Regional energy efficiency networks – what factors make them successful?

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Abstract

Energy efficiency networks have received increasing attention over the last few years, not only from national governments (Austria, China, Germany, Sweden and Switzerland), but also from utilities, consulting engineers, chambers of commerce, and city councils. This paper examines the factors that contribute to the success of such networks by drawing on unique data from two pilot projects with 34 energy efficiency networks in Germany. The objective is to explain why companies participating in such networks are much faster at reducing their energy costs than the average in similar businesses. Possible explanations for the success of energy efficiency networks include: (1) energy audits make profitable potentials visible; (2) the joint network targets for efficiency and emissions increase the motivation of energy managers, decision-makers and other staff members; (3) the meetings and site visits to the network participants act like an intensive training course. They increase the knowledge of efficient solutions, change decision routines, and lead to trust among the participants, thereby reducing transaction costs. In our data, we find support for the first and the third explanations, i.e. the audits make profitable potentials visible and networks function as a training course to increase knowledge. The impact of network goals, on the other hand, appears to have both up- and downsides. We conclude with the need for further research in order to capture these mechanisms in more detail.

Introduction

Realising cost-effective energy savings could help to cover half of Europe's 2050 goal for reducing greenhouse gas emissions (Wesselink et al. 2010). In this context, energy efficiency networks have received increasing attention over the last few years, not only from national governments (Austria, China, Germany, Sweden and Switzerland), but also from utilities, consulting engineers, chambers of commerce, or city councils. These networks are intended to promote economically viable energy efficiency improvements.

An energy efficiency network consists of a group of organisations, usually between eight and 15, mostly companies, but sometimes also public institutions. They are often either from the same local area or the same line of business. The networks are established for a minimum of two, but generally for three to four years[1]. During this period the participants initiate an individual energy audit or refer to an existing one, identify the most promising measures which are then implemented and the success is monitored. This process is accompanied by continuous exchanges between network participants to facilitate energy efficiency improvements.

The concept of Learning Energy Efficiency Networks (LEEN) was first implemented in Switzerland and transferred to Germany in 2002 and has undergone continuous refinement since then. From 2008 to 2014, the German government supported a pilot project, which set up 30 LEEN across Germany ("30-Pilot-Networks" project). This is one of the sources for the empirical data used in this paper. This successful project was followed by

1. However, they may also run much longer depending on political framework conditions, e.g. in Switzerland, companies commit themselves to 10-year-targets as part of CO_2 legislation.

two further initiatives to promote energy efficiency networks. Firstly, the German government and 20 industrial associations agreed on a target of 500 energy efficiency networks until 2020 in Germany with a negotiated minimum standard regarding network structure and performance. Secondly, and supporting this initiative, the German Ministry for the Environment initiated a project to extend the LEEN concept to 100 networks in Germany until 2017. Based on findings from the pilot project with 30 networks, it is expected that these additional networks will achieve energy savings of 75 PJ of primary energy and thereby reduce greenhouse gas emissions by 5 million tonnes until 2020 (BMWi 2014).

The LEEN concept targets companies which spend at least 0.5 million euros each year on energy. These companies are usually not SMEs according to the EU definition (European Commission 2003). There is also an adapted concept for smaller companies with lower energy costs called Mari:e. ("Mari:e – mach's richtig: energieeffizient", i.e. "do it right: be energy efficient". For a detailed comparison of the concepts in German, see https://www.energie-effizienz-netzwerke.de/een-wAssets/docs/Vergleich-LEEN-und-Marie.pdf, last accessed 18.04.2016.) In this paper, we also draw on data from the first four Mari:e networks. Both network approaches have in common that participants start with an energy audit to obtain a detailed evaluation of the status quo and, more importantly, to identify potentially profitable energy efficiency measures. These audits are extensive and include structured data collection by the participating company prior to a field visit from an engineer who supports each network as a consultant. Participating in the networks automatically enables non-SMEs as defined in the Energy Efficiency Directive (EED) to fulfil their mandatory energy audit according to Article 8 of the EED. If an audit has already been conducted before the company joined the network, its outcomes can be adapted and where necessary complemented to meet LEEN-standards. Based on the audit's findings, each participating company defines an individual quantitative goal regarding efficiency. Starting at the same time, the participants attend regular meetings (3–4 per year), which usually take place at the site of one of the participants. A site tour focusing on energy efficiency is part of the standard agenda at these meetings as well as discussions about specific topics that are supported by input from external experts. Each company's progress is monitored on an annual basis as is the network's success as a whole in terms of energy savings and CO_2 emission reductions. The LEEN concept includes a training programme for the consulting engineer and the network moderator, who support and organise the network processes and provide technical tools for the energy audit and other network components. The network activities including the audit and the work of the consulting engineer and the moderator are funded by contributions of the participating companies. It is assumed that the money saved through the identified and implemented energy efficiency measures will exceed these contributions. Additionally, public funding may reduce the participants' contributions like in the 30-Pilot networks project.

Generally, companies are expected to constantly improve their energy efficiency independent of any external intervention, e.g. due to the replacement of old equipment and as a consequence of acquiring new technologies. Such autonomous progress is usually assumed to add up to 1 % efficiency gain per year (cf. Worrell 2009; Jochem et al. 2010). Earlier work on the LEEN networks (Bradke et al., 2015) indicates that companies participating in these networks progress about twice as fast in reducing energy costs. Data on the networks' impact will be presented in more detail below. The focus of this paper, however, is on how and why efficiency networks are so successful.

To answer these questions, we summarise the research on the factors hindering the realisation of profitable efficiency potentials, outline the findings of earlier publications on efficiency networks and then discuss the underlying processes that might contribute to network success. Building on this background information, empirical data drawn mainly from the pilot project with 30 networks are analysed to explore whether they confirm the assumptions about underlying processes. It is important to note that this study is not intended to be a thorough test of a hypothesis or an evaluation in the narrow sense, but is more explorative in nature.

Why are energy efficiency networks successful?

In this section we look at why networks are successful in increasing energy efficiency within organisations. However, we begin with a very brief description of the obstacles hindering the realisation of profitable energy efficiency potentials as these have been intensively explored in the literature.

