Lessons learnt from the uptake of energy audits and energy management systems in Germany

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ABSTRACT

Promoting energy audits and energy management systems is a core part of the European Union's policy mix for industry. The EU's energy efficiency directive requires mandatory energy audits for all large enterprises, and encourages the widespread use of energy audits among small and medium sized enterprises (SME). In addition, Germany has promoted the uptake of certified energy management systems by two energy tax relief schemes as well as a funding scheme. As a result, the majority of ISO 50001 certified companies worldwide are from Germany. The impact of those policies on the energy efficiency progress, as well as the uptake of energy efficient technologies, has not been analyzed in detail yet. Within our paper we will present the current state of diffusion of energy audits and management systems in Germany. Secondly, we will empirically analyze the impacts of the audits and energy management systems instruments on the company's activities in the field of energy efficiency. We will show, that the update of energy efficiency measures is significantly increased by audits as well as energy management systems.

1. Introduction and policy background

Germany's energy efficiency policy framework today is not only driven by its own ambitions, but also by the European Union's framework legislation.

Four major instruments represent Germany's energy efficiency policies (Rohde 2015):

1. The European Emission trading scheme, which covers the whole electricity production sector as well as large industrial installations.
2. The Energy taxes for fuels and electricity, including the corresponding tax relief schemes.
3. Minimum energy performance standards set by the European Union for energy-using products.
4. National funding schemes for the uptake of organizational concepts (energy audits and energy management systems) and the implementation of energy efficient technological solutions (cross-cutting technologies as well as process technologies).

With the implementation of the Energy Efficiency Directive, the European Union has introduced several important instruments exclusively or partially targeting industry (EC 2012).

The most important article of the directive for energy efficiency is Article 7, which imposes a savings obligation on member states. The directive states energy efficiency obligation schemes as preferred options, but also allows alternative measures such as funding schemes, or fiscal or regulatory approaches to deliver the required savings. Germany opted for those alternative measures, as the utilities do not play an important role in the energy efficiency

market. For industry, this resulted in the expansion of existing funding schemes as well as the extension of existing schemes. Under those schemes, the uptake of energy audits and energy management systems as well as the implementation of actual (technological) measures is funded by the federal government. In addition, Germany has promoted the uptake of certified energy management systems by two energy tax relief schemes. As a result, the world wide majority of ISO 50001 certificates worldwide have been issued in Germany.

The second important part of the EU's energy efficiency directive targeting industry is the requirement of mandatory energy audits for all large enterprises in Article 8 of the directive. This has resulted in an estimated 30,000 energy audits in 2016 for large enterprises in Germany. Article 8 also encourages the widespread use of energy audits among SME without a formal obligation (Rohde 2016).

Thus, a broad policy mix exists to encourage or force the uptake of energy audits and energy management systems. The impact of those policies on the energy efficiency progress as well as the uptake of energy efficient technologies has not been analyzed in detail yet.

The aim of the present paper is to present the current state of diffusion of energy audits and energy management systems in Germany. Furthermore, we will empirically analyze the impacts of energy audits and energy management systems on companies' energy efficiency.

2. Data and methods

2.1 Data

To analyze the status of diffusion of the two instruments, energy audits and energy management, as well as to investigate their impact we use different data sets (see Table 1). These data sets were partly collected in the context of evaluations of funding programs as well as independently collected. The particularities of each data set are described in the following.

