NON-PEER-REVIEWED PAPER

Organisational energy-efficient measures in industry – a neglected energy saving potential

Dr. Annette Roser
Institute for Resource Efficiency and Energy Strategies
Schoenfeldstr. 8
DE-76131 Karlsruhe
Germany
a.roser@irees.de

Farikha Idrissova
Institute for Resource Efficiency and Energy Strategies
Schoenfeldstr. 8
DE-76131 Karlsruhe
Germany
f.idrissova@irees.de

Edith Hollaender
Institute for Resource Efficiency and Energy Strategies
Schoenfeldstr. 8
DE-76131 Karlsruhe
Germany
e.hollaender@irees.de

Ursula Mielicke
Fraunhofer Institut für System- und Innovationsforschung (Fh-ISI)
Breslauer Straße 48
DE-76139 Karlsruhe
Germany
Ursula.Mielicke@isi.fraunhofer.de

Keywords

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Abstract

Energy efficiency in industry is largely linked to investment measures. Measures at the organisational or behavioural level are often neglected. The aim of this paper is to demonstrate the potential of organisational measures for energy saving and their cost effectiveness. The paper is based on the results of the public funded *30 pilot networks project.* These networks comprise 366 industrial companies in Germany. During an initial consultation phase, 7,759 measures were identified and analysed in relation to their energy saving potential, greenhouse gas (GHG) reduction effect and economic profitability. About 13 % of these measures are classified as organisational and the correlation between organisational measures, sectors and company sizes are provided and discussed in this paper. Examples include the implementation of an energy management system, automatic and non-automatic switch off of unused equipment and machines, procurement guidelines and staff training on efficient energy use. The paper brings together the potential for organisational energy efficiency measures in large-scale industries and the service sector for different types and categories of companies.

Introduction

In order to tackle climate change (and to achieve sustainable economic growth) the reduction of worldwide energy demand along with the mitigation of energy-related CO_2 emissions are essential. Global science institutions suggest several approaches and technological paths that have one thing in common: the significant relevance of energy efficiency (International Energy Agency [IEA] 2013b). Furthermore energy prices for both oil and natural gas are expected to rise in the long term. This factor, combined with the price volatility of energy carriers, puts the subject of energy efficiency at the top of the political and economic agenda (IEA 2013a).

In Germany, energy efficiency represents one of the main pillars of the energy system transition (Federal Ministry for Economic Affairs and Energy, Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety 2012). There is an ambitious target of an 80 % reduction of greenhouse gas (GHG) emissions between 1990 and 2050 in Germany. This is a major challenge that covers a broad cross-section of policies and includes all sectors of economic life.

The German industrial sector with its 29 % contribution to final energy consumption in 2012[1] is an important one. The reduction of final energy demand through more efficient energy use is therefore one of the most cost-effective options for German industry (Jochem et al. 2010).

CURRENT STATE OF RESEARCH

Schröter and colleagues (2009) demonstrate that there can be an energy saving potential, from production, of up to 20 %. Their study is based on a survey of estimated energy saving potential from 15,576 companies. The awareness of existing energy efficiency potential is essential in order for a company to proceed with the identification of specific organisational and

1. http://www.ag-energiebilanzen.de/DE/daten-und-fakten/energieflussbilder/energieflussbilder.html (checked on 24/1/2014).

technological energy efficiency measures. In most cases German companies are quite aware of their energy saving potential: almost half of the companies estimated it to be between 1 and 10 %, regardless of company size. Some companies indicated a potential saving of up to 20 %.

The proportion of energy costs to total costs differs between industrial sectors. Schröter and colleagues (2009) demonstrate that the lower energy intensive sector in particular (e.g. motor vehicle construction, mechanical engineering and electrical industries) has an energy saving potential of at least 10 % to 20 % still available. Energy intensive sectors where the energy costs are considerably higher have already made efforts to implement energy efficient measures. Therefore the maximum available energy efficiency potential for these industries is estimated to be 10 %. The same study has examined the implementation of environmental management systems (ISO 14031). At least 17 % of the evaluated companies have already implemented such standards.

Studies in this area mainly focus on technological measures (cross-cutting or process technologies). Organisational measures, including behavioural aspects and their respective energy saving potentials, are not in the scope of research (Schröter et al. 2009; Hesselbach et al. 2009; Schlomann et al. 2011; Jochem, Gruber 2007).

