



Learning networks as an enabler for informed decisions to target energy-efficiency potentials in companies



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ABSTRACT

This paper deals with possibilities of targeting energy efficiency potentials in German companies by delivering information and support within a cooperative management system “Learning Energy Efficiency Networks” (LEEN). Information deficits are pointed out as a relevant barrier to implementing energy efficiency measures in literature that can be aimed at by energy programmes such as audits. Our concept combines aspects of cooperation, shared experiences and moderated learning processes. The programme sought to go beyond the sole provision of consultation, by qualifying companies to decide and act on implementing energy efficiency measures by delivering the individual practical know-how they need.

After having analysed evaluation data of several hundred companies, our results show that the participants were mainly motivated by the need for practical knowledge and specific information. The networks could well satisfy this need. The benefit for the participants in such delivered information was also reflected in the decreasing of the barrier of imperfect information and the programme enabled companies to make informed decisions on energy efficiency measures. But the gain of the programme was not solely restricted on an increase in knowledge: The majority of participants reported implementation of suggested measures, which would not have been implemented without the programme. Hence, LEEN can be indicated as a policy instrument enabling informed decisions on efficiency measures and supporting their implementation. Possibly tailoring the programme to different target groups and aiming at dismantling other barriers directly in addition to tackling information deficits could be undertaken to improve the process.

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1. Introduction and background

Increased concentrations of carbon dioxides and other greenhouse gases (GHG) in our atmosphere cause the occurrence of climatological changes (Thomas et al., 2004). Under the Kyoto Protocol, the European Union was committed to reducing GHG emissions by eight per cent from 1990 levels by 2012 (Vatalis et al., 2012). The threat of those changes directed the attention of researchers and policy makers to the issue of sustainability resp. low carbon transition (Markard et al., 2012). Low carbon pathways will

require fundamental changes in economies. Heading towards such a more sustainable energy system, a more efficient use of energy is seen as a cost-effective possibility to mitigate climate change and to contribute to enhancing supply security. But the changes cannot be reduced to technological innovations or policies – the whys, whats and the hows of expedient transformations have to be understood to upscale effects of promising practical measures.

Taking companies into the focus, a considerable potential can be expected, as industry still presents a share of about 28% in final energy consumption in Germany (UBA, 2014) and a little less with about 26% at the level of the European Union (Odyssee-Mure.eu, 2014). In emerging countries the share of industry is frequently the highest among all end-use sectors, for example in China it is about 51%, in India 34% (ENERDATA, 2014). Usually, remarkable cost-saving potentials can be identified for many energy-efficiency

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measures, as engineering-economic studies reveal (Blok, 2004; Granade et al., 2009; Worrell et al., 2009; Fraunhofer ISI et al., 2014; Ecofys and Fraunhofer ISI, 2010; Eichhammer, 2013). But obviously those potentials are by far not fully exhausted by companies despite the supposed high economic pressure to realize cost reduction and profitability of possible measures (IEA, 2012a). The difference between the cost-efficient energy saving potential and the actual adoption of corresponding measures has been named the “energy efficiency gap” (Jaffe and Stavins, 1994; Stern, 1992) and investigated by many researchers since then (for example Sorrell et al., 2004; Backlund et al., 2012). Thus, the existence of various barriers and uncertainties prevents companies from realizing those theoretical opportunities (Worrell et al., 2009). In recent years, unused promotional factors have been identified as an additional aspect (Jochem et al., 2014). Nehler and Rasmussen (2016) investigated the role of non-energy benefits that should also be taken into account when decisions on energy-efficiency investments are made. Besides the problem, that those benefits can often hardly be monetised, many firms lack knowledge of those additional gains. Additionally, those effects interact in complex ways and appear on different levels (IEA, 2012b).

Different typologies and reviews of barriers exist (e.g. Jaffe and Stavins, 1994; Hirst and Brown, 1990; Brown, 2001; Sathaye et al., 2001; Sorrell et al., 2004, 2011; or Cagno et al., 2013; Trianni et al., 2013a). One barrier of general importance for the process of decision-making is prevalent in literature (Gruber and Brand, 1991; Thollander et al., 2007; Schleich and Gruber, 2008; Schleich, 2009; Schröter et al., 2009; Trianni and Cagno, 2012; Cagno and Trianni, 2014) and its elimination seems more like a precondition for the decision to undertake a measure than a reason: lack of information.

Compared to the restructuring of financial allocation, technological conditions or internal organisational barriers, the supply with information is less invasive and can be delivered without obligation, which might make this barrier comparatively easy to reduce. Some studies have even highlighted a greater need to focus on information barriers than on economic issues (Trianni et al., 2013a; SPRU, 2000); above all, it is necessary for companies to make an informed decision anyway. This means that information might be a key to lower the threshold to comply with energy efficiency measures.

To overcome the barrier of imperfect information, Hirst and Brown (1990) suggest government-funded industrial energy programmes to increase energy efficiency in industry, but point out that information programmes might be appropriate for tackling many of the barriers discussed above as well. They also highlight that the absence of such information leads to greater perceived risks and might impede the adoption of efficiency measures.

