Barriers to and decisions for energy efficiency: what do we know so far? A theoretical and empirical overview

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Abstract

To achieve any of the energy conservation and climate goals on a national, European or global level, much more action is required in the field of energy efficiency (EE). To achieve this, barriers of various types need to be overcome and drivers for the decision to act on energy efficiency need to be identified and broadly applied.

Building on earlier findings, this paper empirically investigates the major barriers for EE and what characteristics may play a role in determining the perceived severity of barriers. Underpinned by data of 1,005 manufacturing companies gathered in context of the Energy Efficiency Index of the German Industry (EEI), the Institute for Energy Efficiency in Production (EEP) at the University of Stuttgart and Reutlingen University's REZ explore the role of company size, energy productivity, and in comparison with qualitative studies also geography (Northern Italy) and type of intervention (market ready innovations) in relation to barriers to energy efficiency measures (EEM). Overcoming these barriers often subsequently requires action by the management.

How to trigger that subsequent action, the decision for energy efficiency and notably raising awareness for it, is being looked at in part two of the paper. As previous work indicates, having the staff's support is beneficial in the context of energy efficiency. Exploring how and by whom awareness is raised in aforementioned companies brings to light that whilst a vast majority of companies do it, there are differences depending on size and energy productivity of a company and quite a clear reasoning is found why the majority of the remaining companies don't raise staff awareness.

Introduction

The topic of energy efficiency (EE) is currently receiving a lot of attention in political, economic and social discussion. Advertising campaigns such as "Deutschland macht's effizient" of the Federal Ministry for Economic Affairs and Energy are implemented to show the importance of EE and generate a broader awareness e.g. of the energy-efficient use of electrical equipment. But where does this great attention and bustle come from? Already in the 1970s, resource scarcity, oil crises, rising energy prices and the first signs of climate change led to a growing awareness of climate-friendly energy production. This development slowly grew over the decades and some international climate conventions. Climate agreements such as those of Kyoto 1997 or Paris 2016 include measures, which are necessary to restrict climate change. According to the climate agreement of Paris, which has been ratified by over 170 contracting parties so far, man-made global warming should be limited to well below 2 °C against the preindustrial level.

In order to achieve this very ambitious goal, a massive expansion of renewable energies as well as extensive improvements in the area of energy efficiency are necessary. Whilst a feed-in tariff for renewable energy led to a massive expansion of wind power and photovoltaics in Germany, the 'catalyst' energy efficiency has not received sufficient attention until March 2016, when German Vice-Chancellor Sigmar Gabri-

el and others called for "Efficiency First" (Bauernhansl and Sauer 2016).

Whilst there are large energy saving potentials in the industrial sector, many of these efficiency potentials remain untouched. To address this, substantial work on 'barrier research' emerged over the past two decades, addressing the implementation of energy efficiency measures in predominantly industrial enterprises. In order to provide evidence for the current discussion, the Institute for Energy Efficiency in Production of the University of Stuttgart (EEP) conducts semi-annual surveys in the manufacturing industry, the Energy Efficiency Index (EEI).

More specifically, this paper aims at exploring critical aspects for energy efficiency decision making, utilising results of the EEI in the light of other theoretical and empirical work. Barriers to energy efficiency measures need to be better understood so that they can be addressed effectively by policies and programmes in the implementation phase (chapter 1). Implementation of energy efficiency measures (EEMs), however, will only happen if relevant decision makers decide positively on taking action and with the support of affected users. Triggering decisions for energy efficiency and raising staff awareness are hence focus of chapter 2.

Barriers to Energy Efficiency

The key phenomenon of all scientific efforts around barriers over the past decades recaps in the notion of the "Energy-efficiency-gap" (Jaffe & Stavins, 1994, Thollander et al., 2010, Gerarden et al., 2015). Why profitable energy saving measures are not undertaken – famously called the "Energy-efficiency-paradox" (Jaffe & Stavins, 1994; DeCanio, 1998) – appears to be an ongoing challenge for both researchers of various fields and policy makers. As Stern points out (2007: 610), the "low take up of energy efficiency as purely rational response to investment under uncertainty is difficult to explain". The ongoing research on barriers tries to bridge this gap scientifically.

THEORETICAL APPROACH

Various researchers have been dealing with the barriers to energy efficiency – particularly during the past two decades. Different approaches and several taxonomies have emerged in recent years. An early literature review from Weber (1997) led to a typology of "institutional barriers", "organizational barriers", "behavioural barriers" and "obstacles conditioned by the market". A rather frequently quoted classification originates from Sorrell et al. (2000) who differentiate between "economic", "behavioural" and "organizational barriers". Thollander et al. propose another and interdisciplinary classification based on theoretical approaches and distinguish between barriers addressing the "technical system", the "technological regime" and the "socio-technical regime" (2010).

Sudhakara Reddy developed a multilevel-approach for organizing barriers of energy efficiency (2013). The so-called taxonomy "M3T" classifies barriers on the micro-, meso- and macro-level. The micro-level addresses the lowest level such as the designing of a program or a measure; the meso-level applies organisations or firms affiliated with the measures, whereas the highest level, the macro-level represents the state, market and civil society (2013).

In case of the EEI survey, the researchers made use of the extensive taxonomy by Cagno et al. (2013). The taxonomy (Table 1) allows an accurate classification of the individual barriers to seven predefined categories and was modified by addressing the three different levels of origin suggested by Sudhakara (2013).

All attempts of categorizing barriers to energy efficiency have in common that they are derived from various research studies following different theoretical perspectives which the authors tried to get integrated. Economic perspectives often follow the path of neo-classical theory; behavioural perspectives rely on theories such as transaction costs economy, psychology or decisional theories, organisational perspectives (Sorrell, 2000). The EEI generally takes an organisational perspective and refers to an open systems approach based on contingency theory which claims that the firm's course of decision is dependent (contingent) upon the internal and external situation of an industrial firm (Kieser, 2006; Scott, 2007; Morgan, 2007).

EMPIRICAL APPROACH

For the typology it is also relevant which methodology is used collecting the data. There are quantitative and qualitative approaches. Both are equipped with advantages and disadvantages, which we briefly explain in the following. The qualitative approach has been used by Trianni et al. 2016 in northern Italy, as well as by EEP in the context of a study on innovative technologies for the German Federal Ministry for Economic Affairs and Energy (BMWi, 2017). The qualitative interview is based on an interview guide that provides open answers and gives the respondent the opportunity to describe his/her individual experiences with barriers to the implementation of EEM. The advantage of this type of questioning is the detailed findings gained in the interaction between interviewees and interviewers. Furthermore, a clear allocation of the individually occurring barriers to the predefined categories of barriers is possible.

