Energy Management for Office Buildings

Made Easy

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GUIDEBOOK
for a Practical Implementation of Energy Management for Office Buildings

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Content

Introduction

The constant increase in electricity prices, as can be seen in figure 01, is putting more and more strain on the consumer. Private home-owners are not the only ones to be affected. Industrial companies and service providers are also affected. We have now come to the point in the German economy where particularly energy-intensive companies are being relieved of this burden through tax cuts so that they can maintain their competitive edge. These drastic measures reveal how important it is for the economy to use energy more wisely. By using energy more efficiently, strain is also taken off of the environment and dependency on electricity and gas imports is reduced. According to the Umweltbundesamt [Federal Environment Agency], simply leaving electronic devices on stand-by costs around 4 billion euros every year and wastes over 22 billion kWh. This equates with the energy output from two nuclear power stations in one year. In Germany, 16% of all energy used in 2011 was in the commerce, trade and services sector. Since existing buildings in particular tend to have an excessive rate of energy consumption, they also have great potential for making large savings.

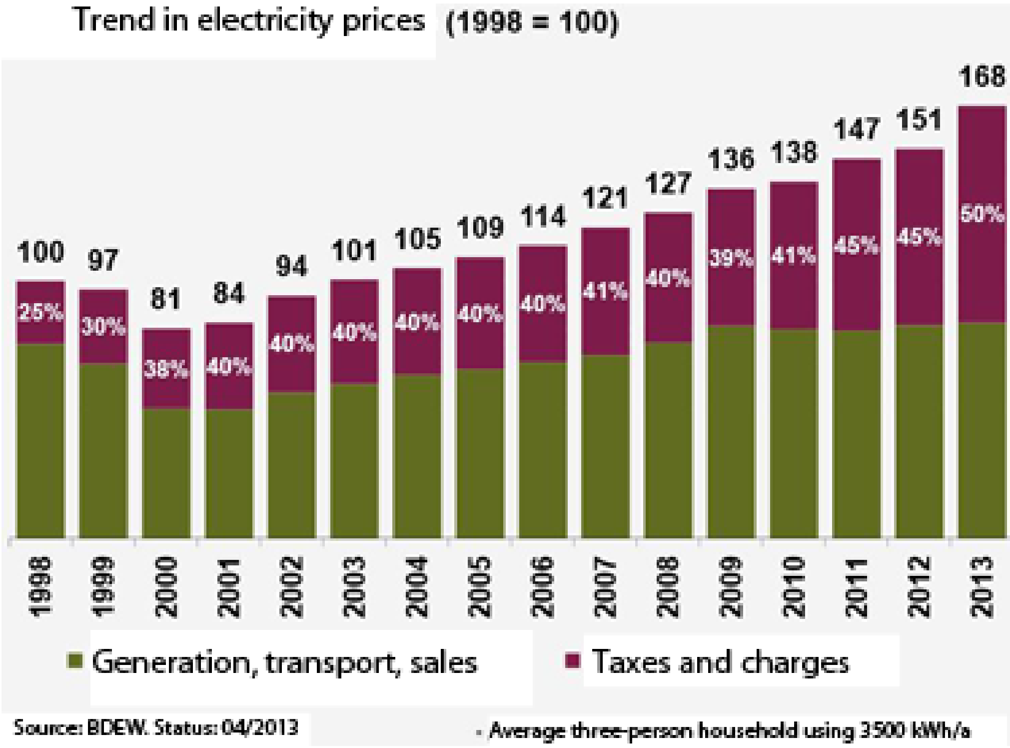


Figure 01: Trend of electricity prices in Germany from 1998 to 2013

This handbook deals with the subject of 'Energy Efficiency in Office Buildings'. Considering what many office and administration buildings are used for, they display an extremely high rate of energy consumption. Essential factors that affect energy demand are primarily service facilities (heating, ventilation, air conditioning) and the building. High savings potentials can often be attained by using simple and cost-effective measures. The central aim of this handbook is to provide guidance on how to identify potential savings and how to make them a reality. The primary focus of this guidance will be on potential savings which require little to no investment. Moreover, it will highlight how important user behaviour is for affecting energy consumption.

The foundation for this handbook was laid by the Climate Knowledge and Innovation Community (Climate KIC) which is part of the European Institute of Innovation and Technology (EIT). A team project was begun as part of a programme supported by the EU entitled 'Pioneers into Practice'. The projects question was: 'Is the international standard ISO 50001 sufficient for energy management (could be worth putting Energy Management System (EMS) here and change it to EMS throughout the guide instead of having energy Management every time) in office buildings?' This project revealed that the standard is indeed sufficient for introducing energy management to office buildings. However, the norm does not provide any clear advice as to how savings potentials can actually be reached. Further, it became clear that this kind of energy management is associated with a great deal of effort and costs, making any such management only suitable for large office buildings.

A pilot project initiated by the Energy Department of the city of Frankfurt provided an opportunity to review energy consumption in nine buildings. The result was that on average energy consumption could have been reduced by 25% and heat energy consumption by more than 15%. This project revealed that effective measures are possible with very low financial means.

The handbook is organised into three chapters. The first chapter contains an introduction to energy management. First of all, ISO 50001 is discussed, before finally presenting an effective way of implementing the PDCA cycle in small to medium-sized office buildings. The roles of those involved as well as their assignments are also defined and detailed. It was highly important to allocate responsibilities to complete the work effectively and quickly.

The second chapter is the main focus of this handbook. Firstly, steps towards using energy efficiency measures are explained to the reader so as to allow for a structured approach. Following this, practical measures for energy consuming sectors are explained in detail. Potential areas where savings could be made are highlighted for the reader. Consequently, technical details are explained so that the reader can create their own method of approaching this issue. This section therefore serves as a step by step guide, especially for non-professionals, that primarily offers uncomplicated solutions to energy efficiency measures.

Case studies that particularly deal with issues in user behaviour are also discussed at points, since user behaviour plays an equally central role in energy saving. Moreover, these case studies provide solutions relevant to particular problems.

The final chapter deals with the issue of factors of success when introducing energy management. Here, various different aspects such as communication, information and incentives for adjusting user behaviour are discussed.

1. Introducing energy management to small and medium-sized office buildings

Work processes for service providers, administration work and other similar establishments mainly take place in office buildings. This provides a first clue as to why these kinds of establishments think less about introducing energy management than others: It is difficult to identify 'energy sinners'. Further, the cost-benefit factor is very confusing for company management. Will costs for requesting advice from external energy advisors be higher than the savings potentials? Is it in the company's interest to do this? These are the main reasons why many companies deal very little with energy management systems.

A sustainable (long-term) reduction in energy consumption in office buildings is not possible simply by systematically identifying weak points, monitoring energy consumption continually or by setting service facilities to operate efficiently. In fact, a reduction is only possible when office lighting, electricity for the computers, monitors, printers, photocopiers and coffee machines in office buildings are used frugally. High savings are already possible by changing user behaviour.

In practice, it has been shown that measures for reducing energy consumption have usually only had a long-term effect when energy consumption and the efficacy of the measures in place have been regularly monitored and evaluated for further savings potentials. In cases where measures for improving energy efficiency were only implemented once and then no longer maintained, the ‚old' rate of energy consumption would be reintroduced over the space of 2 years.

To ensure that measures for reducing energy consumption have a long-term effect, they must be subject to a 'constant improvement process'. This is the basis for the quality standard, ISO 9001, that has been recognised and established for years and that of the new standard in energy management, ISO 50001, as well as the German EN DIN 16247.

Definition of energy management

1. General: Energy management is the combination of all measures which ensure a minimal use of energy at a required rate of output. It relates to structures, processes, systems and structural elements as well human behaviour and changes to that behaviour.

2. Objectives: One aim of energy management is to lower private or operational energy consumption and the use of raw, auxiliary and additional materials. Energy efficiency must be improved for the long-term both in the home and in the company.

Source: Wosnitza, F./Hilgers, H. G.: Energieeffizienz und Energiemanagement: Ein Überblick heutiger Möglichkeiten und Notwendigkeiten – Wiesbaden, 2012.

The standards on energy management provide no information as to which measures actually lead to energy being saved. They simply describe an organisational process that enables energy management strategy. Only once the management process has been organised and documented can measures begin to be planned and implemented. The aim of these standards is to certify the management process.

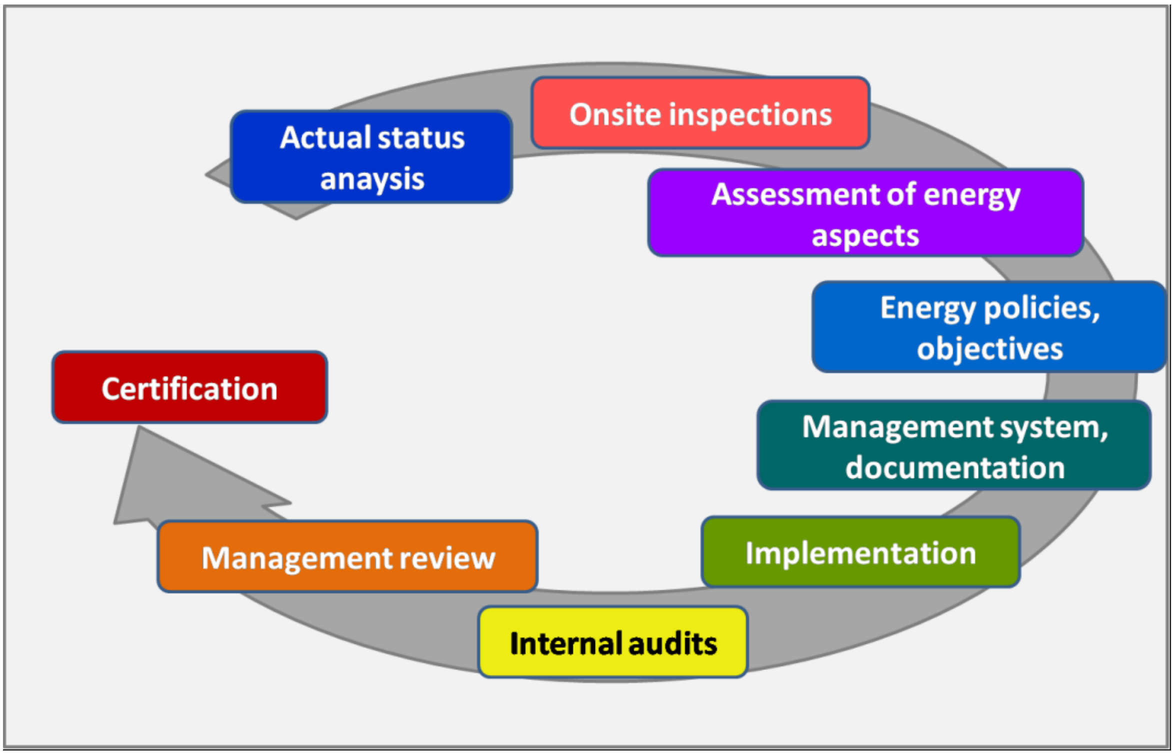


Figure 02a: Energy management process in accordance with ISO 50001 and EN DIN 16247