Other studies have already investigated concrete instruments targeting the information barrier. General information campaigns usually induce higher awareness of energy efficiency, but they rarely end up by adopting efficiency measures, while local energy programmes containing company-specific information, ideally presented by trustworthy facilitators, are more successful in increasing the adoption of energy efficiency measures (Stern and Aronson, 1984).

The Australian EEAP (Commonwealth Government's Enterprise Energy Audit Programme) was a large-scale energy efficiency programme between 1991 and 1997, which offered energy audits at a 50% discount. Over 1000 firms, with an average of about 300 employees, participated and achieved an adoption rate of about 82% for the suggested measures (about six recommended measures per firm, Harris et al., 2000). Another large energy programme for

industry in the USA was the American Information Assessment Center's (IAC) programme, which offered energy audits for SMEs. Over 10,000 manufacturing firms participated and more than half of the recommended measures were implemented. Those measures which were not implemented were usually neglected for economic reasons (Anderson and Newell, 2004). This reason is in itself an obstacle, given the findings of Schröter et al. (2009) that 85% of companies base their decisions on energy efficiency investments with short term payback periods and do not consider profitability criteria. Fleiter et al. (2012) came to comparable results, analysing energy-efficiency measures in SMEs, that high investment costs still impede the adoption even for profitable measures. Considering that non-energy benefits are often overseen while deciding on energy-efficiency investments, Nehler and Rasmussen (2016) found profitability and payoff crucial criteria for adopting investments, too. Thollander et al. (2007) evaluated the Highland programme in Sweden funded partly by the European Union's programme *Objective 2 South Sweden*. This local energy programme included 340 energy audits in six municipalities, of which 139 audits were made in manufacturing companies and an adoption rate of about 40% for suggested measures was achieved. The evaluation indicates that the involvement of intermediates (e.g. local energy agencies or energy consultants) contributes to the effectiveness of such programmes but states that further work in order to improve the energy auditing procedure is suggested as an area for future research.

Our study aims at enriching the empirical basis of information barriers to energy efficiency in companies by making use of recent evaluation results of a new policy instrument introduced in Germany as a large pilot project between 2009 and 2014. This instrument are the “Learning Energy Efficiency Networks” (LEEN). These networks are one of the immediate actions within German Government's National Action Plan on Energy Efficiency (NAPE; BMWi, 2014). Therefore the success of this instrument in terms of overcoming informational barriers and thus initiating concrete energy efficiency measures in companies is also of high importance for the success of a new German energy efficiency strategy with regard to the industrial sector. Other instruments within the immediate actions for this target group have other focuses, like financial support or solely informational character (audits). Amongst the immediate actions, the networks are one of those with the highest expected savings. Around 75 PJ of energy savings per year are expected by the extension to 500 planned energy efficiency networks in 2020 (about 3% of total industrial energy use in Germany) and avoided CO₂ emissions of around 5 million tonnes (BmwI, 2014). The outcome of the networks running so far in Germany is that energy efficiency progress has doubled compared to the autonomous progress (that is, progress that occurs on average for non-participants; Klimaschutz.de, 2014). The transaction costs for the companies to undertake energy efficiency measures are lowered (Mai et al., 2014). This new policy instrument was originally developed in Switzerland in the late 1980s (Bürki, 1999, 1999; Kristof et al., 1999) and is now widely applied in Switzerland due to the possibility that companies can avoid the payment of the CO₂-surcharge (presently 60 € per tonne of CO₂), if they join an energy efficiency network (EnAW, 2014).

2. Focus and hypotheses

The idea of the networks is to target the idle potential for energy efficiency in medium-sized and large companies by cooperation on a regional level, focusing on the companies' own interest rather

than framework settings and regulations. Target agreements for energy savings as well as individual energy audits with direct involvement of companies concerning the collection of appropriate measures are part of the concept. However, the participants moreover benefit from systematic information, a quarterly exchange of experiences, site visits, and yearly monitoring over several years as well as the support of a network manager, a moderator and a consultant engineer who bring technological knowledge to the networks. Apparently, the LEEN are far more than an “audit programme”. Thus, one aim of the LEEN was to enable the participating companies to learn about given possibilities by exchanging of their experiences to make informed decisions and profit from synergies to make the implementation of energy-efficiency measures possible.

Additionally, the data collected during the network-phase, including surveys, allow a systematic investigation of the role of information, of the needs of participating companies, their effect on the barrier of lacking or imperfect information and the decision making routines concerning efficiency measures.

The hypotheses to be investigated in this paper are:

- (1) first that the participants' expectancies and needs can be met so that those informative voluntary networks can reduce barriers affecting the implementation of energy efficiency measures, especially information deficits;
- (2) second that the networks can overcome these informational barriers (besides others) and trigger companies to actually implement energy efficiency measures.

The methods we use to analyze the role of information in the decision making and routines of the companies are a factor analysis of the companies' expectations before entering the networks to clarify the dimensions of their motivation and t-tests to identify changes between the beginning and the end of the network phase, concerning experiences and their perception of barriers.

The paper is organized as follows: In Section 3 we provide a description of the basic evaluation study together with descriptive statistics and the methodological approach used in the analyses. The analyses results are presented in Section 4. In Section 5, we interpret and discuss these results. In the concluding Section 6 we derive some implications for further research and development of efficiency instruments.