The quantitative approach, on the other hand, facilitates many participants with relatively little effort and therefore makes it easier to obtain representative results over a large number of participants. On the other hand, the ability to clearly allocate all experienced types of barriers is limited leading to an additional category of "other" barriers. Whilst expanding the categories by introducing a series of concrete subcategories could address this limitation, it would significantly grow the questionnaire. Twice a year, the Institute for Energy Efficiency in Production EEP of the University of Stuttgart surveys companies from across 27 manufacturing sectors to gather evidence for the *Energy Efficiency Index of the German Industry (EEI, #EEIndex)*. In the spring/summer data collection 2017, 1,005 companies provided evidence – mainly via phone based market research (ca. 80 %) and an online questionnaire (ca. 20 %) – regarding their experience in relation to the aforementioned barriers, as well as their approach to raise awareness for energy efficiency among their workforce. The latter has become a focus in consequence of previous findings that implemented measures that have been proposed by employees overshot expectations twice as often as measures proposed by other roles (EEP, 2016).

Our analysis, based on the quantitative and qualitative approaches, enables a comparison between the Italian region Lombardy and Germany. Both regions have a strong manu-

Table 1. Taxonomy of Barriers to Energy Efficiency. Sources: Cagno et al. 2013, Sudhakara Reddy 2013.

Perspective	Barrier	Origin/Level		
		Micro	Meso	Macro
1. Technology-related	Technologies not adequate			•
	Technologies not available			•
2. Information-related	Lack of information on costs and benefits			•
	Information not clear by technology providers			•
	Trustworthiness of the information source			•
	Information issues on energy contracts			•
3. Economic	Low capital availability		•	
	Investment costs			•
	External risks			•
	Intervention not sufficiently profitable		•	•
	Intervention-related risks		•	•
	Hidden costs		•	•
4. Behavioural	Other priorities		•	
	Lack of sharing the objectives	•	•	
	Lack of interest in energy-efficiency interventions	•	•	
	Imperfect evaluation criteria		•	
	Inertia		•	
5. Organizational	Lack of time		•	
	Divergent interests		•	
	Lack of internal control		•	
	Complex decision chain		•	
	Low status of energy efficiency		•	
6. Competence-related	Implementing the interventions		•	
	Identifying the inefficiencies	•		
	Identifying the opportunities	•	•	
	Difficulty in gathering external skills		•	
7. Awareness	Lack of awareness	•	•	

facturing sector and are highly productive. To be able to adequately compare the data, both BMWi (2017) and EEP (2017) applied the taxonomy provided by Cagno et al. (2013) and used by Trianni (2016).

RESULTS AND DATA COMPARISON

Figure 1 summarizes the results of the three aforementioned surveys. All three surveys are dealing with the same question and apply a scale from 1 = "not relevant" to 4 = "very relevant". However, the comparison does have limitations due to the different empirical methods applied in gathering the data. Thus, the EEI survey can offer a very large number of participants, but a deeper investigation into individual barriers as well as an exact allocation of the "other barriers" to the predefined categories is not possible.

If we compare the results across all three surveys, it is striking that the *economic barriers* are the most severe in Italy and in Germany, and the difference between the results of Trianni and EEP is smallest. That difference is growing significantly looking at the other barriers. A frequent obstacle in the category of the *economic barriers* is using the ROI method (return on investment) when assessing investments, which makes energy efficiency measures (EEM) with ROIs longer than 2–3 years appear as less profitable investments. EEM's often miss the management's requirements by only a small amount, despite being economic and are thus excluded from the investment decision (BMWi 2017, Bauernhansl 2014). The "Life-Cycle-Analysis" assessment method could provide a remedy. Another problem, which mainly affects German companies, is the current design of the "EEG-Umlage" (EEG apportionment). Two effects can occur here. First, this tax increases the price of electricity and companies try to avoid these higher prices by implementing EEM's. Second, in the existence of alternative (fossil) technologies, this tax increases the relative price of electricity against fossil fuels and thus leads to misplaced incentives (increasing opportunity costs of conventional technologies) and a discrimination of consumers of electricity. Avoidance reactions of the companies lead to the use of fossil technologies. Likewise as shown in BMWi 2017, the adoption of market ready innovations – often using electricity – is burdened. Above all, the integration of power sectors towards fewer fossils, more renewable electricity – necessary for the energy transition –, and the adoption of innovative & marked-ready technologies, is thereby slowed down.

Another interesting result can be seen in the *information-related* barriers. This clearly shows that the acquisition of information is a considerable problem for innovative technologies. Due to the very small number of technology providers of innovative technologies, this is a serious obstacle especially at the beginning of market penetration (BMWi 2017). In contrast to this, the workforce's *awareness* for energy efficiency is a relatively small barrier, it appears. However, the effect of the *social desirability* needs to be mentioned here, as the interviewees evaluate themselves which means that a slightly too positive self-assessment cannot be excluded. A particularly clear difference between qualitative and quantitative surveys is shown by the category of *technological barriers*. Respondents of the EEI survey assessed this obstacle as much more serious than the

