Chances for changes – tailoring energy-efficiency measures to target groups

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Keywords

energy efficiency measures, barriers, energy management, energy efficiency policy, SME, target groups, manufacturing sector

Abstract

In energy policies contributing to the energy transition, the improvement of energy efficiency in industrial companies plays a crucial role. Although significant economic potentials have been identified, the concerned actors are still struggling to realise them fully. To support the implementation of energy efficiency measures by policies, a deeper understanding of the barriers affecting different kinds of companies is necessary in order to be able to better match the options to their needs and requirements. This paper considers companies' characteristics and individual barriers to draw conclusions on energy efficiency policies and specific recommendations on EEMs (energy efficiency measures). The paper thus designs a compromise for energy efficiency policy between high administrative effort for designing individual solutions for companies and too generic approaches which are not tackling the specific barriers of companies with certain characteristics.

Our analysis is based on monitoring data of two programmes in Germany, the Learning Energy Efficiency Networks LEEN, focusing on large (LE) and small/medium-sized companies (SME), as well as the KfW programme "Energieberatung Mittelstand" (energy consulting SME), focusing more on micro companies (MC). These two programmes support energy audits and company networking, and assess implemented energy efficiency measures for SME. Based on factor and regression analysis, we found that financial barriers were the most prevalent, but there was no general correlation with company size. Smaller companies usually conduct energy audits less often, even though information is a precondition for good decision making rather than simply providing financial means which may not be taken up adequately by companies. Reasoning in decision making plays a role for the implementation of measures, especially in SME where expenses are a crucial criterion. Thus financial policy instruments should aim at promoting more long-term decision making. Lack of information combined with unfavourable reasoning in decision making might impede the adoption of profitable measures. Motivational barriers have a stronger influence in LE, especially influenced by the expected organizational effort. Reducing transaction costs by delivering the necessary information can increase the willingness to invest greater efforts in energy efficiency measures. The number of implemented measures is related to company size, as well as the choice of specific measures, while there were differences between SME and LE and between SME and MC.

Introduction

Studies on energy efficiency and improving energy performance typically encounter the so called "energy efficiency gap" (Jaffe and Stavins, 1994; Stern, 1992), which is often referred to as the difference between the status quo and economically attractive energy-efficiency improvements. Barriers impeding improvements in energy efficiency issues need to be lowered to bridge this gap. A number of studies have already revealed the considerable potentials of energy-efficiency measures (Blok, 2004; Grenade et al., 2009; Worrell et al., 2009; Fraunhofer ISI et al., 2014; Ecofys and Fraunhofer ISI, 2010; Eichhammer, 2013). Accordingly, improving energy efficiency has received increasing attention in energy policy in many countries (IEA, 2012).

The technical potential of EEMs in companies is limited by the available processes or technologies where measures can be applied. As previous studies have already shown, non-technical barriers tend to be the main obstacle to implementing EEMs (IEA, 2012). The energy efficiency gap must be ascribed to barriers that are associated with internal routines, procedures or decision making, ways of reasoning, organizational or financial possibilities and external restrictions (cp. Sorrell, 2011). Recent research differentiates between economic, information-related, organizational, behavioural, competence-related, technology-related and awareness barriers (Cagno et al., 2013). Previous work has shown that companies often have misconceptions about the profitability of energy efficiency measures – taking risk indicators such as pay back period as profitability indicator (Schöter et al., 2009). Especially if energy intensity is low, improvements in energy efficiency might be underrated (Harris et al., 2000; Cooremans, 2013), possibly due to a lack of information to fully assess its value. Especially SME might not be able to reduce their uncertainties because of lack of time and money to afford these transaction costs (Stern and Aronson, 1984). Providing information and then accompanying the implementation process of measures can lead to significant improvements in energy efficiency despite the existence of other, not only informational barriers (cp. Wohlfarth et al., 2016). Trianni et al. (2016) provide an overview of empirical studies on barriers to industrial energy efficiency, highlighting the decision making process. These aspects should also be taken into account when EEMs are suggested.

The persistence of these barriers is one important justification for the introduction of policy instruments[1] in the field of energy efficiency aiming at overcoming the barriers and thus fully exploiting the cost-effective potential. Typically, regulative, informative and economic policy instruments can be distinguished (Rogge and Reichardt, 2013). Policy measures targeting SME can predominantly be classified as financial or informational/ educational measures. The majority of the existing measures fall under the category of financial measures including funds, loans, subsidies, financial support schemes, subsidised consultations, financial incentives and aids for SME. Informational/ educational measures include resource planning and management and the behavioural training of employees towards more responsible energy-related practices (Lapillonne et al. 2015). An overview of typical barriers and remedial policy tools is given in IEA (2012) and EEFIG (2015). Ringel et al. (2016) and Fleiter (2013) give indications of the saving potential which can be exploited by the respective policies.

However, each of these instruments usually only addresses parts of the barriers. Therefore, several policy studies in the field of environmental research have argued for the need to combine different policy instruments in so-called policy mixes (see Rogge and Reichardt, 2013, for an overview). Concepts like the German National Plan for Energy Efficiency (NAPE) combine instruments for information and market transparency, financial incentives and regulations in a broad policy mix to address different barriers and enhance the implementation of EEMs. A suitable policy mix to support the implementation of energy-saving measures in companies might also make use of scarcely addressed driving forces like social and psychological factors, such as improved motivation of energy managers and workers, high environmental awareness or a better public image as a responsible company regarding sustainability and climate protection (see, e.g. Lapillonne et al. 2015).