OBSTACLES TO ENERGY EFFICIENCY IN INDUSTRY

Barriers to energy efficiency help to explain the so called energy efficiency gap (e.g. Jaffe and Stavins 1994; Brown 2001), i.e. why cost-effective energy efficiency measures are often not put into practice. A barrier is usually defined here as "a mechanism that inhibits a decision or behaviour that appears to be both energy efficient and economically efficient" (Sorrell et al. 2004). The widely cited classification of barriers suggested by Sorrell et al. (2004) distinguishes six categories of barriers, which can be summarised as follows:

- Risks: Risks are negative consequences associated with the introduction of energy efficiency measures, e.g. unintended changes to product quality or the stability of the production process.
- Imperfect information: Imperfect information is incomplete, preliminary or uncertain information that impedes a decision-maker from making a well-informed decision.
- Hidden costs: Hidden costs are reductions in utility or effort that are not fully accounted for in techno-economic considerations, e.g. overhead or transaction costs.
- Access to capital: Access to capital describes a situation where companies do not have the financial means to invest in otherwise cost-effective measures, e.g. due to other priorities or limited credit lines.
- Split incentives: Split incentives describe a situation where the incentives of implementing energy efficiency measures do not appropriately encourage all the involved actors, e.g. when expenditures for investments and the resulting energy savings are accounted for in different departments.

- Bounded rationality: Bounded rationality describes constraints that impede rational decisions, e.g. decision-makers' lack of time or focus on more prestigious projects.

Various studies have suggested extensions of the conceptual foundations, e.g. by stressing the drivers of or motivators for energy efficiency (e.g. Thollander et al. 2013; Cagno and Trianni 2013; Meath et al. 2016), by considering the dynamics and interconnections among barriers (e.g. Chai and Yeo 2012; Cagno et al. 2013), by stressing the social and cultural dimensions of barriers (e.g. Palm 2009; Bell et al. 2014) or by addressing other contextual factors (e.g. Cooremans 2012; Langlois-Bertrand et al. 2015). There are also indications that certain organisational characteristics can affect the relevance of particular barriers, e.g. the size or sector of an organisation (Trianni & Cagno 2012).

Despite a general consensus on the relevance of barriers, it remains difficult to pinpoint the overarching relevance of individual barriers in empirical studies. This is probably due to different taxonomical approaches, heterogeneous industrial segments as well as the usually overlapping and often elusive nature of barriers. Sorrell et al. (2011) attempted to identify indications for the relevance of each barrier according to the previously mentioned categories. Their findings suggest that barriers related to imperfect information, access to capital and bounded rationality are particularly relevant.

EARLIER RESEARCH ON ENERGY EFFICIENCY NETWORKS

As soon as energy efficiency networks were implemented in Germany and other countries, they also became the subject of research. The above mentioned pilot project for 30 LEEN included an extensive evaluation process, which produced a rich amount of data from several sources that served as the basis for several papers. Research from other countries has also contributed to this literature (e.g. Paramonova et al. 2014). In the past, some research has already been done on the approach of energy efficiency networks and their influence on the increasing energy efficiency in companies. Table 1 gives an overview of scientific papers published either in journals or conference proceedings between 2007 and 2016. Some authors, e.g. Köwener et al. (2014) or Jochem and Gruber (2007), identified the structured process of an energy efficiency network that includes an energy review in each company, regular meetings and yearly monitoring as a relevant factor for its success. Two papers investigated how the above mentioned barriers are addressed by energy efficiency networks. Wohlfarth et al. (under review) identified information deficits as a relevant barrier for companies and demonstrated empirically that this barrier could be overcome by energy efficiency networks. Mai et al. (2014) investigated the relevance of transaction costs for the adoption of energy efficiency measures and found that energy efficiency networks are able to overcome this barrier mainly due to the regular exchange of experiences. Thus, the information gained from the network seems to be an important factor. However, literature that explores the mechanisms of efficiency networks is still emerging.

ASSUMPTIONS ABOUT THE WORKING MECHANISMS OF ENERGY EFFICIENCY NETWORKS

In this paper, we want to explore the mechanisms that make efficiency networks effective in more detail. The main idea regarding the working mechanisms of efficiency networks is that these networks are social constructs (cp. Jochem & Gruber 2007, who look at networks from a social relations perspective). They trigger progress in energy efficiency on an individual (energy managers, decision-makers) and group level (the organisation, i.e. the company or institution, as a whole, across the network participants) and thereby reduce the perceived barriers that hindered the organisation from realising relevant profitable potentials. In the following we present three assumptions about the working mechanisms of energy efficiency networks.

First of all, we assume that the networks act as an agenda setter, i.e. energy efficiency becomes a topic of organisational decision making through the participation in the network. Although the relevance of this step has been recognised in the literature, knowledge about it is poor (cf. Hutzschenreuter & Kleindienst 2006; Cooremans 2012). Agenda setting is the precondition for decision-making about specific issues. In addition to agenda setting, the initial energy *audits make profitable potentials visible* – for the individual as well as for the group. This is likely to help reduce problems related to barriers like imperfect information and bounded rationality.

Secondly, while agenda setting leads to awareness of profitable efficiency potentials, actually initiating measures and putting them into practice needs further motivation. It is assumed that this *motivation* grows *from the joint network targets* on efficiency and emissions. Literature on organisational goal setting (e.g. Locke & Latham 2002) has shown that (common) goals are a powerful means to sustain motivation for actions. It is likely that they also address barriers like split incentives.

Thirdly, we assume that the regular meetings and site visits to network participants act like an *intensive training* course that sustains motivation and also increases the knowledge about efficient solutions. This increase of knowledge is likely to have effects on several of the barriers outlined above: It obviously reduces information deficits (cf. Wohlfarth, under review, for first results). It also reduces the perceived risk of measures, especially as within networks, participants are able to profit from the experiences of other network members. Again, it is likely to help reduce bounded rationality by focusing attention and adding facts as the basis for decision making. We also expect this to reduce transaction costs.

