Center for European, Governance and Economic Development Research
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Discussion Papers

Number 275 – March 2016

ENERGY AUDITS IN A PRIVATE FIRM ENVIRONMENT - ENERGY EFFICIENCY CONSULTANTS' COST CALCULATION FOR INNOVATIVE TECHNOLOGIES IN THE HOUSING SECTOR

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ISSN: 1439-2305

Energy audits in a private firm environment - Energy efficiency consultants' cost calculation for innovative technologies in the housing sector

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Abstract:

During recent international climate negotiations like in Paris 2015, the European Union agreed to reduce the emissions of greenhouse gases. Policy-makers target the residential sector as a major user of fossil energy because potential to improve the energy efficiency in existing houses is observable. Energy audits have been implemented to offer information to homeowners within the aim of reducing the uncertainty concerning energetic refurbishment. Nevertheless, the impact of energy efficiency consultants (EECs) on retrofit measures is described as low in the literature. We conducted an online survey on German EECs, emphasizing their personal attitudes and contextual conditions, analyzing the implementation of an exploratory energy audit and providing recommendations for improving energy audits. The EECs answered the questions regarding the personal factors in a highly confident way. We explain this using the market framework in Germany, which requires a high-level performance due to the competition on the EEC market. The contextual conditions are evaluated critically, with about 49% expressing concerns about acquiring and managing financial resources for energy audits. The case study showed that EECs recommend innovative technologies to a limited degree, while the upfront costs are estimated very low. Finally, in the survey, the respondents prioritized an information policy improvement.

Keywords: energy audits, change agents, energy policy, diffusion of innovation

1. Introduction

In late 2015, the 21st Conference of the Parties (COP 21) for the United Nations Framework Convention on Climate Change took place in Paris, within the aim of discussing effective and best practices policies. One central actor - the European Union - had already agreed beforehand to lower their greenhouse gas emissions to 20% by 2020 based upon 1990 levels, followed by further reductions up to 95% by 2050 (da Graça Carvalho, Maria 2012). Since the housing sector contributes substantially with about 20% to 40% of the end-energy use in the member states, policy-makers agreed to target effective energy efficiency measures to fulfill the agreed goals (Pérez-Lombard et al. 2008). In Germany, with about 40 Mio. residential buildings, the stock of buildings has great potential to reduce energy consumption, since 75% of the buildings that were built before the first heating regulation in 1978 have not been renovated (Diefenbach et al. 2010). Hence, since the rate of complete energetic retrofit currently only constitutes about 1%, German energy policy aims to double the retrofit rate to achieve an almost climate neutral stock of residential buildings by 2050 (UBA 2014).

The energy efficiency gap has been used as an explanation why people invest inefficiently in energy-saving measures due to a lack of complete information (Jaffe and Stavins 1994; Jaffe et al. 2005). While the effect of informational impediments on energy policy has been controversially discussed (Allcott and Greenstone 2012; Gillingham and Palmer 2014), it has had a substantial impact on the design of information policy (Bartiaux 2008; Ek and Söderholm 2010; Ramos et al. 2015). Based upon the Directive on Energy End-Use Efficiency and Energy Services (Directive 2006/32/EC), member states are encouraged to adopt energy audits and energy-related services.[1] In particular, the complexity of retrofit (Galvin and Sunikka-Blank 2013; Owen et al. 2014) combined with uncertainty about the outcome due to customer-related rebound effects (Madlener and Hauertmann 2011) has led to a high degree of informational uncertainty, which attributes a central role for the homeowner's decision (Palm 2010) to energy efficiency consultants (EECs).

The seminal paper on EECs by Gram-Hanssen et al. (2007) analyzed the effectiveness of energy performance certificates (EPCs) for comparative Belgium-Danish cases focusing on the provision of additional information. The authors critically evaluated the benefit of EPCs since the new information transferred with the energy labels led to interpretation and questioning of the additional knowledge. The customers' trust in the EPCs depended on individual everyday life situations and the personal attitudes towards the energy advice. Bartiaux (2008) argued that

[1] For further discussion on the naming of EECs, see Feser and Runst (2015).

the social norms need to comply with the new information, otherwise the customers do not react to the provision of new information. Additionally, EECs lack information about homeowners' behavior and everyday situations, which influences the success of their service (Palm 2010; Revell and Stanton 2015). The education and profession of EECs has been identified as leading to heterogeneous information for customers (Virkki-Hatakka et al. 2013).

The institutional framework for energy audits and related energy services significantly differs across the EU member states (Mahapatra et al. 2011b). While in Sweden and Finland, EECs are partially employed as public servants (Mahapatra et al. 2011b; Virkki-Hatakka et al. 2013), Germany has established a subsidy scheme organized by mandatory energy audits from certified EECs in private companies (Prognos et al. 2013). For the case of the UK, Owen et al. (2014) emphasized the impact of informal advice given to the customers about retrofit measures by installers. In the US, the EEC market appears separated in two groups: utility companies and construction companies; and independent EECs only focusing on energy audits (Palmer et al. 2013).

To contribute to the international climate goals, policy-makers rely on the quality of EECs (Rosenow and Galvin 2013), since the latter are largely subsidized to act as change agents endorsing a sustainable reduction of energy use in the residential sector. Change agents are those actors in markets who increase the technological progress and offer assistance to customers to limit their uncertainty (Rogers 2003). Implementing a system of experts for guiding homeowners towards energy efficiency measures has been discussed in the literature, finding a low impact of experts on customers' decisions to conduct energetic retrofit (Gram-Hanssen et al. 2007; Palm 2010; Palmer et al. 2013; Mahapatra et al. 2011b; Gillich 2013; Virkki-Hatakka et al. 2013). Especially the low acceptance of EEC services (Gram-Hanssen et al. 2007; Mahapatra et al. 2011b), the public policy orientation as well as the public subsidies of experts (Palmer et al. 2013; Gillich 2013) have been identified as barriers for EECs in terms of substantially increasing the retrofit rate. Nevertheless, given hypothetical choices, customers request support from EECs during the retrofit (Achtnicht and Madlener 2014), while the empirical evidence of using EECs has brought mixed results (Weiss et al. 2012; Gaspar and Antunes 2011; Murphy 2014a). Although the literature is rich with conceptual and qualitative insights, large-scale and quantitative evidence is rare. The literature has insufficiently discussed the impact of EECs on the diffusion of innovative technological solutions and homeowner-friendly solutions. In particular, research on German EECs is relevant, since the German building renovation program is one of the largest in Europe (Murphy 2014b; Rosenow and Galvin 2013).