It is already known that companies' characteristics influence implementing EEMs, e.g. manufacturing companies are more active than those from the tertiary sector (DeCanio & Watkins, 1998) and larger companies are usually more likely to invest in energy-efficiency technologies (ib., Florax et al., 2011; Trianni & Cagno, 2012; Arens & Worrell, 2014). A policy instrument differentiating between companies' characteristics (in this case companies' size) by addressing informational deficits, is Article 8 of the Energy Efficiency Directive EED (EC, 2012). It requires Member States since 2015 to implement a four-yearly energy audit obligation for LE and to develop programmes to encourage small or SME[2] to voluntarily undergo energy audits and to implement audit recommendations. Although audits for SME are not mandatory, they seem especially important as SME are usually less aware of EEM options (cp. Table) and therefore tend to underestimate their potential (Gruber & Brandt, 1991; Frahm et al., 2010). This aspect is especially important as the majority of companies in most countries including Germany belong to the category of SME (Statistisches Bundesamt, 2013). Their energy consumption is indeed lower than for LE in the same sector, but they remain important energy consumers. Their potential for energy efficiency improvements is typically more cost-effective, as it is largely untapped and improvements can already be made with lesser effort (IEA, 2015; Thollander et al., 2014). While several EEMs are already in place in a variety of countries for SME (cp. Price and Lu, 2011; Fleiter et al., 2012; IEA, 2015), more tailored programmes are needed to deal with their special needs (Trianni & Cagno, 2012; Trianni et al., 2016).

In order to give recommendations for policies, a connection between types of companies and barriers should be drawn to identify specific target groups for specific policy measures. According to Stern and Aronson (1984), effective information is specific and personal, so the aim is to personalize and specify EEMs to target groups. The idea is to differentiate policies and EEMs more adequately without the need of an individual audit for every single company. This more general approach could be a marketing strategy that reduces the effort needed for searching and information processes and could also serve as the basis for recommendations addressing company-types on a larger scale. On the other hand, knowing about the differences between target groups allows the promotion of energy efficiency policies to be tailored to their needs.

Hence, taking SME into the focus, the research questions of this paper are:

- Which kind of barriers hindering EEMs are the most prevalent and are they related to specific types of companies?

1. Policy instruments are concrete tools to achieve overarching policy objectives such as the removal of barriers. The term 'instrument', can also be described in studies as 'implementing measures', 'programs', 'policies', or 'policies and measures' (for a comprehensive overview see Rogge and Reichardt, 2013).

2. The definition criteria for SME are in this case: number of employees, turnover and balance sheet total (EC 2003).

Table 1. Available data from LEEN used for the analyses.

	Total available data for companies from the manufacturing sector	Data available from evaluating survey	Data available on implemented measures
Number of participants	263	160	137

- On which general company characteristics (like size, energy costs or autonomy in decision making) does the potential to implement measures depend?
- Are specific measures a better fit for specific kinds of companies?
- How could the present policy mix addressing companies be improved based on the results of our analysis?

Methods and data base

METHODS

For our analyses, we use evaluation data from projects that aimed to identify and implement EEMs in companies – namely from LEEN "Learning Energy Efficiency Networks" (Jochem and Gruber, 2007; Rohde et al., 2015) and the KfW's SME Energy Consulting Programme "Energieberatung Mittelstand" in Germany (Mai et al., 2014) – focusing on companies from the manufacturing sector. We use two different data sources because LEEN addresses small and medium-sized enterprises (SME) and large enterprises (LE), while the KfW programme addresses micro companies (MC) and SME (see Table 2 later on for the definition of those categories).

We analyze the relations between companies' characteristics and barriers or implemented measures to find categories of target groups and suitable support measures. Focusing on SME, we compare SME with LE and SME with MC in a more detailed analysis, and try to derive policy implications from our results. Rating scales for barriers during the implementation process of EEMs as well as the number of implemented measures and a broad collection of company characteristics for SME and LE were taken from the LEEN data. The items for barriers were worked out by the project team based on long-time experience with comparable projects (Jochem and Gruber 2004; Jochem and Gruber, 2007; cp. DiNucci, 2012). The categorization of measures (cp. Table 9) was developed within a bachelor thesis (Leinweber, 2014) by clustering those measures that were recorded during the monitoring of the project by the criteria kind of measure and location of implementation. The technologies the categorized measures refer to are thereby treated as an entity, i.e. measures are not counted twice (e.g. measures on pumps are not included in measures on refrigeration although the refrigeration system may contain pumps).

From the KfW-data we derive implemented measures and company characteristics for micro companies and SME. Besides descriptive statistics, we used factor analysis to describe the relevant dimensions of barriers to the implementation of measures. Factor analysis is a method to reduce complexity in data by combining similar variables to factors which describe different underlying concepts. Above all, we tried to draw connections between companies' characteristics and variables of interest (like barriers or the number of implemented measures) using regression analyses. A regression analysis estimates the relationship between variables – a dependent variable and different independent variables (here companies' characteristics). The aim is to understand how the dependent variable changes when the independent variables vary (see Howell, 2012).

Typically, the formula for a regression analysis can be expressed as:

$$\hat{y}_i = a + \sum_j \beta_j \cdot x_{i,j} \quad \text{(for i = 1, …, N and j = number of independent variables)}$$

Where $\hat{y}_i$ represents the estimated value of the dependent variable, $x_{i,j}$ the independent variables, β_j are the weighted factors b elonging to the independent variables and a represents a constant.

To analyse differences between subgroups, we used t-tests – a method that analyses differences of means for significance.

DATABASE

LEEN data

The first part of our analysis concerning SME is based on detailed monitoring data from the scientific evaluation of the Learning Energy Efficiency Network process in Germany between 2009 and 2014. Participants in such a network are committed to regularly exchange experiences in regional groups of 10–15 companies and to set themselves a voluntary energy saving target for the next 3–4 years. A fee is paid by the companies to finance the energy audit, network meetings and monitoring. For our analysis, we especially drew on the evaluating survey data collected towards the end of the networking process (second half of 2013) and monitoring data on the implemented measures in each company. These data were merged for our purpose, but due to the different sources, available data may differ for the individual companies (Table 1).