As evident from figure 02a, a lot of effort is required to introduce energy management in accordance with international standards, and it is also expensive. Consequently, energy management is only truly considered feasible for very large office buildings or those which are part of a company-wide energy management process.

So that small and medium-sized office buildings can benefit from the advantages of energy management, individual activities and processes need to be made lean and cost-effective.

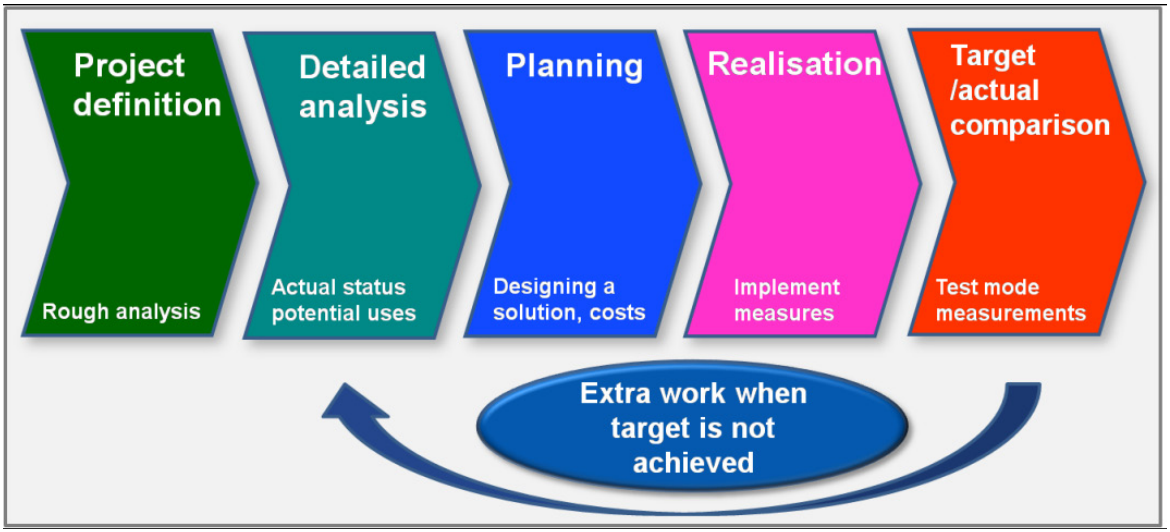


Figure 02b: Core process of energy management

The sequence of steps in energy management, which is illustrated in a simpler form in figure 02b, is suitable for use in small and medium-sized office buildings. The core process, stated in the norms on energy management, are implemented as a result.

This handbook uses a lean cycle to systematically analyse the current situation, to plan measures for reducing energy consumption, monitor the efficiency of these measures and to constantly compile statistics on energy consumption as well as amend any measures which were not successful. Therefore, the cycle for the ongoing improvement process as prescribed in the norm is ensured.

In contrast to the general, conventional introduction of management systems, the structure of the management system used in this handbook has been constructed by using practical steps. This enables potential savings to be reached easily with minimal effort.

Participants in Energy Management

The following stakeholders are involved in energy management:

Participants	Assignments
Management level, senior management	• Project definition • Approving planned measures • Communicating objectives to the users • Management review
Energy officer, (e.g. caretaker)	• Analysis of the actual state • Planning measures • Compiling energy consumption levels and statistics • Monitoring measures • Monitoring the efficacy of the measures • Compiling reports on the success of the measures
Purchasing/accounting	• Reviewing energy supply contracts • Reviewing invoices for energy consumption
Employees of the company	• Implementing measures which affect user behaviour
Building services or facility management (internal/external)	• Maintaining and optimising service facilities • Implementing technical measures to improve energy efficiency in connection with specialised companies
Energy advisor (external)	• Support in analysing the actual state and with introducing energy management (optional) • Planning technical measures for complex systems and/or larger investments (e.g. replacing heating systems and air conditioners)

Table 03a: Participants in energy management

Requirements essential to the effectiveness of the energy management system for office buildings described in this handbook are:

- The management must help introduce energy management.
- An ‘energy officer‘ must be appointed who is able to independently analyse the current si-

tuation, plan measures to improve energy efficacy and compile energy consumption statistics. This work can usually be done by the caretaker or persons from building services and facility management.

- The purchasing and accounting departments also have to provide documentation and data in order to assess energy supply contracts based on the actual amount of energy consumed and to check invoices with readings from the meter.

A highly important point is that the management authorises energy representatives to carry out necessary activities as part of the energy management programme.

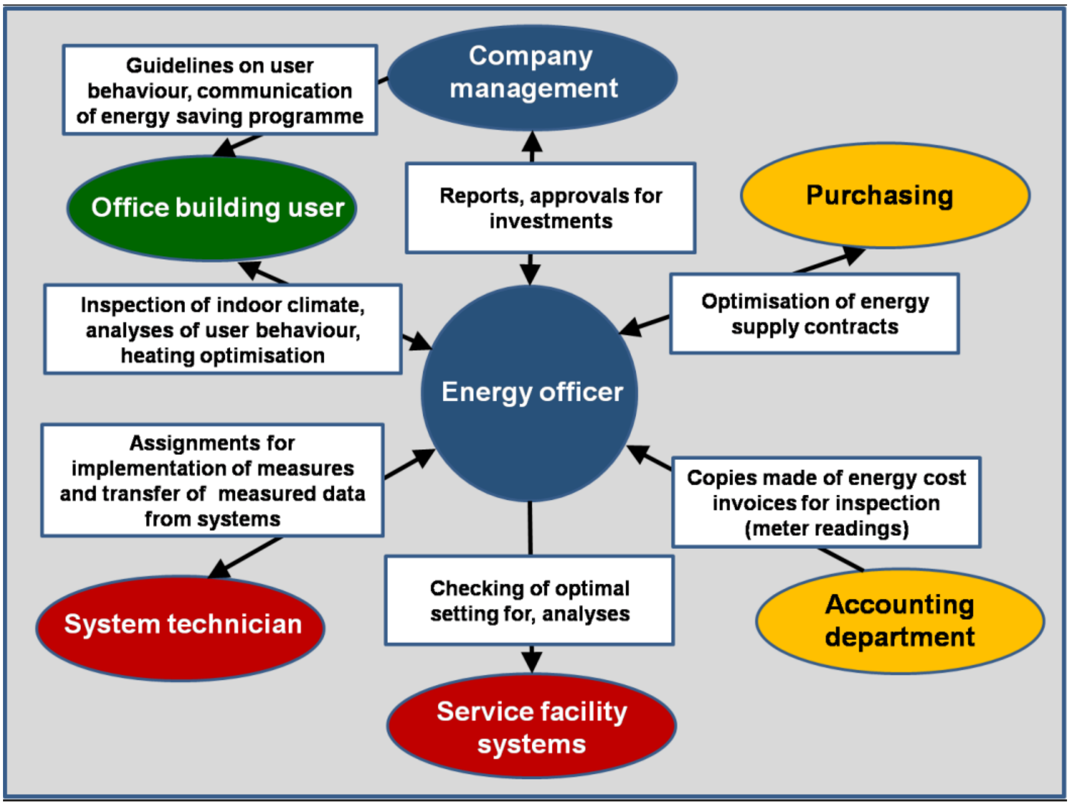


Figure 03b: Overview of the energy officer's work and communication and of those participating in the energy management programme

This handbook provides a step by step guide as to how to carry out single activities as part of energy management in office buildings. These activities mainly concern measures that can be realised without costs being incurred or with little investment being made.

Costs	Measures
Low costs	• Constant monitoring and analysis of energy invoices and electricity supply contract. • Defining energy indicators (EnPI – Energy Performance Indicators, e.g.: kWh/m2)
Medium costs	• User analysis and evaluation. • Constant monitoring of the settings of service facilities.

	• Reducing the number of unnecessary energy consumers, e.g. old fridges and those not being used. • Employee training sessions on saving energy. Advice posters and tips to encourage a conscious use of energy. • Introducing energy saving lights instead of retaining conventional lighting. Integrating movement sensors in stairwells.
High costs	• Purchasing a new energy-efficient ventilation system. • Adding more insulation to the building envelope.

Table 04: Examples of measures in different cost categories

The next chapter of this handbook describes in detail which steps should be carried out by the energy officer as well as when and in what manner.