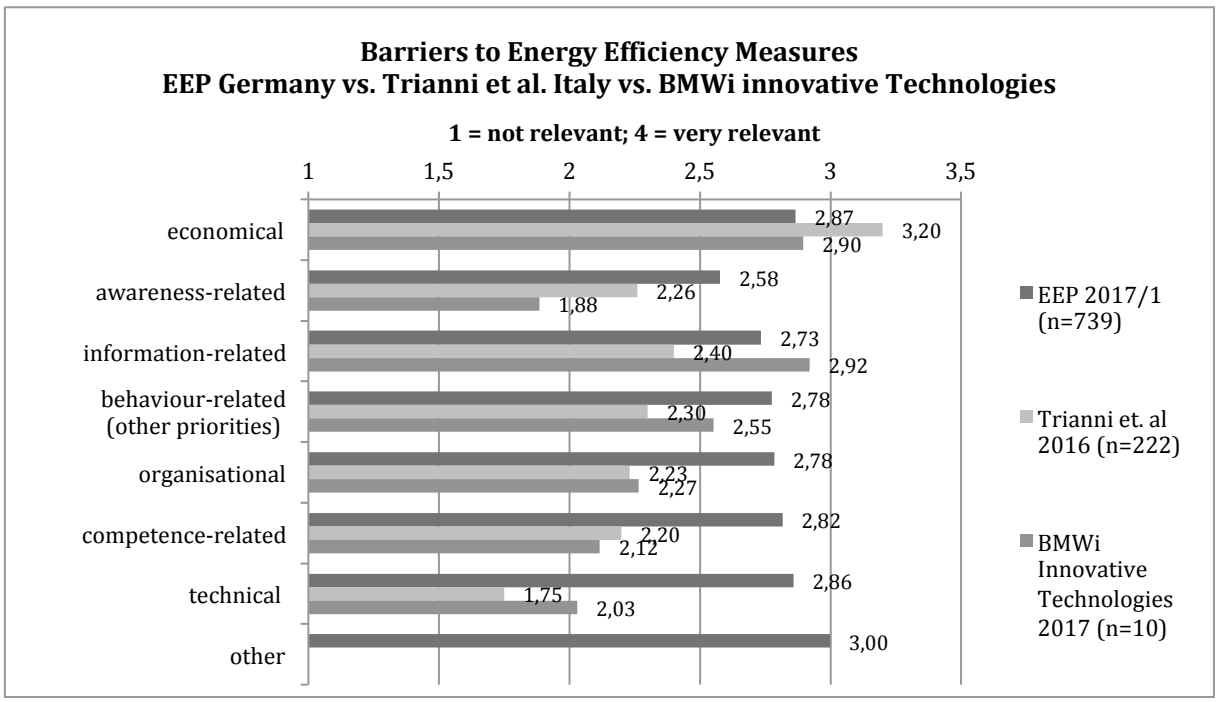

Figure 1. Comparison: Barriers to Energy Efficiency Measures, sorted by difference between EEP and Trianni: Source: EEP Energy Efficiency Index of the German Industry 2017/I, Trianni et al. 2016, BMWi 2017.

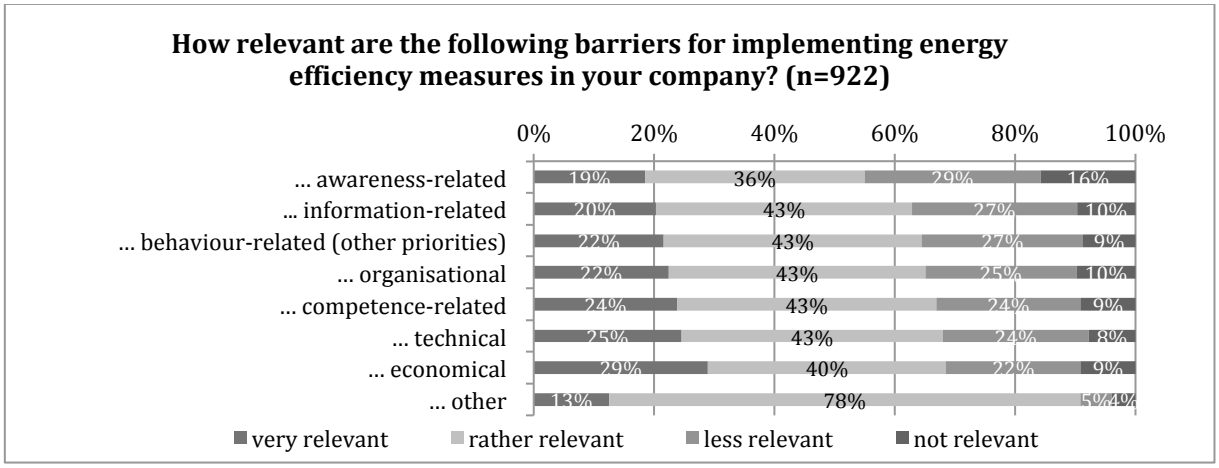

Figure 2. Frequency analysis: Barriers to Energy Efficiency Measures: Source: EEP Energy Efficiency Index 2017/1.

respondents of both qualitative surveys. The EEI results in Figure 1 can be analysed in greater detail in Figure 2.

The graph displays a frequency analysis of the different barrier categories. The 100 % scales are showing the percentage allocation of the respondent companies regarding the respective barrier categories. It is thus clear that *economic barriers* are the barrier type, which contains the largest proportion of companies that consider this barrier to be very relevant. Here, too, the *awareness-related barriers* appear the least relevant. The extremely large proportion of companies, which consider *other barriers* to be rather relevant, is striking. At the same time, it is the smallest group in absolute numbers that identifies this obstacle as very relevant and it is likely to be due to the fact that whatever barrier cannot be allocated to a category and is still mentioned is likely to be relevant enough to participants to do so.

Figure 3 shows the barriers in relation to energy intensity. The line peaking at *technical* and *economic* barriers represents the 20 % of the companies in the sample with the highest energy intensity. By comparison, the line peaking at *other barriers* contains the remaining 80 % of companies with lower energy intensity. The remaining line, however, shows the 20 % of companies with the lowest energy intensity.

An interesting result can be seen in the area of *technical barriers*. The 20 % of the companies with the highest energy intensity assess this obstacle to be more severe than companies with lower intensity. This is in contradiction with the results obtained by Trianni et al. (2016) in northern Italy. The assumption that energy-intensive companies evaluate the current existing technologies as adequate and available is not apparent from our data. One possible explanation for

this is that energy-intensive companies have higher demands on the technology they use as interventions have a significant impact on their process and consequentially operations in principle – during and after the intervention –, which in turn means that the technological barriers are assessed more severely. Even in the case of *economic* and *behavioural barriers*, energy-intensive companies seem to see greater barriers than less energy-intensive companies, where for *economic barriers* this may result from anticipated higher capital costs required and higher associated risks in contrast to other companies. Regarding *behavioural barriers* one could speculate, prior to deeper analysis, that in energy intensive companies one relies on technical interventions with individual behaviour having a comparatively small impact. The picture only turns when looking to the category of *other barriers*. In general, the differences between the single energy intensity categories are not as large as in other research studies.

Another distinction to be mentioned between the German and Italian incentive structure is the exemption of energy-intensive companies from the EEG apportionment. To maintain the competitiveness of German companies in an international comparison, there exists the possibility for particularly energy-intensive industries, under certain conditions, of not having to pay the full EEG contribution rate. Taking into account the two above-mentioned effects of the EEG apportionment, which is part of the economic barrier, this can lead to a reduction in the incentive to save electricity for companies bordering on promotion and non-promotion. Attaching a price tag to CO_2 instead could be a way out as it stimulates switching to low carbon fuels and energy efficient equipment.

Figure 4 presents the barriers of the individual categories in relation to company size. When comparing the mean values, it is noticeable that the assessment of the barriers varies significantly depending on the size of the company.