Those companies can be assigned to the manufacturing sector (NACE classification sector C[3]), especially the subsectors manufacture of food products (NACE 10), chemicals and chemical products (NACE 20), rubber products (NACE 22), basic metals (NACE 25) and machinery and equipment n.e.c (NACE 28) (each between 7.6 and 13.3 %, remaining subsectors with smaller shares). These rather small groups of subsectors impeded analyses on the basis of subgroups within the manufacturing sector. Therefore, conclusions on the influence of core businesses and underlying production processes are hardly possible for our dataset. We tried to take structural ef-

3. Industrial sector classification, see http://ec.europa.eu/competition/mergers/cases/index/nace_all.html.

Table 2. Clustering of subsectors for LEEN dataset.

N = 263	1 low energy intensive processes n=50 (SME = 24 %)	2 medium energy intensive processes n=116 (SME = 33 %)	3 high energy intensive processes n=97 (SME = 53 %)
(NACE) Subsectors of manufacturing sector	(12) tobacco products (14) wearing apparel (15) leather and related products (16) wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials (18) printing and reproduction of recorded media (21) basic pharmaceutical products and pharmaceutical preparations (26) computer, electronic and optical products (27) electrical equipment (31) furniture (33) Repair and installation of machinery and equipment	(10) food products (25) fabricated metal products, except machinery and equipment (28) machinery and equipment n.e.c. (29) motor vehicles, trailers and semi-trailers (30) other transport equipment (32) other manufacturing	(13) textiles (17) pulp and paper products (19) coke and refined petroleum products (20) chemicals and chemical products (22) rubber and plastic products (23) other non-metallic mineral products (24) basic metals

fects into account anyway by grouping subsectors by energy intensity of their processes (Table 2). Category 2 is used as reference category for our regression analyses.

The set of companies is far from representative regarding the shares of company size; this data set contains no micro companies. This is because participation in the LEEN was recommended especially to medium-sized and large companies with annual energy costs between €0.5 million and €50 million because otherwise participation in the networks would have been too costly for companies in comparison to expected savings. For this reason, implications are only drawn for SME and LE for analyses using this data set. We covered the case of MC with the dataset of the KfW's programme.

KfW data

In Germany (but also in the EU), over 60 percent of the total number of companies within the manufacturing sector are categorized as micro companies (Statistisches Bundesamt, 2013). Therefore, we refer to a second data source covering micro companies (number of employees <10) to obtain information on their efficiency potentials. Data on the suggested measures for these micro companies are drawn from the evaluation of the KfW's programme "Energieberatung Mittelstand", where EEMs were funded between 2008 and 2012. The data from this evaluation contained information on company characteristics as well as the type of measures implemented after the audit had taken place. To allow comparability to the LEEN data, we reduced this data set to the companies belonging to the manufacturing sector, including the subsectors manufacture of basic metals (35.3 %), manufacture and repair of motor vehicles, trailers and semi-trailers (12.2 %), other energy-intensive production (36.1 %), other non-energy-intensive production (16.4 %). This approach yielded N=720 companies with information on the implemented measures, of which 55 were micro companies and the rest SME. Table 3 shows an overview of the two databases differentiated by company size. Comparing average energy costs in SME of both samples shows that especially companies with high energy consumption were invited to participate in LEEN.

Results

COMPARISON OF SME AND LE BASED ON LEEN

We first evaluated LEEN participants' ratings of the barriers at the end of the networking process, asking which ones were observed during the network phase. So those barriers refer to the perspective of the companies as energy consumers (not to manufacturers of energy efficiency technologies, consultants or banks). This especially concerns the barrier *measures not profitable*, because the measures suggested by the energy consultants are expected to be profitable. The rating given for this category reflects the perception of the person in charge within the company which might be different to the one of the consultant (e.g. due to internal rates of return). Table 4 shows the mean ratings as well as the overall ranking comparing barriers. *Technology supplier can't deliver*, *missing information or market overview* and *management hard to convince* are ranked the lowest, which is comprehensible because technologies for suggested measures were available and one main issue within the network process was delivering information. Concerning management approval, one can assume that management was already generally convinced of the idea of implementing efficiency measures, because this was the purpose of the project they chose to participate in.

The barriers ranked the highest mostly concern issues of time and money with a clear emphasis on financial restrictions: *Measures not profitable, limited financial possibilities, concerned parties lack time* and *priorities on other investments*. The difference between *difficulties in implementation* and the higher ranked barriers with values greater than 3 turned out to be significant (T(157)=2.653**).

Table 3. Overview of analyzed datasets.

	KfW Energieberatung Mittelstand			Learning Energy Efficiency Networks LEEN		
Data described as mean (Median Md; Standard Deviation SD)	**Total number of manufacturing companies**	**MC**	**SME**	**Total number of manufacturing companies**	**SME**	**LE**
Number of companies (N)	720	55	665	263[a]	95	150
Number of employees per company	70 (51; 58)	6 (6; 2)	75 (60; 57)	635 (331; 957)[b]	122 (119; 65)	961 (565; 1108)
Energy costs Mio €	0.40 (0.12; 1.32)	0.07 (0.01; 0.13)	0.42 (0.13; 1.36)	2.95 (1.54; 4.44)	1.34 (0.68; 2.01)	4.07 (2.38; 5.35)
Energy intensity (MWh/employee)	183.69 (20.84; 865.71)	692.63 (39.02; 1840.73)	145.39 (20.61; 731.59)	183.97 (49.01; 463.71)	259.24 (75.13; 583.47)	135.98 (43.01; 361.77)
Implemented measures per company	2.6 (2; 2.23)	2.3 (2; 1.88)	2.62 (2; 2.26)	12 (8; 10.7)	8.48 (6; 7.7)	13.87 (11; 11.8)
Audit already conducted (%)	10.0	3.7	10.6	48.4	37.2	56.9
Share of cluster 1; 2; 3 (%)	n/a[c]	n/a	n/a	19; 44; 38	12; 37; 52	23; 48; 29

