4 The influence of energy audits on the energy efficiency investments of private owner-occupied households in the Netherlands

Abstract

Energy audits are promoted as an effective tool to drive investment in energy efficiency measures in the residential sector. Despite operating in many countries for several decades details of the impact of audits are mixed. The aim of research presented here is to explore the role of audits on investment in energy efficiency measures by private owner-occupied householders in the Netherlands. Results showed that the main influence of the energy audit was to confirm information held by householders. A significant portion of audit recommendations was ignored, the main reason being that householders considered their dwellings to be adequately energy efficient. A comparison of audit recipients to non-recipients showed that audit recipients did not adopt, plan to adopt or invest in more energy efficiency measures than non-recipients. In fact, non-recipients adopted more and invested more in measures. It is concluded that energy based renovation is driven by householder perception of comfort and acceptable outlay on energy bills and not necessarily to expert technical tailored information on the potential to reduce CO_2 emissions and environmental impact. Results support arguments for minimum energy efficiency standards and performance based incentives.

This chapter is published as Murphy, L. (2014) The influence of energy audits on the energy efficiency investments of private owner-occupied households in the Netherlands. Energy Policy 65 398-407.

§ 4.1 Introduction

Climate change policy gives existing dwellings a key role in reducing greenhouse gas emissions by 20% by 2020 and 50–80% by 2050 (EC, 2011). In quantity and quality terms there is considerable scope in existing dwellings for energy efficiency

improvement. The European Commission (EC) (2006a:5) estimates a cost effective potential to reduce energy use by 27% in the residential sector primarily through measures such as roof and wall insulation. Moreover, it is stated that energy savings can be achieved in existing dwellings more cost effectively than any other sector (Levine et al., 2007; Ürge-Vorsatz et al., 2007). Alongside meeting climate change targets there are multiple positive spin-offs, such as, reduced household expenditure on energy bills, improved occupant health, reduced dependence on non-renewable fuels and protection of environmental resources. However, despite the much lauded benefits a considerable gap between estimated energy saving potential and reality persists (Blumstein et al., 1980; Jaffe and Stavins, 1994; Weber, 1997; Curtain and Maguire, 2011). There are a number of explanations as to why householders do not invest in energy efficiency measures. One explanation is that they do not have adequate information to assess options and potential savings (Gates, 1983; Schleich, 2004; Löfström and Palm, 2008).

A range of policy tools are considered capable of overcoming this information deficit. Promoted as one of the most effective is face-to-face advice that is tailored to a particular household's energy requirements and dwelling characteristics (Gates, 1983; Stern, 1992; New Perspectives 2002; Benders et al., 2006). Energy audits are endorsed by organisations such as the IEA, the OECD and the EC (OECD, 2003; EC, 2006b; OECD/IEA, 2010). The EC urges Member States to establish programmes for audits: "In order to realise the energy savings potential in certain market segments where energy audits are generally not sold commercially, such as households, Member States should ensure the availability of energy audits" (EC, 2006b, p. L114/66).

However, despite the endorsement and theoretical assumptions about cause and effect there is a little empirical data that proves if energy audits function as intended. This knowledge gap is not unique to energy audits but is pervasive for policy instruments designed to improve household energy efficiency. For several decades, researchers have bemoaned the lack of systematic evaluation of instruments and the consequent lack of understanding about the true nature of barriers, the overall effectiveness of instruments and general principles underlying the formulation of instruments (Blumstein et al., 1980; Jaffe and Stavins, 1994; Fairey and Goldstein, 2006; Lowe and Oreszczyn, 2008; Maio et al., 2012).

In response to this research gap an extensive survey of Dutch households was conducted in 2012. The main aim of the survey was to examine the energy efficiency measures adopted and planned by households and the awareness, use and influence of different policy instruments on their action and plans. The focus of the survey was the uptake of energy efficiency measures requiring considerable monetary investment, for example, insulation and micro-generation technologies. These measures hold the most potential to reduce energy use for space and water heating (accounting for over 70% of residential energy use) (Itard and Meijer, 2008). The survey was limited to

homeowners as this represents the single largest share of the housing market in the Netherlands and is therefore considered to represent the largest possible savings[5] . Furthermore, the instruments developed for owner-occupiers are distinct from those aimed at social and private landlords for which it is considered separate surveys would be more appropriate.

One objective of the survey was to identify the impact of energy audits. This objective was reached by (a) analysing the influence of audits as reported by respondents and (b) analysing the difference in energy efficiency investment behaviour between audit recipients and non-recipients. In the next section the theoretical background is outlined followed by an overview of previous research. The survey design and statistical tests adopted for analysis are presented in Section 4. Results are presented in Section 5 and in the last section results are discussed and recommendations are proposed.

§ 4.2 Theoretical background

§ 4.2.1 Barriers and information

The barrier model is typically used as a basis for the development of instruments. Along with financial constraints, lack of time and hassle; lack of information is viewed as a barrier preventing an otherwise assumed natural pursuit of cost effective household energy performance improvement (Jaffe and Stavins, 1994; Vedung and van der Doelen, 1998; Schleich, 2004). According to the OECD/IEA (2010, p. 11) "The theory is simple: barriers can be overcome with the design and implementation of targeted energy efficiency policies".