It is true that all companies evaluate the *awareness-related barriers* as the lowest, but the values of the most important obstacles are clearly different. Thus, the *other barriers* were assessed relatively heavy. This reflects the problem of a quantitative survey. Since respondents did not have the exact definition of the individual categories of barriers, they may tend to provide a more general response. Deeper interviews enable the interviewer to look closer at the individual barriers and to make an exact assignment to the existing barrier categories; alternatively a more detailed quantitative approach with barrier sub-categories could be applied.

If we now look at the size of the company and the specific categories of barriers selected, we note on the one hand, that micro- and small-sized enterprises are above average in all categories – because they focus their resources on their core business and often do not have in-house assistance to address energy efficiency. On the other hand, medium-sized and large companies generally evaluate the barriers below average. It is interesting to look at the *competence-related barrier*. Large companies – mostly with low rated barriers – are equal to the average here. This may be partly explained by the high heterogeneity of types of EEM in the industrial context and the difficulties finding suitable specialists for specific EEMs. Also, medium-sized companies rate barriers similarly to large companies in most cases, but in relation to *behaviour* they are closer to small companies – possibly due to both time and lacking dedicated staff raising awareness.

It becomes clear that the different company sizes do assess the barriers very differently and thus also have different needs for the successful implementation of energy efficiency measures for instance efficient production machinery.

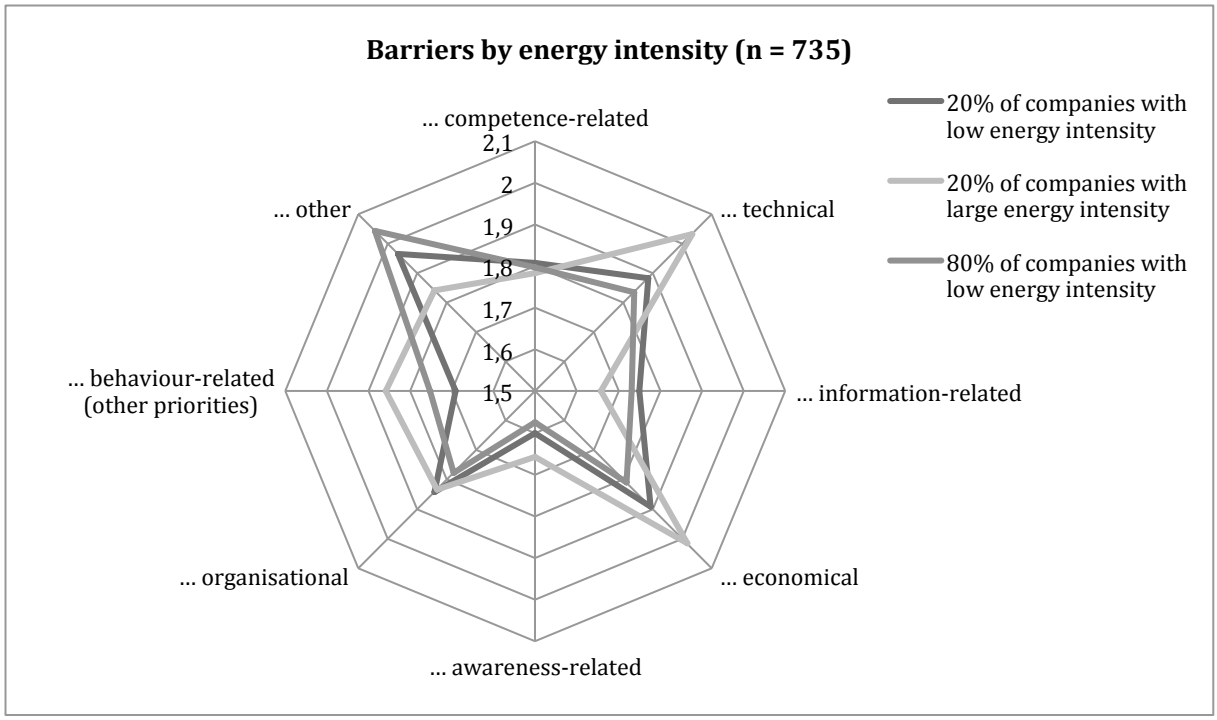

Figure 3. Barriers by energy intensity: Source: EEP Energy Efficiency Index 2017/1.

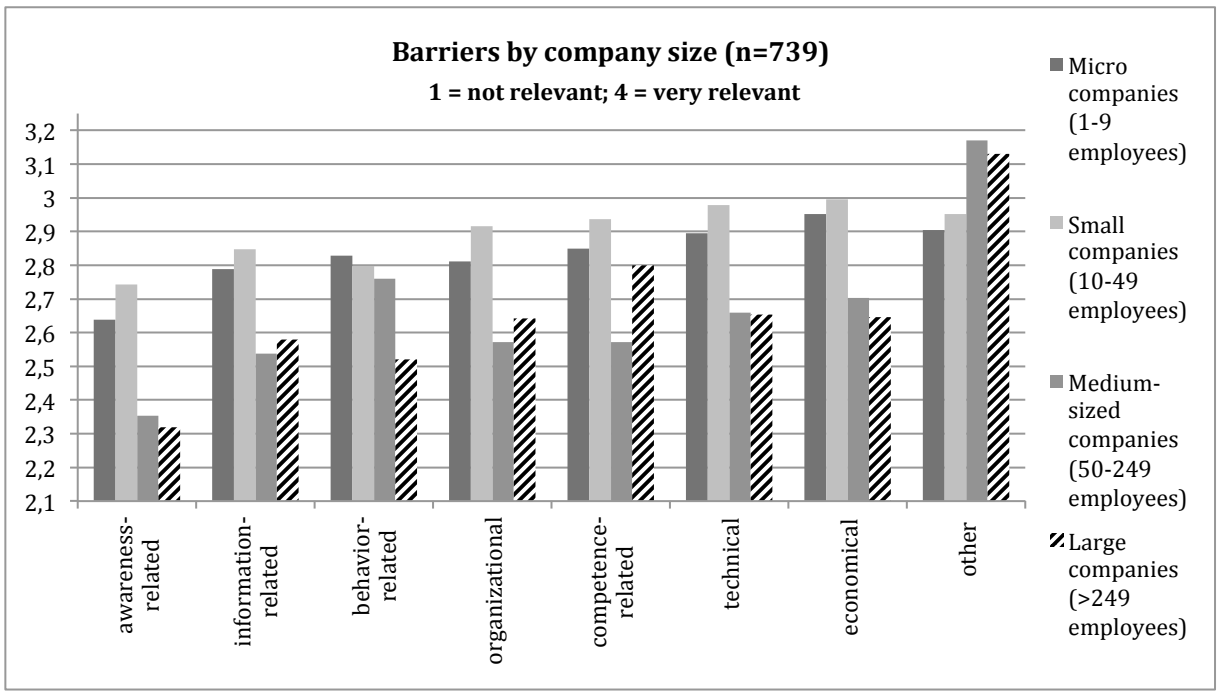

Figure 4. Barriers by company size: Source: EEP Energy Efficiency Index 2017/1.