Transaction costs cover all the resources that need to be invested due to an exchange of goods or services (Richter et al. 2003), i.e. the costs for searching and analysing relevant information, for negotiations and decision making processes as well as for control and realisation. Energy efficiency measures are also accompanied by these kinds of transaction costs, but it is assumed that they are lower for companies participating in networks for the following reasons: As network participants exchange experiences and also engage in bilateral consultation, the transaction costs for gathering information and evaluating it should be lower for the participating companies. Similarly, the effort for negotiations and decision making can be reduced by building on the experience of other network participants. The issue of transaction costs in networks has been studied by Mai et al. (2014), who analysed 40 investment decisions of 35 companies participating in networks. They found that a majority of the surveyed companies agreed that network participation had reduced their transaction

Table 1. Scientific papers on energy efficiency networks.

Authors, year (Journal/Conference)	Country focus	Database	Methodology	Main results
Wohlfarth et al. *(under review)* (Journal of Cleaner Production)	Germany	30 networks, two surveys (beginning and end of the network phase) in 300 participating companies	Descriptive analysis; t-tests and factor analysis; n = 300	participants were mainly motivated by the need for practical knowledge and specific information resulting from the participation in networks; the majority of participants reported that measures were implemented that would not have been realised without the network
Rohde et al. 2015 (Proceedings aceee)	Germany	30 networks, data from 366 reports from the energy review phase	Descriptive analysis; n = 366	a major share (~85 %) of the identified measures requires investments below €50,000; average payback time for the profitable measures between 2.2 years (for compressed air systems) and 4.3 years (for air conditioning)
Paramonova et al. 2014 (Proceedings aceee)	Sweden	8 networks, >420 companies	Descriptive analysis; n = 420	networks deliver energy efficiency improvements beyond those a stand-alone energy audit can achieve; however, a structured model for the networks is necessary, including how to move through the various phases in a network process
Köwener et al. 2014 (Proceedings aceee)	Germany	30 networks, data from 366 reports from the energy review phase	Descriptive analysis; n = 366	7,000 measures were identified; 3,600 of these were profitable measures (with an internal rate of return >12 %); on average, nine profitable measures were identified for each company; energy saving potential of about 2,700 MWh and a CO_2 emission reduction potential of approx. 940 tons p.a.
Mai et al. 2014 (Zeitschrift für Energiewirtschaft)	Germany	survey in 35 companies participating in energy efficiency networks	Regression; n = 35	a negative correlation was shown between energy efficiency investment and relative transaction costs; hypothesis: transaction costs confirmed as an obstacle to investments in energy efficiency; however, inhibitory effect of transaction costs is small (share of transaction costs of an investment of €60,000 below 20 %; therefore no influence on profitability of energy efficiency investment)
Köwener et al. 2011 (Proceedings eceee)	Germany	4 networks, data from 50 initial consultancy reports	Descriptive analysis; n = 50	average efficiency target agreed between companies of around 2 % per year; average energy cost savings of €120,000 per year and 500 tonnes CO_2 reduction (per company)
Jochem et al. 2010 (Zeitschrift für Energiewirtschaft)	Germany	10 energy efficiency networks; 115 companies	Descriptive analysis; n = 115	average energy savings per site and year are €100,000 and average CO_2 emission reduction about 500 t CO_2 per year and site assuming a maximum potential of 700 networks; additional emission reductions of some 10 million t CO_2 seem to be possible in Germany by 2020
Jochem, Gruber 2007 (Applied Energy)	Germany	1 pilot energy efficiency network; 17 companies	Descriptive analysis; n = 17	results show substantial progress in implementing organisational measures and energy efficiency investments in the participating companies

costs. More specifically, it could be shown that the personal exchange of experiences during networking meetings, the presentation of good practice examples by participants and expert presentations on energy efficiency technologies led to high reductions of transaction costs, especially in the search and decision phase before the actual investment decision.

In the next section we examine empirical data to see if it supports our three assumptions.

Methods

This paper draws on empirical data from the two LEEN pilot projects, the "30-Pilot-Networks" project and Mari:e. The 30 pilot networks project had the goal to initiate and manage 30 LEEN and was accompanied by a parallel evaluation process. This evaluation process had two main goals: one, to continuously improve network management by providing feedback; two, to accumulate data for scientific analysis. Both pilot projects focused on local and regional networks. This implies that companies from different lines of business were involved. As a result, the networks tend to focus on cross-cutting issues that affect all the participants like lighting or waste heat utilisation and less on efficiency potentials in the companies' individual production processes.

The main sources of data are: i) the lists of measures from the initial audits ii) the annual monitoring data iii) three surveys of the participating companies (after network initiation, after completing the audit, at the end of the network phase) and iv) the interview series with the main network actors, i.e. network initiator, consulting engineer, and network moderator. The data used here will be described in more detail in this section. All four sources of data were drawn from the 30 pilot network process while four networks from Mari:e provided additional data for i) and ii).

ENERGY AUDIT AND MONITORING DATA

Various quantitative technical data were collected during the "30-Pilot-Networks" project and the Mari:e project. Consulting engineers and network moderators used standardised tools for the initial energy audits and the annual monitoring that were developed within these projects. The energy efficiency, CO_2 saving potentials and the profitability of the proposed measures can be analysed based on the energy audit reports of 400 companies. The monitoring methodology was changed during the "30-Pilot-Networks" project (Ott 2012) so that monitoring results are available for only roughly 260 companies. Currently, the LEEN management system defines an annual monitoring process for all companies based on final energy and primary energy. Both the energy audits and the monitoring process conform to DIN EN ISO 50001.

Monitoring is intended to provide evidence of the effects realised by the measures. It provides a way to track the progress made towards the individual energy efficiency targets and the commonly agreed network target. The base year of this target is the year when the network started. During the network's lifetime of three to four years, the individual targets of all companies are aggregated, monitored yearly and compared to the agreed network target to track the progress made.

QUESTIONNAIRES AND INTERVIEWS

The social scientific part of the evaluation process documented the expectations and satisfaction or dissatisfaction of all the actors involved with the different network elements and processes. These actors include the network participants, i.e. the companies, but also the further network actors, i.e. network initiators, consulting engineers and network moderators.