3. Methods and data

3.1. Database – the LEEN

The recruiting of companies for the LEEN is done by the network operators (e.g. utilities, industrial associations and platforms, Chambers of Commerce and Industry, city governments, or consulting engineers) by information events or personal acquisition. They often draw on existing structures like environmental working groups, which offer easier access to potential participants or membership and sales structures of utilities or banks. There are presently two types of networks (1) for medium sized and large companies with yearly energy cost between 0.5 and 50 million €/a and (2) for small and medium sized companies with yearly energy costs between 30,000 and 500,000 €/a. This structure ensures that participation is profitable for the participating companies.

The focus of the energy audit and the information and exchange of experience is on a set of common cross-cutting technologies (technologies which are not limited to special industries, but applied across different sectors such as heat generation, electric

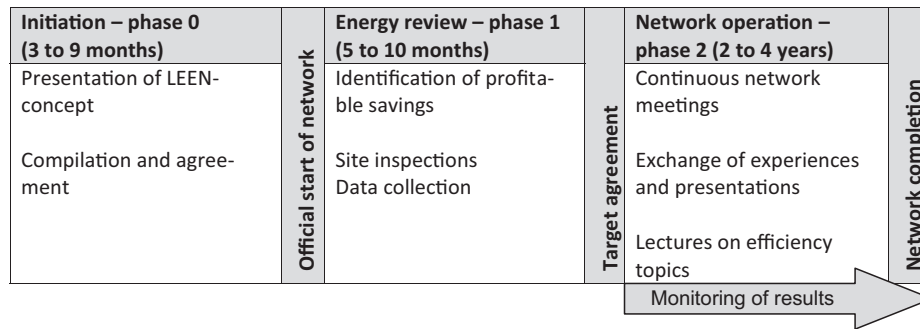
motors and their applications in pumps, ventilation, compressed air or cooling systems, heat recovery etc.) but also on organisational measures such as staff motivation, involvement of the energy manager in the tender process for new production machines etc. In order to secure an open exchange of ideas, plans and experiences the companies participating in the network should not be in competition with the same customer.

After an information event (phase 0), a consultant engineer analyses existing saving potentials by conducting an energy audit on the sites of the participating companies (phase 1, see [Graph 1](#)). The companies fill in a data form concerning their energy situation and the certified consultant engineer carries out the energy audit by means of a set of available electronic tools. On that basis the participants decide individually on an efficiency target (confidential) and commit themselves to a voluntary energy saving target of the network and regular exchange of experiences in groups of 10–15 companies for at least the next 3–4 years (phase 2).

A LEEN-certified moderator plans and conducts the meetings. All network participants report on planned or implemented measures so that the other participants can benefit from their experiences. This information exchange, which allows an exchange of experiences as well as mutual confirmation and appreciation, the site visits during the meetings, and the possibility to utilize synergies in the networks are central success factors for the concept ([Köwener et al., 2014](#)). This exchange is especially valuable as the provided information is presented by a colleague and not a sales representative or consultant ([Köwener et al., 2011](#)). Additionally, the peer pressure concerning the common network target promotes progress towards the common goal ([Jochem and Gruber, 2007](#)). These social-psychological effects facilitate the diffusion of energy-efficiency innovations as an informal competition in achieving energy efficiency progress among the companies and the energy managers can be observed ([Jochem et al., 2012](#)).

The companies pay a fee, which is used to finance the energy audit, the regular network meetings and the yearly monitoring, which accounts for up to 2/3 of the network costs (approximately €35,000 to €40,000 for a typical participant with annual energy costs of about €1 million to €2 million and four-year network operating period, [Köwener et al., 2011](#)). The success is measured through the annual monitoring and documented by the consultant engineer. Those results are fed back to the companies' management. Participation in the LEEN can also be used as preparation for the implementation of energy management systems, as some requirements of DIN 16001 or (today) ISO 50001 are met ([Di Nucci, 2012](#)).

The quantitative monitoring performed jointly by the energy manager and the consulting engineer came to the following conclusions and cover all results: the annual average efficiency improvement of all 366 companies was 2.1% ([Jochem et al., 2010; Köwener et al., 2014](#)). In comparison to the average energy efficiency progress attained by German industry as a whole, autonomous energy efficiency increases by approximately 1% per year ([Di Nucci, 2012; Schlomann et al., 2014](#)). In absolute terms this resulted in energy savings of about 5 PJ/a after 4 years of the duration of the 30 networks (in monetary terms: 72 million € energy cost savings per year). The investments involved were less than 200 million € over four years ([Jochem et al., 2014](#)). Moreover, when 100 efficiency measures were realized in the networks, about 60 new ideas for further efficiency measures were generated as a result of the increasing knowledge and competence of the participating companies and due to technical innovation reaching profitability. Furthermore, energy managers' knowledge enhanced due to the course of the intensive engagement within meetings and exchange



Graph 1. Procedure of the LEEN (illustration based on Rohde et al., 2015).

of experiences; it even led to suggestions and concise demands for improving the energy efficiency of machinery and plants of machine and plant manufacturers (Jochem et al., 2014).