Cost effectiveness is a matter that has to be considered in the decision-making process. Therefore the total costs over the life cycle of a product or a management measure are as relevant as the investment costs (New Zealand Government [NZG] 2013). Many companies calculate and take decisions based only on the payback method (Blesl, Kessler 2013). However, companies that use the life cycle costs calculation method/model are more likely to invest in energy efficiency measures (Schröter et al. 2009).

Data

The German Federal Ministry for Environment has financed a project on learning energy efficiency networks in industry. Companies participating in energy efficiency networks gather data on their energy consumption, identify savings potentials, implement energy efficient measures and exchange their experiences. The networks connect companies at the regional or local level and can be characterised as industrial self-organisation. The regular and moderated exchange of experiences aims to reduce transaction costs and increase effectiveness and productivity. An existing network management system, the LEEN standard (LEEN® Local Energy Efficiency Networks) has been developed in order to guarantee a minimum standard for the networks' structure and operation (Jochem, Gruber 2007).[2]

Consultant engineers within the networks carry out the initial consultation in the participating companies, based on data collected by the company itself. These engineers analyse the data in detail and estimate the energy saving potentials. Then they suggest energy efficient measures at a technical and organisational level and calculate their cost-effectiveness. This paper analyses these data collected from about 366 companies within the 30 pilot networks from the first phase of the networks. Together with the initial reports, their suggested organisational measures and expected energy saving are examined. The proposed measures consider investment costs, life cycle assessment, energy savings and GHG-emission reduction. In order to evaluate the investment, the internal rate of return, static and dynamic payback period and the net present value are also compared. At the company level, there is information on the total energy demand, the total energy costs and the total greenhouse gas emissions as well as the branch (NACE-code) and the company size.

The original dataset contains 7,984 measures in the described 30 networks, comprising measures at the technical and organisational level. As the networks include companies from different industrial sectors, only cross-cutting technologies are proposed and discussed within the networks. A total of 1,584 organisational measures remain once the database is reduced as described below (20 % of all proposed measures).[3]

The 366 companies considered in this analysis belong to 50 different industrial branches. For the analysis we compare three categories of sectors: *energy intensive industry*, *less energy-intensive industry* and companies which belong to the *service sector*. The *energy intensive industry* comprises mining for coal, quarrying of ornamental and building stone, manufacture of pulp, coke, chemicals, rubber and plastic products, basic metals and other non-metallic mineral products. The *less energy intensive industry* includes the manufacture of food products, beverages, textiles and products of wood and cork, printing and reproduction of recorded media, manufacture of basic pharmaceutical products and fabricated metal products, electricity, gas, steam and hot water supply, waste collection, treatment and disposal activities; materials recovery, site preparation, construction. Examples for the *service sector* are wholesale and retail, warehousing and support activities for transportation, hotels and restaurants, information service activities, financial intermediation and service banks, activities of head offices, architectural and engineering activities, education, health and social work. Most of the companies in the database belong to the industrial sectors (Figure 1) but differ in size (Table 1). The greatest proportion comprises medium sized companies.

Organisational measures

Organisational measures for energy efficiency need to be differentiated from technical measures such as insulation of the building's envelope, the replacement of a heating system, investment in energy-efficient equipment or the change of an energy carrier (e.g. from oil to gas). In general, organisational measures require little or no investment as they relate to a different handling of equipment or a change in behaviour of the employees.

To enable comparison, we classify the measures into three clusters and 10 categories. The clusters are: *low-investment measures*, measures regarding behavioural aspects or *setting adjustments* and *management measures*.

Low-investment measures are measures that can directly increase energy efficiency through little investment. These include:

2. For more information visit the project's homepage: www.30pilot-netzwerke.de and www.leen.de.

3. Status: November 2013.

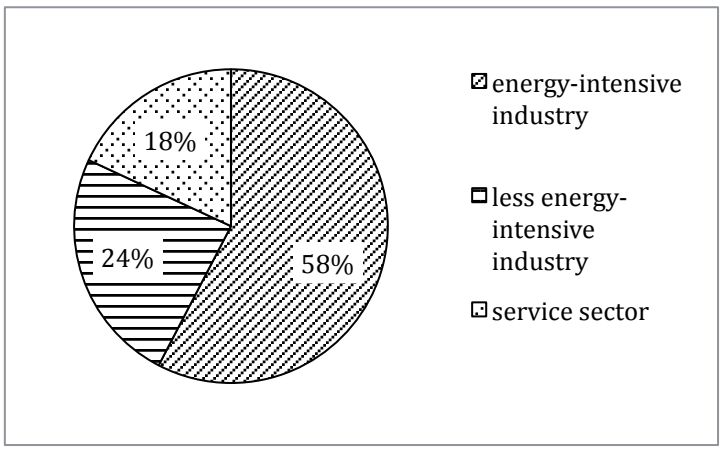

Figure 1. Distribution of the companies by industrial sector (N=354, 12 Missing).