Thus, in this paper we analyze the sample of an online survey conducted with German EECs in 2015, analyzing EECs' performance during energy audits. The evaluation of service quality has created a broad strand of literature reflecting upon the impact of the offered service on customers' demand (Wilson and Frimpong 2004). Mahapatra et al. (2011b) offered a first framework measuring the performance of EECs used in different sectors, based upon the assessment of interviewed EECs evaluating their own work (Netemeyer and Maxham 2007; Eva and Regehr 2005; Sarikaya et al. 2010). Mahapatra et al. (2011b) used the perception of EECs about the customer satisfaction as the dependent variable to explain EECs' impact on energy audits. Our approach builds upon the Swedish survey (Mahapatra et al. 2011b) focusing on EECs as private firms. However, the adaptation of innovative technological solutions in its political and social environment is crucial for the acceptance and energy efficiency of retrofit in the housing sector (Ravetz 2008). Therefore, we follow Owen et al.'s (2014) approach to analyze the technical and adaptive skills as a prerequisite for understanding the performance of EECs.

We find that EECs have a positive perception about their own performance, while contextual factors - including the institutional framework - are critically evaluated. Specifically, only about half of the EECs perceive their payment as fair. This perception significantly relates to the contextual factors of workload, subsidies, technical support from public authorities and a clear job description, which affect the EEC's success on markets. The trade-off between positive personal factors and mixed evaluated contextual factors also appears in our case study about the diffusion of innovation at energy audits. The EECs proposed to some extent innovative measures, except disruptive measures, while the respondents systematically underestimate the upfront costs in case of ambitious energy goals.

The remainder of this paper is structured as follows. In section 2, we review the situation of EECs in Germany, including the current situation and the legal framework. Subsequently, we present our theoretical framework in section 3, while in the fourth section the methodology used is explained. We discuss our results in section 5, followed by recommendations for the prospective framework of energy audits in section 6, before concluding with policy implications in section 7.

2. Energy efficiency consultants in Germany

The task of EECs is to support homeowners with technical support during the retrofit of their residencies targeting the service to private homeowners, as well as public and private housing companies. This support is mostly focused on scenarios about which customers lack

information (Novikova and et al. 2011). Essentially, what is foremost expected from EECs is the distribution of innovative solutions to improve the energy efficiency (Madlener and Hauertmann 2011). Informational barriers before and during the retrofit create uncertainty about the outcome of energy efficiency measures. In particular, the technical complexity, the uncertainty about the quality of the building companies and inhabitant-related rebound effects after the retrofit influence the anticipated benefit through the retrofit (Feser and Runst 2015).

There is no regulation that obliges homeowners to consult EECs for refurbishment measures. Nevertheless, from a public policy perspective, the development of the EEC market is based upon the low energy efficiency of the housing stock. Therefore, publicly supported energy audits attempt to support the diffusion of innovation, which has to be organized by change agents (Rogers 2003; van Lente et al. 2003). The market intervention drives the EEC market in two ways. First, the Energy Saving Regulation (EnEV) organizes the implementation of EPCs and limits its energy audits to consultants with a professional background in the building sector. Customers have to hire certified EECs to receive EPC, which has to be presented in case of selling a residential house or renting a house to new tenants (Amecke 2012). Second, homeowners need to consult an EEC to receive subsidies for energy audits and subsidies for energetic retrofit. Particularly the subsidies from the building rehabilitation program organized by the public KfW bank are an important incentive for homeowners to access EECs (Schroeder et al. 2011). In order to apply for subsidies for retrofit, specific training with a minimum of 70 hours of certified courses is mandatory, in addition to the prior completion of training or studies in engineering, architecture or a craftsmen business (KfW 2014). More than 13,300 publicly listed EECs have the permission to participate in the subsidy programs. [2] The EEC certification scheme has been reformed several times to guarantee the quality of energy audits and increase the demand for EEC services (Feser et al. 2015).

Despite the efforts of the German government, EECs' role for energetic retrofit has been critically evaluated. Galvin and Sunikka-Blank (2013) presented evidence for the urgent need of change in the retrofit market. The ambitious aims for 2050 to reduce the greenhouse gas emissions by 80% can solely be achieved with further improvements. Under the current conditions, the housing sector contributes to a reduction of emissions by only about 25%. In a theoretical choice experiment, German customers revealed the need for support by EECs (Achtnicht and Madlener 2014). Especially the promotion of EECs since 2007 has brought improvements in the quality of retrofit, albeit with no noticeable effect on the retrofit rate (Stieß

[2] The web list is publicly accessible at https://www.energie-effizienz-experten.de.

and Dunkelberg 2013). Moreover, the demand for energy audits has been characterized as low and decreasing in recent years (Prognos et al. 2013). In particular, the variety of actors offer low-quality and low-cost energy audits, leading to little transparency and a low willingness to pay for energy audits (Prognos et al. 2013).

In the following section, we provide our framework to comprehend EECs' impact on retrofit, specifically concerning the diffusion of innovative technologies via energy audits.