BARRIERS: DISCUSSION AND CONCLUSION

This paper, for the first time to our knowledge, provides a direct comparison between different countries in barrier research. Based on a uniform taxonomy we were able to show the first differences between two different regions (Figure 1). Although the methodology of quantitative data collection within this specific research area quickly reaches its limits, these results can serve as a first assessment of the current situation. Based on the present findings and the limitations of this investigation, new fields for further studies are emerging. For example, a combination of a quantitative and qualitative survey with sample-based interviews could make the results more concrete due to more precise responses from the respondents. Furthermore, the barrier research can be extended or supplemented by drivers which support EEM. Thus, effective policies could be developed to effectively reduce the existing barriers to EEM and to push energy efficiency to a higher level. As barriers perceived by SMEs are consistently higher, the efforts to understand, trigger and support decisions for energy efficiency should be strengthened, and pricing CO_2 instead of the EEG may stimulate accelerated action in the industrial sector. Such accelerated action and the elimination or at least reduction of said barriers is indispensable to achieve the national and EU targets, after the 2020 goals will not be met (on time).

On the recent pages, we introduced the reader to the issue of barrier research and discussed the taxonomy of Cagno et al. 2012. Based on the seven predefined barrier categories, a special issue question on barriers to EEM was included in the EEI 2017 summer survey. The comparison of these EEI results, the results of Trianni et al. 2016, and the results of a qualitative survey of the EEP in 2017 produced some interesting insights, such as the finding that the *economic barrier*s in Italy seem to be higher than in Germany. Conversely, a reverse picture is found in all other categories of barriers. Above all, the difference in *technological barriers* between the two countries is strongly divergent. The different survey methods can increase this real existing difference. The quantitative method (EEI) does not allow a (confirmable) exact assignment of the individual barriers, whereas the qualitative methods (Trianni et al. and innovative technologies BMWi 2017) are very time-consuming and still leave room for errors.

Furthermore, we could show in a frequency analysis that *economic barriers* are rated as "very relevant" most frequently. In addition, the analysis of barriers according to energy intensity revealed that energy-intensive companies are more likely to rate *technological barriers* more serious than less energy-intensive firms, which surprisingly also applies to *behavioural barriers*. The analysis according to company size showed that large companies rate the *competence-related barriers* relatively severe. There is also a clear tendency towards barriers being perceived more severe by micro and small enterprises in general. *Awareness barriers,* that are deviating most, are being explored further in the next section. Looking forward, moving from rather generic barrier categories to more specific sub-categories in further empirical work would allow to get a more detailed understanding of the respective barrier, as well as hints on a recipe to overcome them, similarly it would enhance comparability to apply the same quantitative approach in further countries via the *Energy Efficiency Barometer of Industry (#EEBarometer)*, EEIs equivalent for all other countries.

Decision for Energy Efficiency

The research on barriers is tightly interrelated with the question on how a firm's decisions and behaviour are made. Various theoretical and empirical attempts have been undertaken ranging from discrete choice-modelling (De Groot et al., 2001), to studies of planned behaviour (Zierler et al., 2017), attention-

based views (Palmié et al., 2015) or contingency-theory-based approaches (Trianni et al., 2016).

The collaborative study "Decision for energy efficiency in manufacturing SMEs in Baden-Wuerttemberg" led by REZ and realized in cooperation with EEP, several agencies and associations and, finally, a large group of industrial companies, focuses on the decision making process of industrial SMEs in Baden-Wuerttemberg regarding energy efficiency. The study is funded by the Ministry for Science, Research and the Arts, Baden-Wuerttemberg. Within this still ongoing study, we use a qualitative multi-case-study design to attain a deeper understanding for the driving forces for energy efficiency within the firms. A subsequent and quantitative survey will be carried out later in 2018 to enrich and validate our results. Yet, we have already gained interesting results, including from the EEI. The following pages focus on how the participating firms evaluate awareness-barriers and what they do to raise awareness among their employees. While the empirical approach of the EEI was already elucidated, we briefly present the approach conceptualized for these case studies.

EMPIRICAL APPROACH

The research uses a multi-case-study design (Yin, 2003) of industrial SMEs in the German state of Baden-Wuerttemberg. While aiming for a transdisciplinary perspective and including a cultural perspective, the study was conceptualized as explorative. Eleven SMEs of different industrial sectors (chemicals, minerals, engineering, and machinery) were selected by theoretical sampling (Glaser/Strauss, 1998). All participating firms are, and have been, engaging in energy efficiency measures as it was the aim to find driving processes and factors that push decisions for EE.

The data collection was conceptualized non-standardized and carried out by "narrative interviews" (Schütze, 1983) and field-work-observation (Ybema et al., 2009) on site. Interviews were held with owners, managing directors and energy-managers, as well as with production workers, controlling, marketing and human resources staff. The data was analysed by system-analysis (Froschauer/Lueger, 2003).

RESULTS REGARDING AWARENESS-BARRIERS AND AWARENESS RAISING

Although the awareness-related barriers were rated rather low in relation to others within the EEI survey, it is remarkable how relevant the issue of awareness is perceived among the participating companies of the study. This might be surprising regarding results of the EEI. However, one reason might be linked to the ambiguous notion of awareness, being more an elemental precondition for any decision than an additional other factor (Sorrell, 2000). To think about awareness without having sufficient awareness might be a difficult task for potential respondents in the quantitative EEI study.

Raising awareness has proven to be one of the most vital aspects in reducing energy consumption and increasing energy efficiency for the firms participating in the study. A result that is also backed by the results of the EEI – about ¾ of the surveyed companies raise their staff's awareness regarding energy efficiency. As shown in Figure 5, the proportion of large companies raising their staff's awareness for energy efficiency is larger than in smaller companies that are more or less on the same level. Furthermore, differences in the share of companies raising staff awareness are much smaller across different company sizes than between the various sectors.

Increasing awareness for energy efficiency leads to a higher focus and allocation of attention within the management team and amongst employees of the SMEs.