Table 1: Description of data sets

Data set	**EMS2015**	**EBM2014**	**GHD2016**	**Effizienzfonds 2016**	**RE2016**
Name of data set	European Manufacturing Survey	Energy audits in SMEs ("Energie-beratung Mittel-stand")	Rational use of energy in the trade, commerce and services sector	Evaluation of the funding program "energy management systems"	Rational use of energy in industry
Year of survey	2015	2014	2016	2016	2016
Sectors	Manufacturing industries	Industry & trade, commerce and services	Trade, commerce and services; manufacturing industries < 20 employees	Industry & trade, commerce and services	NACE 22, 25-30

Sample size	1,282	1,471	336	246	402
Particularities of the sample	Representative data sample of the manufacturing industries (>19 employees)	All companies in the sample had an energy audit	-	Majority of companies in the sample has an energy management system	Subsample of the EMS2015 Data set
Further information	Mattes et al. (2015)	Mai et al. (2014), Schleich et al. (2015)	-	Nabitz et al. (2016)	Mattes et al. (2016)

The first data set is based on the European Manufacturing Survey. This survey is carried out by Fraunhofer ISI every three years and consists of a representative sample of the manufacturing sector in terms of the distribution of company size and industry affiliation (Mattes et al. 2015). In terms of content, the use of technical and organizational innovations in production, and the resulting improvements in the ability to perform in the manufacturing sector, have been surveyed. Due to the time series data, this sample is especially relevant for the status of diffusion of energy managements systems. Fraunhofer ISI together with IREES collected the second data set, “Energy audits in SMEs”, in the context of the evaluation of the funding program "Energy Consulting for SME" (Mai et al. 2014). As a result, a subsidized energy audit was carried out in all surveyed companies. The auditors within this federally funded scheme had to fulfil qualification requirements and a representative sample of the audit reports was checked to ensure consistency. Within the framework of the project "Evaluation of the Energy Efficiency Fund", the funding program "Promotion of energy management systems" was evaluated and a survey was carried out among the subsidized companies. In this third data set, the majority of companies have already installed an energy management system (Nabitz et al. 2016). Thus, this sample is particularly suitable to assess the impact of energy management systems. The fourth data set “Rational use of energy in industry” is a subsample of the European Manufacturing Survey and contains information on the rational use of energy, energy monitoring and the relevance of energy efficiency in industry (Mattes et al. 2016). In addition, the fifth data set “Rational use of energy in the trade, commerce and services sector” covers analogous data on the rationale use of energy for these branches.

2.2 Methodology

In order to analyze the structure and distribution of the existing data sets, univariate descriptive analyses, by means and standard deviations, are carried out first. Since the data sets always represent one particular sampling of the entire population, the mean value in the data set can differ from the mean of the respective sample. For this reason, the mean of each sample is provided with an uncertainty band, the so-called confidence interval. In a second step, to analyze whether a statistically relevant difference exists between companies with an energy management system (“treatment group“) and companies without an energy management system (“control group“) we perform simple t-tests using the t-test function in R (R core team 2016) which allows

for unequal variances. In a third step, we perform a regression model and calculate marginal effects. For the evaluation of influencing factors, which are relevant with regard to the effect of energy audits and energy management systems, more than one influencing factor is interesting. Thus, multivariate statistical methods are used. This allows us to determine the effects of several variables, measured as independent variables (e.g. energy cost and size) on a dependent variable (e.g. the implementation of an energy management system).

3. Results

3.1 Diffusion of energy management measures

3.1.2 Current Diffusion of Audits

We analyze the share of companies that have implemented energy audits. We use the RE2016 data set (from the "Rational use of energy in industry" survey – see data section) since it provides a representative sample of German companies.

The overall share of companies with an audit is 58 ± 5 % (95% confidence interval). Figure 1 shows the share of companies with audits differentiated by company size (measured in number of employees) including 95 % confidence bands. We observe an increase of the audit share with growing company size. The overall share of 58 % is highlighted as a vertical gray line in the figure.