2. Guidelines for making energy consumption more efficient in the long-term

As previously stated, this handbook is written for persons who possess basic understanding of technical matters, but who are not expert in energy advice, planning and servicing in-house service facilities. You are introduced to the individual topics step by step so that you are able to identify problematic areas yourself, suggest solutions and then put these solutions into action on your own or with specialist personal who have been called in (e.g. heating engineer, ventilation engineer).

Office buildings are complex systems when viewed from an energy consumption perspective. Essential factors for energy consumption are:

- User behaviour (e.g. room temperatures, ventilation, lighting, user times, standby use).
- The most efficient setting for heating, ventilation and air conditioning systems.
- Heat loss through the building envelope (building physical properties).

Individual factors which influence energy consumption are described in the appendix 'Energy consumption in office buildings'.

Key areas in office buildings with high savings potentials in energy consumption (increase in energy efficiency) are:

- Lighting (in the building, outdoor areas, thoroughfares, adjoining rooms)
- Office equipment (PC, printers, photocopiers, network technology, server computer)
- Heating the office building/ventilation/air conditioning

Considerable savings can be made in energy consumption in these areas by

- setting equipment and service facilities to a more efficient setting,
- switching off equipment and lights when not in use and outside of work hours
- user behaviour that takes energy use in office buildings consciously into account.

What does it mean to run energy efficient offices?

The central subject of this handbook is how to use small to medium-sized office buildings in an energy-efficient way. An example of this is the following:

> *"An energy-consuming device is operated efficiently when it only uses as much energy as is necessary for completing its prescribed function."*

Figure 05 shows the three core functions required to run an energy management programme effectively in office buildings. This illustrates that it is only by observing these three functions that measures regarding energy efficiency can be implemented in the most efficient way.

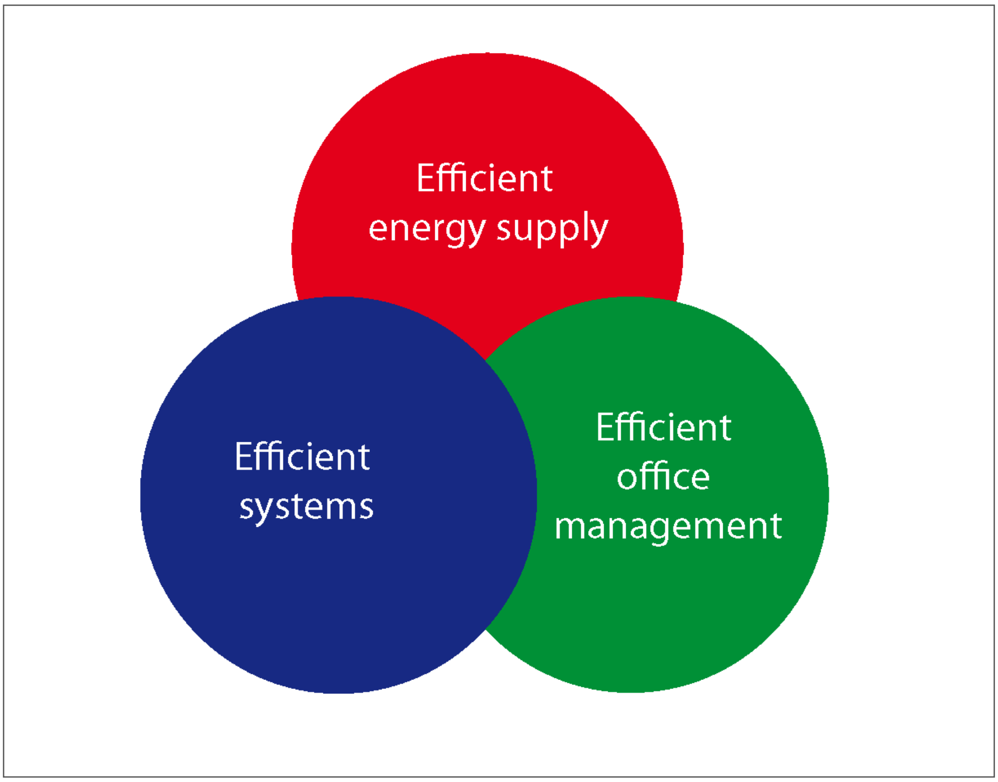


Figure 05: The three key functions required for effective energy management

Advantages of using office buildings in an energy-efficient way:

- Reducing energy consumption
- Reducing operating costs for the building
- No loss of comfort (indoor climate) or productivity
- Better information on energy saving potentials so that company management can make decisions

Key functions required to run energy efficient office buildings

- Appoint a person who will be responsible for reducing energy consumption: 'Energy officer'
- Involve persons who may have a positive influence on the process required to make the office buildings energy efficient.
- Introduce a management process
- Calculate the pattern of consumption for energy consumption
- Ensure that the measures that are planned are cost-effective.

The keys to success in energy management are explained in more detail in chapter 3.

7 steps towards increasing the energy efficiency of office buildings

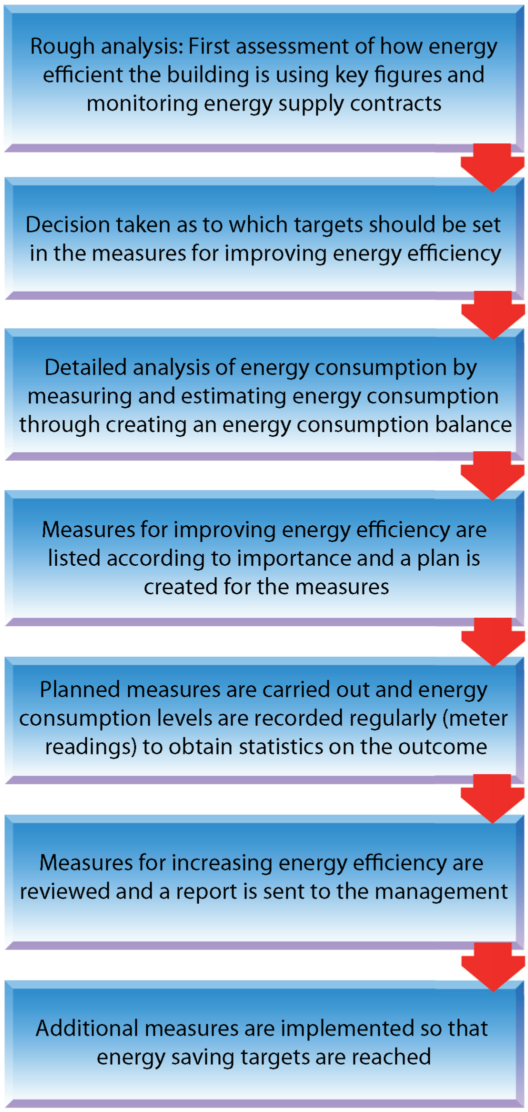


Figure 06: 7 steps towards increasing energy efficiency

The seven steps shown in figure 06 are explained in detail in the following.

2.1. Step 1: Rough analysis

The aim of the rough analysis is to make an initial assessment of the actual state of the building's level of energy efficiency at the point when an energy management system is being introduced to improve the energy efficiency of office buildings.

2.1.1. Reviewing energy supply contracts and invoices

To be able to get an overall picture of a building's state, the amount of energy calculated for consumption (electricity, heat energy, and water use if necessary) and energy supply contracts need to be reviewed.

By using the invoices and the suppler contracts, one can see whether

- the supply contract is suitable for the actual rate of consumption.
- the limits for the fixed tariff are maintained by the load profile or whether they fall very short of the load profile.
- the meter readings match the invoices.

If the annual rate of electricity consumption is over 100,000 kWh, a special tariff usually comes into effect. The invoice for electricity consumption is calculated using a 'fixed price' and a 'variable price'.

The fixed price is based on the maximum rate of consumption within 1/4 of an hour (peak consumption). This price is given in EUR/kW (fixed price relating to the agreed maximum peak rate). This way of calculating invoices is also used by large-scale consumers of gas.

If the fixed price has been set too high to be on the safe side, then you will be paying more for electricity usage each month than is needed. It is worth reviewing the load profile (load curve) to see whether the fixed tariff is justified or whether it is too high or too low. If the agreed peak consumption rate within 1/4 hour is exceeded, this results in additional high consumption costs which may incur a considerably higher fixed tariff over one year. So that the load profile can be monitored, data from the last 12 months can be requested from the energy provider by submitting the customer number and meter number.

Data is usually sent electronically in an Excel table. A specimen copy of the form to request the load profile from a network operator/provider has been included in the appendix 'Authorisation_Load Profile Request'. This form can be used for the load profile, electricity consumption and gas consumption. More information on 'load profile analysis' is available in chapter 2.3.4.

The energy supply contract can also be reviewed in relation to the energy prices (electricity and natural gas). An overview of competitor prices is provided by various different energy comparison portals (e.g. www.verivox.de, www.stromvergleich.de, www.toptarif.de). There are also service providers for optimising energy supply contracts.

It is only possible to optimise energy supply contracts in cooperation with the management, purchasing department and energy officer. The energy officer's job is to evaluate the technical parts of the supply contract. This work relates to energy consumption (meter readings for normal and low rates), the fixed price and variable price in special contracts (usually over 100,000 kWh of electricity) and the load profile.

2.1.2. Initial analysis of the actual state

The first evaluation of the current state of energy efficiency for an office building provides an initial overview as to whether energy consumption is within normal parameters or whether it is too high. To do this, a comparison is made with benchmark values (Key Performance Indicators). This comparison is formed by using figures gained from average energy consumption in similar buildings.

The benchmark values are specific energy consumption data that are either provided in kWh/m^2 of used space per year or in kWh/employee per year. Only site-specific 'Key Performance Indicators' (KPI as described in the ISO 50001 standard for energy management) are used. This allows the building to undergo a better comparison because the factor of use is not affected by the number of users as much.