3. Evaluation framework

3.1. Influence of personal and contextual factors

From a public policy perspective, subsidized EECs have to contribute to reduce emissions in the residential housing sector. EECs' impact on diffusion of innovative measures for retrofit depends on the fulfillment of homeowners' expectations (Michelsen and Madlener 2012). Most importantly, the interaction with customers affects the quality of the energy audit and is decisive for the buying decision (Taylor and Baker 1994). Hereby, EECs' performance can be explained by personal and contextual factors (Stern 2000). We look at the personal and contextual factors with the self-perception of EECs. Consequently, this can be highly subjective and may differ from the customers' perspective, thus requiring careful interpretation (Wilson and Frimpong 2004).

Based upon Mahapatra et al. (2011b) seminal approach to conceptualizing the personal factors, we include job satisfaction, attitude towards the job, age, gender, level of education and educational background, perceived level of knowledge and working experience asan EEC as personal factors. In addition to the Swedish example of Mahapatra et al. (2011b), the active exchange of knowledge in networks has been described as an influencing factor for the performance of services, especially in terms of highly specialized expert services (Muller and Zenker 2001; Probert et al. 2013).

Besides the personal factors, EECs' capability to diffuse innovation can explain the way in which EECs manage the contextual conditions that cannot be immediately influenced by the individual EEC (Backhaus 2010). This includes the form of occupation (conducting part or fulltime energy audits), the clarity of job description, payment for energy audits and the workload, which have proven to have a strong impact on the performance of EECs, measured by the customers' satisfaction with EECs' service (Mahapatra et al. 2011b). In addition, the institutional framework depends on the innovative capability of the regional (Bettiol and Di Maria 2013; Cooke et al. 1998) and national innovation system (Lundvall 1992; Castellacci and

Natera 2013). Consequently, energy audits are affected by the legal dimensions, the public subsidizing scheme and the technical know-how provided by the public authority (Weber and Rohracher 2012).

3.2. Evaluation of retrofit measures

The suggestions of technologies during energy audits influence the diffusion of technologies, thus affecting the role of EECs as change agents. The mechanism of selecting the technology for energetic retrofit has been discussed in an acknowledged strand of literature based upon the seminal paper of Jaccard and Dennis (2006). Research has focused on homeowners' decision process about energy efficiency measures in various countries; for example, in Sweden (Nair et al. 2010), Germany (Achtnicht and Madlener 2014) and Switzerland (Banfi et al. 2008). It was proven that energetic refurbishment measures depend on the homeowners' willingness to pay (Grösche and Vance 2009; Kwak et al. 2010). In particular, the willingness to pay for improved energy efficiency concerning investments in insulation, heating and under-floor insulation differs between landlord and tenant (Phillips 2012). While homeowners' intention to conduct retrofit measures has been revealed, the willingness to pay for energy efficiency measures is insufficient to compensate for the higher costs for renewable technologies compared with standard technologies (Scarpa and Willis 2010). Economic efficiency has been identified as key for homeowners to decide in the first place whether to conduct retrofit measures, followed by the volume of the project (Popescu et al. 2012; Achtnicht and Madlener 2014). Besides the economic profits, the customers value any environmental benefits of energy saving (Banfi et al. 2008; Achtnicht and Madlener 2014), regardless of the criticism about the outcome of retrofit measures - especially insulation - in the public discussion in Germany, attributing it to low additional environmental and energy efficiency profits (Holm et al. 2014).

To understand EECs' impact on diffusion of innovative technologies advising homeowners' on retrofit measures, the EECs had to choose for one case study from different insulation material (Phillips 2012; Kwak et al. 2010), heating technologies (Michelsen and Madlener 2012; Madlener and Hauertmann 2011) and renewable energy applications (Scarpa and Willis 2010; Claudy et al. 2011). Mirroring the willingness of homeowners to pay, EECs can have a strong impact on the discussion about the economic efficiency due to the provision of technical knowledge and information regarding the upcoming costs for the customer (Ryghaug and Sørensen 2009). We followed an approach from the literature to estimate the upfront costs of energetic retrofit, including the costs of the suggested measures (Wilson et al. 2015). The

information on upfront costs is important for homeowners' perceptions of economic efficiency since the development of prospective energy costs is always based upon risky assumptions (Alberini et al. 2013; Jaccard and Dennis 2006). Due to uncertainty during the construction process, EECs had to estimate for the case study minimum and maximum upfront costs for the measures to create an indicator concerning how innovative technology suggestions affect the retrofits' cost calculation.

The estimated EPC level contributes to demonstrate the influence of energy audits on the general energy efficiency level in the housing sector. The impact of labeling with transparent information has been analyzed using a discrete choice experiment, leading to the preference towards environmental-friendly technologies (van Rijnsoever, Frank J. et al. 2015). We conceptualized the labeling using the energy level for receiving subsidies from the KfW bank, since the EECs' proposal is decisive in terms of making the energy level transparent for homeowners from the legally required minimum standard until the passive house standard, which is the basis for EECs to plan the refurbishment.

4. Methodology

4.1. Structure of the questionnaire

Modeled following Mahapatra et al. (2011b), we developed a questionnaire tailored for energy audits in Germany elaborated based upon 17 expert interviews discussed in detail in Feser and Runst (2015). The questionnaire was structured in four sections as follows. First, general demographic and business-related topics were discussed, including questions about the educational background, participation in public subsidy programs and membership in networks. Second, the respondents received information about a detached house provided with relevant information to conduct energy audits. The respondents had to select the EPC level, EPC level calculation and decide upon insulation material, heating technology and renewable energy technology (see table 1). Subsequently, the EECs were asked to estimate the minimum and maximum upfront costs of the proposed measures. The third section asked about attitudes connected to personal and contextual factors influencing the work of EECs. Fourth, recommendations about public interventions in the future were evaluated by the respondent.