[a] *Number of companies does not sum up to total number, because data for number of employees (used as classification for SME or LE) was not given for all companies.*

[b] *Due to the large spread we assume that some indicated employees for the whole corporation.*

[c] *Due to broader categorisation of sectors.*

Definitions of companies' sizes: MC (<10 employees); SME (<250 employees); LE (≥250 employees).

To ensure a reasonably homogeneous data set, we removed the highest 3 % of energy intensity in the KfW-data due to over-proportionately high values over 10,000 MWh/employee. Such high intensities could be due to errors in the data collection process. This particularly affected companies from subgroups of the manufacture of basic metals.

Table 4. Rating of barriers that occurred during the LEEN network phase (rating on a scale from 1 to 5).

Barriers	Number of companies	Mean rating	SD
Technology supplier can't deliver[a]	159	1.76	0.96
Missing information or market overview	159	2.02	0.96
Management hard to convince	160	2.06	1.11
Departments hard to convince	160	2.40	1.07
No energy management	159	2.43	1.34
Only small share of energy costs in production costs	158	2.53	1.37
Staff hard to motivate	158	2.54	1.05
Difficulties in implementation	158	2.78	1.04
Measures not profitable	159	3.12	1.27
Limited financial possibilities	160	3.28	1.32
Concerned parties lack of time	158	3.51	1.10
Priorities on other investments	160	3.61	1.21

[a] *This refers to material and technology needed to implement the energy efficiency measure of interest.*

Overall, the ratings are quite moderate with a mean of 2.7 on a scale from 1 to 5 (1: a low rating of the barrier; 5: a high rating). One should note that, at the end of the project, over 96 % (N=153) of the participants that completed the last survey reported that they implemented at least some of the suggestions resulting from the network process. This supports the assumption that the networks did well in addressing possible barriers. This also means that the barriers stated here did not prevent measures in general, but did at least hinder the process or impede the implementation of additional suggested measures beyond those that have been implemented. We assume that companies usually are affected of more than one barrier when

Table 5. Categories of barriers.

Factor	Items (barriers)	Description	Mean of scale (SD)[a]
1	*Management hard to convince* *Departments hard to convince* *Staff hard to motivate* *Only small share of energy costs in production costs*	Motivation/internal relevance	2.38 (.79)
2	*Limited financial possibilities* *Priorities on other investments* *Measures not profitable*	Financial/economic restrictions	3.33 (.98)
3	*Missing information or market overview* *Technology supplier can't deliver*	Deficits in information or external market-related factors	1.90 (.79)
4	*Difficulties in implementation* *No energy management* *Concerned parties lack of time*	Constraints in technical/structural circumstances	2.90 (.83)

[a] *The means of scales do not differ in their ranking order comparing SME and LE.*

Bartlett's sphericity test $Chi^2(66)= 343.0$; $p<.001$; Kaiser-Meyer-Olkin measure=.612 (moderate, Kaiser and Rice, 1974).

Table 6. Factors influencing barriers.

Factor	Variables of significant influence	Model
1 Motivation/internal relevance	Number of employees*** (β=0.257) Energy costs* (β=-0.178) Cluster subsector 3 (β=-0.147)	F(10)=2.330**, R^2=.084 (.048)
2 Financial/economical restrictions	Decision based on amount of expenses** (β=0.175) Autonomy of enterprise*[1] (β=0.129)	F(10)=2.513**, R^2=.091 (.055)
3 Deficits in information or external market related factors		n.s.
4 Constraints in technical/structural circumstances		n.s.

*R^2: explained variance; F: test value for significance; Level of significance: * = p≤.05, ** = p≤.01; *** = p≤.001.*

[1]0: autonomous, 1: part of another corporation.

Relatedness to customer means that products are directly supplied to end customers.

they are struggling to implement measures, and that some barriers are more likely to co-occur. The simple ranking of barriers does not indicate which aspects interact or are regarded as interrelated from the perspective of the participants. Therefore, we conducted a factor analysis with the aim to find underlying structures and content-related categories in the ratings of barriers mentioned by the participants. This resulted in four factors consisting of co-occurring barriers that are shown in Table 5.

The identified factors are in line with taxonomies of barriers in other studies. Compared with one of the later taxonomies introduced by Cagno et al. (2013), which distinguishes economic, information-related, organizational, behavioural, competence-related, technology-related and awareness barriers, we found some of these categories concurred in our case. We therefore used a smaller set of items on which to base our categories. We assigned behavioural barriers to "motivation/internal relevance" (1), economic barriers to "financial/economic restrictions" (2), information-related and awareness barriers to "deficits in information or external market-related factors" (3) and organizational, technology-related and competence-related barriers to "constraints in technical/structural circumstances" (4).

We conducted regression analyses to examine whether the dimensions of barriers are dependent on specific characteristics of the participating companies, using barriers as the dependent variable. The following company characteristics were treated as independent variables: number of employees, energy intensity (annual MWh per employee), energy costs, autonomy of enterprise, relatedness to customer and how EEM decisions are made (stating that the decision is influenced by organizational effort, profitability calculation, amount of expenses or else) (Table 6).