- Insulation: the insulation of pipes, fittings and devices. These types of measures have a high energy saving potential.
- Free cooling: the difference between outdoor and indoor temperature can be used to cool rooms with almost no energy consumption. Sometimes existing equipment can be used, sometimes a little investment is necessary to automate this process.
- Leakage detection: a regular control detects and quantifies leaks so they can be eliminated. This is particularly relevant to the efficient running of technical equipment but it is often overlooked.

Another measure to increase energy efficiency in companies is to optimise the setting of control systems (machine settings, temperature settings etc.) with almost no investment (*setting adjustment*). This can be achieved as follows:

- Automatic and manual switch off of unused equipment: in many companies, electrical devices and appliances are not switched off when not in use; they remain in an active or passive standby mode. This might be office equipment, technical equipment, lighting, or heating etc. In some cases, there is even a consumption of energy when the device has been switched off (off-mode electricity) and they have to be disconnected from the grid before electricity consumption ceases.
- Pressure reduction: the adjustment of the operating pressure for compressed air and vacuum systems can improve efficiency. Compressed air is the most expensive energy carrier and is used in nearly every field of production.
- Temperature adjustment: in many cases the temperature is higher in heated areas or lower in air conditioned areas than necessary (e.g. in server rooms) and an adjustment can significantly contribute to energy efficiency.

The above mentioned measures have a direct effect on energy efficiency. But there are also indirect measures which only have an effect if they lead to specific actions. These are *management measures* and examples include:

- Energy control/energy management: exact consumption recording and billing of energy consumption can raise awareness of the responsibility of employees and is therefore an essential prerequisite for achieving energy efficiency goals in a company. Major electricity consumers can be detected and improvements made to increase energy efficiency.
- Procurement guidelines of energy-related equipment: new machines and systems should be assessed according to their energy consumption.
- Staff training: the every-day actions of employees might have an energy saving potential that should be considered. Employees should be trained in careful handling of equipment and general awareness of energy issues and specific demonstrations may lead to more energy efficient behaviour.

Table 1. Companies by size.

N (companies by size)	Company size (cluster)	Company Size (employees)
63	Small companies	Up to 50
		50–99
165	Medium sized companies	100–249
		250–499
122	Large companies	500–1,000
		More than 1,000
350		Total
16		Missing Values

There are several measures which cannot be categorised because they occur only once in the database or they have not been specified in detail. These include, for example, reducing the quantities of cooling water, closing rolling doors during winter and the exchange of several private coffee machines for a central one. A special case is the so-called "green IT" measure. This means, for example, the configuring of a computer to systematically shut down when not in use. The use of cloud computing and virtual servers in place of running several servers can also reduce energy demand. Overall about four organisational measures per company were proposed by the energy consultants (ranging between one and 14 measures per company).

Figure 2 shows that the measures proposed are quite evenly distributed as a proportion of all organisational measures. Several proposed measures were classified as 'others' which will not

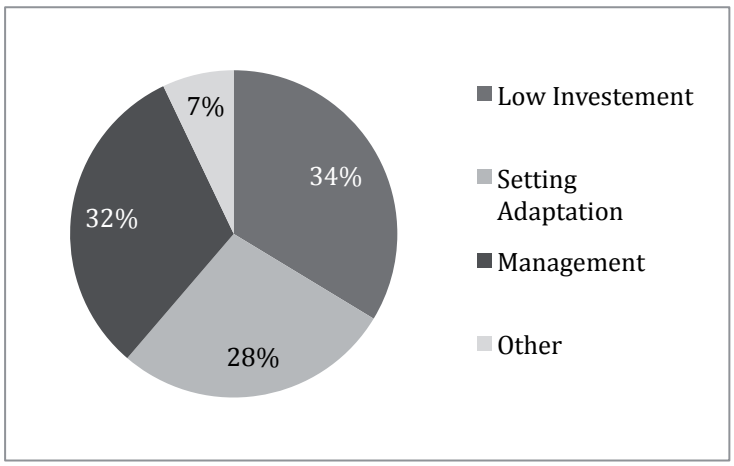

Figure 2. Distribution of the proposed organisational measures within clusters (N=1,583).