An array of tool comes under the information banner. As well as energy audits mass media campaigns, promotional pamphlets, interactive web based tools, workshops, smart meters and informative billing are common examples. A number of efforts have been made to categorise information tools. Hood (1983) discusses information instruments as 'general', 'group targeted' and 'custom- made'. Others categorise information as antecedent (goal setting, information etc.) and consequence (feedback)

5 Housing tenure in the Netherlands is approximately 60% owner occupied, 10% private rental and 30% social rental.

(Abrahamse et al., 2005). Further categorisations focus on the role of the energy end user with the division of 'opportunistic advice' (provided when new equipment is installed or householders move dwelling) and 'client-led advice', when householders request the information (New Perspectives, 2002).

Energy audits belong to the 'custom made' and 'antecedent' categories and they can be either 'opportunistic' or 'client-led'. In the information tools family, it is custom-made audits that are viewed as holding the most potential in stimulating the installation of energy efficiency measures (Gates, 1983; Stern, 1992; New Perspectives, 2002; Benders et al., 2006). "Social psychologists and marketing professionals know that information is more likely to change behaviour when it is specific, vivid and personalised" (cited in Stern, 1992, p. 1227).

The specificity and comprehensiveness of energy audits are illustrated in definitions and descriptions. The European Energy Service Directive defines an energy audit as: "a systematic procedure to obtain adequate knowledge of the existing energy consumption profile of a building or group of buildings, identify and quantify cost-effective energy savings opportunities, and report the findings" (EC 2006b: L114/68). National or international standards are typically followed during the audit process (Novikova et al., 2011). Breukers et al. (2009, p.82) and Novikova et al. (2011) emphasise the face-to-face contact associated with an energy audit as a distinguishing feature. This face-to-face element makes audits more engaging than tools such as the Energy Performance Certificate (EPC) required under European legislation when buildings are constructed, sold or rented but without the involvement of the 'would-be' occupant.

To summarise, the theoretical assumption is that an energy audit can remove the information deficit and unnecessary information overload by providing bespoke advice on the extant efficiency of the dwelling, recommended energy efficiency measures and expected savings in energy use and energy bills. Once armed with this information it is assumed that householders are more likely to install the energy efficiency measures recommended to them, all the more so if they have requested the audit. This brings benefits to the household and reduces the environmental impact by contributing to, inter alia, climate change policy objectives. The aim of research presented here is to furnish this assumption with empirical evidence from the Netherlands.

§ 4.2.2 Instrument implementation

As well as theories about barriers two commonly accepted theories in this domain are that a mix of instruments should be implemented and that instruments should be performance based. A mix of policy instruments is required to target multiple

barriers and market transformation opportunities (Gunningham and Sinclair, 1999; Ürge-Vorsatz et al., 2007). Meanwhile, a performance based approach is required to encourage deep retrofit instead of the installation of one-off measures (Fairey and Goldstein, 2006). As well as the preferred approach in terms of cost effectiveness it is argued that deep retrofit is required if existing dwellings are to deliver on climate change targets.

§ 4.3 Previous research

§ 4.3.1 Effects of audits

Several research projects refute the assumption that tailored advice overcomes the information deficit and stimulates investment in energy efficiency measures. McDougall et al. (1983) "in their evaluation of the Canadian EnerŞave programme" found no difference between households who had received custom made advice compared to households who had not two years after the advice was provided (cited in Abrahamse et al., 2005). Hirst and Goeltz (1985,p 26) "in their analysis of participants and non-participants of a US energy company audit programme" found only a slight influence of the audit on retrofit activity. Likewise, Frondel and Vance (2012) noted that far less than half of households who participated in an audit reported it as a decisive factor in their investment decision.

Studies into the effect of energy audits in the commercial sector show similar results with one US study finding that only half of the recommended measures from audits were taken even with relatively short (<2 years) average payback periods (cited in Breukers et al., 2009). Schleich (2004) found that energy audits reduced the information deficit but did not necessarily lead to an increase in adoption of energy efficiency measures for small and medium size enterprises in Germany.

However, not all research finds this low to absent impact of energy audits. Hirst et al. (1981) identified positive results on the cause and effect relationship of audits in the US. A study into the energy efficiency measures adopted by recipients of energy audits from six different energy companies showed that, on average, 40–50% of recipients invested in energy efficiency measures. The energy saving investments of non-recipients were only analysed by two energy companies and results showed weak impact of the energy audits. However, when comparing the investments of the energy

company audit recipients to a larger survey of 4081 non-recipients (considered more representative of the general population) the impact of energy audits were considered stronger. While, 40–50% of recipients of audits invested in energy efficiency measures, only one-third of the 4081 non-recipients had installed energy efficiency measures. Unfortunately, results of any statistical analysis associated with this study were not reported.