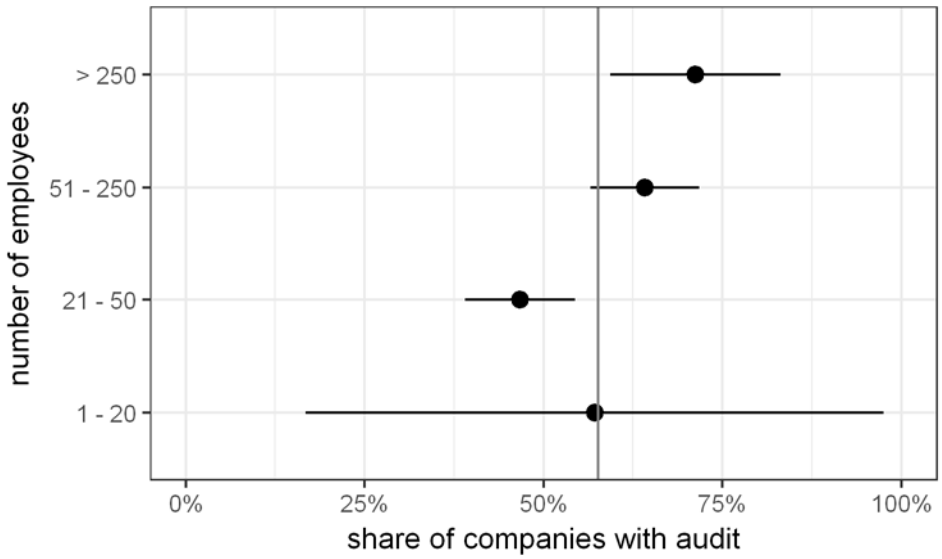

Figure 1: Share of companies with audits by company size. Horizontal bars indicate 95 % confidence intervals.

We compared the share of companies with completed audits among the different data sets. The "Effizienzfonds 2016" has a similar sample, and the resulting share of companies with audits in different company size groups are similar to the findings in the above figure with an

overall share of 64 ± 7 % (95% confidence interval) which is consistent with the previous findings. Furthermore, the trade and services sector generally have a lower share of implemented energy audits than the industrial sector.

3.1.2 Diffusion of energy management schemes

Energy management schemes (EMS) are an important energy management measure in Germany. We can use the large GHD2016 data set to gain understanding about the present state and time evolution of EMS in the German manufacturing industry. We use the year of introduction of the audit as stated by the companies in the survey to back cast the share of companies in Germany with EMS. Figure 2 shows the result differentiated by company size.

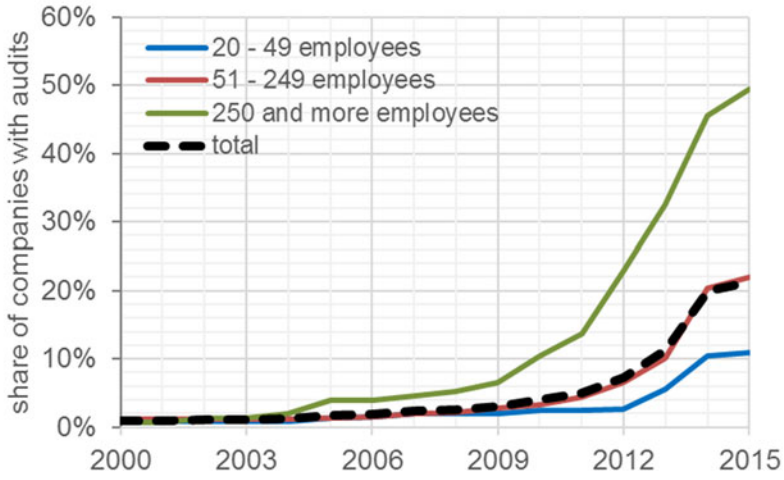

Figure 2: Diffusion of EMS over time in the German manufacturing industry.

The share of companies with EMS in Germany has increased steadily over the past several years, and the share is very likely to change further in the future. Furthermore, the diffusion of EMS in Figure 2 follows the typical S-shaped diffusion curve well-known from the diffusion of innovations. Please note, that the different surveys presented in the graph represent different samples. Thus, no evolution over time can be derived from these graphs.