Due to the large number of over 300 companies participating in the 30 networks, a standardised approach applying a written survey was chosen. This survey was conducted in three waves – wave 1 in the first year of the network including mainly questions about network initiation, motivation for participation and expectations regarding the network. The second wave was conducted after a network had completed the energy audit phase and focused on experiences with the audit. The third and last wave was conducted towards the end of the network and covered types of measures taken, barriers encountered, the decision making process in the organisation, interaction with certain political measures and network ratings. Of the 360 companies participating in the networks, 304 responded to the first survey, 281 to the second and 213 to the third. While it is normal in longitudinal studies for the number of respondents to decrease across survey waves, the relatively low number of completed questionnaires in the final round here was partly due to the high level of network activities during the final period of the network process. Questionnaires were provided as a Word file that could be completed on a computer, or printed and completed as a paper and pencil version. The questionnaires received back from the companies were checked for quality and data were then entered into an SPSS-file for further analysis. For this paper, we only took data from the survey waves 2 and 3 and applied descriptive statistics as well as a multivariate linear regression model to analyse them.

Interviews were conducted with the further network actors in order to protocol their experiences and collect their feedback on possible improvements and encountered difficulties. These interviews followed a guideline to ensure comparability and most of them lasted between 30 and 40 minutes. Interviews were recorded and later transcribed. Each network has an initiator, an engineer and a moderator. Each network has an initiator, an engineer and a moderator. However, the number of interviews in each category is not equal to 30 as e.g. two bigger engineering consultancies were engaged in several pilot networks with small groups of engineers. In other cases, several freelance engineers shared the network activities of a single network between them. Also some of the moderators were responsible for more than one network. Thus, in the end, 30 initiators of networks were interviewed, some of whom were also active as network moderators later on. 29 interviews were conducted with consulting engineers who covered all 30 networks. There were interviews with 26 moderators, who covered all the networks from the pilot project. To draw conclusions and identify relevant results, software was used to code all three interview series. Codes were developed based on the interview guideline and then refined as needed, e.g. by breaking down questions which lead to answers covering many aspects into sub-codes, or by adding codes for additional topics. The analysis uses a thematic approach, i.e. identifying themes and patterns and not a quantitative approach, e.g. like counting the frequency of certain codes. In the following, original quotes from the interviews (shown in italics) will be used to illustrate selected findings.

Figure 1 gives an overview of the network life-cycle and the data sources.

Results

This section is structured using the three assumptions outlined above and combines findings from the sources described in the methods section. It starts with data illustrating the networks' success.

Companies in both pilot projects participated in energy efficiency networks for three years on average. As outlined above, the joint efforts resulted in annual energy efficiency progress that was twice as high as the assumed average of German industry (Bradke et al 2015). The evaluation of the submitted monitoring reports of 30 networks from the pilot networks shows an average increase in energy efficiency of 2.1 % per year and a reduction of CO_2 emissions of 2.4 % per year (Table 2 shows exemplary results from ten of the 30 networks).

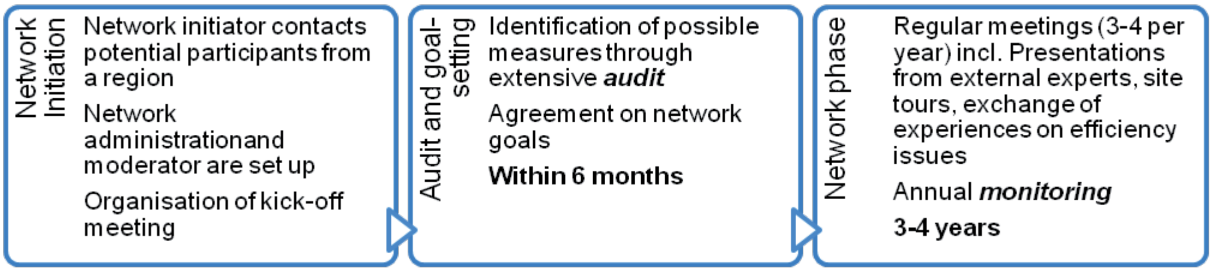

Figure 1. Structure and timeline of a typical network from the 30 pilot networks, including data sources for evaluation.

Table 2. Energy efficiency progress and CO_2 reduction of exemplary networks from the 30 LEEN pilot networks (sorted by efficiency progress).

N	Energy efficiency progress, weighted	Energy efficiency progress, weighted, p.a.	Achieved CO_2 reduction, weighted	Achieved CO_2 reduction, weighted, p.a.
1	12.1 %	4.3 %	12.8 %	4.6 %
2	11.7 %	4.0 %	10.9 %	3.8 %
3	9.5 %	3.4 %	9.2 %	3.3 %
4	8.3 %	2.9 %	7.9 %	2.8 %
5	8.1 %	2.3 %	10.5 %	3.0 %
6	7.6 %	2.5 %	7.6 %	2.5 %
7	7.6 %	2.5 %	7.0 %	2.3 %
8	7.3 %	2.9 %	14.3 %	5.7 %
9	6.1 %	2.1 %	5.8 %	2.0 %
10	6.1 %	1.7 %	11.0 %	3.1 %
Total average result, p.a. based on weighted average results of each network *(30 networks in total)*		**2.1 %**		**2.4 %**

AUDITS MAKE PROFITABLE POTENTIALS VISIBLE

To show how audits make profitable efficiency potentials visible, we draw on (1) data from an evaluation of the energy audit phase that covers 400 reports of the companies participating in both "30 Pilot-Networks" and "Mari:e", (2) findings from the second survey wave, (3) the interviews with consulting engineers. The evaluation focuses on the regional and local energy efficiency networks and does not include other network types (e.g. sectoral, intra-corporate or in-house networks). These results reflect the energy and CO_2 saving potentials identified during the energy audit. The energy audit report received by the participating companies includes an overview of all the identified measures in terms of savings and profitability. Compared to an earlier evaluation of the 30 pilot networks published by Köwener et al. (2014), our analysis is based on a broader sample and identified more than 8,000 potential measures, i.e. on average about 20 per organisation. Of this number, about 3,900 measures were classified as profitable, meaning that their internal rate of return is higher than 12 %. Ten profitable measures were identified on average for each organisation with an energy saving potential of about 2,500 MWh and a CO_2 reduction potential of approximately 900 tons per year (see Table 3).