The Energy Efficiency Partnership for Homes also identified a positive relation between audits and investment in energy efficiency measures. Instead of comparing audit recipients to non- recipients they focused on differences between client-led advice and opportunistic advice. Their results, based on 1900 interviews of households in 2001 in the UK, showed that 70% of households with client-led advice installed some advised measures while the equivalent percentage for opportunistic advice was 63% (New Perspectives, 2002).

Few researchers have focused on why audits might not have the effect intended. Exceptions include Frondel and Vance (2012) who elaborated on a theory from Metcalf and Hassett (1999) (cited in Frondel and Vance, 2012) that audits could negatively influence decisions about adopting energy efficiency measures. They postulated that while audits may encourage some householders to invest in energy efficiency measures they could have the opposite effect on others. This opposite effect would emerge if householders become discouraged to invest if, for example, pay-back is perceived as too long. Such occurrences would result in non-significant average effects. The National Energy Foundation (2009) found another explanation following their research into why householders in receipt of EPCs in the UK do not follow recommendations to invest in energy efficiency measures. The main reason for not acting on recommendations, given by 34% of their 302 respondents, was that they disagreed with them.

Further explanations about why research on audits produces such mixed results are linked to research methodologies and the nature of bottom up research. Abrahamse et al. (2005) found that small sample sizes, especially pertinent given the large variances associated with household energy use, could explain why many studies fail to find statistical significant effects between households using policy instruments compared to those who do not. Meanwhile, Hirst et al. (1981) noted that non-participants who respond to surveys on energy efficiency measures are likely to be more interested in energy saving than the general population of non-participants, therefore skewing results. Another study showed that caution should be adopted when assuming that householders who do not participate in audit programmes are un-informed or uninterested in energy saving. This study found that non-participants could often be better labelled as 'early participants' or 'early adopters' as they were found to have taken out more energy efficiency measures before an audit programme than participants (Hartman, 1986).

§ 4.3.2 Audit recipients

While findings about the effect of energy audits are certainly mixed, agreement exists about the characteristics of householders who participate in audit programmes. Stern et al. (1986), Hirst et al. (1981) and Wirtshafter (1985) found that audit programmes consistently attracted higher income and higher educated households. "People who participate in home energy audit programs were clearly not a cross section of the general public. Utility surveys of the characteristics of programme participants always showed that they had higher educational and income levels than were average for respective locations. Another typical characteristic of participants was a greater interest/awareness/concern with energy conservation than was found among the general population" (Hirst et al., 1981, p. 628). Likewise, Bruel and Hoekstra (2005), in their research in the Netherlands, found that higher income households respond to personalised advice and appeals to improved comfort and societal responsibility while lower income households respond to subsidies and advice on reducing energy bills.

However, other research emphasises that socio-economic and demographic factors are significant variables for energy efficiency renovation in general, not only for audit recipients. Stieß et al. (2010) found that most energy based renovation activity in Germany is carried out by older households (over 50 years) with higher education and income than the average. Barr et al. (2005), Martinsson et al. (2011) and Dillman et al. (1983) found that age, housing type and income were strongly linked to more sustainable use of energy.

§ 4.4 Method

§ 4.4.1 Questionnaire and response

To investigate the role and influence of national policy instruments on the adoption of energy efficiency measures by Dutch private households an extensive online questionnaire was launched in March 2012. The questionnaire consisted of multiple choice and open ended questions divided into several categories; the adoption and planned adoption of energy efficiency measures, energy audits, the EPC, building regulations, the energy tax, financial incentives, information tools and socio-economic and dwelling characteristics.

The results presented and discussed here focus on the influence of the energy audit. An official audit (maatwerkadvies) was introduced in the Netherlands in 2000. The audit must follow national standards (BRL beoordelingsrichtlijn 9500) and includes a comprehensive energy report on energy use and possible savings. An EPC, the issue of which is required by the European Energy Performance of Buildings Directive (recast 2010) when buildings in the European Union are constructed, sold and rented is commonplace in audits. The EPC includes a building rating based on A–G with A as the most energy efficient.

Required survey sample sizes were calculated on the basis of assumptions and several critical components of the questionnaire which required a set response rate to allow statistical analysis. Slightly less than 30,000 letters (with a link to the questionnaire) were sent to households registered as having an EPC because they bought a dwelling or received an energy audit.

To create the sample for comparison over 16,000 members of the Association of Home Owners were emailed a link to the questionnaire. The Association of Home Owners represents the interests of 17.5% of Dutch homeowners (VEH, 2012). It is assumed that members of this association may be more 'engaged' than the general population of homeowners. However, other objectives of the survey meant that the comparison sample had to have purchased their dwelling in the recent past[6]. Accessing data of recent and representative dwelling purchasers was heavily restricted. Associations managing real estate data and mortgage data would not permit the use of contact details due to privacy issues. The National Land Registry would issue only a limited number of addresses, which would not have allowed for statistical analysis.

Following a reminder, a response rate of 17% was received for the EPC database and 10% for the Association of Home Owners. Following the removal of inconsistent cases and division of respondents into different groups for analysis the final count for households with an energy audit was 3737. The final count for households without an energy audit was 1779.