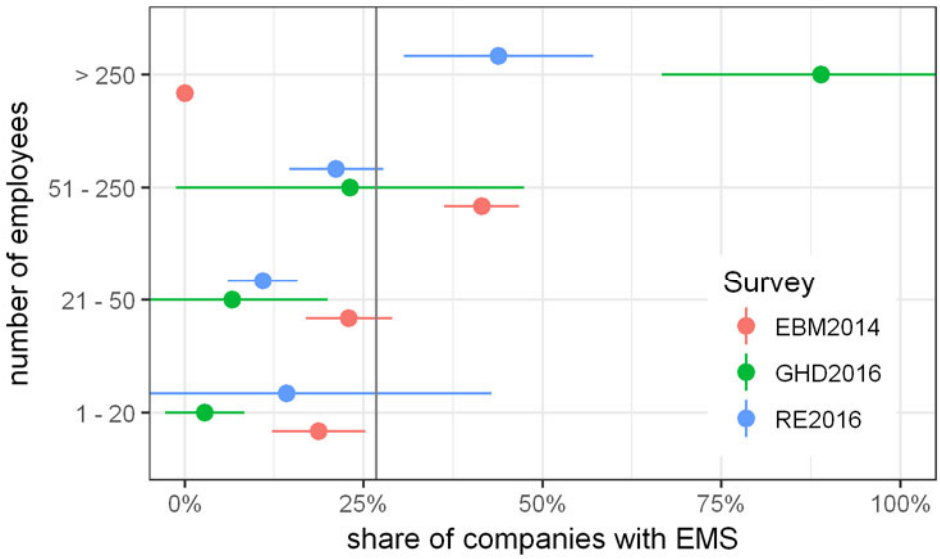

Figure 3: Current state of Diffusion of EMS in the German industry according to different data sources (colors) and company size. Horizontal bars indicate 95 % confidence intervals. The gray vertical is the total average.

The present state of EMS diffusion in the German industry can be further analyzed with the different surveys introduced in the data section. Figure 3 presents the share of companies in the German industrial sector that have an EMS according to three surveys, and differentiated by company size. The gray vertical bar denotes the overall average share 27 ± 2.5 % (95% confidence interval) slightly larger than 2015 values in Figure 2, but consistent with the growing share of companies in Figure 2. The different samples show averages of 31 ± 3 % for the EBM2014 (N = 722), 20± 4 % for the RE2016 (N = 395) as well as of 18 ± 9 % for the GHD2016 (N = 73).

Again, Figure 3 shows that the share of companies with EMS notably grows with company size as measured by number of employees. Please note missing confidence band for the largest company size group of the EBM2014 survey in Figure 3, whichstems from the fact that the EBM2014 survey contains only four companies with more than 250 employees and none of it had an EMS.

Overall, about one fourth of the German industry currently has an EMS and the share can be expected to grow further in time.

3.2 Impact of energy management measures

The actual impact of energy management measures can be measured in different ways. Here, we analyze (1) the increase in the share of implemented energy efficiency measures per company and (2) the different fractions of companies that adopt an energy efficiency measure. The former is a number between zero and one for a given company, e.g. two out of three suggested measures have been implemented, whereas the latter is either zero of one for each company. The former captures the impact within a company, but detailed data per company on suggested versus implemented energy efficiency measures is rare. The latter provides a useful

proxy for the overall impact among many companies and data is more frequently available as the implementation of every energy efficiency measure is surveyed as binary variable (implemented or not). We will use both in the following.

3.2.1 Share of implemented energy efficiency measures per company

The "Effiziendyfonds2016" data contains the number of suggested, as well as implemented, energy efficiency measures per company. Thus, we use this data set to analyze the impact of audits and EMS on the share of implemented energy efficiency measures per company. Figure 4 shows the average shares of implemented energy efficiency measures in companies with and without audits as well as with and without EMS (with 95% confidence bands). We observe a slight increase in the average share of implemented measures for audits and a clear increase for EMS.