The programme of the 30 pilot networks was funded between November 2008 and March 2014. The funding covered the cost of further developing of the LEEN management system, including 17 investment calculation tools for crosscutting technologies, the evaluation of the performance of the 30 networks with its 366 companies as well as public relations to report the successes to a broader audience of the German industry.

3.2. Methods

Our analyses rely on data from two of three sequential surveys, which were conducted within the longitudinal evaluation process of the programme and were filled in by a company representative who is familiar with energy issues. Questions on expectations on the coming process as well as the evaluation of specific elements, questions on companies' characteristics and structure and also attitudes and estimations of possible barriers towards energy efficiency were part of the inquiry. In this study we focus on issues within the first and the last survey, comparing the differences that occurred in the participants' reports as well as an assessment of the knowledgability and expectations the participants entered into the programme on the one hand, and the experience and reported efforts within the programme on the other hand. In detail, those topics are:

- Data concerning the company: independence of company (binary), estimated intensity of energy use (5-point scale), experience with comparable networks (binary)
- Rating (5-point scale) of expectancies (beginning)
- Rating (5-point scale) of fulfilment of expectancies (end of programme)
- Rating (5-point scale) of perceived barriers at the beginning and the end of the network phase

The first survey was carried out at the initial network-phase, mostly in the beginning of 2011, depending on when the network was ready to start. The last survey was conducted in the second half of 2013 for most of the companies.

In the following, we refer to those participants that filled in the first survey. For comparisons between the first survey and the one at the end, we limit the data to those participants, who completed both surveys. Analyses which refer only to data of the last survey were conducted with all participants' data available for that survey.

Our statistical analysis employs survey data relying on 366 companies (of the 30 networks) from the longitudinal evaluation of the networks. The number of companies that responded in the

second survey was thus lower than in the first survey (301 vs. 213 respondents of 366 participants in total). An analysis of the companies' businesses revealed that the participants are predominantly medium-sized and large firms from the manufacturing sector (75%, referred to respondents of the first survey), other groups (e.g. hospitals, large public and commercial buildings) of represented sectors are distinctly smaller. Their yearly energy costs range between 0.4 million and 50 million €. Very energy-intensive companies with energy cost shares of total production costs above 12% did not participate. The companies perceived their own energy consumption as "rather high" (rating of 3.7 on a scale from 1 to 5). Their energy intensity varies between the companies; regarding companies from the manufacturing sector, representatives with energy intense processes (like manufacturing of pulp and paper or chemical products) as well as lesser energy intense processes (like manufacturing of leather products or wearing apparel) are part of the sample.

Descriptive analysis is used to depict the results of interest, especially expectations and efforts of the programme rated by the participants. To analyze changes the programme was able to achieve, we used t-tests to illustrate differences that occurred between the beginning and the end of the programme. This concerns the comparisons of dimensions of expectations and the barriers perceived by the participants. Structuring methods like factor analysis were used to analyze connections between variables – specifically to describe the dimensions of expectations the participants had towards the programme. As the questionnaire contained a set of various possible expectations, we tried to condense those items into a smaller number of relevant dimensions to receive independent describing factors that contain correlating items. To find that underlying structure and to gain clearer parameters to describe our participants' expectations, factor analysis is a suitable, common method (for a critical investigation of the method, see Cureton & D'Agostino, 1983 or Bortz, 2010). We calculated a principal component analysis and extracted factors with an eigenvalue greater than 1 (Kaiser-criterion). To facilitate the interpretation of our factor solution, we used varimax rotation that maximizes variance between the factor loadings to get clearer distinctions between our possible factors. For our calculations we used SPSS 21.

4. Results

We first take a look at expectations before joining the network, which can be considered as motivations to take part, and subsequently compare the fulfilment of those expectations at the end of the network phase. We proceed similarly with the analysis of barriers hindering the implementation of efficiency measures and compare their perception at the beginning as well as at the end of network operations.

4.1. Expectations before joining the network

The participants were partially familiar with energy efficiency issues and had already implemented efficiency measures before the start of the network. For over half of the companies, energy savings have always been a relevant issue, according to their own declaration. 49% had received consulting on energy within the last 5 years. 18% of the companies already had experience of comparable networks on different topics (partially with energy aspects like ÖKOPROFIT or precursor projects, but also e.g. health management or specialists' networks). All companies voluntarily committed themselves to participating in the energy efficiency networks. Firstly, we had a closer look at the motivations and expectations with which the companies considered to participate. In order to get an idea of their anticipated benefits by joining an energy efficiency network, a first survey enquired about those expectations (see Table 1).

The five highest expectations (ranking 4.5 and higher) of the companies are the reduction of energy costs, followed by gaining new ideas, exchange of experiences in energy efficiency investments and organisational measures, information about specific measures or technologies and finding energetic deficits in their production sites.

Some participants used the “else”-category within the survey for own annotations on their expectancies towards the programme. 17 answers were given that way, e.g. expecting that contacts to other companies are established, comparisons to other companies and their energetic situation, meeting energy targets, or the preparation of certification or management processes.

The simple ranking of expectations (Table 1) leaves unclear which aspects are seen as related in the perspective of our participants and which ones were key to take part in an energy efficiency network. A factor analysis was carried out to reveal the underlying structures in the ratings of expectations indicated by the respondents. It converged in four factors consisting of co-occurring expectations (see Table 2).