Table 1: Exemplified energy audits

EPC level	EPC level calculation	Insulation material	Heating technology	Renewable energy technology	Costs of retrofit
Minimum standard	Component method (standard)	Foamed plastic (e.g. polystyrene)	No change	No renewable energy technology	Minimum costs
KfW 100	Reference building method (flexible)	Mineral (e.g. mineral wool)	Condensing boiler	Photovoltaic system	Maximum costs
KfW 70		Organic (e.g. cellulose)	Pellet boiler	Solar thermal system,	
Passive house standard			Heat pump using geothermal source	Transparent cover for hot air	
			Heat pump using air as source		

In sections three and four - as given above - a five-point Likert scale (1=strongly disagree, 5= strongly agree) was used to test EECs' attitudes regarding the personal and contextual factors as well as the ranking of proposals for prospective energy audits. The questionnaire was created and discussed within an interdisciplinary research group comprising experts from the field of architecture, civil engineering, economics and law. The energy audit case was selected from a team of architects in cooperation with a real estate manager. The questionnaire was pre-tested and reviewed by three experienced EECs.

4.2. The survey

The survey took place on the online platform SurveyMonkey. We followed suggestions of Sauermann and Roach (2013) to increase the response rate combining various activities. For instance, before the opening of the survey and within the aim of making our survey known to the broader public, we contacted the two largest professional EEC organizations, whose members constitute about 25% of the web-listed EECs. The EEC engineering craftsmen association (GIH) mostly comprises members coming from the craftsmen and engineering sector, while the energy consultants network (DEN) only accepts in its auspices members with a graduate background, specifically architectural and scientist backgrounds. The professional background on the certified EEC market can also be found in both organizations (Prognos et al. 2013). Additionally, we offered a monetary incentive for the respondents to participate by donating 2€ to a charity organization[3] for every completed questionnaire, as suggested by Smith et al. (2015). Based upon the email addresses of GIH and DEN members found in the public

[3] The participants could choose among three different charity organizations: BUND with 228€ (environmental purpose), Aktion Mensch (general welfare) with 310€ and Aktion Deutschland hilft! (support for refugees) with 140€.

domain, we composed two emails addressing the EECs in person. These emails were distributed around as a call to participate and a reminder of our survey. We sent the first email on the third day and the second on the tenth day. Approximately 1,800 personalized emails were sent[4], which resulted in 459 incomplete and 339 complete responses (see Table 2).

Table 2: Demographic information

Gender (N=459)		**Age (N=454)**		**Degree of education (N=454)**		**Educational background (N=451)**		**Share over energy audits of total turnover (N=320)**	
Female	9.59%	<40 years	9.25%	Vocational Training ("Meister")	29.96%	Architecture	18.63%	Less than 30%	44.69%
Male	90.41%	40-49 years	28.64%	Bachelor	3,94%	Engineering	51.22%	Equally distributed	14.38%
		50-59 Years	44.27%	Master	64.54%	Craftsmen	22.39%	More than 70%	40.94%
		>60 years	16.08%	Promotion	1.54%	Others (e.g. general scientist)	7.76%		
	100%		100%		100%		100%		100%

The majority of the respondents were male and on average 51 years old, holding a master's degree. Furthermore, the majority were graduates in the field of engineering and the sample is almost equally distributed between EECs with a major focus on energy audits with a share of more than 70% of the turnaround and a minor focus with a share lower than 30% from energy audits.

4.3. Analysis

The respondents agreed with a high degree of uniformity with most of the statements. For example, about 49% fully agreed while the same percentage agreed with the statement "I have state-of-the-art knowledge for conducting energy audits". In addition, more than 95% of the respondents agreed/fully agreed with the statement "I think that EEC is an interesting profession". As the analysis of the remarks of the respondents in the open comments section showed, the order of the questionnaire sections influenced the self-perception of EECs. To explain, placing the case study before the self-perception statements framed the answers

[4] We selected the publicly available email addresses found on the homepages of the DEN and GIH, although not all members could be contacted due to missing email addresses.

positively due to the self-affirmation that the respondents felt in the first place after solving the case study (Tversky and Kahneman 1981).

Following Mahapatra et al. (2011b), we summarized the fully disagree, disagree and the neutral category as a neutral/negative category. Furthermore, the fully agree and agree category were merged into a positive category. In questionnaires without neutral options, respondents tend to answer negatively while positive answers remain clearly positive (Graeff 2002; Mahapatra et al. 2011b). Consequently, we tabulated independent variables with the rest of the variables from sections 1, 2 and 3. This facilitated conducting a chi-square test to analyze correlations of EECs' personal and contextual factors.

In the case study, we analyzed the coherence between the choice of EPC level and the calculated costs focusing on the selection of different technologies, which varied from standard to innovative technologies. Experts evaluated these beforehand to measure the impact of EECs on the diffusion of innovation. Due to the complexity of retrofit, the data on upfront costs are scarce. In a meta-study, Henger and Voigtländer (2012) showed the range of possible costs for different EPC levels in Germany. The costs are based upon real data after the retrofit comprising a sample with more than 10,000 retrofit projects. A lower bound for the upfront costs is recalled in DENA (2012), which has been criticized for presenting low costs having selected only a profitable lighthouse project and representing minimum costs for energetic retrofit (Simons 2012). Due to increasing costs, the average costs in the building sector have increased by about 7% since 2011, the date when the last costs are estimated.[5] The minimum and maximum upfront costs were compared with retrofit costs described in Henger and Voigtländer (2012) and DENA (2012) using t-statistics to ascertain whether the costs estimated by EECs match the reviewed costs.