6 Recent dwelling purchasers were required for the survey to compare energy saving action to the EPC sample who purchased their dwelling in 2010.

§ 4.4.2 Analysis

Firstly, the 'self-reported' influence of energy audits by recipients was analysed and the association between recommendations made in the energy audit and energy efficiency measures adopted and planned was investigated using descriptive statistics.

Secondly, the dwelling and household characteristics of energy audit recipients and non-recipients were analysed to highlight any differences. Pearson's chi-square tests were conducted using SPSS v19 to identify these differences. Following Field (2009) contingency tables were created for each variable, entered into SPSS and analysed using the cross-tabulations function.

Thirdly, differences in installation and investment in energy efficiency measures between the two groups were analysed again using Pearson's chi square tests. Whether a statistical difference existed between having an energy audit and installing and planning to install energy saving measures, the quantity and type of measures installed and the amount invested was analysed.

§ 4.5 Results

The final count for recipients of an energy audit was 3737. The final count for non-recipients was 1779. However, audit recipients who were required to get an audit for a subsidy were removed. This is because the energy audit was assumed to play a weaker role in their decision making. This reduced the audit recipient count to 2232. Furthermore, 431 respondents stated that they had received the audit opportunistically, for free from the local authority or energy company. Analysis was re-run with these respondents removed as it was assumed that the audit may have been less significant for this group. Results of this analysis are reported in Section 4.5.3.6.

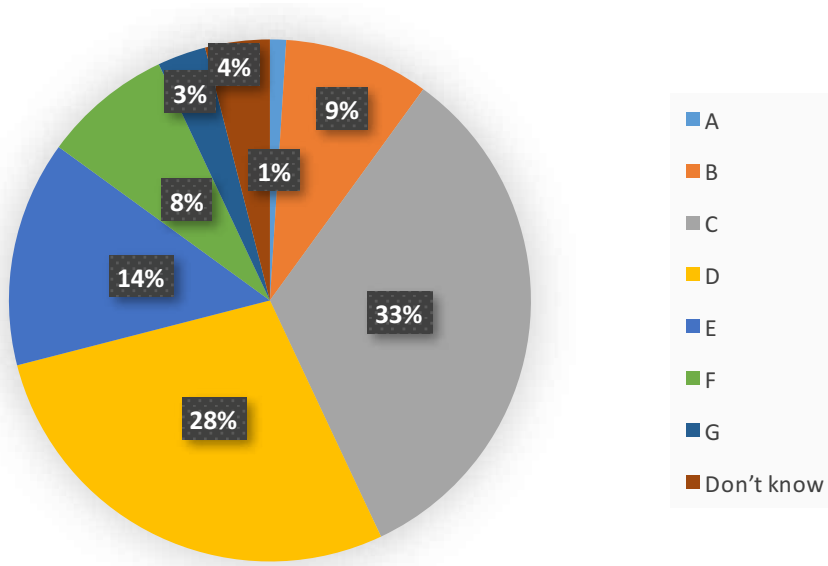

FIGURE 4.1 Energy ratings according to the energy audit

§ 4.5.1 Reported influence of energy audit

A series of questions were included in the questionnaire to seek information on the:

- Context of recipients having audits
- Energy efficiency of their dwellings
- Influence of the audit in terms of whether it led householders to go further than planned with energy efficiency measures
- Relationship between recommendations made in the audit and measures that were adopted and/or planned.

62% (1385) of audit recipients reported to have had an energy audit carried out because they wanted to know more about the energy performance of their dwelling. 26.5% (591) got an audit based on advice that they received from a third party. 31% (701) gave other reasons for having an audit, of which 59% (413) received the audit opportunistically, for free from their local authority or energy supplier. Over half of the respondents received some form of subsidy for the audit.

90% of the audit sample lived in dwellings rated C and below, see Fig. 4.1. Dutch climate change policy includes the ambition of reaching an average B rating for existing dwellings, therefore the majority of dwellings would be considered appropriate for energy performance improvement.

19% (421) respondents stated that either the audit rating or audit recommendations influenced them in their decision to install energy efficiency measures. These respondents were asked how the audit influenced them with questions presented as: Did the audit confirm information that the householder already had? Did the audit influence the householder to install more energy saving measures than planned? Did the audit influence the householder to install measures that they had not thought about previously? Multiple responses were possible. The main influence was that the audit confirmed the householder's ideas about some energy efficiency measures (n=391). This was followed by the audit influencing them to install more measures than they had planned (n=153) and influencing them to install some measures that they had not thought of previously (n=126).

MEASURE	RECOMMENDED	ADOPTED	PLANNED	% ADOPT/ PLAN COMPARED TO RECOM-MENDED	ADOPTED (NOT RECOM-MENDED)	PLANNED (NOT RECOM MENDED)
Boiler replacement	570	265	42	54	300	56
High performance glazing	1227	357	109	38	111	21
Roof insulation	875	183	103	33	96	17
Floor insulation	1089	235	123	33	73	24
Wall insulation	1048	335	80	40	92	23
Heat recovery shower	29	1	2	10	3	19
Heat recovery m. ventilation	31	5	0	16	2	8
Insulation of piping	191	48	8	29	111	19
Draught proofing	373	109	30	37	170	30
Renewable technology	668	87	118	31	60	131
Don't remember	158	-	-			
None	74	-	-			

TABLE 4.1 Measures reported as recommended, adopted and planned by audit recipients

Respondents were asked what recommended measures were listed in their energy audits and which of these they adopted and planned. Results are presented in Table 4.1. This shows that a significant portion of recommendations issued were neither adopted nor planned. Furthermore, results show a significant portion of measures were adopted or planned but not recommended.