Regarding those four dimensions, the expectations summarized under *practical knowledge and specific information* are ranked highest. The difference to the other dimensions is significant (compare Table 3, difference to next lower ranked dimension *decision support by experience*: $T(299) = 9,835$, $p < 0.001$, as well as the differences between each of the dimensions and the next lower ranked). The main motivations to take part in the networks are, besides the aim of reducing energy costs, to gather information about the energetic status on their production sites and to find suitable measures – the practical orientation (meaning implementations and actions and not only analyses and knowledge) is

obviously highlighted. Cooperation for common purchase of instruments or energy seem less important.

4.2. Meeting the expectations

In a second step, we turn our attention to the changes the networks were able to achieve: On the one hand concerning the satisfaction of expectations, on the other hand concerning the reduction of barriers, which had impeded energy efficiency measures so far.

Within the surveys, the expectations in the beginning were ascertained (see above) and again their fulfilment at the end of the programme. The participants gave their ratings on a scale of 1–5 for each expectation. For our comparison between the ratings in the beginning and in the end, these expectations were summarized into the dimensions drawn from the factor analysis of expectations (Table 2 above). A closer look reveals that concerning the dimension *practical knowledge and specific information*, expectations were fulfilled best, as it was ranked highest. The same dimension was ranked highest in the assessment of initial expectations (Table 3). The difference to the next-higher ranked dimension *decision support by experience* again is significant ($T(178) = 3,031$, $p < 0.05$). The differences between each dimension and the next lower one are again also significant.

To find out if the network participation came up to what participants expected, a comparison between ratings at the beginning and end of the programme was calculated for the four dimensions (see Table 3). The ranking of the dimensions' ratings is the same as in the first survey. As already spotted in the analysis of the first survey (pre), again the provision of practical knowledge and specific information is rated highest in the end (post). This means that this expectation is fulfilled best, but not as much as the participants anticipated in the beginning, as the significant difference between pre and post ratings show. The results show that the expectations regarding cooperation and image were ranked lowest, but were fulfilled as the participants anticipated them to be: There was no significant difference between the ranking of expectations and the ranking of the fulfilment of those expectations. All other expectations were a bit higher at the beginning (pre) than actually eventuated (post), although the general reported fulfilment of expectations in the end is rather high (minimum 2.99 on a scale from 1 to 5).

Regarding the single expectations *confirmation of own ideas*, *possibilities for cooperative purchase of measuring instruments*, *improvement of environmental image*, *information about profitability* show no significant differences between the ratings in the beginning (pre) and in the end of the programme (post), which means

Table 1
Assessment of expectations at the beginning of the programme (5-point Likert-scale).

Expectation	N	Mean	Standard deviation (SD)
Reduction of energy costs	278	4,79	,51
New ideas for reduction of energy costs	299	4,71	,52
Information about specific measures and technologies	299	4,57	,68
Information about energetic deficits	300	4,54	,61
Exchange of experiences	299	4,53	,70
Analysis of energy-related situation	289	4,39	,87
Information about profitability	300	4,36	,77
Support in priority setting of measures	287	4,20	,90
Reduction of transaction-costs (search and decisions)	285	4,15	,94
Confirmation of own ideas	299	3,97	1,00
Information about crucial planning aspects	300	3,86	,92
Information about difficulties in implementation	299	3,80	,99
Improvement of environmental image	275	3,76	1,13
Possibilities for exchange of measuring instruments	297	2,93	1,15
Possibilities for cooperative purchase of measuring instruments	299	2,91	1,18
Possibilities for cooperative purchase of energy	220	2,42	1,27

Table 2

Results of factor analysis (rotated, N = 210).

Items (expectation)	Dimension	Mean of scale (SD)
<ul style="list-style-type: none"> - Reduction of energy costs - Analysis of energy-related situation - Information about energetic deficits - Information about specific measures and technologies - New ideas for reduction of energy costs 	Practical knowledge and specific information	4.60 (0.45)
<ul style="list-style-type: none"> - Reduction of transaction-costs (search and decisions) - Exchange of experiences - Confirmation of own ideas 	Decision support by experience	4.22 (0.61)
<ul style="list-style-type: none"> - Support in priority setting of measures - Information about profitability - Information about crucial planning aspects - Information about difficulties in implementation 	Organization and implementation	4.05 (0.68)
<ul style="list-style-type: none"> - Possibilities for cooperative purchase of measuring instruments - Possibilities for exchange of measuring instruments - Improvement of environmental image - Possibilities for cooperative purchase of energy 	Cooperation and image	3.04 (0.90)

Bartlett's test on sphericity $\chi^2(120) = 1049.7$; $p < 0.001$; Kaiser-Meyer-Olkin measure = 0.815, which indicates our method as suitable (KMO > 0.8 stated as "merituous", Kaiser and Rice, 1974).

We assume that points on our scale are equidistant and can be treated as interval.

Component matrix with factor loadings see Table 5 in appendices.

Table 3

Comparison of expectations (pre = start of network) and their fulfilling (post = at the end of network)).