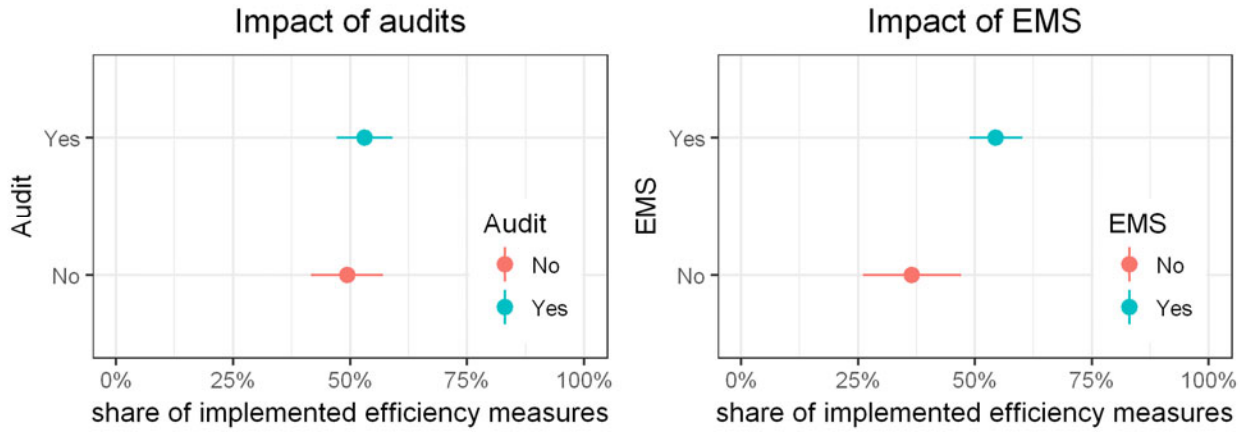

Figure 4: Average share of implemented energy efficiency measures in companies with and without audit as well as with and without EMS in the German industry. Horizontal bars indicate 95 % confidence intervals.

We use average marginal effects of a logit regression to quantify the impact of the energy management measures. We ran a logit regression of the presence of an audit and energy management system on the implementation of at least half the suggested energy efficiency measures ("Effizienzfonds" data, N = 180). Further control variables are the use of energy saving targets and energy usage indicators within a company. Table 2 shows the average marginal effects of logit regression indicating that an audit increases the likelihood to implemented more than half the suggested energy efficiency measures by 17 percent points (marginally significant) and an EMS by 26% (highly significant). Furthermore, the included control variables have a significant impact on the likelihood of a company implementing energy efficiency measures.

Table 2. Average marginal effects of audits and EMS on the share of adopted energy efficiency measures in the German industry.

Variable	Marginal effect	Std. error	z-value
Audit	+17.2%†	9.2%	1.88
Energy Management system	+25.6%**	9.7%	2.65
Energy saving target	–41.3%**	12.9%	-3.20
Energy usage indicators	+42.9%***	4.6%	9.34

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '†' 0.1.

The average marginal effects demonstrate the positive impact of the energy management measures on the implementation of energy efficiency measures. The regression results differ from the simple linear effects shown in Figure 4 since they include the joint effect of several variables, i.e. both audit and EMS as the same time as well as the control variables (multiple regression). Furthermore, our findings are consistent with the more detailed analysis of Schleich et al. (2015).

Overall, both audit and EMS increase the average share of implemented energy efficiency measures per company.

3.2.2 Share of companies adopting energy efficiency measures per technology

The second way to quantify the impact of energy management measures uses the different shares of companies that have implemented energy efficiency measures. Please note that the implementation per company is a binary variable now: A company either has or has not implemented measures in the realm of a given energy consuming technology sector.

We use the "RE2016" data set to analyze the implementation shares for different technology sectors. Figure 5 shows the share of companies that have implemented energy efficiency measures differentiated by companies with or without audits and with or without EMS.