5. Discussion of results

5.1. EECs' perception of personal and contextual factors

The customers' acceptance is central for the success of energy audits, which influence the implementation of energetic refurbishment measures (Mahapatra et al. 2011a). About 95% of the respondents agreed/fully agreed with the statement "I fulfil the expectation of the homeowner who is in renovating process", while only 15 of 348 respondents answered neutral or disagreed/fully disagreed. In contrast to our survey, only 52% in the Swedish survey agreed

[5] Statista (2015): http://de.statista.com/statistik/daten/studie/70134/umfrage/baupreisindex-fuer-wohngebaeude-in-deutschland/.

to the latter statement (Mahapatra et al. 2011b). Regardless of the efforts of Germany and Sweden towards energy efficiency in the residential sector, the institutional framework substantially varies between the two countries (Kiss et al. 2013). While the Swedish EECs are mostly employed as public servants offering information for homeowners about energetic retrofit (Mahapatra et al. 2011b), in Germany there are foremost independent energy services offering energy audits. In this case, the satisfaction of customers has a direct impact on EECs' profit. In recent years, a considerable number of EECs have had to leave the EEC market since it has become no longer possible for them to offer energy audits in a sufficient quality (Feser et al. 2015).

The market structure requires that EECs orient themselves carefully to homeowners' demand for energy audits. Consequently, EECs positively evaluate personal factors, since - as it is observed - the respondents believe that they fulfill the quality standards on the EEC market. Especially complaints of EECs about unfair competition indicate the necessity to offer an optimal service to customers (Feser and Runst 2015). About 98% agreed/fully agreed to the statement of having up-to-date knowledge concerning their service, while about 86% confirmed using networks to receive new knowledge. The aforementioned positive answers can explain why 95% of the respondents agreed/fully agreed to the EEC profession being an interesting profession. Additionally, about 81% of the EECs confirmed that being an EEC satisfied them. We thus recognize a positive self-evaluation of knowledge- and personality-based attitudes on the market framework, which means that EECs must adapt to the general quality level to benefit from energy audits. About 47% of the respondents work in micro-sized companies with only one or two employees, whereby this high degree of personal involvement can justify the positive perception of personal factors.

The answers regarding the contextual factors are assessed more heterogeneously in comparison to the personal factors. Specifically, the consent from the respondents is weaker for the questions regarding the contextual factors, even though about 72% agreed/fully agreed with facing no problem working with the current legal framework. The improvement of the general retrofit level and the support of energy audits can explain the high level of confirmation for the German regulation (Galvin and Sunikka-Blank 2013).

A major barrier for EECs is the low willingness to pay for energy audits, with about 49% of them answering neutral or disagreeing/fully disagreeing to this topic, which is consistent with previous surveys on German EECs (Prognos et al. 2013). Nonetheless, only about 42% fully agreed with the statement "I get a fair compensation for the offered energy audits", which indicates disparities of payment in the EEC sector. The problems of the low willingness to pay

was also emphasized in the open comments, highlighting problems in financing energy audits, which have been discussed in the exploratory interviews (Feser and Runst 2015).

We found significant correlations with the perception of fair payment at $p<0.05$ in the chi-squared statistics exclusively in the contextual factors, which is consistent with the description of the German housing sector substantially driven by public interventions (Galvin and Sunikka-Blank 2013). There are the four key variables. First, the workload is significantly correlated with fair payments for the energy audit (approximately 73% of the EECs agreed/fully agreed with having a high workload). This may be especially the case in publicly-promoted energy audits, since the subsidies payments often comprise fixed payment contracts that include only a short time framework to conduct an energy audit. Extra work thus does not result in additionally paid work for EECs (Feser and Runst 2015). Second, the administration of subsidies (about 62% agreed/fully agreed to having problems with the administration of subsidies) has a significant correlation, while the permission to grant subsidies is not significantly correlated, since a vast majority of about 93% of the EECs have it. Especially in recent years, dynamic changes and the low interest rate have reduced the motivation of customers to include EECs in the retrofit measures (Henger et al. 2015). Third, the support from public authorities supplying technical and non-technical expertise significantly correlates with fair compensation. In particular, the regional and national energy agencies appear as major actors to deliver information to customers and EECs (Feser et al. 2015). The quality of information from public institutions has been criticized since the information partially contradicts EECs' recommendations and is not tailored towards homeowners' needs, which is perceived to hamper the willingness to conduct retrofit measures. The mixed results of general information policy in the residential sector support our results. (Bartiaux 2008; Ramos et al. 2015). Fourth, the job description (about 64% agreed/fully agreed to having a detailed job description) is significantly correlated to the fair compensation for EECs. The quality of descriptions varies depending on the customer and the complexity of the retrofit. The description of the project is decisive for the EEC's outcome since it affects the time of planning and implementing the refurbishment measures. The rest of the contextual factors are not significantly correlated with the payment of EECs.

The customers' satisfaction and personal attitudes sections gather a high degree of agreement from the EECs. We explain this with the confidence of the respondents who survive the competition on the EEC market. The situation in the contextual factors is different, whereby especially the payment for energy audits is an impediment for EECs' work. This could indicate the relevance of the institutional framework, particularly concerning the economic and regional

conditions. The requirements from the legal framework are evaluated positively, since it affects the EECs in the same way. However, the customers' individual characteristics, the circumstances of the retrofit project, access to subsidizes and support from public institutions influence EECs' profit and can result in a competitive disadvantage.

5.2. Case study on energy audits

The case study illustrates the influence of EECs on energy efficiency in the housing sector during energy audits. Due to the limited choice of technologies, this exemplary energy audit has exploratory character but can offer useful insights into the role of EECs in the diffusion of innovation. The focus is on the suggestion of refurbishment measures and the evaluation of the proposed retrofit. In the following section, we show EECs as partially supporting the diffusion of innovation while the respondents systematically undervalue the costs.

5.2.1. Implementation

The selection of the method for the energy calculation determines the choice of the technical solution. The component method approach calculates the energy level based upon the energy use of each component. Only about 27% of the respondents admitted to applying this method to calculate the energy efficiency from the refurbishment measures, while the rest showed a preference for the reference building method. The reference building method compares the energetic status of the entire house with a reference housing fulfilling the desirable EPC level. This method allows EECs to combine the measures in a more innovative way. By contrast, the component method is a more standardized approach.