Heat energy consumption and electricity consumption have to be calculated for one whole year in order to compare these figures with the benchmark values. This consumption is distributed across the space used. Usually, benchmark reference values relate to the 'net floor area' (NFA).Factors for converting individual spaces are provided in the appendix entitled 'Conversion Factors'. This allows benchmark values to be converted to match the building in question.

Individual area definitions are illustrated on the following image and are explained in detail in the table that follows.

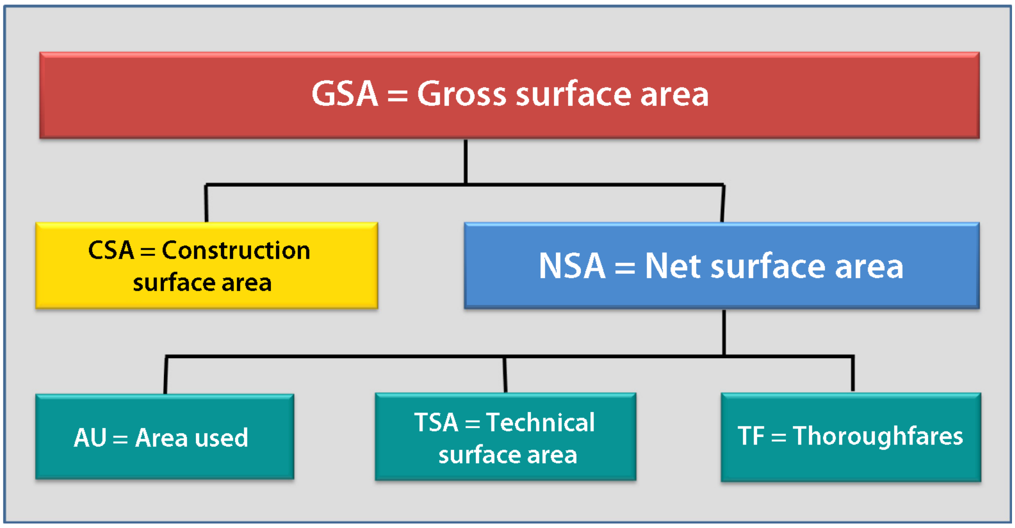


Figure 07: Definition of developed spaces in accordance with DIN 277

2.1.2.1. Heat energy consumption

Reference values for energy consumption are provided in table 08. To do this, buildings need to be classified into age groups because it is not possible to compare a new build with an old build since their building physical properties are different.

Specific heat energy consumption values (kWh/m² per year)					
Age of building	**very good**	**good**	**medium**	**poor**	**very poor**
1900 – 1977	<120	140	160	200	>250
1978 – 1995	<110	130	150	180	>220
1996 – 2003	<75	90	110	160	>200
from 2004	<60	80	95	125	>160

Table 08: Specific heat energy comparison values depending on age of building
Source: Special print from: Bauphysik [Building physics] 32 (2010), book 1 (dependant values)

The heat energy consumption assessment serves to estimate how much more efficient the heating system, settings for room temperatures and user behaviour could be made. Considerable energy savings can be made in these areas by implementing measures that either require no or very little investment.

2.1.2.2. Electricity consumption

In table 09 further reference values are detailed with additional classification for different types of building.

	Specific electricity consumption values (kWh/m² per year)					
Type of building	**very low**	**low**	**medium**	**high**	**very high**	**extremly high**
Office buildings	<15	20	26	32	41	>52
Office buildings with normal technical equipment	<15	19	24	29	35	>45
Office buildings with more advanced technical equipment	<14	20	32	45	57	>90
Data processing centre	<100	125	150	240	351	>500
Buildings for academic teaching and research	<18	25	35	50	70	>100
Institution buildings for teaching and research	<16	23	32	48	65	<100

Table 09: Specific electricity consumption values according to building type based on values from energy management in the city of Frankfurt am Main (www.energiemanagement.stadt-frankfurt.de)

The electricity consumption assessment gives some indication of the potential savings that can be reached. It is quite possible that an office building is already being used in an energy-efficient way. In this case, there will be no large savings to be made. This then affects how measures for reducing energy consumption are planned.

2.1.3. Calculating energy consumption to create parameters

The last invoices (possibly from the last 3 years) need to be analysed in order to calculate parameters for heat energy consumption and for electricity consumption. Energy consumption is required in kWh (kilowatt hours). Since the electricity meter shows consumption in kWh, it is not necessary to make any other calculations.

When calculating gas usage, consumption may be calculated in kWh or m^3. The conversion factor for gas consumption in m^3 is approximately 10 kWh/m^3, and the value for heating oil is at 10 kWh/litre. Calculations for district heating are made in kWh. If calculations are provided in m^3, the conversion factor is noted in the invoice. Other conversion factors are detailed in the appendix, “Conversion factors”.

Creating parameters for the office building

The specific energy consumption parameter is formed as follows:

$$\text{Parameter} = \frac{\text{Annual energy consumption (kWh)}}{\text{Net surface area (m2)}}$$

This parameter is created for heat energy consumption and electricity consumption.

2.1.4. Energy certificate

Another way of evaluating the energy efficiency of an office building is by using an energy certificate – known as an Energy Performance Certificate (EPC) or Display Energy Certificate (DEC) in the UK. An energy certificate documents the building's level of energy consumption.

In Germany there are two types of energy certificates for buildings (residential and non-residential):

- Energy certificate relating to demand ("Demand Certificate")
- Energy certificate relating to consumption ("Consumption Certificate")

For a demand certificate, the theoretical energy demand of a building is calculated using complex methods of calculation. Heat loss from individual components (outer wall, windows, roof, cellar ceiling, etc.) and installations (heating, ventilation and air conditioning systems) is calculated in these calculations. The data compiled do not depend on the individual use/heat ratio. They allow the building to be compared directly with other buildings.

The consumption certificate shows the building's actual amount of energy consumption. Heating and water heating are included in this. Additional values are included for non-residential buildings for cooling, ventilation and integrated lighting. Energy consumption is calculated based on invoices of the last three years for heating costs. Specific data on consumption are adjusted depending on the weather. Individual user behaviour, however, is included in this consumption data. Figure 10 illustrates an example of a German energy certificate.

ENERGIEAUSWEIS für Nichtwohngebäude

gemäß den §§ 16 ff. Energieeinsparverordnung (EnEV)

Gültig bis: 11.04.2024 (1)

Gebäude

Hauptnutzung/ Gebäudekategorie	Verwaltungsgebäude
Adresse	Voltastrasse 43, 80333 München
Gebäudeteil	ganzes Bürogebäude
Baujahr Gebäude	1979
Baujahr Wärmeerzeuger[1]	2010
Baujahr Klimaanlage[1]	
Nettogrundfläche[2]	11.900 m²
Erneuerbare Energien	keine
Lüftung	Lüftungsanlage + Fensterlüftung
Anlass der Ausstellung des Energieausweises	☐ Neubau ☒ Vermietung/Verkauf ☐ Modernisierung (Änderung/Erweiterung) ☐ Aushang bei öffentlichen Gebäuden ☐ Sonstiges (freiwillig)

Hinweise zu den Angaben über die energetische Qualität des Gebäudes

Die energetische Qualität eines Gebäudes kann durch die Berechnung des **Energiebedarfs** unter standardisierten Randbedingungen oder durch die Auswertung des **Energieverbrauchs** ermittelt werden. **Als Bezugsfläche dient die Nettogrundfläche.**

☐ Der Energieausweis wurde auf der Grundlage von Berechnungen des **Energiebedarfs** erstellt. Die Ergebnisse sind auf **Seite 2** dargestellt. Zusätzliche Informationen zum Verbrauch sind freiwillig. Diese Art der Ausstellung ist Pflicht bei Neubauten und bestimmten Modernisierungen. Die angegebenen Vergleichswerte sind die Anforderungen der EnEV zum Zeitpunkt der Erstellung des Energieausweises **(Erläuterungen – siehe Seite 4).**

☒ Der Energieausweis wurde auf der Grundlage von Auswertungen des **Energieverbrauchs** erstellt. Die Ergebnisse sind auf **Seite 3** dargestellt. Die Vergleichswerte beruhen auf statistischen Auswertungen.

Datenerhebung Bedarf/Verbrauch durch: ☒ Eigentümer ☐ Aussteller

☐ Dem Energieausweis sind zusätzliche Informationen zur energetischen Qualität beigefügt (freiwillige Angabe).

Hinweise zur Verwendung des Energieausweises

Der Energieausweis dient lediglich der Information. Die Angaben im Energieausweis beziehen sich auf das gesamte Gebäude oder den oben bezeichneten Gebäudeteil. Der Energieausweis ist lediglich dafür gedacht, einen überschlägigen Vergleich von Gebäuden zu ermöglichen.