1. *Distribution of attention and awareness.* Sharing the issue of energy and energy efficiency on many shoulders by organisational, behavioural- and competence related measures supports establishing an energy-efficiency culture within the firm. Continuous efforts must be made by the management while the range of different measures seems to be an important driver.
2. *Sensitization for the internal legitimation of energy efficiency measures.* Shaping energy efficient business processes is generally a long-lasting, continuous internal project which requires both acceptance and conformity of the employees. Stipulating and mediating energy targets, strategies, efficiency measures and successes promotes internal legitimacy for energy efficiency in the long term.
3. *Raising awareness for changing practices and behaviour.* The everyday behaviour of decision makers within companies regarding energy is highly routinized. Raising awareness means broaching the issue of habits, which can rarely be changed within days as habits and routines always include resistance. Sensitization for change therefore requires particularly socially-competent management staff. The role of "integration-staff" with sufficient social skills as well as technical knowledge has proven to be a vital driving force.

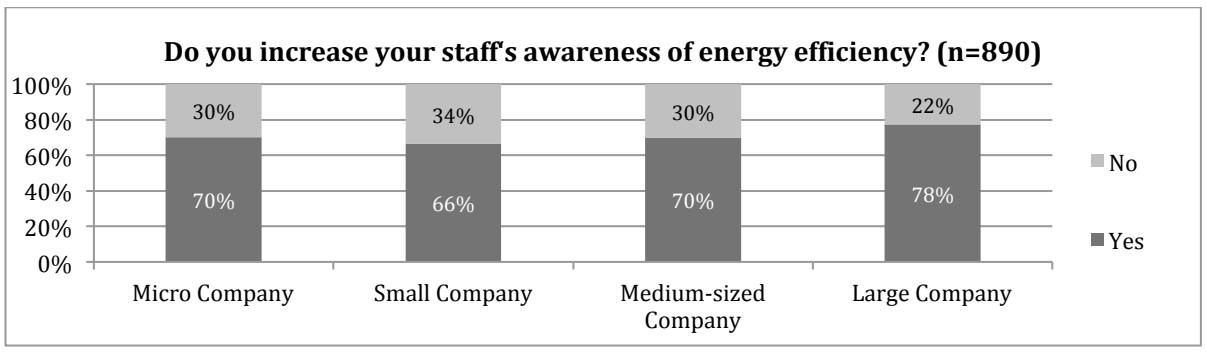

Figure 5. Raising awareness by company size: Source: EEP Energy Efficiency Index 2017/1.

4. *Raising awareness for technical and energy-related information.* The attention for waste of energy and the effects of individual action depend on the knowledge about technical and energy-related issues. The mediation of information proved to be more successful than the stipulation of rules of conduct.
5. *Sensitization for the existence and use of internal information and establishment of self-initiative.* SMEs depend on the individual engagement of their employees. Sensitized staff not only promotes the reduction of energy consumption, but ultimately also relieves the management from having to execute every detail in person. Deliberate or unconscious centralization of decision-making within SMEs is often taken for granted (Cagno/Trianni, 2013). This can constrain the successful reduction of energy consumption when it comes to gathering information and ideas, changing routines and behaviour, and establishing self-initiative.

Figure 6 shows that in the EEI survey, companies that raise their staff's awareness use the different formats of raising awareness. 1/5 of the respondents attempt to create a sense of awareness by convincing employees in one-on-one discussions, or integrate energy efficiency into their company suggestion scheme. 25 % of micro companies make their staff aware mainly (and thus significantly more frequently compared to the average) through other activities.

As the EEI data shows, in companies where staff awareness is not raised (Figure 7), this is mainly due to the lack of knowledge which steps need to be taken (>50 %). 21 % have no interest in raising their staff's awareness and 23 % have other reasons. The smaller the company, the less interest the respondents have to raise their staff's awareness. While the lack of interest in large companies is only 15 %, it makes up 30 % in the smallest companies. The higher the energy productivity, the more companies raise their staff's awareness for energy efficiency (Figure 8). However, if the energy productivity exceeds a certain level, the share of awareness-raising companies decreases. It is unclear to what extent the relief from the EEG levy (mentioned above) influences awareness-raising activities.

Figure 9 confirms that the more important the role of energy efficiency is in the participating companies, the higher is also the share of them raising awareness for energy efficiency among their workforce.

AWARENESS: CONCLUSION AND NEXT STEPS

Is raising staff awareness for energy efficiency paying off? For SMEs, the question can be clearly answered: Yes! Although awareness-raising requires patience as well as constant management efforts, the establishment of a culture beneficial for energy efficiency relieves the managers and sustainably institutionalises energy efficiency within the firm.

Unfortunately, there seems to be no one-best-way for raising awareness. Targets can be reached with different strategies. However, raising awareness is indispensable. Managers need to constantly support and push the process.

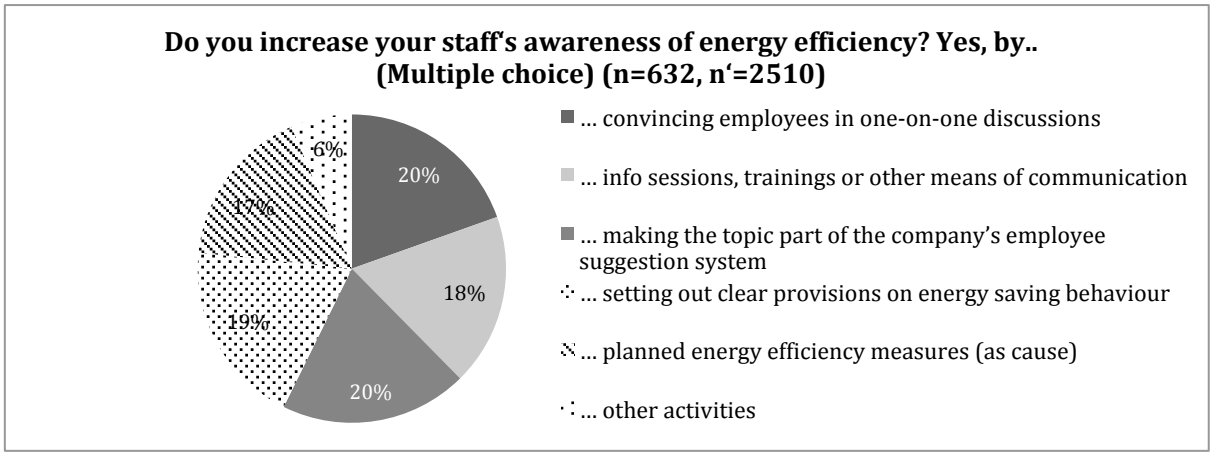

Figure 6. Awareness raising methods: Source: EEP Energy Efficiency Index 2017/1.