Only about 16% selected foamed plastic to insulate the house in the case study. However, about 80% of the insulation in German houses is made from synthetic material. The partially desirable response behavior of the respondents explains the disparity between choice and the use of material in reality. German media has strongly discussed ecological problems and possible security risks in recent years (Sprengard et al. 2012). About 46% suggested using mineral material for the insulation, while approximately 37% selected organic material. The latter offered an innovative and economic alternative, which the description of the case study explained in detail.

Only about 4% proposed maintaining the existing condensing boiler, while about 37% suggested replacing it with a modern condensing boiler. About 29% recommended a pellet-fired system, which has the advantage of being an energetic system with renewable energy. The

geothermal energy in combination with a heating pump was only selected by about 14%. However, the preconditions for the implementation of the geothermal technology were described as positive in the case description. About 12% of the respondents advised to install a heat pump using hot air as source, which was ex-ante evaluated as the most innovative technological choice.

Comparable to the heat generation technologies, almost all respondents proposed to integrate renewable energy technologies on the roof. In particular, about 41% consulted to add a photovoltaic system and 54% a solar thermal system. However, the respondents neglected the collector facades (only three proposed it). This option was evaluated in advance as disruptive, when tested in publicly-promoted research projects (Rudolph-Cleff and Pfeifer 2014).

To carefully interpret the results, desirable answering behavior needs to be considered, which cannot be precluded due to the evaluation character of the hypothetical energy audit and missing monetary incentives. Nevertheless, the contribution to the diffusion in retrofit is observable since EECs prioritize innovative measures, while disruptive innovations are scarcely suggested and not recommended for this case study. In particular, according to EECs' comments, energy audits are oriented intensively towards the socio-economic characteristics of homeowners and regional market conditions.

5.2.2. Contribution to the energy efficiency in the residential sector

The majority of the respondents (about 93%) offer certified energy audits where more energy-efficient retrofits receive higher monetary incentives. The energy level of renovated houses determines the energy efficiency of the housing stock in the long-run until 2050, since the renovation cycle is estimated from 30 up to 50 years (Feser et al. 2015). The contribution to the energy efficiency of the retrofit is measured with the EPC level. The homeowners' decision is crucial in the retrofit of residential houses (Stieß and Dunkelberg 2013). For customers, the EECs' calculation of upfront costs forms the basis for assessing the benefit from the energetic retrofit.

The respondents suggested that higher EPC levels require more expenditure (see 3able 3). This goes in line with the literature, which claims higher investment costs for more efficient EPC levels (Steinbach and Schultmann 2015; Henger and Voigtländer 2012). This observation shows that the offered exposé included the necessary information to offer a reliable estimation of the upfront costs.

Table 3: Retrofit costs per square meter

	Minimum standard (SD)	KfW 100 (SD)	KfW 70 (SD)
Henger and Voigtländer (2012)	355.00	630.00	736.00
DENA (2012)	-	400.00	470.00
EEC_minimum	330.17 (38.85)	343.09[a, b] (15.09)	427.42[a] (32.16)
EEC_average	418.16 (44.46)	438.53[a, b] (17.57)	507.91[a] (24.41)
EEC_maximum	506.13[a] (51.33)	533.96[a, b] (21.70)	588.41[a, b] (25.61)

a) t-test is significant at the 5% level for Henger and Voigtländer (2012).

b) t-test is significant at the 5% level for DENA (2012).

The largest group of EECs (about 49%) advised the KfW 100 standard fulfilling the legally required energy standard for new built residences, which is consistent with the statistics on publicly-promoted houses (Diefenbach et al. 2014). The reported maximum costs are significantly lower than the costs described by Henger and Voigtländer (2012). The respondents seem to prefer the lower bound of expenses since the average and minimum costs are closer to the costs of DENA (2012) than Henger et al. (2015). Interestingly, the minimum costs are even significantly lower than in the case of DENA (2012). Furthermore, we find similar characteristics in the second largest group of EECs (about 35%) proposing the KfW 70 standard (30% less end-energy use in comparison to new residences). The only exception is the maximum estimated upfront costs, which are significantly higher than DENA (2012) and significantly lower than Henger and Voigtländer (2012). In our example, the respondents underestimated the upfront costs by more than 25% in comparison to Henger and Voigtländer (2012) for the KfW 100 and KfW 70 standard.[6]

Only about 13% aimed towards the legally required minimum standard comprising no more than 140% of the end-energy use of new residential houses. One explanation is that certified EECs tend not to aim towards this standard because subsidies for it are only granted for historic buildings and thus they do not reflect the core of EECs' business model (only 16% are registered for this specific renovation program). The reported average costs are slightly higher (not significantly) in comparison to Henger and Voigtländer (2012).

[6] We excluded the evaluation of the passive house standard in the analysis since only nine respondents suggested implementing the latter.

The EECs emphasized the difficulties concerning the calculation of costs, particularly because the energy audit had been conducted virtually. In particular, details about the specification of applied technologies have a considerable impact on the range of retrofit costs. For example, a group of EECs commented that they would decline estimating costs for customers in the first meeting due to the high level of uncertainty. Moreover, both the evaluation and announcement of the costs have been recognized as problematic due to regional and socio-economic differences.