In addition, the energy efficiency measures were categorised using a detailed cluster system (Leinweber 2014). Selected results in Table 4 show the three most frequently suggested technical subcategories for selected technology areas. The evaluation of these categories indicate that, according to the initial energy audit estimations, measures such as the introduction of energy management systems in companies turn out to be profitable, resulting in a fairly high energy saving potential (465 MWh on average). In addition, compressed air is the only technology area where all three subcategories have an average internal rate of return (IRR) of well over 40 %, while optimisation measures concerning the adjustment and control of equipment are the most profitable.

We also look at the network participants' perception of the energy audit drawing on the evaluation data from the 30 pilot networks. The second questionnaire featured questions asking for evaluations of several aspects regarding the energy audit. Of the 267 respondents answering a question asking for an overall evaluation of the energy audit on a five-point scale, 71 rated it with 5 points as very good, and 149 rated it with 4 points, i.e. 82 % gave a positive evaluation. 39 rated it with 3 points and were therefore neutral or undecided; and 8 respondents chose 2 points and a negative evaluation. These results show that, overall, participants had a positive perception of the energy audit.

To learn more about the factors influencing the overall evaluation of the energy audit, the variable was regressed on several

Table 3. Evaluation results of the measures identified in the audits of the 400 participating companies.

Evaluated reports (measures overview)	**400**
No. of measures	8,050
thereof evaluated in monetary terms	7,920
thereof profitable (profitable: IRR larger than 12 %)	3,870
Ø IRR of all profitable measures	47 %
Ø static payback period of all profitable measures	2.1 years
Ø investment per measure [EUR]	40,730
Ø values per organisation/site	
Ø energy savings if all profitable measures realised [MWh/year]	2,520
Ø CO_2 reduction if all profitable measures realised [t/year]	900
Ø No. of measures evaluated in monetary terms	20
thereof profitable	10
Ø total additional investment realising all profitable measures [EUR]	**365,000**
Ø reduction of energy cost if all profitable measures realised [EUR/year]	**173,000**

ratings of single aspects of the energy audit. Those single aspects included 15 items, of which five were identified as relevant by a stepwise linear regression model (Table 5).

Overall 55.6 % of the variance in the overall evaluation of the energy audit is explained by the independent variables that remained in the final equation. The most important influencing factor indicated by the highest β-value is that the report is comprehensive. From the perspective of the surveyed companies, other relevant factors included the identification of new aspects, sufficient audit length, and the perception that the received advice is competent and comprehensive. Overall, these factors can be interpreted as aspects that contribute to the audit making profitable potentials visible and therefore of value to the participants.

The effects of the energy audit were also addressed within the interview series with the consulting engineers. The consulting engineers agree that the main effect of the energy audit is to get the relevant member of the participating company involved in the topic of energy efficiency and engaged in looking at the relevant data, e.g. the respective facilities and machinery, the current energy demand, and the factors influencing this demand. According to the statements of the consulting engineers, one of the audit's effects is that it gives a more general perspective and directs attention as illustrated by the following exemplary quote:

> They [the participating companies] often no longer see what is under their noses, or have any new ideas. It is useful if someone from outside comes and points out the main issues regarding possible measures, state of technology etc. That's the main task of the energy audit.

MOTIVATION FROM JOINT NETWORK TARGETS

In order to analyse whether the joint network targets enhance the motivation to engage in energy efficiency, we draw again on the interview series with the consulting engineers and complement this by findings from the second survey wave and the interviews with the moderators.

It turns out that a few comments of the engineers refer directly to the motivational effects of the joint network targets. Some point out that they had the impression that the targets are less important, especially as they have no effect if they are not reached:

> It was good to have defined goals! However, I did not have the impression that it was important what these were exactly, when to reach them or how the effort was shared within the network. Maybe this was too abstract. The specific measures were always exciting topics of interest, but whether they contributed to the network target and how feasible that target is did not seem so relevant.

Many networks did not have problems with defining a network target (nearly 50 % of the surveyed companies agreed with a respective statement in the second survey wave), but if problems arose (reported by 32 % of the surveyed companies), this led to unsettledness in the network as pointed out in the interviews by the consulting engineers:

> If there is a participant who is very cautious about this and then makes a critical statement, this influences the whole group. However, in reality, it depends on the group.

Another difficulty that emerged was that the network timeframe repeatedly turned out to be too short to reach (ambitious) targets as many companies needed a relatively long time, e.g. to settle investments. This is suggested by comments that were added from survey participants as well as by statements from the moderator interviews.

Overall there is little support from the evaluation data for the assumption that network targets are an important factor contributing to network success but that their role is ambiguous.

INTENSIVE TRAINING

To explore whether network participation increases knowledge we analysed the third survey wave as well as the moderator interviews.

Table 4. Evaluation of measures in accordance with the detailed cluster system, selected results.