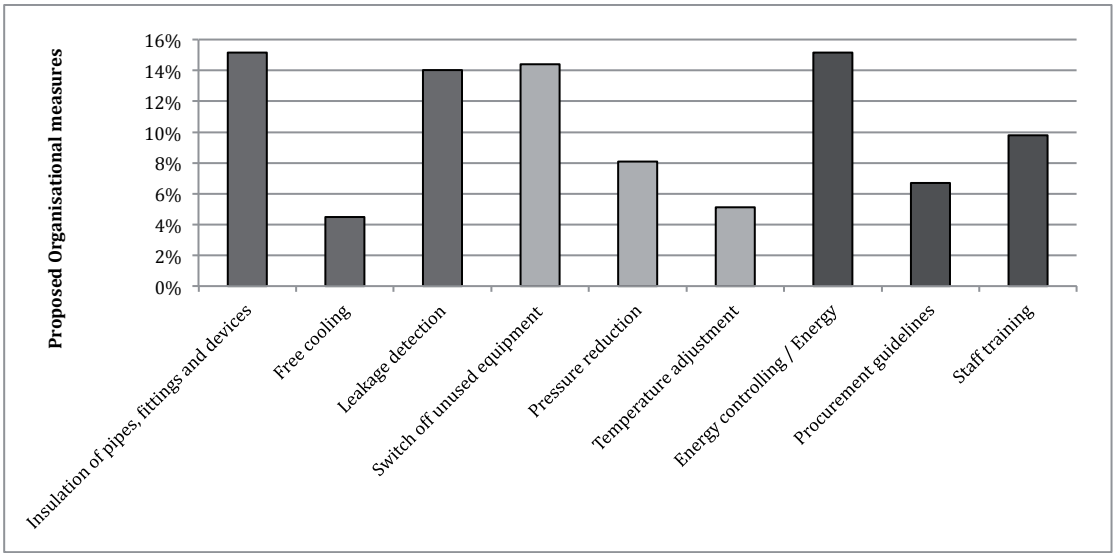

Figure 3. Distribution of the proposed organisational measures by category (N=1,583).

be further considered in this article. Figure 3 shows that insulation measures and leakage detection dominate *low investment measures* while the predominant measure within the *setting adjustment* cluster is the switching off of unused energy-related equipment. Of the *management measures*, the installation or improvement of energy controlling systems is the most highly recommended.

Table 2 shows that there are most measures in the less energy-intensive industries (51.0 %) and fewest in the service sector (7.2 %). This distribution is not surprising because more than half of the companies included are lower energy-intensive industrial companies, while 37 % are from the energy-intensive industrial sector and just 9 % from the service sector (Figure 1). The distribution of measures over the clusters is fairly even within both industry sectors, while the service sector stands out as being dominated by *management measures*.

In summary, *low investment measures* are those most frequently proposed (Figure 4), within which, free cooling measures occur relative rarely. Insulation of pipes, fittings and devices is surprisingly common in the service sector (20 % of all organisational measures). A closer look at the *setting adjustment* measures shows that switching off unused equipment it is more often recommended in the industrial sectors than in the service sector. Temperature adjustment was proposed just once within the service sector, whereas in the industrial sectors this measure accounts for about 16 % of the organisational measures. Within *management measures,* energy control is cited more often than measures such as working out of procurement guidelines or offering a staff training to raise awareness for energy efficiency.

Company size was also considered (Figure 5). For small companies up to 100 employees *management measures* are more often proposed. For medium-sized companies (100–500 employees) *low investment* and *setting adjustment measures* are preferred. In large companies (more than 500 employees), low investment measures are suggested more often than in small and medium sized enterprises.

ENERGY SAVING POTENTIAL

For some measures, however, no data on investment or energy and cost saving was available. Once we reduce the database for these items, a dataset of 901 organisational measures remains in 305 companies.

Table 2. Proposed organisational measures (cluster) by industrial sector.