§ 4.5.2 Sample characteristics

Table 4.2 displays the type and age of the dwelling for the two sample groups. A significant difference between the two sample groups was identified in the dwelling type category, χ^2 (5) = 144.83, p < .001. Audit recipients were more dwellings likely to live in detached dwellings and less likely to live in apartment dwellings with values for standardised residuals significant at <.01 and <.001 respectively

A significant difference was also identified between the two sample groups for the dwelling age category, χ^2 (5) = 231.56, p < .001. 96.5% of audit recipients lived in pre-1990 dwellings and 84% of non-recipients. Audit recipients were more likely to live in the 1971–1990 category. Furthermore, audit recipients are under-represented in the post 1991 category compared to non- recipients.

DWELLING CHARACTERISTICS	AUDIT RECIPIENTS		AUDIT NON-RECIPIENTS		STANDARDISED RESIDUALS *	P***
	#	%	#	%		
Type						
Apartment	28	1	151	9	<.001	.000
Detached	600	29	351	22	<.01	
2 under 1 roof	504	24	331	21	**	
Corner	345	16	261	16	**	
Terraced	554	26	455	28	**	
Other	67	3	56	3.5	**	
Age						
Pre 1945	589	28	488	30	**	.000
1945-1970	510	24	331	21	**	
1971-1990	927	44	523	33	<.001	
1991-2000	67	3	158	10	<.001	
2001-	2	<1%	102	6	<.001	
Don't know	3	<1%	3	<1%	**	

*+Missing cases are respondents who did not complete the entire survey; * Based on chi-square test; **No statistical difference; ***Using Monte Carlo method*

TABLE 4.2 Dwelling characteristics (including missing cases)+

Compared to the national average[7] apartment dwellers were under-represented for both groups and householders in detached dwellings over-represented (national averages taken from Eurostat, 2009). Compared to the national average, older dwellings were over-represented among the audit recipient group with the non-recipient group being more representative, 28% of the audit sample lived in pre 1945 dwellings with the national average at approximately 21% (national averages taken from Itard and Meijer, 2008).

Table 4.3 shows household characteristics for audit recipients and non-recipients. With the exception of 'income', χ^2 (5) = 14.30, p >.05 there were significant differences in all categories. Most differences between the two samples appear to stem from different life stages between the two groups.

7 According to Eurostat (2009) 16% of the national population lives in apartments but this figure includes social housing (30% of total housing in the Nether- lands). Meanwhile, 17.6% of the national population live in detached dwellings.

HOUSEHOLD CHARACTERISTICS	AUDIT NON-RECIPIENTS		AUDIT NON-RECIPIENTS		STANDARDISED RESIDUALS *	P***
	#	%	#	%		
Size						
1 person	263	13	249	15.5	**	.000
2	1127	54	727	45	<.001	
3	241	11.5	258	16	<.001	
4	347	17	244	15	**	
4>	114	5	125	8	<.001	
Age						
20-39	193	9	464	26	<.001	.000
40-65	1120	50	842	47	**	
66-79	606	27	190	11	<.001	
80>	40	2	18	1	**	
Not stated	273	12	270	15	**	
Education						
School	8	<1	6	<1	**	0.001
High School	134	6	84	5	**	
Lower vocational	49	2	22	1	**	
Middle vocational	401	19	265	17	**	
Higher vocational	892	43	660	41.5	**	
University	572	27	535	34	<.001	
Other	38	2	18	1	**	
Employment						
Part-time	340	16	314	20	**	.000
Full-time	744	36	879	56	<.001	
Unemployed	52	2.5	31	2	**	
Retired	802	39	261	16.5	<.001	
Student	0	0	8	<1%	**	
Other	133	6	85	5	**	
-Monthly net income						
<1,000	17	<1%	7	<1	**	0.13
1,000-1,350	44	2	44	3	**	
1,350-1,800	155	7	116	7	**	
1,800-3,150	816	39	548	35	**	
3,150>	692	33	540	34	**	
Not stated	360	17	327	20	**	
Duration of occupation						
<1 year	3	<1	92	6	<.001	.000
1-5 years	285	13	968	61	<.001	
5>	1784	80	530	33	<.001	

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HOUSEHOLD CHARACTERISTICS	AUDIT NON-RECIPIENTS		AUDIT NON-RECIPIENTS		STANDARDISED RESIDUALS *	P***
	#	%	#	%		
Plans to move						
Within 1 year	54	2	40	2.5	**	.028
1-5 years	183	8	144	9	**	
>5 years	384	17	235	15	<.05	
None	1463	65,5	1177	74	**	

*+Missing cases are respondents who did not complete the entire survey; * Based on chi-square test; **No statistical difference; ***Using Monte Carlo method.*

TABLE 4.3 Household characteristics (including missing cases+)

Age appeared as a significant factor in having an energy audit χ^2 (4) =331.08, p<.001. Recipients of audits were more likely to be older with a highly significant difference in the over 66 age category and 20–39 category compared to the non-recipients. Significant differences were found for employment status, χ^2 (5)=249.43, p<.001 and education, χ^2 (6)=24.36, p<.01 with audit recipients more likely to be retired and less likely to have a university education compared to non-recipients which also presumably relates to generational differences.