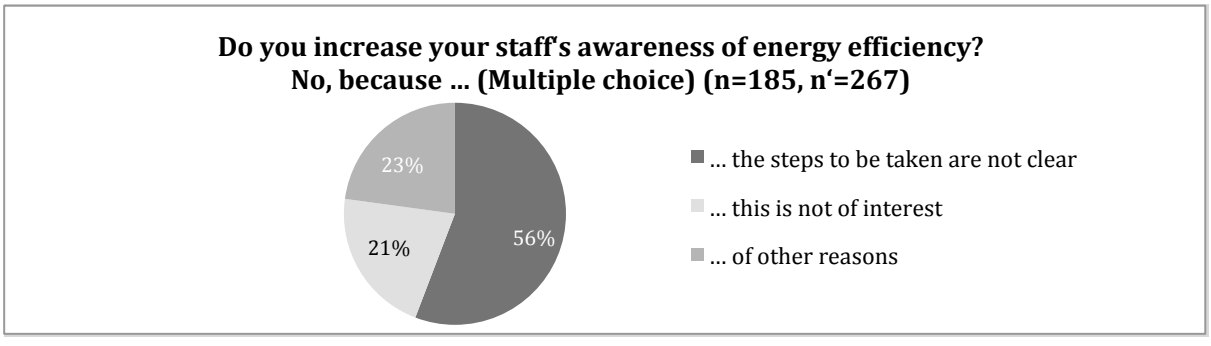

Figure 7. Reasons for not raising awareness: Source: EEP Energy Efficiency Index 2017/1.

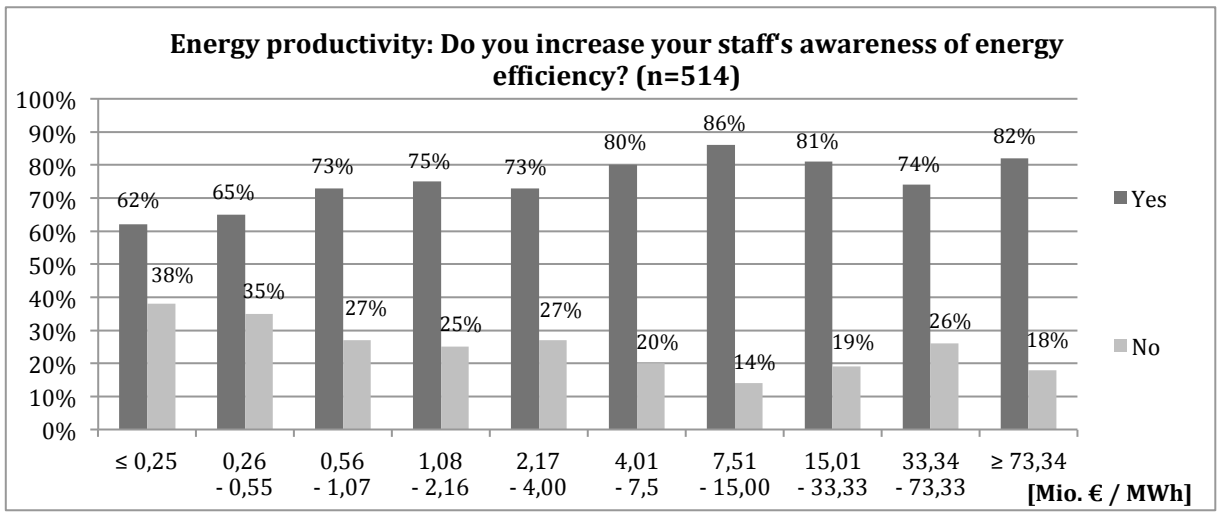

Figure 8. Energy productivity: Source: EEP Energy Efficiency Index 2017/1.

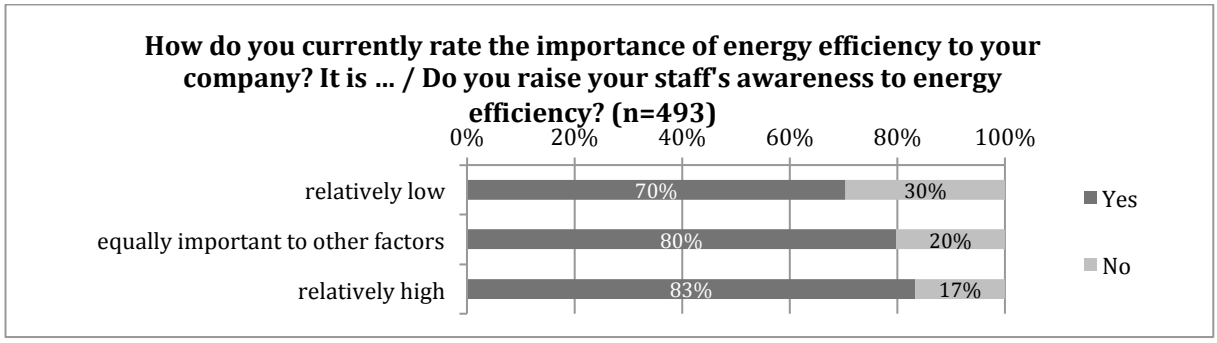

Figure 9. Link between importance and raising awareness: Source: EEP Energy Efficiency Index 2017/1.

In the process of developing a methodology to support 'decision making for efficiency' as default behaviour, this work however only constitutes a first step. It remains to be found out what companies 'behaving' in a particular way have in common and how these groups of similarly behaving companies (and roles within these) can each be triggered to decide for efficiency. These analyses are the core of our research project "Decision for Energy Efficiency in Manufacturing SMEs in Baden-Wuerttemberg" in 2018.

Regarding further research on determinants for energy efficiency, an emphasis should be put on the industry sector as well as its differences across countries resulting from different cultures and environments. This is why it would be of interest to replicate both qualitative and quantitative work in other countries, probably starting with samples of the same language and similar culture. Regarding quantitative research, this could be done in context of the *Energy Efficiency Barometer of Industry (#EEBarometer)*.

Overall Conclusion

Over the past pages, this paper provided insights on obstacles on the way to energy efficiency measures and the role particularly raising awareness has in companies' decision for energy efficiency. Aside from the topical findings we already discussed in the chapter conclusions, we found that surveying companies on "soft topics", such as awareness, is challenging. Applying the same taxonomy is indispensable when comparing different regions, utilising the same empirical method gathering the data would be advantageous. For a more detailed understanding of the individual barriers and the correct allocation to them, the taxonomy should be equipped with more specific sub-categories.