Aussteller

Thomas Möller
Energieberater (HWK)
Brunhamstrasse 43
81249 München

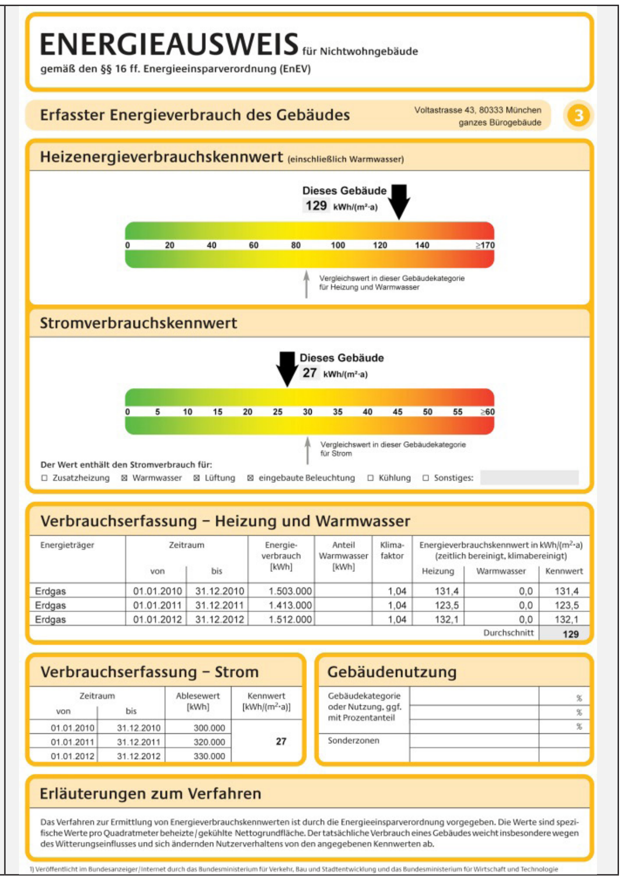
Tel. 089-871 2454

11.04.2014
Datum

Unterschrift des Ausstellers

1) Mehrfachangaben möglich 2) Nettogrundfläche ist im Sinne der EnEV ausschließlich der beheizte/gekühlte Teil der Nettogrundfläche

Figure 10
German energy certificate (demand – non-residential) with data from the building



ENERGIEAUSWEIS für Nichtwohngebäude

gemäß den §§ 16 ff. Energieeinsparverordnung (EnEV)

Erfasster Energieverbrauch des Gebäudes — Voltastrasse 43, 80333 München, ganzes Bürogebäude (3)

Heizenergieverbrauchskennwert (einschließlich Warmwasser)

Dieses Gebäude
129 kWh/(m²·a)

0 20 40 60 80 100 120 140 ≥170

Vergleichswert in dieser Gebäudekategorie für Heizung und Warmwasser

Stromverbrauchskennwert

Dieses Gebäude
27 kWh/(m²·a)

0 5 10 15 20 25 30 35 40 45 50 55 ≥60

Vergleichswert in dieser Gebäudekategorie für Strom

Der Wert enthält den Stromverbrauch für:
☐ Zusatzheizung ☒ Warmwasser ☒ Lüftung ☒ eingebaute Beleuchtung ☐ Kühlung ☐ Sonstiges:

Verbrauchserfassung – Heizung und Warmwasser

Energieträger	Zeitraum von	Zeitraum bis	Energieverbrauch [kWh]	Anteil Warmwasser [kWh]	Klimafaktor	Energieverbrauchskennwert in kWh/(m²·a) (zeitlich bereinigt, klimabereinigt) Heizung	Warmwasser	Kennwert
Erdgas	01.01.2010	31.12.2010	1.503.000		1,04	131,4	0,0	131,4
Erdgas	01.01.2011	31.12.2011	1.413.000		1,04	123,5	0,0	123,5
Erdgas	01.01.2012	31.12.2012	1.512.000		1,04	132,1	0,0	132,1
							Durchschnitt	**129**

Verbrauchserfassung – Strom

Zeitraum von	Zeitraum bis	Ablesewert [kWh]	Kennwert [kWh/(m²·a)]
01.01.2010	31.12.2010	300.000	
01.01.2011	31.12.2011	320.000	**27**
01.01.2012	31.12.2012	330.000	

Gebäudenutzung

Gebäudekategorie oder Nutzung, ggf. mit Prozentanteil		%
		%
		%
Sonderzonen		

Erläuterungen zum Verfahren

Das Verfahren zur Ermittlung von Energieverbrauchskennwerten ist durch die Energieeinsparverordnung vorgegeben. Die Werte sind spezifische Werte pro Quadratmeter beheizte/gekühlte Nettogrundfläche. Der tatsächliche Verbrauch eines Gebäudes weicht insbesondere wegen des Witterungseinflusses und sich ändernden Nutzerverhaltens von den angegebenen Kennwerten ab.

1) Veröffentlicht im Bundesanzeiger/Internet durch das Bundesministerium für Verkehr, Bau und Stadtentwicklung und das Bundesministerium für Wirtschaft und Technologie

German energy certificate with data on specific energy consumption

2.2. Step 2: Targets for measures to reduce energy consumption

Measures can be planned to improve energy efficiency by using specific parameters for energy consumption (heat energy and electricity). In buildings with low parameters for heat energy consumption, the main focus would be on introducing measures to reduce electricity consumption.

Buildings with a good level of energy efficiency are only able to maintain this level in the medium-term if energy consumption is measured regularly (e.g. by reading the energy consumption meter on a monthly basis) and follow up any anomalies. This particularly applies to office buildings where energy efficiency has been improved by introducing targeted measures in order to review the efficiency of these measures.

If you stop measuring consumption values and comparing them with set targets and periods from previous years, energy consumption reverts back to the old, high level of consumption within just a few years. This is the experience of those involved in energy management in the city of Frankfurt am Main and of those in facility management companies.

Targets for measures to reduce consumption must be defined in such a way that they can be implemented simply, quickly and cost-effectively (or even without investment whenever possible). On the one hand, this leads to rapid success and on the other hand, it provides the management and the user with the motivation to carry on supporting the savings programme.

Key points necessary for achieving the targets set in place to save energy in office buildings are explained in the following chapter, 2.3.

2.3. Step 3: Detailed analysis of energy consumption

The detailed analysis of energy consumption includes:

- Introducing regular (monthly) checks for energy consumption by taking meter readings and continuing to document the findings
- Making adjustments to specific consumption parameters due to the weather by using climate factors
- Analysing the load profile for electricity consumption (for special contracts with high energy consumption)
- Estimating energy consumption for individual consumers by listing key consumers (electricity consumption balance)
- Inspecting the lighting
- Measuring the room temperature of individual offices
- Inspecting the heating controller, settings for radiator control systems and ventilation rates (open windows or volume of air from ventilation and air conditioning systems)
- Inspecting operating times for individual devices and equipment, as well as the lighting (luminance and user behaviour)

2.3.1. Meter readings and monthly statistics

All meters must be read regularly, that is, every month, and the monthly rate of consumption must be documented so that the success of the measures can be calculated. The Excel tables 'Energy Consumption Analysis.xls' (see figure 11) and 'Electricity Consumption Analysis.xls' (see figure 12), are provided for this purpose.

The following image shows the form for the electricity meters and a calculation of the electricity consumption. There are also other forms for the consumption of gas, heating oil and wood in this Excel tool. The tables tolerate statistics up to the year 2019 (figures 12 and 13).There is also a graphic evaluation of energy consumption rates after they have been corrected using climate factors.

	Electricity									
	Meter No.									
	Place:									
Year	**Month**	**Date of meter reading:**	**MPP meter reading**	**AP meter reading**	**Meter with converter: Factor**	**MPP monthly consumption (kWh)**	**AP monthly consumption (kWh)**	**Total monthly consumption (kWh)**	**Previous year (kWh)**	**Change**
2014	January				1	0	0	0		
2014	February				1	0	0	0		
2014	March				1	0	0	0		
2014	April				1	0	0	0		
2014	May				1	0	0	0		
2014	June				1	0	0	0		
2014	July				1	0	0	0		
2014	August				1	0	0	0		
2014	September				1	0	0	0		
2014	October				1	0	0	0		
2014	November				1	0	0	0		
2014	December				1	0	0	0		
2014	**Total**					**0**	**0**	**0**		
On electricity meters with converters, the meter reading must be multiplied by the conversion factor										
(factor is provided on the electricity meter).										
On electricity meters without a converter, the factor is 1.										
Electricity consumption for December can only be calculated once the meter reading has been taken the following January.										

1	Month and year of the meter reading
2	Date of reading
3	Meter for main payment plan (MPP) – electricity consumption during the day and at times of greater load on the electricity supply network
4	Meter for additional plan (AP) – reduced price for times when there is less load on the electricity supply network
5	Conversion factor for electricity meters with a higher connected load (standard = 1)
6	Calculated monthly consumption (MPP)
7	Calculated monthly consumption (AP)
8	Calculated total monthly consumption
9	Consumption from previous year
10	Alteration
11	Annual consumption (= total of monthly rates of consumption)

Figure 11: Screenshot of Excel table 'Energy Consumption Analysis.xls' for meter readings and for adjustments made to the monthly energy consumption

Single Excel sheets allow energy consumption to be evaluated in a table and a graph.