Household size was found to be significant, χ^2 (4) = 41.73, p<.001 with audit recipients more likely to live in two person households. Significant differences were also found for length of occupation, χ^2 (2) = 1090.68, p < .001 and plans to move, χ^2 (3) = 9.03, p < .05. In these cases, audit recipients were more likely to have lived in their dwellings for longer than five years and non- recipients were less likely to plan to move dwelling within five years.

Compared to the national average the two samples were more highly educated with higher incomes (based on national averages from CBS, 2010). However, the samples could be considered more representative of the private owner-occupied sector where incomes are higher than the national average (based on national averages VROM and CBS, 2009). In terms of age the non-recipient group could be considered more representative than the recipient group with an average age of 49 and 58 respectively compared to a national average of 41[8] (based on national averages CIA, 2012).

8 Total population including non-home owners.

§ 4.5.3 Energy efficiency measures and the energy audit

In this section results of statistical analysis into the differences in installation, investment and plans for the installation of energy efficiency measures between the audit recipient group and the non-recipient group are presented. Results are displayed in Table 4.4 and further elaborated in the sections below.

§ 4.5.3.1 Adoption of energy efficiency measures

64% (1370) of the audit sample stated that they had adopted energy efficiency measures since receiving the energy audit. 63% (1091) of the non-recipient group had adopted energy efficiency measures since buying their dwelling. There was no significant association between having an audit and carrying out energy efficiency measures, $\chi^2(1)=.280$, $p>.05$

§ 4.5.3.2 Quantity of energy efficiency measures adopted

When examining the quantity of energy efficiency measures adopted by the two groups a significant difference was identified, $\chi^2(6)=100.94$, $p<.001$. This test initially had to be limited to seven measures because of low sample size for those respondents who adopted eight and nine measures. Standardised residuals for the adoption of one and two measures are significant with audit recipients more likely to install this quantity of measures. This bottoms out at the adoption of three measures which does not show significance for either group. However, from the adoption of four measures upwards the standardised residuals are again significant but reversed with non-recipients more likely to adopt four or more measures. This peaks at the adoption of five measures which shows a highly significant relationship with residuals of 4.0 and -3.6 for non-recipients and recipients respectively ($p<.001$). To explore these results further measures are clustered into two groups: one and two measures, and four to nine measures.[9]

Grouping the measures into one and two measures and four to nine measures confirmed significant differences between the two samples, $\chi^2(1) = 94.93$, $p<.001$. Audit recipients were significantly more likely to have installed one and two energy

9 Adoption of eight and nine measures are now included as together counts are large enough for the chi-square test

efficiency measures and non-recipients significantly less likely with standardised residuals of 2.9 and -3.2 respectively ($p < .01$). When measures are increased to four to nine there is a reversal with standardised residuals of 6.5 and -5.8 highly significant at $p < .001$ showing that non-recipients installed more measures and recipients less than expected.

VARIABLE	AUDIT RECIPIENTS N=2148		AUDIT NON-RECIPIENTS N=1733		STANDARDISED RESIDUALS	P
	#	%	#	%		
Adoption of energy efficiency measure(s)	1370	64	1091	63	**	.615
Number of energy efficiency measures adopted*						
One	564	42.5	353	33	<.01	.000 ***
Two	434	33	274	26	<.05	
Three	190	14	177	17	**	
Four	85	6	122	11	<.01	
Five	32	2	75	7	<.001	
Six	14	1	36	3	<.01	
Seven	4	1	20	2	<.01	
Eight	0	0	5	<1%	--	
Nine	0	0	1	<1%	--	
Number of energy efficiency measures grouped						
One-two	998	88	627	71	<.01	.000
Four-nine	135	12	259	29	<.001	
Investment in energy efficiency measures						
>€4,000	400	29	379	36	<.01	.000
€2,000-€4,000	393	29	284	27	**	
€1,000-€2,000	357	26	227	21	**	
€500-€1,000	117	9	83	8	**	
<€500	96	7	93	9	**	
Planned adoption of measure(s)						
	n=2130		n=1680			
	600	28	586	35	<.01	.000
Estimated investment in planned measures						
>€4,000	167	28	173	30	**	.209
€2,000-€4,000	200	33	158	27	**	
€1,000-€2,000	134	22	141	24	**	
€500-€1,000	67	11	74	13	**	
<€500	31	5	37	6	**	

**Excluding 'other answers'; **Not significant; ***Using Pearson's chi-square test with Monte Carlo Method.*

TABLE 4.4 Differences in adoption, investment and plans to adopt and invest in energy saving measures

§ 4.5.3.3 Types of energy efficiency measures adopted

Table 4.5 displays frequencies, percentages, χ^2 values and p values relating to the types of energy efficiency measures installed by recipients and non-recipients. Significant differences are noted in the adoption of all measures except for floor insulation and heat recovery from showers The reason(s) for these differences were not known..