The analysis showed that especially motivational and financial barriers are more prevalent in specific kinds of companies (Table 6). Larger companies, companies with lower energy costs and companies that do not belong to those with energy intensive processes (cluster 3) tend to face motivational barriers to a stronger degree. We assume that more effort is required to

motivate a larger number of employees resp. the management of LEs and that higher energy costs act as a motivating force as well as energy intensive processes where saving potential can be found. Autonomous companies (which might be able to make decisions concerning expenses on their own) are affected to a lesser extent by financial barriers as are companies that do not base their EEM decisions only on expenses. This suggests that how decisions are made affects the barriers to EEMs.

The analysis showed that company size has a highly significant influence on at least one of the barrier factors. We assume that the influencing variables differ within different kinds of companies, so in order to reveal other factors which might be overlooked under the influence of the number of employees, we decided to conduct the same regression analyses within the two subgroups of SME and LE (cp. Table 3 for group sizes and information on their characteristics). The results are shown in Table 7.

This more detailed analysis revealed differences between SME and LE concerning barriers: Energy intensity, the number of employees and small energy costs indicate greater motivational barriers for SME. At first glance, it may seem irrational that higher energy intensity is combined with greater motivational barriers. But knowing that the average energy consumption in SME is half as much as in large enterprises, high energy intensity alone may therefore not be sufficient to motivate companies to introduce changes. In particular, small enterprises are more likely to not have a person responsible for energy issues, which might also explain motivational barriers. Alike for this subgroup of SME as for the complete sample, a larger number of employees seems harder to be motivated while higher energy costs can serve as motivating factor. For LE, motivational barriers occur when great organizational effort is expected, e.g. the activity of responsible or affected employees. For LE, too, a larger number of employees is harder to motivate. In SME, financial barriers are perceived to be higher if EEM decisions are based only on the amount of expenses rather than other reasons. For LE, deficits in market-related factors are perceived to be smaller when decisions are based on the amount of expenses. We assume that if the available budget respective to cash flow is low, interesting measures or technologies are perceived as unaffordable – regardless of whether the investment would be profitable considering longer payback periods. If budget is high enough to afford investments, the aspect *technology supplier can't deliver* might become more important. For SME, constraints in circumstances like difficulties in implementation or lack of time are associated with a larger number of employees, low energy costs (that might not justify the effort) and if decisions are based on amount of expenses or (quite reasonably) on organizational effort.

Complementary to the analysis of companies' characteristics concerning barriers, we also conducted a comparable regression analysis for the absolute number of measures the companies implemented (dependent variable) to find out whether becoming more energy efficient is easier for certain kinds of companies than for others.

Our result shows that the number of implemented measures usually increases with the number of employees, most likely due to a concomitant larger production site, i.e. more facilities and technologies available for EEMs. No such effect was found within the subgroups of SME and LE. In contrast to companies' characteristics, a similar regression analysis examining the influence of stated barriers on the number of conducted measures revealed no significant results. We do not imply that perceived barriers had no influence on the process of implementing efficiency measures, but with this result in mind, we did hypothesize that companies facing specific

Table 7. Factors influencing barriers in SME and LE based on LEEN.

Factor	SME		LE	
	Variables of significant influence	**Model**	**Variables of significant influence**	**Model**
1 Motivation/internal relevance	Energy intensity** (β=0.461) Number of employees* (β=0.260) Energy costs* (β=-0.404)	F(10)=2.607**, R^2=.237 (.146)	Number of employees* (β=0.213) Decision based on organizational effort** (β=0.252)	F(10)=2.505**, R^2=.153 (.092)
2 Financial/economic restrictions	Decision based on amount of expenses*** (β=0.461)	F(10)=3.671***, R^2=.304 (.221)		n.s.
3 Deficits in information or external market-related factors		n.s.	Decision based on amount of expenses** (β=-0.273)	F(10)=2.388*, R^2=.147 (.085)
4 Constraints in technical/structural circumstances	Number of employees** (β=0.362) Energy costs* (β=-0.349) Decision based on amount of expenses* (β=0.265) Decision based on organizational effort** (β=0.298)	F(10)=2.335*, R^2=.217 (.124)		n.s.

R^2: explained variance; F(df): test value for significance.
*Level of significance: * = p≤.05, ** = p≤.01; *** = p≤.001.*

barriers tend to implement different measures than companies not facing these barriers. If barriers vary between EEMs this information can be useful when suggesting EEMs to companies facing specific barriers (cp. Sorrell et al., 2011, Cagno & Trianni, 2014). We used T-tests to see whether the values of stated barrier dimensions varied between those companies that conducted specific types of measures and those that did not (Table 9).

VAC measures are more often implemented by larger companies with lower energy intensity which can be expected, as these characteristics prompt a higher importance of energy consumption due to building issues. The dimensions of VAC are probably correlated with the number of employees and therefore make such measures more profitable in larger companies. Organizational measures such as staff motivation also seem more sensible and maybe more necessary given a larger number of employees. Lighting or compressed air measures seem to be feasible with lesser effort as they are especially implemented in companies with high motivational barriers. Measures concerning the building envelope can also be suitable for companies that lack technologies with energy efficiency potential or if they have low energy intensity. The latter might apply as well to the use of waste heat. Change or control of motors and pumps seem to be measures which can be implemented with comparatively low organizational effort. Measures dealing with process heat or an energy carrier change usually deliver the highest absolute savings. On the other hand, these measures also require high investments (Rohde et al., 2015). Cost-effective saving potentials in industry can be found especially in the field of cross-cutting technologies such as motors (fans, pump systems, cooling devices, compressed air systems) and electricity-driven system optimisation or CHP (Lapillonne et al. 2015).