Cluster/Sectors		Energy-intensive industries	Less energy-intensive industries	Service Sector	Total
Low investment	N	190	216	27	433
	% in sector	34.7 %	32.7 %	28.7 %	33.3 %
Setting Adjustment	N	164	186	19	369
	% in sector	30.0 %	28.1 %	20.2 %	28.3 %
Management	N	155	207	43	405
	% in sector	28.3 %	31.3 %	45.7 %	31.1 %
Other	N	38	52	5	95
	% in sector	6.9 %	7.9 %	5.3 %	7.3 %
Total	N	546 (42.0 %)	661 (51.0 %)	94 (7.2 %)	1,301 (100 %)
	% in sector	100.0 %	100.0 %	100.0%	100.0%

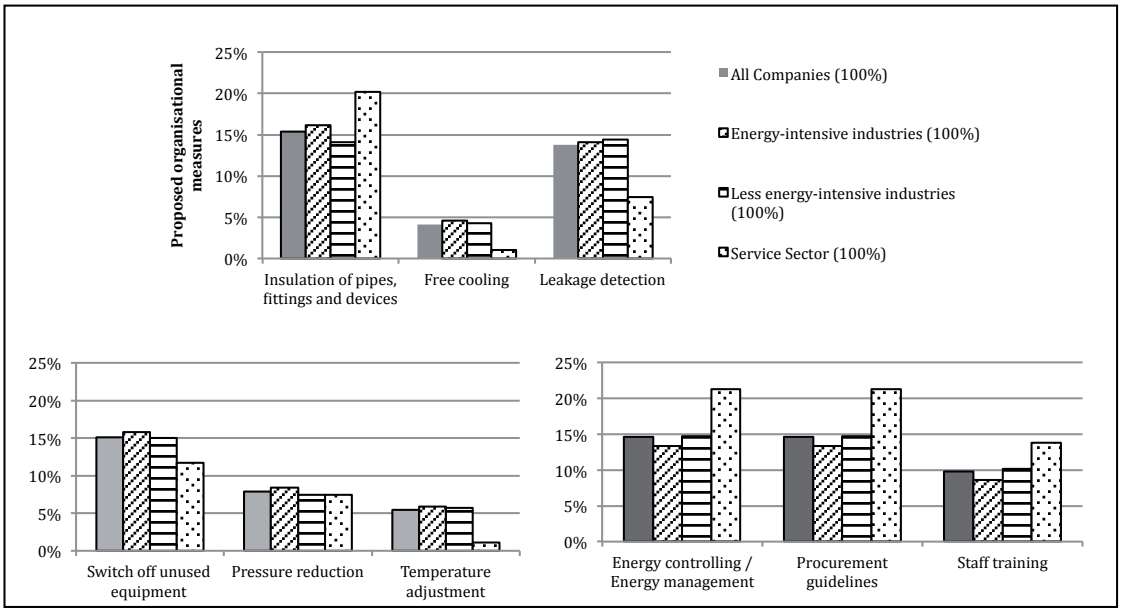

Figure 4. Distribution of the proposed organisational measures by category within industrial sector (N=1,301).

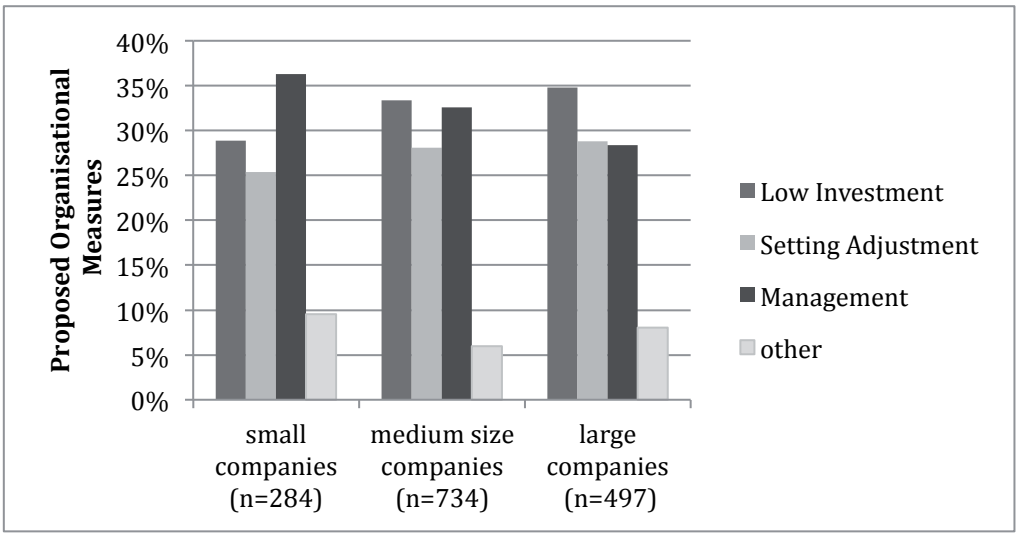

Figure 5. Proposed organisational measures by company size (N=1,515).