Non-recipients were more likely to install the following measures: boiler replacement, high performance glazing, roof insulation, heat recovery from ventilation, piping insulation, draught proofing and 'other'[10] measures. Meanwhile, audit recipients were more likely to install wall insulation and renewable technology compared to non recipients.

MEASURE	AUDIT RECIPIENTS N=1367			AUDIT NON-RECIPIENTS N=1087				
	# ADOPTED	# NOT ADOPTED	% ADOPTED	# ADOPTED	# NOT ADOPTED	% ADOPTED	X2 (1)	P
Boiler replacement	568	799	41.5	634	453	58	68.18	.000
High performance glazing	468	899	34	443	644	41	11.02	.001
Roof insulation	285	1082	21	333	754	31	30.78	.000
Floor insulation	311	1056	23	269	818	25	1.65	.251
Wall insulation	431	936	31.5	228	859	21	35.1	.000
Heat recovery shower	4	1363	<1	9	1078	<1	3.29	.092
Heat recovery m. ventilation	7	1360	<1	15	1072	1	5.13	.030
Insulation of piping	159	1208	12	281	806	26	83.2	.000
Draught proofing	279	1088	20	413	678	38	90.71	.000
Renewable tech-nology	152	1215	11	88	999	8	7.83	.014
Other	111	1214	8	124	937	11	7.27	.007

TABLE 4.5 Differences in types of measures adopted by recipients and non-recipient

10 In the 'other' measures category respondents were free to enter their own comments. Respondents varied in their answers but frequently listed lower level measures such as radiator foil or energy efficient appliance purchases as well as altering habitual behavioural such as reducing number of showers.

§ 4.5.3.4 Amount (€) invested in energy efficiency measures

A significant difference was identified in the amount invested in energy saving measures between the two samples with standardised residuals showing that this significance stems from non-recipients who were more likely to spend over €4000.

§ 4.5.3.5 Future plans for energy efficiency measures

Similarly, non-recipients were more likely to plan on taking energy saving measures $\chi^2(2)1=26.62$, $p<.001$. There was no significant difference between the two groups in terms of the amount planned for future investment, $\chi^2(4)=5.87$, $p>.05$.

§ 4.5.3.6 Opportunistic recipients removed

413 respondents from the audit sample stated that they had received the audit opportunistically, for example, through pilot projects offered by their municipality or from their energy provider. These cases were removed and the remaining sample was compared to the original audit sample for all the analysis categories: differences in whether energy efficiency measures were installed, the quantity and type of measures adopted, amount invested in measures, planned installation and investment in measures. There were no statistical differences identified in any of the categories.

§ 4.6 Discussion and recommendations

§ 4.6.1 The role and influence of energy audits

Results presented here agree with other research findings (Hirst and Goeltz, 1985; Abrahamse et al., 2005; Frondel and Vance, 2012) that show the energy audit as a weak variable in the overall decision to invest in household energy efficiency measures. Only 19% (421) of audit recipients who adopted energy efficiency measures stated that the audit rating or recommendations influenced their decision. The weak influence of the audit is further confirmed in the wide disparity between the measures that were

recommended in the audit and the number and types of measures that were adopted and planned see Table 4.1. Even in the unlikely scenario that all the planned measures are actually adopted it remains that between 60% and 70% of recommendations were ignored. This percentage is even greater for innovative measures like heat recovery measures. Moreover, Table 4.1 shows that some measures were adopted or planned which were not recommended, further questioning the role of the audit in householder decision making. The installation of renewable technology appears the most popular 'planned but not recommended measure'. This could be regarded as one of the least cost effective measures among the typical list of audit recommendations. This shows the competing influences of non-economic and technical variables such as motives and goals in the investment decisions of householders as highlighted authors like Zundel and Stieß (2011). This also casts into doubt popular models like the barrier model based on an understanding of householders as rational economic agents and highlights the complexity of decision making in this area.

Another dimension to exploring the role and influence of the audit was to compare audit recipients to non-recipients. As with the research findings identified by Hirst and Goeltz (1985), Abrahamse et al. (2005) and Frondel and Vance (2012) audit recipients were not more likely to adopt energy efficiency measures compared to non-recipients[11]. In fact, results presented here show that non-recipients were likely to invest more in measures and plan more measures than recipients. Moreover, while the norm among both samples was the adoption of one or two measures, non-recipients were likely to invest in a greater number of measures than audit recipients.