Figure 1 compares the implemented measures for SME and LE. Differences in specific measures can be seen for the production of heat, VAC and distribution of heat, cooling and compressed air, which are all conducted more by LE than SME. In general, lighting, distribution of heat, cooling and compressed air and motors and pumps are among the most implemented EEMs in SME. When interpreting these results, one should mind that there might be structural differences between the subgroups of SME and LE. E.g. there is a larger share of companies with energy intensive processes (cluster 3) in the subgroup of SME.

COMPARISON OF SME AND MC BASED ON KFW-DATA

We included a second set of data focussing on micro-companies to investigate whether the characteristics of this type of company suggests different approaches to tackling energy efficiency barriers.

Table 8. Regression on number of implemented measures.

Factor	Variables of significant influence	Model
Number of implemented measures	Number of employees** (β=0.215)	F(10)=2.466**, R^2=.089 (.053)

R^2: explained variance; F(df): test value for significance.
*Level of significance: * = p≤.05, ** = p≤.01; ***= p≤.001.*

Table 9. Energy efficiency measures and company characteristics influencing implementation.

Energy efficiency measure	Company characteristics influencing measure implementation	Average difference in company characteristics	Test value for significance
1 production of heat	–		
2 refrigeration	–		
3 ventilation and air-conditioning technology (VAC)	Larger number of employees Lower energy intensity Less often cluster 3	488 vs. 1122 283.48 vs. 102.47 41 % vs. 30 %	T(44.0)=-2.449* T(108.2)=2.390* X^2(1; 137)=6.58*
4 lighting	Higher motivational barriers	2.22 vs. 2.66	T(83)=-2.654**
5 compressed air	Higher motivational barriers	2.31 vs. 2.69	T(83)=-2.312*
6 building envelope	Lower energy intensity More often in cluster 2	267.62 vs. 80.98 41 % vs. 58 %	T(115.2)=2.822** X^2(1; 137)=4.90*
7 utilization of waste heat	Lower energy intensity	291.89 vs. 118.81	T(89.5)=2.139*
8 motors and pumps	Higher organizational barriers	2.88 vs. 3.23	T(83)=-2.082*
9 distribution of heat, cooling and compressed air	–		
10 organizational measures	Larger number of employees	449 vs. 908	T(84.3)=-2.582*
11 other measures	Higher energy intensity	119.24 vs. 296.10	T(111.5)=-2.035*

*Level of significance: * = p≤.05, ** = p≤.01; ***= p≤.001.*

Independent variables: Barriers, number of employees, energy intensity.

Barriers measured on a scale of 1 to 5, energy intensity: MWh/employee, cluster: share within cluster that implemented concerning EEM compared to share in other cluster.

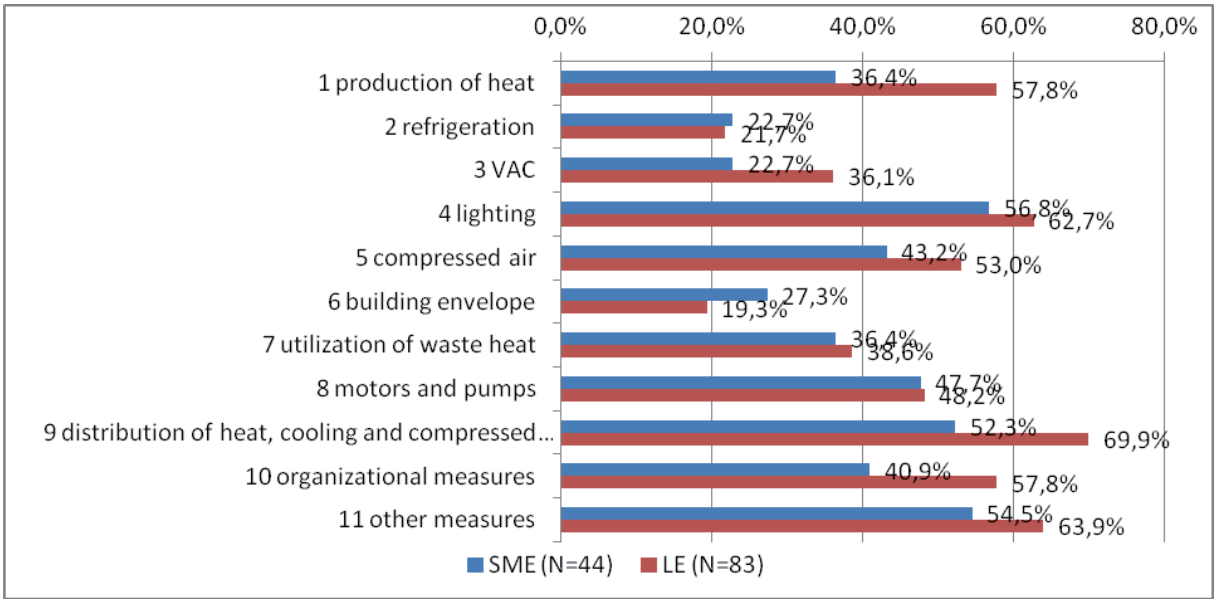

Figure 1. Comparison of conducted measures for SME and LE within LEEN.