Dimension expectation	Mean (post)	Mean (pre)	Difference	SD	T	df	Sig
Practical knowledge and specific information	4.06	4.60	,54	,74	9734	177	***
Reduction of energy costs	3.70	4.84	1,14	1,10	12,91	154	***
Information about specific measures and technologies	4.01	4.60	0,58	1,12	6,85	172	***
Analysis of energy-related situation	3.86	4.38	0,51	1,10	6,03	167	***
New ideas for reduction of energy costs	4.22	4.69	0,47	0,99	6,31	175	***
Information about energetic deficits	4.20	4.59	0,38	0,94	5,36	171	***
Decision support by experience	3.93	4.22	,29	,85	4566	177	***
Reduction of transaction-costs	3.49	4.12	0,63	1,39	5,33	137	***
Exchange of experiences	4.12	4.54	0,43	1,04	5,37	170	***
Confirmation of own ideas	4.07	3.99	−0,08	1,11	−0,98	165	n.s.
Organization and implementation	3.62	4.04	,42	,86	6334	172	***
Information about difficulties in implementation	3.30	3.78	0,48	1,31	4,30	140	***
Information about crucial planning aspects	3.40	3.83	0,43	1,18	4,50	149	***
Support in priority setting of measures	3.81	4.16	0,35	1,36	3,24	161	**
Information about profitability	4.18	4.35	0,17	1,22	1,83	167	n.s.
Cooperation and image	2.99	2.93	−0,06	1,26	−,556	142	n.s.
Possibilities for exchange of measuring instruments	2.41	2.95	0,54	1,52	3,20	81	**
Possibilities for cooperative purchase of energy	1.89	2.37	0,48	1,61	2,18	52	*
Possibilities for cooperative purchase of measuring instruments	2.63	2.89	0,26	1,42	1,71	84	n.s.
Improvement of environmental image	3.62	3.76	0,14	1,48	1,04	120	n.s.

Levels of significance: $p < 0.05^*$, $p < 0.01^{**}$, $p < 0.001^{***}$, n.s.: not significant.

that they were fulfilled the way the participants expected. In contrast, *reduction of energy costs* shows the most considerable difference between expectations in the beginning and their fulfilling at the end. Compared to items belonging to other dimensions, those belonging to dimension 3 achieve lower significance levels concerning the differences between ratings.

4.3. Overcoming the barriers

In the last sections, we considered if expectations could be fulfilled showing that the participants' needs to implement energy efficiency at their production sites were met. Considering barriers, we expect that their perception changed in the course of the programme, especially regarding information deficits, as the need for information was well satisfied in accordance with the participants' expectations.

Table 4 shows a direct comparison between the reported

barriers that existed or were expected in advance of the programme (pre) and those which were perceptible during and at the end of the programme (post). Because of the multitude of comparisons between the 11 items, a conservative assessment of the significance levels is done to avoid alpha inflation (alpha after Bonferoni-correction: 0.0045), that is why only highly significant differences are interpreted as substantial results.

Thus, the barriers *only small share of energy costs in production costs* and the barrier *missing information or market overview* have changed during the programme: While the first one increased due to more awareness of this obstacle, the latter decreased as a consequence of the meetings and site visits. The reduction of the information deficit and lack of market overview should be considered as a positive assessment of the energy managers as they felt better informed about the possibilities of energy efficient solutions, one of their major motivations to join their network (see Table 2, factor 2).

Table 4
Change of perception of barriers (beginning versus end of network operation).

Barrier	Mean (pre)	Mean (post)	N	Difference	T	df	Sig.
1. Concerned parties lack of time	3,28	3,44	174	−0,16	−1,52	173	n.s.
2. Measures not profitable	3,19	3,12	172	0,07	0,59	171	n.s.
3. Narrow financial possibilities	3,02	3,31	121	−0,28	−2,25	120	*
4. Missing energy management	2,78	2,44	171	0,33	2483	170	*
5. Difficulties in implementation	2,71	2,77	176	−0,06	−0,578	175	n.s.
6. Staff hard to motivate	2,70	2,59	175	0,1	0,943	174	n.s.
7. Missing information or market overview	2,62	2,03	173	0,59	5469	172	***
8. Departments hard to convince	2,42	2,35	178	0,06	0,583	177	n.s.
9. Only small share of energy costs in production costs	2,17	2,62	169	−0,44	−4057	168	***
10. Management hard to convince	1,89	2,15	179	−0,26	−2622	178	*
11. Manufacturer can't deliver	1,74	1,73	128	0,01	0,081	127	n.s.

Levels of significance: $p < 0.05^*$, $p < 0.01^{**}$, $p < 0.001^{***}$, n.s.: not significant; Table sorted by initial ratings (pre).

4.4. Implementation of energy efficiency measures

The mere reduction of the barriers' size does not yet guarantee that energy efficiency measures are implemented. The success of the energy efficiency networks in terms of real energy savings, however, depends on the implementation of such measures. Therefore, the last step of our analysis was dedicated to the actual energy efficiency measures the participants reported to have implemented.

At the end of the programme, almost 96% ($N = 212$) of those participants that filled in the last survey, reported that they implemented the suggested energy efficiency measures drawn out of the network process. This is considerably higher than the percentages reported in the introduction on the fulfilment of energy audit recommendations (cp. Gruber et al., 2011: 53% resp. 77% if planned measures are included). 75% ($N = 208$) reported that a part of those measures would not have been implemented without the networks. As stated above, this led to an annual average improvement of efficiency of 2.1% (compared to 1% autonomous improvement) and resulted in about 5 PJ/a energy savings after 4 years.