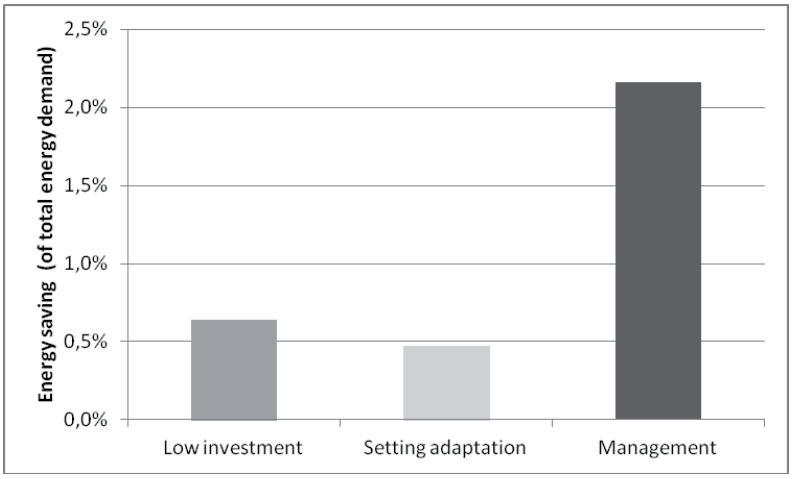

Figure 6. Energy saving potential with regard to the total energy demand of each company by company size (N=872).

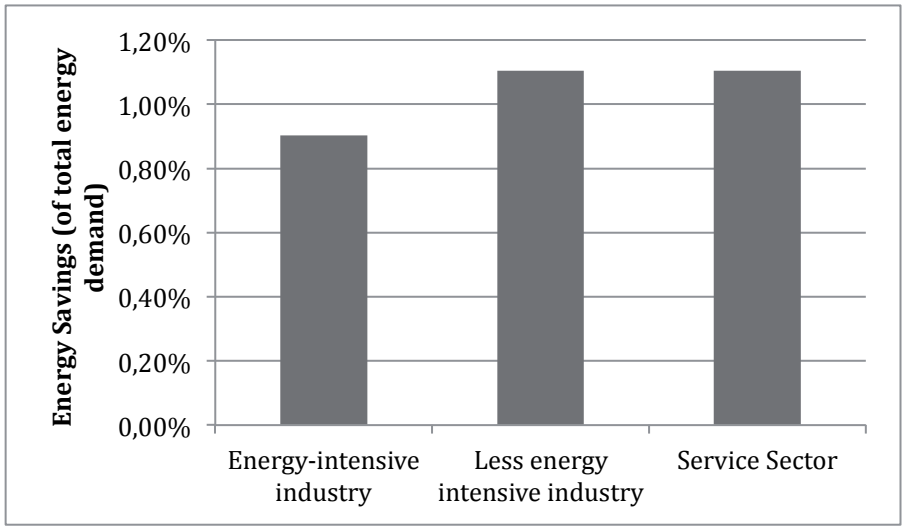

Figure 7. Energy saving potential of organisational measures with regard to the total energy demand of companies by industrial sector (N=715).

We compare the measures across and between sectors for the energy saving potential and the GHG reduction effect. The energy saving factors *demand reduction*, *reduction of GHG-emissions* and *cost reduction* are calculated as a percentage of the total consumption for each company.

Which measure leads to the highest energy saving rate?

As shown in Figure 6, the highest energy saving potential with regard to the total energy demand of each company is provided by the *management measures*. A company can save up to 4.3 % of their annual energy demand, 4.4 % of the annual GHG-emissions or an average of 4.2 % of their annual energy costs, particularly through energy control or energy management systems. Energy control was estimated to achieve the greatest energy reduction and staff training also has a high potential for energy savings (1.5 %). Within the *low investment measures* free cooling has the highest energy reduction potential (0.8 %) while *setting adjustment measures* are less effective with the highest potential of 0.6 % energy reduction through temperature adjustment.

Indirect *management measures* seem to be highly relevant, followed by *low investment measures* and *setting adaptation measures*. Energy control provides the maximum reduction in energy demand with up to 12 %.

