leads to the conclusion that multicollinearity does not negatively affect the quality of our results.

4.3. Discussion

In this study we analyzed multiple factors that influence the realization of EERM in owner-occupied single- and two-family houses in Germany. The specific subjects of our empirical analysis, which is based on a relatively highly educated sample, were owner-occupiers of single- and two-family houses who stated their intention to conduct EERM ("Future-Refurbishers") and those owner-occupiers of such houses who stated a need to undertake EERM but do not intend to take action ("Non-Refurbishers").

Utilizing an extended version of the TPB as a framework for our analysis appears justified in our point of view as it has already been previously used successfully in the context of buildings and energy efficiency and factors of all predictor domains contribute to group differentiation in our study. Additionally, Wilson and Dowlatabadi [45] state, that "Residential energy use is characterized by a wide range of decision types and contexts, as well as psychological and contextual influences on behavior. [Thus] Decision models from different research traditions are all relevant to some aspect of residential energy use". Adding further aspects in connection with the original TPB is not unusual and provides, as Kastner and Stern [18] state, the possibility to improve and adapt the purpose of the analysis. Additionally, considering house owners' perceived specific *Building conditions* and *Environmental awareness* in this study contributed to a better differentiation of "Future-Refurbishers" and "Non-Refurbishers".

Before discussing the results of our study some limitations and methodological aspects need to be addressed. As outpointed earlier, our data was collected with an online survey in June and July 2016. Choosing this time of the year might have led to a bias of our results due to an omission or an overrepresentation of certain house owners. Evidence for such effects can be found in [46]. Additionally, some limitations refer to the depth of further statistical evaluations, e.g., carrying out a more detailed analysis of our research framework differentiated by older or younger respondents in

interaction with their income. The reason for not realizing such type of analysis relates to the limited sample size. Even though the number of respondents was suitable for the statistical analyses presented, the sample size was not sufficient for such more specific statistical analyses. The limited sample size was also the reason why further statistical tests to underpin the predictive power (e.g., cross-validation; for details see [47]) were omitted.

Related to our results, specifically referring to the considered *Behavioral beliefs*, the literature states that individuals are likely to perform energy efficiency measures in order to increase indoor comfort and to reduce energy bills and their environmental impact [32]. However, the results of our study regarding the last aspect suggest the opposite as the perception that EERM do have a positive effect on the environment is more characterizing for the group of "Non-Refurbishers." A reason for this result could originate from house owners' thoughts about the necessary building components and the origin of the materials for these components that are required for carrying out EERM. While "Non-Refurbishers" might only consider the usually desired positive effects of EERM on the environment, "Future-Refurbishers" answers could be influenced by their higher involvement and know-how about the refurbishment such as the necessary amount of insulation material or construction material for windows and doors, which are often based on fossil fuels. Regarding the factors *Indoor comfort* and *Energy bills*, our results are congruent with the thesis of Organ et al. [32]. Further underpinning results referring to these aspects originate from empirical studies conducted in Ireland [48] and Sweden [49]. The Irish study concluded that EERM are mainly driven by monetary goals while comfort gains were identified to be of secondary relevance. Environmental benefits of EERM were identified to be of low relevance in both studies. In terms of *Doubts about desired effects*, our results go along with the cause-effect relationship stated by Zundel and Stieß [19] who identified doubts concerning the results of EERM as a hindering aspect.

Regarding the *Normative beliefs*, our results associated with the factor *Esteem friends/family* indicate that a supportive opinion of friends and family favors the uptake of EERM, what is supported by Earl and Peng [50] who state that the desire of an enhanced standing within the social surrounding (e.g., friends and family) is a motivating factor for the uptake of EERM. Furthermore, a case study carried out in British communities [51] also suggests that 'social capital' is important for home energy innovations what partly is related to the wish of individuals to gather information from people they know—e.g., from friends or family members who value such home energy innovations or EERM.

When considering *Control beliefs* and the factor *Financing problems*, our results go along with Organ et al. [32] and Zundel and Stieß [19], who state a lack of financial resources as a barrier for energy efficiency measures. Concerning the factors *Consulting during conduction* and *Consulting during planning*, our results indicate that a refurbishment is more probable in the case of a low demand of professional help or advice. This could be influenced by the house owners' *Own capabilities*, but also by low trust in energy advisers. Support for the latter reason can be found in the study of Risholt and Berker [52] who identify a lack of knowledge and expectation of bad advice from professionals as impeding aspects for homeowners. Lacking possibilities to conduct EERM by themselves is also stated as impeding factor in our study. A further result in the field of the *Control beliefs* shows that high availability of time results in a higher probability of realizing EERM (*Time conduction, Time planning)*, what is in line with the findings of Zundel and Stieß [19] who show that house owners who conducted EERM have had more time to deal with the planning than those who conducted standard refurbishment measures. A higher time intensity for larger home improvement projects is also outlined in [53]. Further support for our findings can be found in empirical studies conducted in Greece [54], Norway [55] and The Netherlands [56]. In the latter two studies financial aspects were also identified as barriers for the adoption of EERM. Moreover, in [54] a missing expertise or knowledge was identified as an impairing factor, too. Further critical influencing factors identified were a lack of reliable experts and information, time and effort to find information and complexities in the refurbishment process. The latter aspects found in [56] do not only support our finding regarding the relevance of time to carry out EERM but also our findings referring to the trust in energy advisers.