In addition to that, about 75% of the participants rated the benefits of network participation as “rather high” or “very high”, while about 73% evaluated the expenditure of time required for network participation as “low” or “rather low”.

5. Discussion and conclusions

In line with our hypotheses, our results show that the participants of the LEEN are satisfied with their participation in their network as demonstrated by the high ratings for the fulfilment of their expectations. Especially their requirement for practical knowledge and specific information they needed to implement efficiency measures was met. The respective barriers of imperfect information and lacking market overview decreased. Most of the participants implemented measures that would not have been carried out without the networks. Thus, they were able to overcome other important barriers (like missing energy management, narrow financial possibilities or difficulties in implementation) while the perception of those barriers did not necessarily decrease. The matching of the programme to participants' needs seems to be a key success factor of the concept of the Learning Energy Efficiency Networks.

The results show that participants focused on practical information and support, less on organisational aspects. We interpret that the intensive processual supervision over 3–4 years and access to practical experience was the additional value seen in the participation in the networks, especially compared to other informative, more isolated one-time consultation like in energy audits, conferences, or individual workshops. Some experiences at the end

were somewhat lower than the expectations. The reason for this change remains open as the answer could signal successful exchange of experiences during the meetings and site visits leading to even higher expectations or some resignation caused by internal obstacles such as narrow financial possibilities and management who was hardly convinced (see Table 4, No. 3 and 10). If they come up with additional energy efficiency investments, it is quite likely that it is harder to convince the management and the obstacle of limited financial possibilities becomes even more evident, particularly if those investments are financed by cash flow and not by additional credits. This goes in line with the findings mentioned above, that profitability and investment costs are focused when deciding about the implementation of energy-efficiency measures (Fleiter et al., 2012; Trianni et al., 2013b; Nehler and Rasmussen, 2016).

The barrier of a small share of energy costs in production costs increased. This share is between 0.7% in car manufacturing to 2.4% in metalworking and up to 8% in branches with heat and surface heat treatment (DESTATIS, 2014). Usually such small shares in production costs are common when energy efficiency has a low priority (Fleiter et al., 2012). Of course saving energy decreases energy costs, but the effect on the relation to total production costs is very small and energy efficiency is not considered to be a strategic investment (Cooremans, 2013). Harris et al. (2000) and Cooremans (2013) argue, that energy efficiency is often overlooked in companies because it is not “core business”. Often energy-efficiency investments do not exist as an investment category, which makes them generally perceived as weak strategies by companies and therefore upper management is not interested in the investment project (Cooremans, 2013). To support the energy managers' additional financing possibilities (e.g. contracting, efficiency funds, crowd financing) could be developed as part of a new efficiency policy programme, to target financial restrictions. Emphasizing the high profitability of energy efficiency solutions may help to convince the management. In fact, recent analyses of the energy efficiency networks have already revealed that more than half of identified possible efficiency measures (3.600 of 7.000) were classified as profitable ($IRR > 12\%$). Although low investment measures are those most frequently proposed (Roser et al., 2014), for each company an energy saving potential of about 2700 MWh on average was identified, while the most profitable investments were expected in the areas of compressed air and electrical devices (Köwener et al., 2014).

As all companies implemented profitable measures suggested by the consulting engineer or one of the colleagues during the meetings, one can also reinforce the observation that further profitable options of energy efficiency investments and organisational measures beyond the already implemented measures do exist. Compared to other programmes, LEEN have achieved

remarkable adoption rates of energy efficiency improvements (see chapter 5.4).

However, the perception of a barrier is an evaluation based on subjective information – and the level of information of the energy managers may have changed during the programme. This explains that the participants became more aware of the relatively low cost shares in production costs as an obstacle which also is reflected by increasing difficulties to convince the management in contrast to a slight improvement to convince the department (see Table 4). This prompts that different barriers have more or less influence on implementing measures, depending on the stage of decision making. Studies of Trianni et al. (2016) and Cagno et al. (2014) investigated that and found that barriers and drivers vary along the decision-making process of the adoption of energy-efficiency measures. It can be expected that the participants may have become sensitized by the involvement with those issues, which raised awareness for the barriers and therefore might have influenced the perception of their existence. Such sensitizing effects are a familiar issue in test theory, impairing internal validity of the analysis. A distinction between sensitizing effects and changes in companies' situations cannot be drawn on the basis of our questionnaires, but should be kept in mind for further research. Trianni et al. (2013c) dealt with that issue of perceived and real barriers investigating on energy efficiency in SME. For future network activities it may be very important that the management of a participating company is regularly informed by the energy manager and the consulting engineer taking the yearly monitoring results which can be a good occasion for a review meeting.

Interestingly, barriers are rated lower on average than expectations; this could reflect that for the participants, incentives such as high profitability or green image generation predominate despite the barriers.