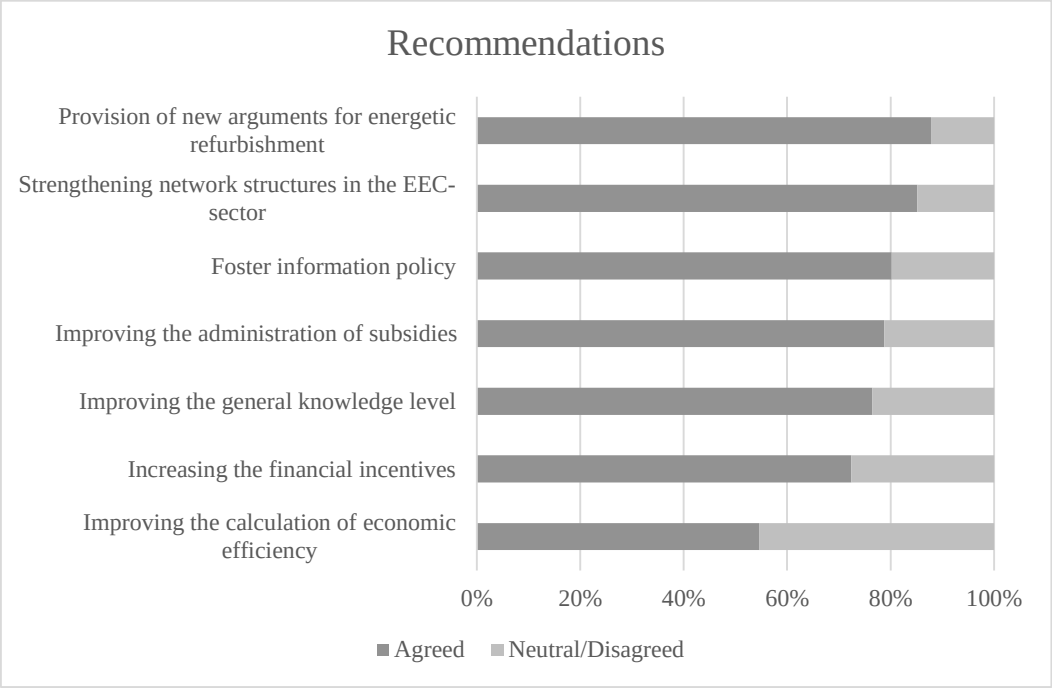
Since about 62% of the respondents selected the minimum and KfW 100 standard, energy audits' contribution to the energy efficiency goals in the housing sector is questionable due to the support of lower energy standards than required to fulfill the energy-related climate goals.

Furthermore, the systematic underestimation of the costs in the KfW 100 and KfW 70 standards is problematic and answered too optimistically, particularly with the recommendation of innovative measures. Due to the increasing general price level in the building sector, the calculation of the prices for the exemplified case appears risky. The lower estimated costs reveal the results from Scarpa and Willis (2010), which found a lower willingness to pay for innovative retrofit measures from the customer side. The uncertainty with reference to the regional and social background of the costs is - on average - not translated into higher costs of the retrofit, although the EECs criticized the missing information in their comments. These difficulties in the EECs' cost calculation of the retrofit can partially explain the low willingness to pay for EECs (Feser and Runst 2015).

6. Recommendation for EECs

In the following section, we present the results of recommendations that were previously proposed by experts of the retrofit sector (see Figure 1).

Figure 1



The recommendations generated a high level of support, whereby on average about 76% fully agreed or agreed with all the statements. The low impact of energy audits on the retrofit rate explains the need for improvement (Ramos et al. 2015; Feser and Runst 2015), which consequently requires changes in the German framework, particularly in the subsidy scheme (Stieß and Dunkelberg 2013).

The largest share of respondents agreed/fully agreed to improve the marketing policy, offering new arguments for customers to conduct energetic refurbishment. This could be grounded upon a specific German characteristic, whereby non-professional landlords and owner-occupiers control about 77% of the total number of apartments (Hopfner and Simon-Philipp 2013) and they are described as having a lower interest in profit maximizing (Stieß and Dunkelberg 2013). For example, changing the focus from the economic benefit to environmental benefits has been discussed as a possible solution based upon environmental-friendly and energy-saving preferences of homeowners (Ek and Söderholm 2010; Zundel and Stieß 2011). However, the provision of additional environmental information has brought mixed results in the literature (Gram-Hanssen et al. 2007; Bartiaux 2008). Closely related to the diffusion of new arguments is the statement of delivering more general information to customers about retrofit measures, to which 80% agreed/fully agreed. In the case of Germany, Galvin and Sunikka-Blank (2013) criticize the missing ex-post information, which can explain both success and barrier factors of retrofit, providing information for prospective customers.

In the second most agreed statement, about 85% recommended strengthening network structures in the EEC sector. Although the EEC sector has only been present for the last ten years, it has considerably grown. Nonetheless, the network structures have developed weakly in comparison to the originating sectors of EECs (Feser and Proeger 2015). Networks can influence the supply side of knowledge diffusion, supporting the EECs' role as change agents (Feser and Runst 2015). From a systemic perspective, intermediate organizations are necessary in the energy transition process to ensure the quality of knowledge processes in return (Hodson et al. 2013). Regardless the positive self-evaluation of the service quality and the personal knowledge basis, about 76% agreed with the need for quality improvement in the EEC sector. Additionally, this was expressed in the comments, complaining about the low level of quality observable during the energy audits. Information asymmetries between EECs and customers make the knowledge diffusion for retrofit rather complex (Feser and Runst 2015).

In the literature, the German subsidy scheme is positively evaluated as a role model for other comparable European states (Murphy 2014b; Rosenow and Galvin 2013). Nevertheless, our survey showed that about 78% demanded improvements in the administration of the programs. These are often influenced by dynamic changes and the variety of programs (Feser and Runst 2015). In the comments, the responsibilities for EECs raised critique since the EECs have to guarantee the quality of the subsidized retrofit while the public administration only monitors the formalities (Feser and Runst 2015).