Besides the TPB components we also analyzed *Environmental awareness* aspects in the study on hand. From six initial factors, only the factor *Impacts of decisions* was identified to contribute significantly to a differentiation of "Future-Refurbishers" and "Non-Refurbishers." This factor indicates that individuals who do not put high relevance on environmental aspects during decision-making rather belong to the group of "Non-Refurbishers." When additionally considering the results associated with the factor *Reasonable for environment*, both findings together allow for the conclusion that even though "Non-Refurbishers" might support the idea that EERM are good for the environment, it might be less likely that environmental aspects are of high relevance during the decision-making in terms of EERM for this group. This conclusion suggests to regard political initiatives critically that emphasize the environmental benefits of energy-related refurbishment activities to influence house owners' decisions positively in order to persuade them to conduct EERM.

When considering the predictor *Building conditions*, our analysis shows that the perceived *Energy efficiency* as well as the *Comfort and visual appearance* strongly contribute to a differentiation between the analyzed groups. At a first glance, it is reasonable that those house owners who perceive a greater need for actions belong to the group of "Future-Refurbishers." However, when considering the construction periods of the houses of the analyzed groups, it comes up that the houses of "Non-Refurbishers" are on average older compared to those of "Future-Refurbishers" and thus should generally call for a higher need of action. Taking into account the finding of Stieß and Dunkelberg [20] who conclude that house owners with standard refurbishment measures are more likely to believe their house to be in a good condition, this might support the assumption that the actual (energy) status of the houses of "Non-Refurbishers" is more negative than perceived by their owners even though they have performed some efforts to reduce the energy consumption of their houses in the past.

German and European goals and legislations have become steadily more important to fulfill the *Legal requirements* in the context of EERM. Our results suggest that a future refurbishment is more likely the lower the perceived problems are to comply with existing regulations. According to the review of Kastner and Stern [18] neither approving nor disproving results could be detected in the existing literature for this factor.

Further initially surprising results refer to the variables *Complex promotion* and *Appropriate craftsmen.* Our findings suggest that house owners are more likely to belong to the group of "Non-Refurbishers" if they think it is easy to find appropriate craftsmen for carrying out EERM or if they do not perceive governmental promotions as complex. These results might be explained by the low involvement and experience of "Non-Refurbishers" related to the practice of refurbishment activities. Thus, such house owners might not be very concerned when it comes to aspects as finding craftsmen or dealing with governmental promotions. This might originate from a lack of a threat of "Non-Refurbishers" compared to house owners who intend to undergo EERM and who not only risk losing time but also money, due to potential incorrect craftsmen-work, missed grants and subsidies because of non-compliance with legal requirements. This reasoning is supported by Pepels [57],who points out that extensive investments (such as in EERM) are associated with more extensive risk evaluations or intensified search for information.

5. Conclusions

In order to increase the currently rather low energy efficiency-related refurbishment activities in Germany it is necessary to take a wider range of measures into account. While it is widely acknowledged that private house owners and their respective buildings play a key role for achieving the climate targets until 2050 set by the German Government [4] and elsewhere, the results of this study show that pure political appeals to house owners to conduct specific energy-related measures are not expedient.

Based on the results of our analysis and with respect to our second research target, we suggest that, along with already existing financial support *(Financing problems)* that was identified as relevant, an increased non-monetary support might supplement existing efforts to trigger individual house

owners towards increased energy-related refurbishment activities. An enhanced presentation of refurbished "best-practice houses" and their owners, who already have mastered the task of refurbishment, could be such an additional non-monetary support activity.

These kind of measures could supplement existing information and capacity building measures that are provided by the German Energy Agency (Dena, "Deutsche Energieagentur") or the KfW ("Kreditanstalt für Wiederaufbau"), which support interested house owners inter alia during financing EERM activities. An enhanced provision of best-practice houses could be provided by regional contact points for energy efficiency or by the German Energy Agency itself, as their objectives involve the design of campaigns in the context of energy efficiency, the distribution of information to the public, and the support of the building sector (architects, craftsmen, etc.) in order to ensure aligned work with current standards and regulations [58].