Electricity				
Meter No.				
Place:				
Year	Electricity consump-tion (kWh)	Comparison of energy consumption from previous year (kWh)	Target and consumption (kWh)	Comparison of target consumption
2014	81033	15%	80000	-3%
2015	93385	-11%	78000	-3%
2016	82678	-6%	76000	-3%
2017	77903	0%	74000	-1%
2018	78045	-1%	73000	-1%
2019	77456	-6%	72000	-1%
2020	73078		71000	

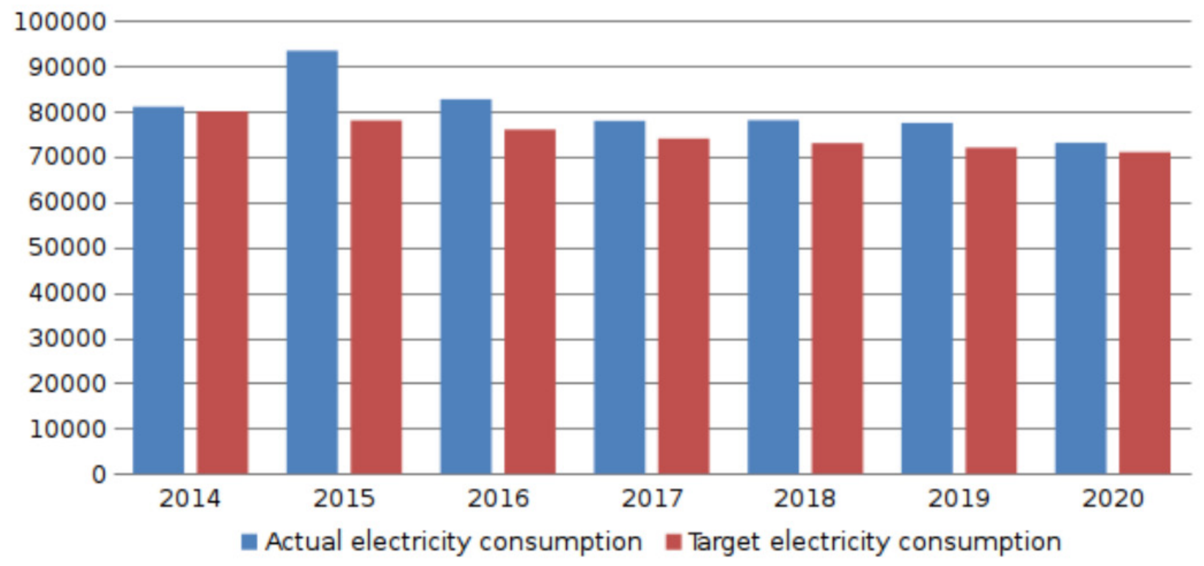


Figure 12: Comparison of electricity consumption

Gas						
Heating oil						
District heating						
Meter No.						
Place:						
Year	Energy consump-tion (kWh)	Comparison with energy consumption from previous year (kWh)	Climate factor	Revised energy consump-tion (kWh)	Target and consumption (kWh)	Comparison of target and consumption
2014	79280	-26%	0,99	78487	75000	6%
2015	58440	22%	1,13	66037	70000	-17%
2016	71380	-2%	1,02	72808	68000	5%
2017	70060	-13%	1,06	74264	67000	5%
2018	60760	12%	1,09	66228	66000	-8%
2019	67800	-11%	1,02	69156	65000	4%
2020	60550		1,05	63578	64000	-5%

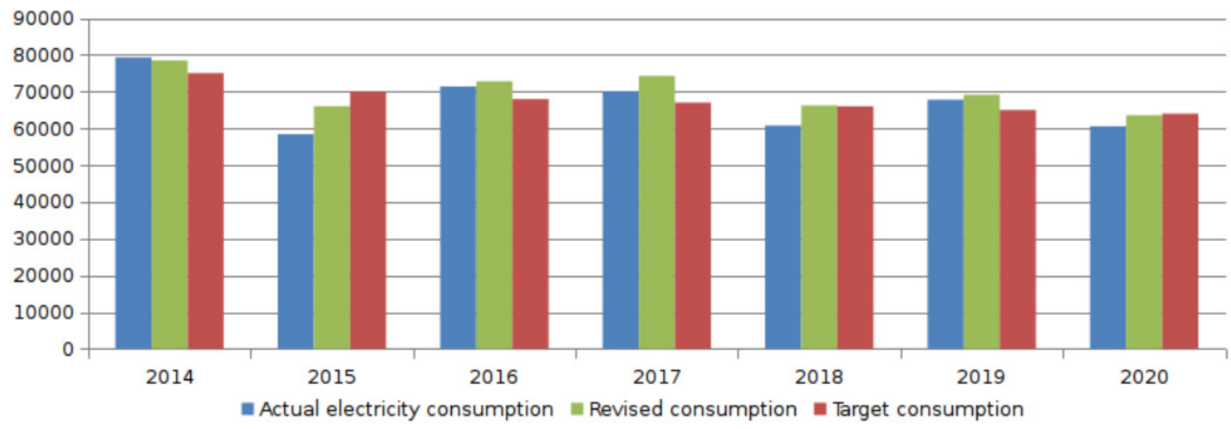


Figure 13: Comparison of heat energy consumption

2.3.2. Correcting the specific heat energy consumption level using climate factors

Variations in the level of energy consumption recorded can be seen in the table and graph on annual energy consumption illustrated above. Less heat energy is consumed in mild winters, while more heat energy is consumed in cold winters.

2.3.2.1. Case study in Germany: Climate factors for energy passes from German Meteorological Service [Deutscher Wetterdienst] (GMS)

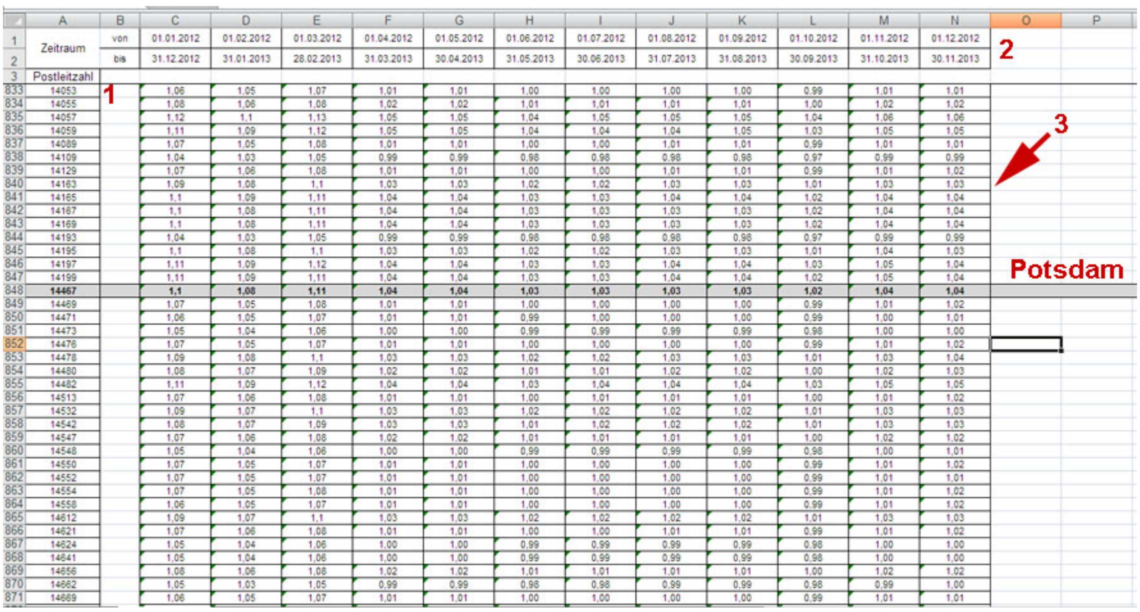
Specific consumption parameters for the building need to be corrected by using the climate factor so that the change in energy consumption, and thus the success of the measures being taken to reduce energy consumption, can be demonstrated without including the effects of the climate in the results.

The influence that the weather and the climate have on energy consumption is calculated using a so-called climate factor' which takes into account both temperature ratios for the period being calculated and the weather conditions in Germany. The climate factor is calculated by the GMS and is based on weather data from different weather stations distributed across the whole of Germany.

These climate factors can be obtained from the GMS' website in their download section for all post code areas. **www.dwd.de/klimafaktoren.**

Climate factors can either be obtained for the last 12 months or for the past several years on the selection page.

The climate factor Excel tables provided by the GMS are like this:



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Zeitraum	von	01.01.2012	01.02.2012	01.03.2012	01.04.2012	01.05.2012	01.06.2012	01.07.2012	01.08.2012	01.09.2012	01.10.2012	01.11.2012	01.12.2012
2		bis	31.12.2012	31.01.2013	28.02.2013	31.03.2013	30.04.2013	31.05.2013	30.06.2013	31.07.2013	31.08.2013	30.09.2013	31.10.2013	30.11.2013
3	Postleitzahl													
833	14053		1,06	1,05	1,07	1,01	1,01	1,00	1,00	1,00	1,00	0,99	1,01	1,01
834	14055		1,08	1,06	1,08	1,02	1,02	1,01	1,01	1,01	1,01	1,00	1,02	1,02
835	14057		1,12	1,1	1,13	1,05	1,05	1,04	1,05	1,05	1,05	1,04	1,06	1,06
836	14059		1,11	1,09	1,12	1,05	1,05	1,04	1,04	1,04	1,05	1,03	1,05	1,05
837	14089		1,07	1,05	1,08	1,01	1,01	1,00	1,00	1,01	1,01	0,99	1,01	1,01
838	14109		1,04	1,03	1,05	0,99	0,99	0,98	0,98	0,98	0,98	0,97	0,99	0,99
839	14129		1,07	1,06	1,08	1,01	1,01	1,00	1,00	1,01	1,01	0,99	1,01	1,02
840	14163		1,09	1,08	1,1	1,03	1,03	1,02	1,02	1,03	1,03	1,01	1,03	1,03
841	14165		1,1	1,09	1,11	1,04	1,04	1,03	1,03	1,04	1,04	1,02	1,04	1,04
842	14167		1,1	1,08	1,11	1,04	1,04	1,03	1,03	1,03	1,03	1,02	1,04	1,04
843	14169		1,1	1,08	1,11	1,04	1,04	1,03	1,03	1,03	1,03	1,02	1,04	1,04
844	14193		1,04	1,03	1,05	0,99	0,99	0,98	0,98	0,98	0,98	0,97	0,99	0,99
845	14195		1,1	1,08	1,1	1,03	1,03	1,02	1,02	1,03	1,03	1,01	1,04	1,03
846	14197		1,11	1,09	1,12	1,04	1,04	1,03	1,03	1,04	1,04	1,03	1,05	1,04
847	14199		1,11	1,09	1,11	1,04	1,04	1,03	1,03	1,04	1,04	1,02	1,05	1,04
848	**14467**		**1,1**	**1,08**	**1,11**	**1,04**	**1,04**	**1,03**	**1,03**	**1,03**	**1,03**	**1,02**	**1,04**	**1,04**
849	14469		1,07	1,05	1,08	1,01	1,01	1,00	1,00	1,00	1,00	0,99	1,01	1,02
850	14471		1,06	1,05	1,07	1,01	1,01	0,99	1,00	1,00	1,00	0,99	1,00	1,01
851	14473		1,05	1,04	1,06	1,00	1,00	0,99	0,99	0,99	0,99	0,98	1,00	1,00
852	14476		1,07	1,05	1,07	1,01	1,01	1,00	1,00	1,00	1,00	0,99	1,01	1,02
853	14478		1,09	1,08	1,1	1,03	1,03	1,02	1,02	1,03	1,03	1,01	1,03	1,04
854	14480		1,08	1,07	1,09	1,02	1,02	1,01	1,01	1,02	1,02	1,00	1,02	1,03
855	14482		1,11	1,09	1,12	1,04	1,04	1,03	1,04	1,04	1,04	1,03	1,05	1,05
856	14513		1,07	1,06	1,08	1,01	1,01	1,00	1,01	1,01	1,01	1,00	1,01	1,02
857	14532		1,09	1,07	1,1	1,03	1,03	1,02	1,02	1,02	1,02	1,01	1,03	1,03
858	14542		1,08	1,07	1,09	1,03	1,03	1,01	1,02	1,02	1,02	1,01	1,03	1,03
859	14547		1,07	1,06	1,08	1,02	1,02	1,01	1,01	1,01	1,01	1,00	1,02	1,02
860	14548		1,05	1,04	1,06	1,00	1,00	0,99	0,99	0,99	0,99	0,98	1,00	1,01
861	14550		1,07	1,05	1,07	1,01	1,01	1,00	1,00	1,00	1,00	0,99	1,01	1,02
862	14552		1,07	1,05	1,07	1,01	1,01	1,00	1,00	1,00	1,00	0,99	1,01	1,01
863	14554		1,07	1,05	1,08	1,01	1,01	1,00	1,00	1,00	1,00	0,99	1,01	1,02
864	14558		1,06	1,05	1,07	1,01	1,01	1,00	1,00	1,00	1,00	0,99	1,01	1,02
865	14612		1,09	1,07	1,1	1,03	1,03	1,02	1,02	1,02	1,02	1,01	1,03	1,03
866	14621		1,07	1,06	1,08	1,01	1,01	1,00	1,00	1,01	1,01	0,99	1,01	1,02
867	14624		1,05	1,04	1,06	1,00	1,00	0,99	0,99	0,99	0,99	0,98	1,00	1,00
868	14641		1,05	1,04	1,06	1,00	1,00	0,99	0,99	0,99	0,99	0,98	1,00	1,00
869	14656		1,08	1,06	1,08	1,02	1,02	1,01	1,01	1,01	1,01	1,00	1,02	1,02
870	14662		1,05	1,03	1,05	0,99	0,99	0,98	0,98	0,99	0,99	0,98	0,99	1,00
871	14669		1,06	1,05	1,07	1,01	1,01	1,00	1,00	1,00	1,00	0,99	1,01	1,01

Climate factors for Potsdam

1 = post code

2 = annual period (month and year)

3 = climate factor for post code and periods

Figure 14: Climate factors (GWS)

Energy consumption levels affected by the weather are calculated using the following formula:

$$Q_H = Q_{Hg} * Cf$$

Q_H = weather adjusted energy consumption
Q_{Hg} = calculated energy consumption (local)
C_f = GMS climate factor for the period of consumption

The climate factors provided by the GMS are between approx. 0.9 (cold regions, e.g. Hof) and 1.3 (warm regions, e.g. Freiburg).

Weather adjusted, specific heat energy consumption values are not only suitable for assessing how energy consumption in an office building changes over several years, but can also be used to compare the energy efficiency of the building with other buildings in Germany.

2.3.2.2. Weather-related adjustments using degree day numbers

The degree day number (DDN) and the heating degree day (HDD) are used to calculate the heating a building requires during a heating period. They represent the ratio between room temperature and the outside air temperature over the days in an assessment period where the heating is used. They are therefore helpful for determining heating costs and the amount of heating fuel required.

The annual DDN for the location of a building can be calculated using the frequency distribution of outdoor temperatures. The DDN is a measure of climatic conditions which affect annual transmission heat loss and so also the heating required for a building. A related measure is the HDD.

The basic principle of the DDN is that for each of the outside temperatures which register below the heating limit (15°C in Germany) you multiply the difference between the inside temperature (20°C) and the outside temperature by the relevant number of days. For example, the DDN was 30x15 = 450 when the outside temperature was 5°C for (e.g.) 30 days (= 15°C below room temperature at 20°C).

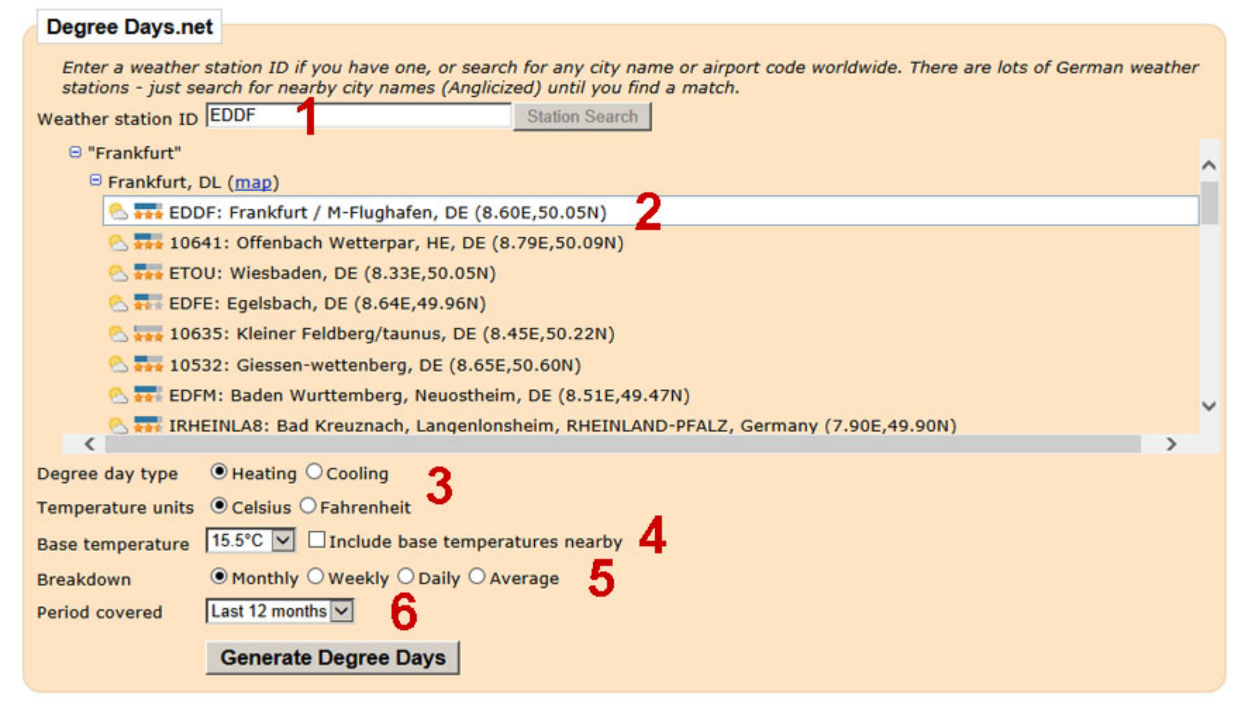
Days where the outside temperature is above the heating limit (e.g. 15°C) and days outside of the heating period (the maximum heating period in Germany is from 1 September to 31 May) are not included.

There are often considerable differences between the mean annual daytime temperatures in a country. Within Germany, for example, Freiburg may have a value of 3400, Lübeck in contrast may be 4000 and Munich may be 4265.

The annual DDN can be used to estimate the transmission heat loss for a house. Solar and interior heat recovery as well as ventilation losses should be taken into account separately when the heating required for a building is being calculated.

For international regions, there is the option of calculating the DDN online. The link to this degree day number calculator is: **www.dwd.de/gradtagzahlen**

As can be seen in figure 16, on the first screen you have to select the weather station and calculation criteria:



1 = weather station code	4 = heating limit temperature
2 = name of the weather station	5 = type of calculation
3 = select calculation criteria	6 = period of calculation

Figure 16a: Degree day number calculator for international regions – screenshot of the DegreeDays.net page

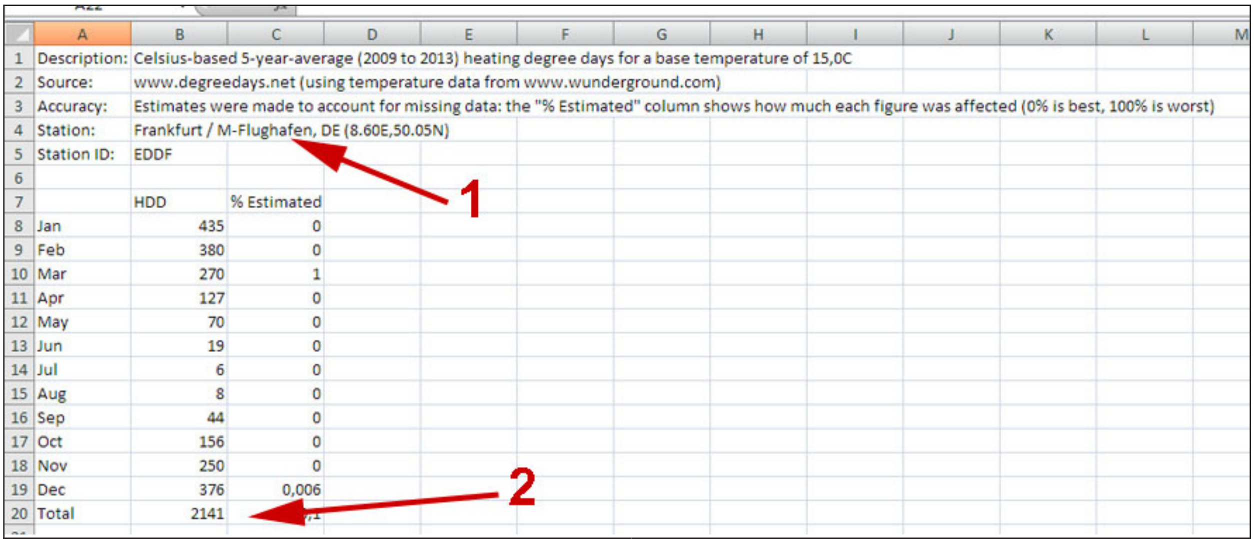
The calculation is made on the second screen (figure 16b).