We stated the information barrier/lack of market overview as one major obstacle to be reduced by energy efficiency networks. We would have awaited or at least hoped for developments in the networks that positively influence the decrease of other surveyed barriers, too – which did not occur at a first glance. Looking at the monitoring data, intensive implementation of efficiency investments and reduced energy cost can be found which occurred mostly as a consequence of the networks, as stated by the participants.

One might hypothesize, that barriers do not necessarily need to all be simultaneously reduced, but can be often overcome for other reasons – maybe due to an informed decision, an upcoming competition among the network participants, or the present low level of interest rates. Furthermore, the implementation of some measures – e.g. additional small investments within a re-investment or organisational measures – may have even been that unexpectedly uncomplicated that they could be performed despite the perceived barriers. To check those assumptions, additional research should consider a deeper analysis of conducted measures, reasons for decisions and circumstances of their implementation.

Further research might take a closer look at the characteristics of those companies that named specific barriers as persistent, which might help to find target groups for corresponding offers. Like this, specific measures or technologies could be tailored to the specific problems and needs of the types of companies. In particular because we expect different barriers to be prevalent for different kinds of companies, as the work of Trianni et al. (2016) suggests, this might be an insightful attempt. Former research revealed that barriers to energy efficiency depend on factors such as company size, capital owners, energy intensity, management preferences,

and high transaction costs (Jochem et al., 2014; Fleiter et al., 2013; Trianni et al., 2016). Mai et al. (2012) found that especially lesser energy-intensive SMEs face more barriers than other companies. Notably smaller enterprises (SMEs) tend to have lower priority on energy efficiency issues (Cagno et al., 2010) and face more barriers (Fleiter et al., 2012). Schlomann and Schleich (2015) found company's characteristics influencing adoption of energy efficiency measures within the tertiary sector, but on the other hand little influence of sectoral heterogeneity on the adoption of low-cost energy efficiency measures. Suchlike differences apply to different measures, as Trianni et al. (2014) and Cagno and Trianni (2014) found barriers to vary according to the considered technology.

On the basis of this analysis of the questionnaires, we cannot answer the question if some of the participating companies with special characteristics benefit more than others from their participation. Roser et al. (2014) concluded that efficiency potentials through organisational measures depend on the energy intensity or the size of companies. Ownership of the company as well as the kind of sector (e.g. relatedness to the final customer) or internal circumstances (like routines of making decisions on investments or share of energy costs) also influence the realization of efficiency measures (IREES, 2015). First analyses led to the conclusion that lesser informed companies would reach the same or even better results in such energy efficiency networks and especially benefit from experiences and expertise of peer companies within the networks (IREES, 2015).

Furthermore, the participants joined the programme voluntarily and some even already had energy audits before they joined their network. Because of that motivation and preparedness of most participants, the results are not representative for all companies of the branches represented by the 366 companies in the 30 networks.

Our sample consisted primarily of medium-sized and large firms of the manufacturing sector (cp. Section 3.2). This means that a generalization of highly energy-intensive branches or small companies should be avoided. One of the recommendations (Di Nucci, 2012) was to examine if the concept of the energy efficiency network can be extended to smaller companies with yearly energy cost far below 0.5 million € per year. This extension was started in 2012 within the Foundation of Resource Efficiency and Climate Protection (2015) as a first pilot project in this target group.

Due to the lack of a systematic experimental design with control groups, the effects achieved during the programme cannot be broken down or traced back to single influencing factors and their impacts. Anyway we assume that especially the network as a local or regional entity exchanging company-specific information and involving facilitators (consulting engineers and moderators) made the effectiveness (compare Stern and Aronson, 1984). This suggests that this combination of informative, supporting, cooperative, involving, and monitoring elements of the concept of LEEN makes them a successful instrument targeting existing profitable efficiency potentials in industry, but also in trade, commerce, and crafts.

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Appendix

Table 5

Rotated matrix of components for factor analysis on expectations.

Item (expectation)	Extracted factors			
	Organization and implementation	Practical knowledge and specific information	Cooperation and image	Decision support by experience
Reduction of energy costs	–,081	,738	,175	,117
Reduction of transaction-costs (search and decisions)	,099	,348	,038	,442
Analysis of energy-related situation	,460	,533	,151	–,115
Support in priority setting of measurements	,624	,354	,177	–,084
Information about energetically deficits	,307	,618	,095	,043
Information about specific measures and technologies	,393	,708	,101	–,009
Information about profitability	,715	,220	,116	,035
Information about crucial planning aspects	,833	,045	,156	,165
Infos about difficulties in implementation	,677	,076	,187	,315
Exchange of experiences	–,060	–,008	,097	,783
Confirmation of own ideas	,350	–,007	,114	,558
New ideas for reduction of energy costs	,060	,564	–,025	,441
Possibilities for cooperative purchase of measuring instruments	,219	,020	,840	,153
Possibilities for exchange of measuring instruments	,155	,134	,853	,129
Improvement of environmental image	,075	,096	,409	,340
Possibilities for cooperative purchase of energy	,135	,159	,747	–,078

Method of extraction: principal component analysis.

Rotation: Varimax with Kaiser-normalization.^a

This table shows the factor loadings for each item. Highest loadings are highlighted in bold and are the basis for the allocation of items to the underlying factors. The names of the factors more abstractly describe the items which are included in the factor.

^a The rotation converged in 9 iterations.

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