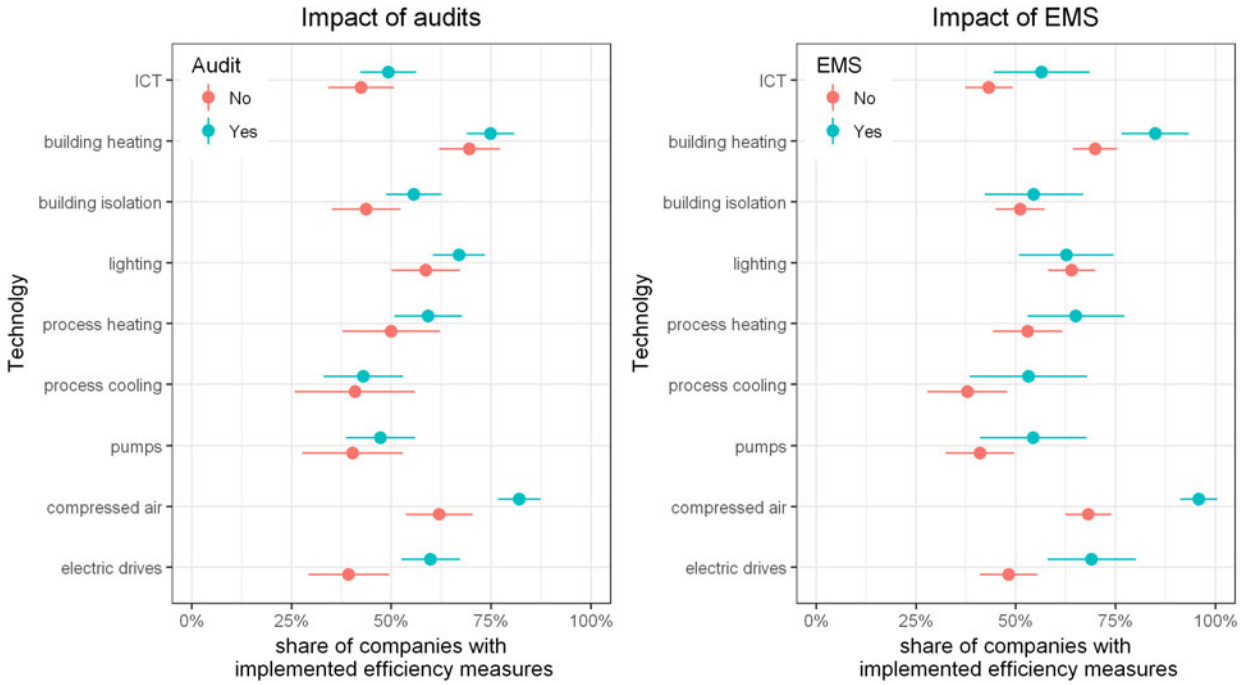

Figure 5: Average share of companies that have implemented energy efficiency measures in technology sectors with and without audit (left panel) as well as with and without EMS (right panel) in the German industry. Horizontal bars indicate 95 % confidence intervals.

We observe the share of companies that have implemented energy efficiency measures to be in the groups with audits and with EMS for almost all energy consuming technology sectors. In some cases, the difference is quite large, i.e. companies with audits or EMS are more likely to implement energy efficiency measures.

To analyze the effect of an energy management system in more detail, the activities with regard to different cross-cutting technologies in the area of production and infrastructure of the companies with and without an energy management system are compared with each other. For this purpose, we compare the “treatment” group based on the “Effizienzfonds2016” data set with a control group based on the “RE2016” data set. The results presented in this section are derived from a study evaluating the funding program "Funding of energy management systems" (Nabitz et al., 2016). As shown in Table 3, there is a statistically significant difference between the two groups, particularly in the areas of electrical drives, compressed air systems, and lighting. In these areas the adoption rate (defined as the share of companies which implemented measures in the respective technological area) in the "treatment" group is significantly higher than in the control group. Concerning heating systems in buildings, we do find a weakly significant difference between the two groups, but in the opposite direction.