However, as with much research in this area difficulties with representativeness were encountered. Audit recipients were older, lived in their dwellings for longer, lived in older dwellings and were more likely to be retired. Non-recipients meanwhile moved into their dwellings more recently and on this basis may have been more likely to have carried out some key energy efficiency measures in the recent past. Although, this fact could be offset by the fact that non-recipients were more likely to live in newer dwellings; especially post 1990 when performance based building energy standards were introduced into Dutch legislation. Nonetheless, it is assumed that non-recipients who responded to the questionnaire may have been more interested and likely to have carried out energy efficiency measures than the general population and be at a stage in their dwelling occupation where they are more likely to be adopting and planning energy efficiency measures.

11 There was no significant association found for having an audit and carrying out energy saving measures. Results of research presented in chapter 3 did not find this which is explained by sample differences. The sample in this chapter did not contain respondents who had an audit because it was required to receive a subsidy while the sample in chapter 3 did.

While respondents from the two sample groups showed some divergence in key aspects, respondents, in general, are not representative of the national population. Research findings presented here agree with other conclusions that survey respondents/audit participants have higher income and education levels than the national average (Hirst et al., 1981; Wirtshafter, 1985; Stern et al., 1986; Stieß, et al., 2010). However, when compared only to the private owner occupied sector, respondents might be more representative.

Results presented here highlight interesting dimensions of the barrier model on which instruments are based. One finding is that many barriers are unaccounted for in the policy instrument package used to tackle existing dwellings. This is manifested in the top five reasons for not adopting or planning energy efficiency measures among the audit sample (n=776):

- a) dwellings are considered to be adequately energy efficient- 36% (278)
- b) lack of finances-29% (228)
- c) uncertainty about length of residence at particular dwelling-24% (184)
- d) payback considered too long-18% (143)
- e) measures considered to be too much hassle-14% (106)

Financial (b & d) and 'hassle' (e) related barriers are typically reflected in policy instruments developed for existing dwellings. However, consideration that dwellings are adequately energy efficient (a) and uncertainty about length of residence (c) are not dealt with by the policy instrument arsenal for existing dwellings. Fig. 4.1 shows that 10% of respondents lived in dwellings that are rated A or B which are outside the main thrust of policy attention in the Netherlands. This is significantly less than the 36% who considered their dwellings to be energy efficient. Moreover, almost a quarter of households cited uncertainty about the length of time they will occupy their dwelling as a reason for not investing in measures. In these cases, householders considered that their investment is unlikely to be returned in a future property sale.

Another finding in terms of the barrier model is that removing the information deficit barrier did not lead to a positive outcome in terms of investment in energy efficiency measures among many respondents. Interestingly many respondents who cited payback time as a barrier to investment mentioned that the auditor advised them that measures were not cost effective. Just as audits can confirm ideas about what measures to take it seems likely that they can create adverse feelings about installing measures, particularly if there is a negative emphasis on economic aspects. This links to the findings of other researchers that audits can influence householders not to invest in measures (see Frondel and Vance, 2012).

§ 4.6.2 Recommendations

Results of research presented here show weaknesses of an approach based on addressing a limited number of barriers and on the purely voluntary participation of householders in the energy performance improvement of the existing stock. The main reason for not investing in energy efficiency measures among both sample groups was consideration that dwellings were already energy efficient enough. This is despite over 70% of recommendations being ignored among the audit sample. Moreover, other reasons cited by householders for not investing in energy efficiency measures, for example, uncertainty about length of occupation, are not dealt with by current instruments.

Based on the above it is argued that instruments based on 'take it or leave it' recommendations have to be second place to instruments with a clear signal of what represents an energy efficient dwelling. A possible solution is a minimum standard for existing dwellings or different categories of existing dwellings. Such a standard could be enforced at 'natural' moments such as at the point of sale or renovation. A minimum standard could also offer householders a clearer benchmark when they do carry out energy efficiency measures encouraging them to go beyond their own perception of comfort and acceptable energy bill expenditures. Furthermore, a minimum standard would integrate energy efficiency into property valuations guaranteeing householders who might otherwise not be inclined to install energy efficiency measures because of uncertainty surrounding length of occupation that they will get a return on their investment during a future sale. However, a minimum standard for existing dwellings has possible negative effects not least on householders already living in fuel poverty in inefficient dwellings. Further research is required to fully explore the role and effect of a minimum standard.

A further recommendation stems from the fact that among both sample groups the installation of one or two energy efficiency measures was the norm. This illustrates the need for information instruments that support deep retrofit and incentivising performance based financial instruments. Financial barriers, either through a lack of finances or dissatisfaction with the payback period, are longstanding for energy performance improvement in the existing housing stock. More innovative financial mechanisms such as the performance based approach to deep retrofit promoted by KfW loans in Germany or loans attached to properties and repaid through savings in energy bills as proposed by the Green Deal in the UK could reduce financial barriers while concomitantly promoting deeper retrofit.

Lastly, more research is called for to gain a fuller understanding of (1) whether instruments perform as intended (2) the way different policy instruments interact with one another and (3) how deep retrofit and a performance based approach can be supported in instrument design. As policy interventions can play a key role in altering the business as usual approach to household investment in energy efficiency measures it is crucial that their influence is comprehensively understood.

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