The two factors characterized by the least agreement are first, the improvement of monetary incentives, and second, dealing with the economic efficiency, both of which affect the customers' monetary decisions. About 71% of EECs agreed/fully agreed with the demand for more financial incentives for customers through public funding. The second lowest degree of agreement can be explained by respondents' experience in recent years with improved incentives. The demand for subsidies was partially too low to distribute the complete funds while the budget for subsidies has been increased in recent years. Furthermore, a reform with integrating tax incentives in the building rehabilitation program has been proposed (Neuhoff et al. 2011) yet has failed to be implemented due to political controversies in 2015 (Süddeutsche 2015). Therefore, it seems unrealistic to implement this measure in the near future. Consequently, the discussion about the calculation of the economic efficiency was evaluated as least important, with only about 55% agreement. This goes in line with the result of the cost estimation of our case study providing hints about the difficulties in calculating the upfront costs, which results in a very different perception of economic efficiency (DENA 2012; Henger and Voigtländer 2012).

The section with recommendations is consistent with EECs' attitudes towards personal and contextual factors. While the EECs evaluate the contextual conditions critically, the recommendations emphasize the need for institutional changes to conduct energy audits more effectively. In particular, the decision process of customers appears central for EECs since new arguments and information could influence homeowners to conduct energetic refurbishment measures. By contrast, the economic efficiency seems not to positively influence customers to conduct retrofit, as stated by the EECs. This could be explained by the difficulties concerning energy audits to present liable data on the amortization duration of retrofit measures. Nevertheless, homeowners consider the economic efficiency as crucial to estimate the effect of the retrofit measures (Galvin and Sunikka-Blank 2013).

7. Conclusion

Our paper focuses on the contribution of EECs to improving the energy efficiency and diffuse innovative technologies in the residential housing sector. We identify personal and contextual factors influencing EECs' performance and explore the role that EECs play in the diffusion of innovation during retrofit, conducting a choice analysis based upon a hypothetical energy audit. The aim of this analysis is to evaluate the range of selected choices from mainstream to non-standard measures and their costs.

Our results identify differences between EECs' self-evaluation regarding personal and contextual factors. On the one hand, the responding EECs mainly answered positively concerning the ability to fulfill homeowners' expectations at an energetic renovation. Consequently, the knowledge basis and attitudes towards self-perception are also seen positively. On the other hand, contextual factors were evaluated more critically. Especially the payment for energy audits was perceived as problematic by 49% of the respondents. Further speaking, EECs' financial resources are significantly correlated with factors that offer competitive advantages for only some EECs, including the administration of subsidies, job description, workload and knowledge support from the public sector. The differences in perception between Swedish EECs (Mahapatra et al. 2011b) and our surveyed EECs can be explained by the different institutional frameworks. The competitive structure in Germany creates the positive perception concerning the personal factors since EECs can only operate successfully by fulfilling customers' expectations and adapting to the market conditions.

In our case study, the respondents suggested applying innovative measures aside from the disruptive ones. To evaluate the proposals for energy efficiency measures, the suggested EPC level clearly missed the targeted climate goals. Furthermore, the costs of retrofit were

systematically underestimated in the case of higher EPC standards. A gap between intention to implement innovative solutions and to calculate the upfront costs realistically was also revealed by the analysis of Scarpa and Willis (2010), focusing on homeowners' perspective. Consequently, the uncertainty of costs in the retrofit could explain the negative self-evaluation of the fair compensation. EECs attributed their problems to the contextual factors.

The Swedish and German frameworks of conducting energy audits seem to have different effects on the diffusion of innovation. In the Swedish example, the EECs can recommend innovative solutions within the energy efficiency goals set by policy-makers regardless of the realization of retrofit measures by customers, while German EECs have to orient towards the customers' needs.

Since the energy audits still have not led to a substantially higher retrofit rate, we propose three policy implications for reforms in the EEC sector. First, policy needs to focus on the institutional framework for retrofit since the public sector influences the framework for retrofit and particularly innovation. In particular, the subsidy scheme should be changed into targeting to save fossil energy, allowing more flexible innovative solutions that could support the role of EECs as change agents. Second, the information on costs and the reduction of energy consumption needs to be part of an ex-post evaluation. The problem with the payment of EECs could be partially solved since the customers could assess the additional benefit from the retrofit. The forecasts based upon simulation prognosis could be replaced with real data since it has only little value for the concrete energy audit case (Sunikka-Blank and Galvin 2012). The monitoring should ideally be executed not by the EECs but rather by a neutral actor - for example, the funding authority - to ensure a reliable comparison of ex-ante and ex-post energy consumption from residences. Finally, policy intervention needs to address the entire EEC market. In recent years, interventions have prompted some groups to establish a higher level of quality in the EEC market. This survey showed that EECs have a homogenous attitude towards energy audits, despite the restructuring caused by institutional reforms that required the adaptation of EECs to the market conditions. Respondents seem confident about this adaptation. One suggestion could be to shift from the subsidy scheme to a carbon tax, which would allow more innovative solutions for the customers. Such solutions based upon the aim of reducing the use of fossil energy would make the component specific regulations obsolete, while the emission reduction would be at the center of the regulation.

In our explorative analysis, we focus on energy audits exemplified in only one case study. To deepen the understanding of EEC's impact, a comparison of energy audits could offer new insights into the planning of energy measures in the retrofit sector. In particular, the question

of whether EECs offer coherent consulting in terms of the advised technology and the estimated costs requires further research. Therefore, a vignette survey with evaluating different cases would identify key variables based upon a robust dataset. Furthermore, a similar questionnaire could be established as panel survey to show dynamic developments in the EEC sector to support policy-makers in improving the energy efficiency in the residential sector. Last but not least, the certified EECs represent only a small share of experts in the German retrofit market offering energy audits. Therefore, a comparison with other professional EECs and constructing companies offering informal EEC services seems necessary to fully understand the impact of certified EECs on the quality of retrofit.

Acknowledgments

Financial support for conducting the interviews from the iENG project (grant number 03EK3517A), funded by the Federal Ministry of Education and Research, is gratefully acknowledged.

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