Which industrial sector has the highest energy saving potential?

Energy intensive industry has a very high energy demand (more than 70 % of the consumption in four energy intensive branches in Germany[4]). Is this the sector with the highest potential to save energy through organisational measures?

Figure 7 displays the estimated energy saving potential of organisational measures as a share of the total energy demand of the companies aggregated by industrial sectors. This shows that the energy intensive industry has the lowest potential for energy reduction through organisational measures.

COST EFFECTIVENESS

The cost effectiveness of a measure is normally the precondition for implementation. Very often companies simply look at the payback period to estimate the cost effectiveness. This

4. http://www.odyssee-indicators.org/reports/industry/industry06.pdf (checked on 28/1/2014). Four branches: Paper, Non Metallic, Primary Metall, Chemical.

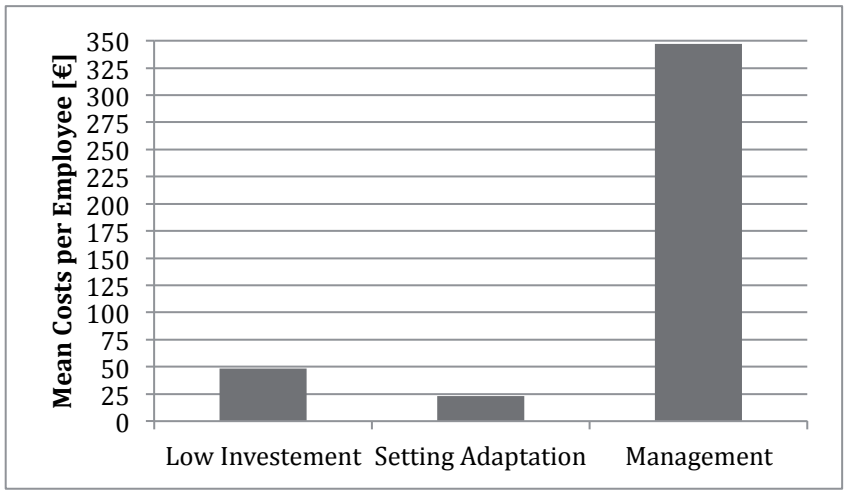

Figure 8. Investment costs per employee for each company by measure categories (N=738).

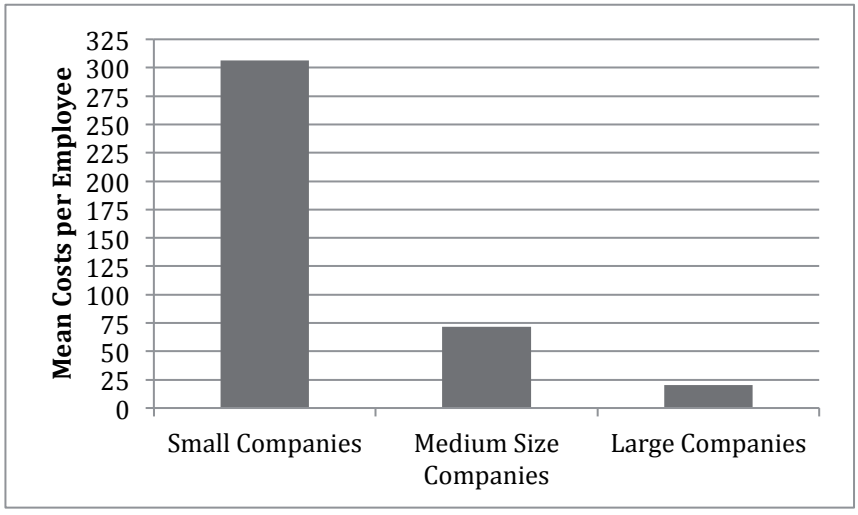

Figure 9. Investment costs per employee for each company by company size (N=759).

tends to underestimate the effectiveness of long-term investments (Herbst et al. 2013). For the concept of the "Total Cost of Ownership" (TCO) the net present value and the internal rate of return also have to be considered (John 2013). In order to do this, repayments of capital as well as any operational and maintenance costs are taken into account and in this context organisational measures are particularly relevant because they have low to zero investment costs.