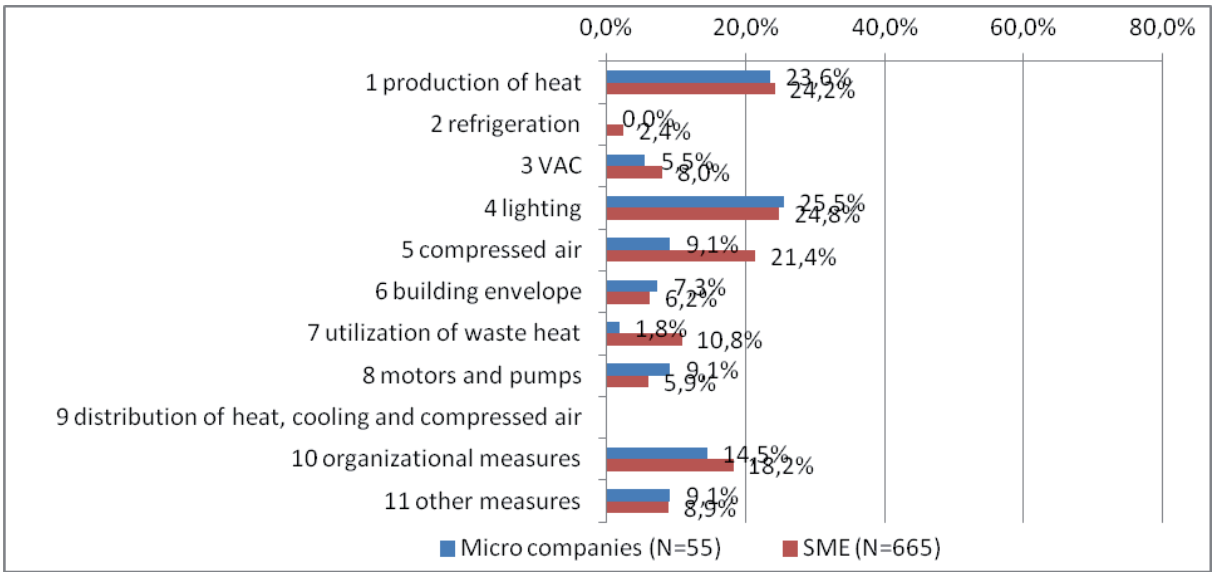

Figure 2. Comparison of conducted measures for MC and SME within the KfW programme.

Evaluation data from the KfW audit programme showed that micro companies usually receive fewer suggestions for efficiency measures than larger companies and also implement fewer measures (Table 3). A smaller share of micro companies has already conducted an energy audit. This implies that micro companies might be less informed about energy issues, maybe because they cannot afford the costs for the audit or expect smaller potentials. Figure 2 shows the implemented measures for micro companies and SME. Visible differences occur for compressed air and utilisation of waste heat; both are conducted more often in SME than in MC. Measures concerning the production of heat and lighting seem to be favoured in general by MCs; SME additionally often choose organizational measures. Again, possible structural effects due to the distribution of subsectors between SME and LE should be kept in mind.

Comparing the shares of implemented measures between the two data sets, companies in LEEN conduct significantly more measures than those in the KfW programme. Within the LEEN, measures are implemented during the network process over 3–4 years while the KfW-data describe measures implemented after the funded audits. Additionally, as the LEEN companies were better informed before participating and received more intensive support than the KfW-companies, we assume that information and support, regular exchange of experience among the participants and regular site visits play a crucial role in influencing the implementation of EEMs.

Looking at the data from LEEN and KfW separately, there are few differences in the conducted measures between different company sizes for each of the single measure types. Bearing in mind the large share of micro companies in the total number of companies, these should not be overlooked as a target group

for untapped energy efficiency potentials. Larger differences can be found between the different measures – obviously some measures are a better fit for a greater share of companies than others.

Discussion and policy implications

Our analyses aimed at gaining deeper insights into the relations between companies' characteristics and barriers in implementing EEMs or the types of measures implemented in order to draw conclusions for policy recommendations. The companies we based our analyses on belong to the manufacturing sector and have in common that they were prepared to make decisions on EEMs, i.e. they were informed about their opportunities and received suggestions of suitable measures.

To tailor instruments well to groups of companies, they should be based on relevant companies' characteristics. Trianni and Cagno (2012) highlight that characteristics additional to companies' size should be taken into account when considering energy efficiency barriers and options, furthermore **SME cannot be regarded as homogenous group**. Our results support these findings: companies' size turns out to be an important factor, but concerning barriers and the implementation of EEMs, several other factors turn out to be influencing as well – even within the groups of SME and LE. Our investigations consider companies' size and consumption resp. intensity as well as other attributes that might influence implementations of EEM like autonomy of enterprise, relatedness to customer, how EEM decisions are made and energy intensity of processes. Finding those characteristics linked to barriers or successful implementation of EEMs allows recommendations or customizing instruments for target groups. This facilitates making compromises between finding much individual information on each company before acting and too general instruments.

Within our analyses, the barriers assessed as highest concerned the availability of time and money which somehow reflects the minor priority of energy efficiency compared to core business issues. This confirms the findings of comparable studies in the literature, e.g. Fleiter et al. (2012), where high investment costs, other priorities and unprofitable measures were found to be the most important barriers in SME, or Thollander et al. (2007), who investigated less energy-intensive SME in the Swedish manufacturing sector and concluded lack of time and the low priority of energy efficiency to be the main barriers. Anderson and Newell (2004) found that too high initial expenditures were the most often mentioned barrier, followed by a lack of staff for implementation and limited cash flow preventing implementation. They also point out institutional and bureaucratic barriers, which are hard to ascertain, because the given reasons are rather vague. Trianni and Cagno (2012) found lack of capital and insufficient information about opportunities and for decision making to be the highest ranked barriers, while lack of time and access to capital seemed more prevalent in smaller companies.