Table 3: Comparison of the two groups “with and without energy management system” by share of companies which implemented energy efficiency measures in the different technological areas

Technological area	Group	N	Share of companies (percentage of N) which implemented measures	Difference	t-value	p-value	Significance level
Electric drives	EMS	72	73.6 %	29.8 %	3.904	0.000	***
	Without EMS	80	43.8 %				
Compressed air	EMS	86	79.1 %	17.7 %	2.778	0.006	***
	Without EMS	114	61.4 %				
Pumps	EMS	64	40.6 %	-2.8 %	-0.280	0.765	
	Without EMS	53	43.4 %				
Process cooling	EMS	54	46.3 %	6.8 %	0.646	0.520	
	Without EMS	38	39.5 %				
Process heat supply	EMS	55	45.5 %	2.8 %	-0.306	0.760	
	Without EMS	60	48.3 %				
Heating systems in buildings	EMS	75	42.7 %	-14.4 %	-1.950	0.052	*
	Without EMS	112	57.1 %				
Building envelope	EMS	77	39.0 %	-3.1 %	-0.432	0.666	
	Without EMS	114	42.1 %				
Lighting	EMS	87	89.7 %	22.5 %	4.202	0.000	***
	Without EMS	125	67.2 %				
Information and communication technologies (ICT)	EMS	80	45.0 %	2.3 %	0.315	0.753	
	Without EMS	124	42.7 %				

* Significance level $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; Source: Nabitz et al. (2016), based on subsamples of the data sets “Effizienzfonds2016” and “RE2016”

In our sample, energy efficiency measures which are "low-hanging fruits" and thus, easy-to-implement, are adopted first by companies thatthat have an energy management system in place. On the other hand, more capital-intensive measures such as those in the field of building heating systems, which are mostly subject to longer investment cycles, appear to be less frequently used by companies with an energy management system. The slight differences in the areas of pumps, process heat supply, building envelope, as well as ICT, do not allow any empirical conclusions on the difference between the two samples. With regard to the interpretation of the results, it must also be taken into account that although the distribution of the size of the companies is almost identical in both samples, there is no complete match with

regard to the affiliation of sectors of the companies. Thus, this may cause differences in the use of energy-efficient production technologies. In addition, the shares of those companies that have implemented measures in the individual technology areas do not allow any conclusions onto what extent they were active. This is due to the fact that the data was surveyed binary (question if measures implemented or not implemented (1/0)). However, irrespective of these limitations, our findings suggest that companies with an energy management system implement significantly more energy efficiency measures than companies without an energy management system.

4. Discussion and Conclusion

With our analysis we can show that energy audits and energy management systems lead to a significantly increased uptake of energy efficiency measures in industry. Although being a no-brainer at first glance, this result is of utmost importance for policy design: not all "no-brainer" conclusions are true. Although companies (and especially trade associations) often claim that they act in a strictly optimal economic fashion, and implement all economically viable measures, there is obviously more untapped potential in the companies, which can be exploited by closing the informational gap and by changing the organizational culture.

Still, the measures triggered by the audits and the management systems are by now the low-hanging fruits. It has to be analyzed whether those instruments will incentivize more complex or capital-intensive measures in the future. Anyhow, the European Emission Trading Scheme (ETS) and dedicated funding schemes already address those measures. Therefore the approach of the European Commission and the German federal government seems promising concerning the further uptake of energy efficiency measures in industry.

Within our analysis, we only looked at measures linked to an investment in technology and not at organizational measures. Nevertheless, their effect is (at least) equally important for the success of an energy audit or in particular an energy management system. With the chosen methodology, their impact could not be quantified, but research on the topic is ongoing and up-to-date results can be expected to be published soon. Especially energy management systems with their deep impact on the companies' energy culture can be expected to have a major impact on behavioral and organizational energy efficiency potentials.

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