As previously mentioned, the implementation of an energy controlling or an energy management system leads to high energy savings. However, when compared to the other groups of measures, energy controlling and management measures have the highest share of investment of all organisational measures (Figure 8). Whereas *low investment measures* require average investments of up to €50/employee and *setting adjustments* up to €25/employee, costs for *management measures* amount to €350/employee. Again this is due to the high costs of energy controlling systems (€438/employee on average with a maximum of €4,237/employee) but also procurement guidelines (€125/employee). Free cooling is €127/employee and accounts for the slightly higher costs of low investment measures. Figure 9 takes the company size into account showing the investment costs per employee. This is what the companies have to invest. But what do they get from it? Table 3 shows the financial evaluation of the cost effectiveness.

All of the proposed measures have an estimated *service life time* of about 12 years, after which new products probably need to be bought or the energy control system needs to be completely rethought.

The *additional investment* is the investment needed to achieve the energy savings.

The *net present value (NPV)* represents the return to the business from the investment costs (NZG 2013), and forecasts the likely financial outcome over the service life time. It takes into account the cost savings and uses a discount rate of 10 %. Positive net present values indicate that money has been earned on the investment while negative net present values suggest that the investment has lost money. Combining all investments the overall NPV is positive but negative net present values exist, particularly for small companies.

The *static payback period* is the time taken for the cost savings to exceed the money invested. At this point the investment

Table 3. Cost effectiveness of measurements.

	Direct, Low investment (N=400)	Direct, Setting adaptation (N=321)	Indirect, Management (N=154)	Other (N=26)
Ø service life time [a]	12.2	11.5	11.6	11.2
Ø additional investment for energy efficiency [€]	12,162	5,877	60,080	12,913
Ø Net present value [€]	37,396	34,152	294,518	23,472
Ø static payback period [a]	2.9	1.3	1.9	2.4
Ø dynamic payback period [a]	3.1	1.6	2.8	2.8
Ø internal rate of return (IRR) [%]	100 %	115 %	203 %	258 %

begins to earn money. However, calculations that only consider a *static payback period* simply indicate a degree of risk rather than profitability. In order to calculate the cost effectiveness accurately the use of the *internal rate of return* is recommended and the *dynamic payback period* takes this into account. The *dynamic payback period* is on average around 3 years for each cluster of measures. *Setting adaptation measures* stand out with a *dynamic payback period* of just 1.6 years, but periods of ten years or more are experienced, for example, by insulation measures.

The *internal rate of return* is the interest rate applied to the investment project that makes the net present value of all the costs and savings equal to zero. It is based on the additional investment and annual operational savings over the life time of a product and is used to compare the profitability of investments. The higher the *internal rate of return*, the greater the value of the investment. We define a measure as economically efficient if it has an *internal rate of return* of 12 % or higher (John 2013). The high costs involved in energy control causes the management measures to be relatively expensive. However, the internal rate of return for such measures is the highest at about 200 % and therefore financially beneficial. All measures are beneficial with an internal rate of return of at least 100 %.

In comparison to the findings of Herbst et al. (2013) the *internal rates of return* of the organisational measures are very high. Herbst and colleagues examined the same database but focused on cross-cutting technologies such as ventilation, lighting, insulation, electric drives, cooling and space heating. They demonstrated that these technologies have *internal rates of return* of up to maximum of 40 %.

What measures are most effective?

All in all we can conclude that management measures, particularly the implementation of energy controlling systems, are the most effective measures with a high energy reduction potential. They can be costly, but worth it with an internal interest rate of about 200 %.

Conclusion and Outlook

We conclude that a company can gain significantly from low to zero investment measures, especially at the organisational level. However, this analysis only covers organisational measures so we cannot claim to estimate the total energy efficiency potential of the industrial sectors. The energy efficiency potential of high investment measures regarding cross-cutting technologies and process technologies also need to be considered. This will be done in a further step of analysis of the 30 pilot networks project.

During the pilot networks project, we became aware that barriers to the implementation of energy efficient measures need to be tackled. The reasons why these measures are not yet implemented are multiple and include lack of knowledge, misleading routines in decision making and high transaction costs[5] (Herbst et al. 2013). As Fleiter and colleagues show (2012) the characteristics of energy efficient measures (e. g. internal rate of return, payback period, lifetime, transaction costs) play a crucial role in the adoption process of these measures.

As a company can overcome some of these barriers by participating in an energy efficiency network, it will be interesting to see whether this can be proved after the monitoring phase of the networks. Once the monitoring has been analysed, a further evaluation will be needed to compare the energy savings achieved after the implementation of measures with the energy savings estimated in the initial consultation report.

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5. Transactions costs were not taken into account in the analysis of the available data.

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