Technology area and corresponding measures	Measures	Ø Energy saving, [MWh/a]	Ø CO2 Red., [t/a]	Ø Red. of energy costs, [€/a]	Ø IRR, %	Ø Investment estimated, €
Ventilation and air conditioning						
Optimisation of interior air condition/rate of fresh air supply/air quantity via adjustment control/ maintenance	272	171.3	65.6	13,594	61 %	24,521
Optimisation of interior air condition/rate of fresh air supply/air quantity via modernisation/ supplement/maintenance of components	143	208.4	65.1	13,370	30 %	45,813
Waste heat recovery in ventilation and air conditioning equipment	53	334.4	66.8	12,373	20 %	44,301
Lighting						
Replacement of lighting equipment	460	74.1	39.8	9,312	21 %	34,762
Optimisation of lighting components/light management	408	39.5	20.1	4,214	27 %	13,599
Switching off lights in production areas when not needed	14	35.3	18.2	3,512	135 %	1,623
Compressed air						
Adjusting and controlling optimisation	351	61.4	32.0	6,326	103 %	9,322
Optimisation of compressor and its periphery via modernisation/supplement/maintenance of components	277	74.5	37.9	7,168	57 %	10,275
Optimisation of the distributing system via demand minimisation	133	73.7	42.3	7,310	53 %	9,339
Electric motors and pumps						
Supplement/replacement of motors	446	69.9	37.5	7,577	27 %	25,393
Controlling/adjusting of pumps	127	62.1	32.3	7,314	41 %	15,655
Supplement/replacement of pumps	80	34.2	18.6	3,500	24 %	12,456
Process cooling						
Optimisation of operation via modernisation/ supplement/maintenance of components	220	111.7	63.0	12,509	41 %	35,200
Free cooling	65	137.1	73.1	15,736	34 %	42,395
Other (mostly due to measures involving ground and well water cooling)	57	71.4	29.5	5,670	28 %	22,650
Process heat						
Waste heat recovery from process exhaust air, steam, waste water and condensate	225	831.9	185.1	28,130	25 %	99,985
Modernisation/supplement/maintenance of components for a steam boiler	154	460.3	103.1	17,421	14 %	103,277
Insulation of fittings, reservoirs and other surfaces	115	244.0	61.5	10,115	37 %	24,917
Miscellaneous						
Management measures (often introduction of energy control system)	711	465.5	142.1	24,694	253 %	29,253
Miscellaneous organisational measures (often introduction of energy efficient procurement guidelines)	363	202.2	4.9	1,017	14 %	4,858
Motivation of employees in energy saving behaviour	67	8.9	2.4	255	34 %	448

Table 5. Regression analyses with overall evaluation of energy audit as dependent variables using a stepwise linear regression model.

Dependent Variable		Overall evaluation of energy audit
		standardised regression weight β
Independent variables	Report comprehensive	.371**
	New aspects identified	.174**
	Sufficient length of audit	.192**
	Competent advice	.180**
	Comprehensive advice	.109*
R^2		.556
R		.751**
F		59.4

Dependent and independent variables were rated on a five-point scale, 1=negative rating, 5=positive rating.

Cells give βs, i.e. standardised regression weights, from final equation.

*Levels of significance are indicated as follows: ** - p<.001, * - p<.050*

R^2=variance explained; R=regression coefficient

Insignificant independent variables include: whether the audit … was complex; was well-priced; confirmed earlier expectations; identified immediate measures; needed adequate time effort; was sufficiently specific; report covered relevant topics; report was well structured; report was comprehensible; report was sufficiently extensive.

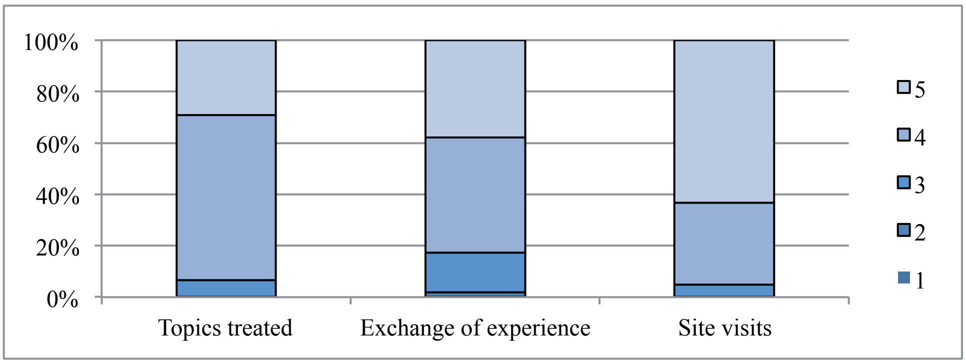

Figure 2. Subjective ratings on aspects regarding the network meetings from the third survey wave. 1=negative, 5=positive.

In the third wave of the survey, participants were asked to rate (1) the topics treated in the network meetings (2) the exchange of experience in these meetings (3) the site visits offered as part of the meetings. All three aspects were rated very positively, with site visits rated the highest (cf. Figure 2).

Furthermore, 59 % of the respondents reported that they are in contact with other network members outside the network meetings. Analysing an open question about the content of these discussions shows that they mainly concern specific technologies, with lighting being a significant topic as well as experiences with certain measures.

Participants were also asked whether their expectations from the network phase were fulfilled (cf. Figure 3). Aspects like identifying new ideas to reduce energy consumption and the exchange with other companies were ranked very positively.

This finding is also supported by the moderator interviews which indicate that the informal exchanges between network participants helped them a lot in making decisions:

> [The direct exchange about experiences] is the most important measure. […] If I [as a participating organisation] talk about topics within the network and if my network friend has already done it and is convinced about it, then it is not a sales event, but then he persuades me as an equal.

Discussion and conclusion

Energy efficiency networks are an increasingly important instrument to help organisations reduce their energy demand. In Germany, the federal government wants to establish 500 such networks. Some research has already been published on these networks and so far their success in improving energy efficiency has not been questioned. However, there has been relatively little research into how and why they work. This paper is a first explorative attempt to close this gap.

We draw on data from a pilot project in Germany which initiated and successfully managed 30 networks and included the collection of a rich data set on technical parameters (from energy audits and annual monitoring of measures taken), and social science approaches (three survey waves with the participating companies, interviews series with network initiators, consulting engineers, network moderators), and additional technical data from the Mari:e project.

We make three assumptions about why networks are successful which we try to explore in this paper: audits make profitable potentials visible; the joint network targets on efficiency and emissions increase the motivation of energy managers, decision-makers and other staff members; the meetings and site visits of the network participants act like an intensive training course to increase the knowledge of efficient solutions, change decision routines, and lead to trust among the participants. This last assumption is closely related to the expectation of reduced transaction costs through network participation. The topic of transaction costs has been explored by Mai et al. (2014) and is therefore only referred to but not discussed in detail in this paper.

The available data was then analysed to see whether it supported our three assumptions. It is important to note that this study is not a test of scientific hypotheses, but tries to identify which of these assumptions is worth investigating further in future research.