Methodological points aside, finding and implementing ways to remove (or at least reduce) barriers, notably information and awareness deficits, is essential but not in itself sufficient to support the decision for and subsequently increasing investments in energy efficiency in the manufacturing industry – and with this addressing the vast efficiency potentials in the industrial sector. The upcoming work of the project "Decision for Energy Efficiency in Manufacturing SMEs in Baden-Wuerttemberg", aiming at equipping decision makers with what it needs to stimulate energy efficiency decisions in SMEs, sets a step into the right direction.

References

Bauernhansl, T., Sauer, A. (2016), *Energieeffizienz in Deutschland – eine Metastudie*. 2. Auflage, Springer Verlag, Berlin.

Bauernhansl, T., (2014), *Energieeffizienz in Deutschland – eine Metastudie*, Springer Verlag, Berlin.

BMWi (2017), *Marktverfügbare Innovationen mit hoher Relevanz für die Energieeffizienz in der Industrie*. Berlin.

Cagno, E., Worell, E., Trianni, A., Pugliese G. (2012), *A novel approach for barriers to industrial energy efficiency*. In: Renewable and Sustainable Energy Reviews 19 (2013), 290–308.

Cagno E and A. Trianni (2013) *Exploring drivers for energy efficiency within small- and medium-sized enterprises: First evidences from Italian manufacturing enterprises*, In: Applied Energy 104, 276–285.

DeCanio, S.J. (1998), *The efficiency paradox: bureaucratic and organizational barriers to profitable energy-saving investments*. In: Energy Policy 26 (5), 441–454.

De Groot, H.L.F; Verhoeff, E. T.; Nijkamp, P. (2001) *Energy savings by firms: decision-making, barriers and politics*. In: Energy Economics, Vol. 23, 717–740.

EEP (2016) Institut für Energieeffizienz in der Produktion, Universität Stuttgart (Hg.): *Der Energieeffizienz-Index der deutschen Industrie. Umfrageergebnisse 2. Halbjahr*, Stuttgart, 2016.

EEP (2017) Institut für Energieeffizienz in der Produktion, Universität Stuttgart (Hg.): *Der Energieeffizienz-Index der deutschen Industrie. Umfrageergebnisse 1. Halbjahr*, Stuttgart, 2017.

Fleiter, T., Schleich, J., Ravivanpong, P. (2012), *Adaption of energy efficiency measures in SMEs – An empirical analysis based on energy audit data from Germany*. In: Energy Policy, 51 (2012), 863–875.

Froschauer, U.; Lueger, M. (2003), *Das qualitative Interview.* Zur Praxis interpretativer Analyse sozialer Systeme. Facultas Verlags- und Buchhandels AG, Wien.

Gerarden, T.D.; Newill, R.G.; Stavins, R. (2015), *Assessing the Energy-Efficiency Gap*. In: Journal of Economic Literature, Vol. 55 (4), 1486–1525.

Glaser, B. G.; Strauss, A.L. (1998) *Grounded Theory*. In: Strategien qualitativer Forschung. Göttingen: H. Huber, p. 51–83.

Hoffman, A. (1999), *Institutional evolution and change: Environmentalism and the US chemical industry*. In: Academy of Management Journal 42, 351–371.

Jaffe, A.B.; Stavins, R.N. (1994), *The energy-efficiency gab. What does it mean?* In: Energy Policy, 1994, Volume 22 (10), p. 804–810.

Kieser, A., (2006), *Organisationstheorien*, 6. Edition, Kohlhammer: Stuttgart.

Morgan, G. (2007), *Images of organization*, Thousand Oaks: Sage.

Ocasio, W. (1997): *Towards an attention-based view of the firm*. In: Strategic Management Journal, Vol. 18, 187–206.

Palmié, M.; Lingens, B.; Gassmann (2015), *Towards an attention-based view of technology decisions*. In: R&D Management, 46 (4), 781–796.

Schütze, F. (1983), *Biographieforschung und narratives Interview*. In: Neue Praxis, 13, 283–293.

Scott, R., W.; Davis, G.F. (2007), *Organizations and organizing*: Rational, natural, and open system perspectives. Routledge: London/New York.

Sorrell, S.; Schleich, J.; Scott, S.; O'Malley, E; Trace, f.; Boede, U.; Ostertag, K.; Radgen, P. (2000), *Reducing Barriers to Energy Efficiency in Public and Private Organizations*. Final report to the European Commission, University of Brighton.

Stephenson, J.; Barton, B.; Carrington, G.; Doering, A.; Ford, R.; Hopkins, D.; Lawson, R.; MacCarthy, A.; Rees, D.; Scott, M.; Thorsnes, P.; Walton, S.; Williams, J.; Wooliscroft, B. (2015), *The energy cultures framework: Exploring the role of norms, practices and material culture in shaping energy behaviour in New Zealand*. In: Energy Research & Social Science, 2015, 7, 117–123.

Stephenson, J.; Barton, B.; Carrington, G.; Gnoth, D.; Lawson, R.; Thorsnes, P. (2010), *Energy cultures: A framework for understanding energy behaviours*. In: Energy Policy 38, 2010, 6120–6129.

Stern, N.H. (2007), *The economics of climate change: The Stern Review*. Cambridge, UK: Cambridge University Press.

Sudhakara, R. (2013), *Barriers and drivers to energy efficiency – A new taxonomical approach*. In: Energy Conversion and Management, Vol. 74, 403–416.

Thollander, P.; Palm, J.; Rohdin, P. (2010), *Categorizing Barriers to Energy Efficiency – an Interdisciplinary Perspective*, Energy Efficiency, Jenny Palm (Ed.), In:Tech, DOI: 10.5772/9828.

Trianni, A., Cagno, E., Farné, S. (2016), *Barriers, drivers and decision-making process for industrial energy efficiency: A broad study among manufacturing small and medium-sized enterprises*. In: Applied Energy, 162 (2016), 1537–1551.

United Nations (2017), The Paris Agreement, http://unfccc.int/paris_agreement/items/9485.php.

Weber, L. (1997), *Some reflections on barriers to the efficient use of energy*. In: Energy policy, Vol. 25, No. 10, 833–835.

Ybema, S.; Yanow, D.; Wels, H.; Kamsteeg, F. (2009), *Organizational Ethnography. Studying the complexities of everyday life*. SAGE Publications Ltd.

Yin, R.K. (2003), *Case study research: Design and Methods*. Third Edition; Applied social research methods series, Volume 5, SAGE Publ., Thousand Oaks, California.

Zierler, R.; Wehrmayer W.; Murphy, R. (2017), *The energy efficiency behaviour of individuals in large organisations: A case study of a major UK infrastructure operator*. In: Energy Policy, Vol. 104, 38–49.

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