This implies a higher importance of financial/economic instruments and in fact, these make up the largest share of energy-efficiency policies in Germany (Lapillone et al., 2015). These policies can provide much needed impulses, especially for those companies with restricted financial options. Some energy audit instruments especially address SME (cp. Price and Lu, 2011). Assuming their smaller financial possibilities, audits and programmes accompanying implementation like LEEN need to be less costly (cp. Mari:e networks, Foundation of Resource Efficiency and Climate Protection, 2015). But a closer look at the barrier of financial restrictions reveals that high scores here are often influenced by the criteria of decision making, e.g. if they are based simply on the amount of invested money and neglect profitability, or if the assessment of profitability is made with the unsuited risk indicator of payback periods. Our analyses revealed this influence is especially high in SME. It can be assumed that all the suggested measures are not unaffordable per se, and generate very high profits after the break even. But most companies seem to be very risk averse or they are not aware that they vote against high profits when deciding on a two or three years pay back period. Funding or other financial support can lower this threshold if decisions are based on the amount of expenditure. In these cases, financial restrictions are declared to be a barrier, but the financial policies introduced to tackle them might actually confirm this short-sighted way of thinking. It might be better for future policies to **incentivize more forward-looking investment behaviour** rather than funding the shortfall to measures which are not classified as profitable due to suboptimal decision criteria. The pro-active development of energy-efficiency investment options by financial institutions can support decision making of companies. In cases where unaffordable equipment still hinders the implementation of efficiency investments, contracting or leasing could be another option.

A large share of companies (about 85 %; Schröter et al. 2009) base decisions on short payback rates and therefore often reject profitable measures that would have been adopted if the internal rate of return had been taken as the decision criterion (Jochem et al., 2010). Jochem et al. (2010) argue that this risk perception can be lowered by exchanging experiences among energy managers in meetings of energy efficiency networks. This indicates that **information measures should not be limited to the period before implementation**, but are also required beyond the phase of identifying options (cp. Trianni et al., 2016).

Lack of time is ranked the second highest problem and might especially affect companies which do not have a person in charge of energy issues. But this may also reflect the reluctance about transaction costs that can only partially be overcome by funding the investment costs as implementation also takes time and effort for gathering information, searching for options and bargaining. Lowering these transaction costs would support the implementation of measures. We assume that this is one illuminating aspect regarding the fast improvement of efficiency progress of companies participating in LEEN. The progress is twice as high compared to non-participants, where exchange of experience and mutual on site visits during the network meetings are the key.

Therefore, the Chinese Government decided to use the energy efficiency networks as a powerful instrument to speed up the energy efficiency progress in the Chinese industry in 2012, as did the German Government in December 2014, when it signed a voluntary agreement with 20 trade associations (Dena, 2015).

Therefore this might be another leverage point for policies: **Promoting actors able to offer one-stop solutions** including consulting, implementation know-how and the necessary

contacts to providers. Organizational effort was found to be a motivational barrier especially for large enterprises. The second highest ranking was for difficulties in technical/organizational circumstances (Table 5): This cannot be linked to specific company characteristics, so we assume that all types of company could benefit from offers that identify the best EE options and implement them without the work effort of the company's own employees, i.e. some kind of outsourcing of the energy efficiency issue, especially given that energy is usually more of a necessity and not the main priority of a company.

Larger enterprises usually implement more EEMs (due to bigger budgets, a dedicated energy manager, larger scaled technologies to implement measures on or a higher awareness of their profitable measures). Some recommendations can be made regarding specific measures related to companies' characteristics and barriers, based on the higher probability of implementation in specific groups of companies. For example, ventilation and air-conditioning measures might be more appropriate for larger companies, even if energy intensity is low. The utilization of waste heat or (provided that they are indicated) measures on the building envelope also seem applicable to companies with lower energy intensities. Measures concerning motors and pumps can apparently be conducted with lower organizational effort. Measures on the production of heat and distribution of heat, cooling and compressed air are more often implemented by LE, but fall under the group of generally favoured measures for SME as well, together with measures on lighting, motors and pumps.

To refine those analyses in order to describe target groups, the single subsectors should be considered as a describing variable to allow tailoring measures also to sectors. We did not add this kind of company characteristics, but created sector clusters, because our sub-sample sizes were too small for statistical relevance (mostly <5 companies/subsector). Especially for the definite comparisons of conducted EEMs between target groups, analyses regarding subsectors might give deeper insights. A mere differentiation between SME and LE might be too vague; generally, we expect differences between the distribution of subsectors between SME and LE that need to be taken into account tailoring policy instruments to target groups. Future extension of policy instruments like the LEEN will provide larger data sets which can be exploited to gain more insight at sector level. Such type of analysis should be carried out in a timely manner and results fed back to the improvement of policy measures.

Typically, when tailoring policy measures to company characteristics on a more general level, company size (number of employees) seems a more appropriate variable than energy consumption. Plötz and Fleiter (2012) also found huge heterogeneities in companies' energy consumption. After corrections for company size, the resulting specific energy consumption per capita still varied substantially. Reducing analyses to industrial sectors reduced heterogeneity, but still left a substantial level of heterogeneity even within the individual sectors (due to many influences such as re-investment cycles, product structure, depth of supply chain, …).

Our data is limited to companies from the manufacturing sector that participated voluntarily in the two programmes LEEN and KfW Energieberatung Mittelstand. Therefore, we can assume that our results cannot be generalized to other sectors and are likely to be biased by the self-selection of (perhaps especially ambitious and interested) participants. More hesitating companies possibly need more communication and the model of pioneer companies to be convinced. This should be kept in mind for the design of policies or when making efforts to upscale the effects.

Comparing findings for different industrial sectors faces the problem that studies differ by sector, technologies, time or considered barriers – as well as methodology. Additional insights could be gained from conducting analyses with a sample of sufficient size (e.g. future extension of LEEN, BMWi, 2014, 2016; dena 2015), containing subgroups with appropriate sizes for subsectors. Ideally, the sample should be representative as we observed data differences in the structure of our subgroups of SME that might influence the statistics.

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