We find some support for the assumption that energy audits make profitable potentials visible. First of all, the technical data clearly show that relevant profitable potentials and corresponding measures could be identified in all participating companies, with an average of 20 measures per organisation – which is a higher number than in other programmes (cf. Fleiter et al. 2014). Secondly, this interpretation of visibility is supported by findings from the survey as well as the interviews. Thus, we assume that the visibility of profitable potentials is an important effect of the networks that should be explored further, e.g. by relating visibility with success indicators. It is important to note that identified potentials are not identical with realised potentials and never will be. Making them visible is a necessary first step to provide companies with a list of starting points that are worth pursuing. Overall, it is not realistic that all of the identified measures will be realised in the end, especially not within the lifetime of the network. Some have a longer implementation time and some do not make sense in the long run due to other restructuring processes within the company etc. Additionally, the monitoring results also show that companies sometimes engage in measures that were not part of the original list identified in the audit.

We also expected that the joint network goals would act as strong motivators. However, we found little support for this assumption and even some indications that difficulties in defining the goals counteracted their intended impact. As these were not unusual across the networks, it is possible that the network moderators and consulting engineers might not have focused enough on emphasising the goals during the network process in the pilot projects. This may be the reason why the goals could not fully develop their motivational potential. In any case, our data did not support our assumption. This does not mean that network goals are not important, but that our evaluation approach was not able to document it.

Finally, we find some support from the evaluation data that network participation resembles a training course in energy issues by increasing and confirming knowledge and thereby reducing the risks associated with energy efficiency decisions. To further develop the network concept, it is important to identify the most relevant network elements and how these can be optimised for maximum impact. A more thorough investigation of these topics could also contribute to defining minimum standards for efficiency networks.

References

Bell, M.; Carrington, G.; Lawson, R.; Stephenson, J. (2014): Socio-technical barriers to the use of energy-efficient timber drying technology in New Zealand. In: Energy Policy, 67, p. 747–755.

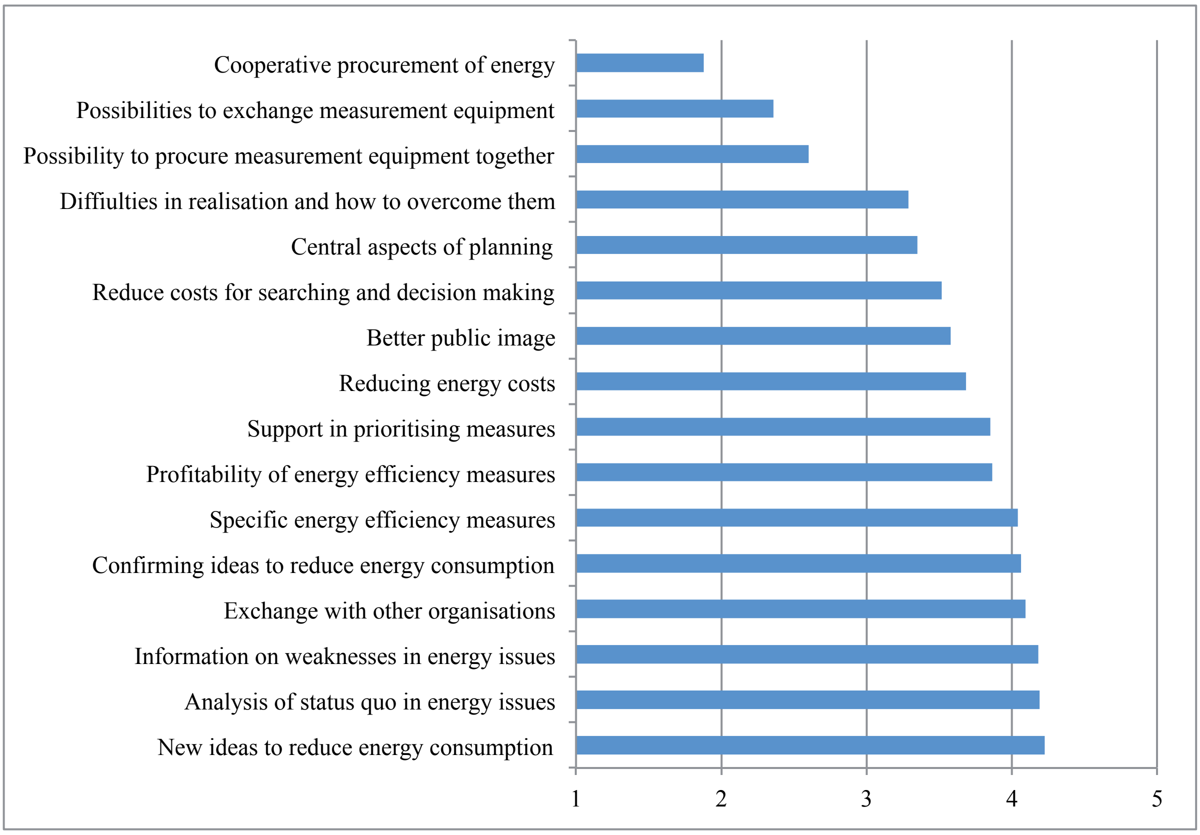

Figure 3. Subjective ratings on fulfilled evaluations by participating organisation in third survey wave. 1=not fulfilled, 5=perfectly fulfilled.

Bradke, H., Jochem, E., Mielicke, U., Ott, V., Mai, M., Köwener D., Idrissova, F., Weissenbach, K., Bauer, J., Meier, N., Hack, M., Diemer, R., Feihl, M., Bergmann, K., Berger, R., Ernst, C., Kubin., K. (2015): Lernende Energieeffizienz- und Klimaschutz-Netzwerke. 30 Pilot-Netzwerke und Entwicklung von Investitionsberechnungshilfen. Abschlussbericht an das Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit und an den Projektträger Jülich. Karlsruhe, Pfedelbach, Stuttgart, Berlin, 2015.

Brown, M. A. (2001): Market failures and barriers as a basis for clean energy policies. In: Energy Policy, 29, p. 1197–1207.

BMWi (Bundesministerium für Wirtschaft und Technologie) (2014): Mehr aus Energie machen. Ein gutes Stück Arbeit. Nationaler Aktionsplan Energieeffizienz. Berlin: BMWi.