Directed towards "Future-Refurbishers," a presentation of already refurbished houses in collaboration with energy advisors and craftsmen could be used to level up the currently low refurbishment efficiency in the residential building sector in Germany. Since our results indicate a rather low acceptance of advice from professionals (*Consulting during planning, Consulting during conduction)*, providing more neutral information during such best-practice events could foster additional efforts from those house owners who already intend to take specific individual energy-related refurbishment measures. Thus, potential doubts (*Doubts about desired effects*) about the implementation and the effects of additional measures of "Future-Refurbishers" could be eliminated. A key role in this regard is assigned to the owners of the refurbished best-practice houses. While professionals could take care of the presentation of the individually conducted measures and the overall refurbished building, or answer specific questions from the visiting house owners, these hosting house owners could ensure the trustworthiness of the professionals and provide further credible answers. Besides information on promised and actual costs and energy savings, those owners can also provide reliable information on technical aspects such as the effort associated with technical systems (e.g., in terms of operation and maintenance aspects) or the refurbishment process itself.

Such a trustworthy and informative situation can also be used to inform and persuade house owners who are aware of energy-related deficiencies, but also perceive financial problems (*Financing problems*) and thus neglect the uptake of efficiency measures. By lowering these house owners' doubts regarding financial savings or costs associated with certain efficiency measures, this could also reduce these house owners' perceived financial problems. Additionally, information on technical aspects provided by the professionals but also the best-practice-house owners can also lower their concerns due to a perceived lack of skills and capabilities (*Own capabilities)*.

A further promising activity could be providing Do-It-Yourself workshops to individual house owners. During such workshops, energy advisors and craftsmen could present measures that allow for identification and removal of energy-related weak points of residential buildings. This could involve for example, the insulation behind radiator niches, or, for technically skilled house owners, the insulation of neuralgic spots like cellar ceilings. In addition to the direct effect of such measures, meaning the provision of capabilities and skills (*Own capabilities*) to "Non-Refurbishers" but also "Future-Refurbishers," there are also indirect effects connected to such workshops, i.e., multiplier effects among house owners, since applied know-how very likely will be spread within the neighborhood and among friends (*Esteem friends/family*). Additionally, such workshops might have positive effects related to trust in and the image of EERM since "Future Refurbishers" as well as "Non-Refurbishers" are likely to look for approval from their social network (e.g., families, friends, neighbors) instead of trusting highly unknown governmental or professional experts.

Workshops of this nature can also be used to provide information on legal obligations (*Legal requirements*) that have to be met according to the German "Energieeinsparverordnung" (energy saving ordinance) when implementing specific EERM. Other relevant information could concern e.g., legal obligations, when old or polluting heating systems need to be replaced. In addition to "Non-Refurbishers" and "Future-Refurbishers," another group of house owners could be targeted

with such workshops, namely those who are basically not aware of the energy efficiency of their houses. By providing information on average energy consumptions for houses of different construction periods as well as information on energy savings associated with different kinds of EERM, all groups of house owners could be triggered to re-evaluate their actual need for energy efficiency measures and their intentions to take measures. This is also true for "Non-Refurbishers" who perceive a lower need for actions (*Building conditions*) but live on average in older houses with mostly lower energy efficiency standards.

A further opportunity associated with the presentation of best-practice refurbishment projects is the possibility to allow visiting house owners to experience a high level of indoor comfort and the nice appearance of a comprehensively refurbished building envelope. Such measures would address important influencing factors according to our results such as *Building conditions* and *Behavioral beliefs* and the factors *Comfort and appearance* and *Indoor comfort*, respectively.

Even though the extent and the effects of best-practice campaigns in private residential houses might be unknown, the realization of the proposed measures is a way forward to increase the energy efficiency in the existing building stock in Germany but also in other European countries. Furthermore, this kind of initiative would largely go along with Article 17, information and training, of the Energy Efficiency Directive 2012/27/EU [2], which demands that "Member States shall, with the participation of stakeholders, including local and regional authorities, promote suitable information, awareness-raising and training initiatives to inform citizens of the benefits and practicalities of taking energy efficiency improvement measures."

Due to the initially mentioned fact that a large share of single- and two-family houses is located in cities and urban districts, such measures might be especially promising when focused on these spatial and social environments. Since financial issues, capabilities and social acceptance were identified as relevant, enhanced initiatives considering these aspects could help to reduce the high energy consumption and GHG emissions in such conurbations. Thereby, the mentioned focus on specific districts is essential. Besides the possibility to enhance the outlined multiplier effect in the regional social surrounding, also regional-typical energy-related weak points of the commonly similar buildings could be addressed. These weak points could be covered during the mentioned practice-orientated workshops as well as in funding programs, e.g., for subsidized refurbishment management or for specific EERM. Increasing prices because of such funding programs, however, could be prevented by contractual arrangements with regional partners.

Nevertheless, the potential negative effects of such local initiatives also need to be considered, e.g., the fact that people with lower incomes might not be able to afford living in such houses or apartments anymore due to increased rental fees after refurbishment activities. Overcoming this phenomenon, however, is another aspect that is and needs to be considered by politicians and also scientists [59].

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