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

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

Chai, K-H.; Yeo, C. (2012): Overcoming energy efficiency barriers through systems approach – A conceptual framework. In: Energy Policy, 46, p. 460–472.

Cooremans, C. (2012): Investment in energy efficiency: do the characteristics of investments matter? In: Energy Efficiency, 5, pp. 497–518.

European Commission (2003): Commission Recommendation of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises (Text with EEA relevance) (notified under document number C(2003) 1422). http://eur-lex.europa.eu/legal-content/EN/NOT/?uri=CELEX:32003H0361. Accessed: 13/06/2016.

Fleiter, T., Hirzel, S., Ostrander, B., Schleich, J., Schlomann, B., Mai, M., Gruber, E., Holländer, E., Roser, A., Gerspacher, A. (2014): Evaluation des Förderprogramms „Energieberatung im Mittelstand". Schlussbericht, im Auftrag des Bundesministeriums für Wirtschaft und Energie, Karlsruhe, Dezember 2014.

Fraunhofer ISI (2016) (ed.): Vergleich des LEEN-Netzwerkmanagementsystems für größere und kleinere Unternehmen/Standorte. Online: https://www.energie-effizienz-netzwerke.de/een-wAssets/docs/Vergleich-LEEN-und-Marie.pdf. Accessed: 13/04/2016.

Hutzschenreuter, T.; Kleindienst, I. (2006) Strategy-process research: What have we learned and what is still to be explored. Journal of Management, 32, 673–720.

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

Jochem, E., Gruber, E. (2007): Local learning-networks on energy efficiency in industry – Successful initiative in Germany. Applied Energy 2007 (84), p. 806–816.

Jochem, E., Mai, M., Ott, V. (2010): Energieeffizienznetzwerke – beschleunigte Emissionsminderungen in der mittelständischen Wirtschaft. Zeitschrift für Energiewirtschaft 2010 (34), p. 21–28.

Köwener, D., Jochem, E., Mielicke, U. (2011): Energy Efficiency Networks for companies – Concept, achievements and prospects. Belambra Presqu'ile de Giens: eceee Summer Study Proceedings, p. 725–733.

Köwener, D., Nabitz, L., Mielicke, U., Idrissova, F. (2014): Learning energy efficiency networks for companies – saving potentials, realisation and dissemination. Arnhem, Netherlands: eceee Industrial Summer Study Proceedings, p. 91–100.

Langlois-Bertrand, S.; Benhaddadi, M.; Jegen, M.; Pineau, P.-O. (2015): Political-institutional barriers to energy efficiency. In: Energy Strategy Reviews, 8, p. 30–38.

Leinweber, L., (2014): Clustering von Energieeffizienz-Maßnahmen aus der Monitoringphase im Projekt „30 Pilot-Netzwerke", Bachelor thesis, Hochschule Karlsruhe, 2014.

Locke, E.A., Latham, G.P. (2002). Building a practically useful theory of goal setting and task motivation: A 35-year-odyssey. American Psychologist, 57, 705–717.

Mai, M., Gebhardt, T., Wahl, F., Dann, J., Jochem, E. (2014): Transaktionskosten bei Energieeffizienz-Investitionen in Unternehmen. Eine empirische Untersuchung in Energieeffizienz-Netzwerken Deutschlands. Zeitschrift für Energiewirtschaft 38 (4), p. 269–279.

Meath, C.; Linnenluecke, M.; Griffiths, A. (2016): Barriers and motivators to the adoption of energy savings measures for small- and medium-sized enterprises (SMEs): the case of the ClimateSmart Business Cluster program. In: Journal of Cleaner Production 112, p. 3597–3604.

Ott, V.; Jochem, E. 2012: Monitoring – reine regelmäßige Reflexion auf dem Zielpfad. U*mweltWirtschaftsForum (uwf)* 20 (2012) 1, pp. 75–84.

Palm, J. (2009): Placing barriers to industrial energy efficiency in a social context: a discussion of lifestyle categorisation. In: Energy Efficiency, 2, p. 263–270.

Paramonova, S., Backlund, S., Thollander, P. (2014): Swedish energy networks among industrial SMEs. Arnhem, Netherlands: eceee Summer Study Proceedings, p. 619–628.

Richter R, Furubotn EG (2003) Neue Institutionenökonomik: Eine Einführung und kritische Würdigung. Mohr Siebeck, Tübingen.

Rohde, C., Mielicke, U., Nabitz, L., Köwener, D. (2015): Learning Energy Efficiency Networks – Evidence based experiences from Germany. Proceedings ACEEE Summer Study on Energy Efficiency in Industry, p. 1–12.

Sorrell, S.; Mallet, A.; Nye, S. (2011): Barriers to industrial energy efficiency: A literature review. United Nations Industrial Development Organisation. Development Policy, Statistics and Research Branch Working Paper 10/2011.

Sorrell, S.; O'Malley, E.; Schleich, J.; Scott, S. (2004): The Economics of Energy Efficiency: Barriers to Cost-Effective Investment. Cheltenham: Elgar.

Thollander, P.; Backlund, S.; Trianni, A.; Cagno, E. (2013): Beyond barriers – A case study on driving forces for improved energy efficiency in the foundry industries in Finland, France, Germany, Italy, Poland, Spain, and Sweden. In: Applied Energy, 111, p. 636–643.

Trianni, A.; Cagno, E. (2012): Dealing with barriers to energy efficiency and SMEs: Some empirical evidences. In: Energy 37, p. 494–504.

Wesselink, B.; Harmsen, R.; Eichhammer, W. et al. (2010): Energy Savings 2020. How to Triple the Impact of Energy Saving Policies in Europe. Online: http://www.roadmap2050.eu/attachments/files/EnergySavings2020-FullReport.pdf. Accessed: 13.04.2016.

Wohlfarth, K.; Eichhammer, W.; Schlomann, B.; Mielicke, U. (under review): Enabling informed decisions to target energy-efficiency potentials in companies.

Worrell, E.; Bernstein, L.; Roy, J.; Price, L.; Harnisch, J. (2009): Industrial energy efficiency and climate change mitigation. Energy Efficiency. 2: 109–123.

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