Figure 16b: Degree day number for international regions – screenshot 2

After a short lead time you can click on the "download" button.

The result is transferred to an Excel sheet:

Evaluation sheet (Excel):



	A	B	C
1	Description:	Celsius-based 5-year-average (2009 to 2013) heating degree days for a base temperature of 15,0C	
2	Source:	www.degreedays.net (using temperature data from www.wunderground.com)	
3	Accuracy:	Estimates were made to account for missing data: the "% Estimated" column shows how much each figure was affected (0% is best, 100% is worst)	
4	Station:	Frankfurt / M-Flughafen, DE (8.60E,50.05N)	
5	Station ID:	EDDF	
6			
7		HDD	% Estimated
8	Jan	435	0
9	Feb	380	0
10	Mar	270	1
11	Apr	127	0
12	May	70	0
13	Jun	19	0
14	Jul	6	0
15	Aug	8	0
16	Sep	44	0
17	Oct	156	0
18	Nov	250	0
19	Dec	376	0,006
20	Total	2141	

1 = name of weather station	2 = degree day number

Figure 17: Evaluation sheet (Excel) for degree day numbers calculated by DegreeDays.net

2.3.2.3. Calculating climate factors from degree day numbers

Degree day numbers for heat energy consumption are related in the same way as climate factors. Climate factors for regions with 'mild' climates (Freiburg, Düsseldorf) have high values, and regions with lower average temperatures have lower values as their climate factors.

The climate factor 'Cf' is calculated using the following formula:

$$C_f = \frac{\text{Degree day number of reference city}}{\text{Degree day number of location}}$$

This formula can be used for annual and medium-term climate factors (long-term mean) where the DDN for the reference city should be the medium-term average value. How to use the climate factor calculated by using the degree day number is detailed in the section where climate factors are described.

2.3.3. Energy consumption meters and sub meters

Additional energy consumption meters are required to obtain a detailed calculation of energy consumption rates and to calculate energy costs for individual users or uses within the building. If meters are not already in place, consideration must be given as to where additional energy consumption meters might be integrated so that the accuracy of energy consumption measurements can be improved. The difference between main and sub meters is clarified again in figure 18.

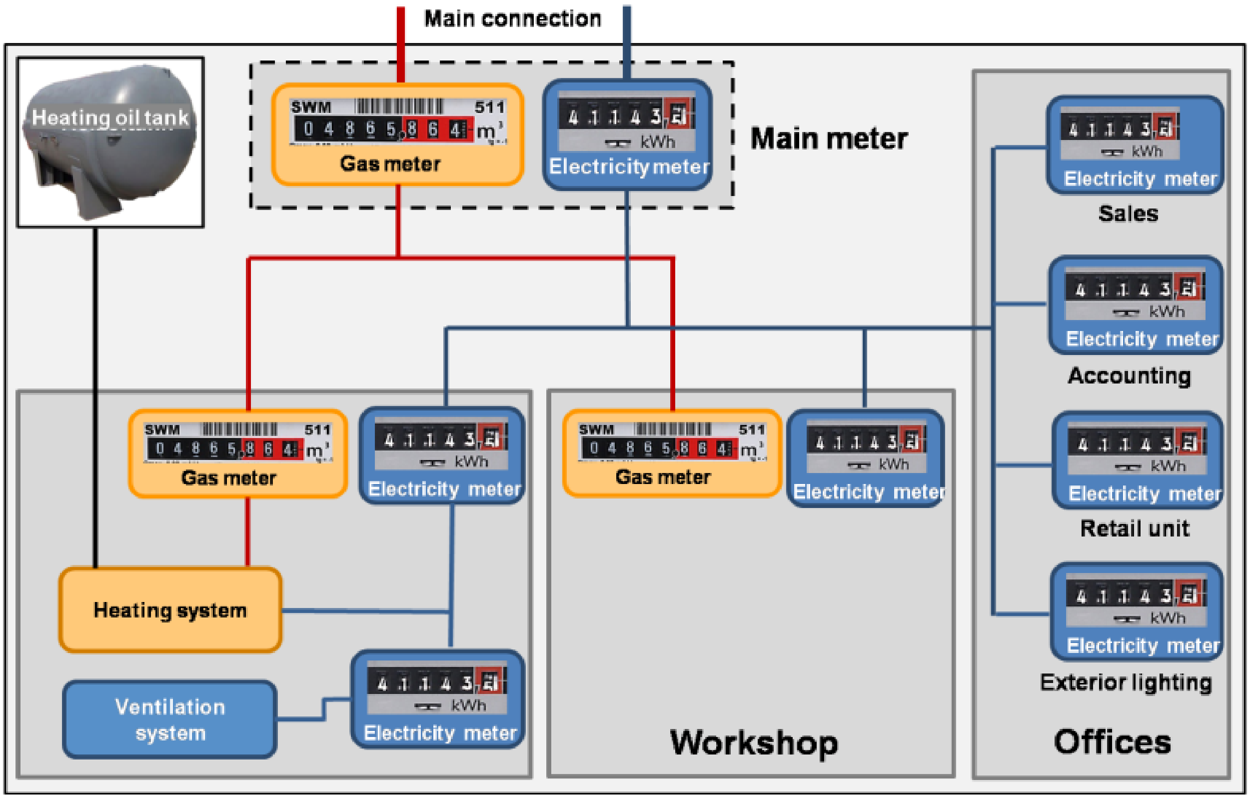


Figure 18: Schematic illustration of energy distribution within a building with main and sub meters for recording energy consumption

When calculating energy consumption in oil-based heating systems, monthly energy consumption has to be calculated using the difference by which the heating oil tank must be filled for it to be full.

1 litre of heating oil = 10kWh heat energy

2.3.4. Analysis of the load profile

The load profile is measured by the supplier using a digital electricity meter (SmartMeter). E.g. in Germany the electricity consumption is measured every 15 minutes using electronic electricity consumption meters. So-called 1/4 hour consumption rates are sent to the supplier in real time. These '1/4 hour rates' can be requested from the supplier for the last 12 months or can be accessed via the internet. Typical load profiles and example load profile data are given in figures 19 to 21.

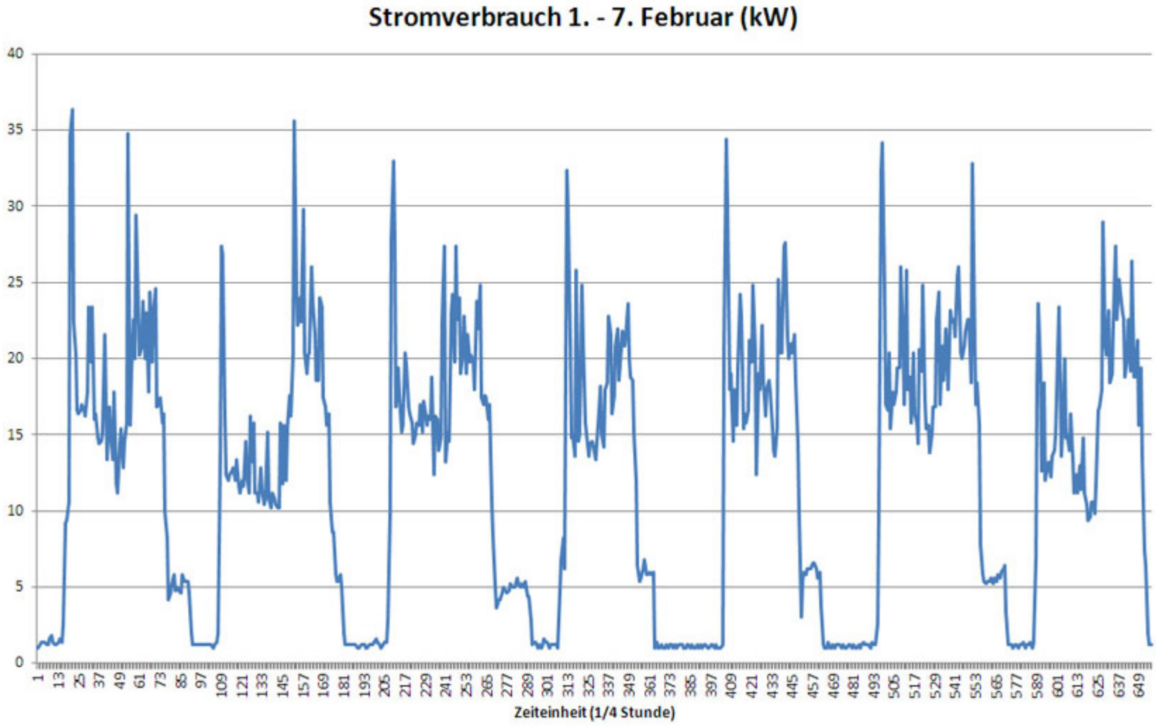


Figure 19: Load profile for typical consumption over one day

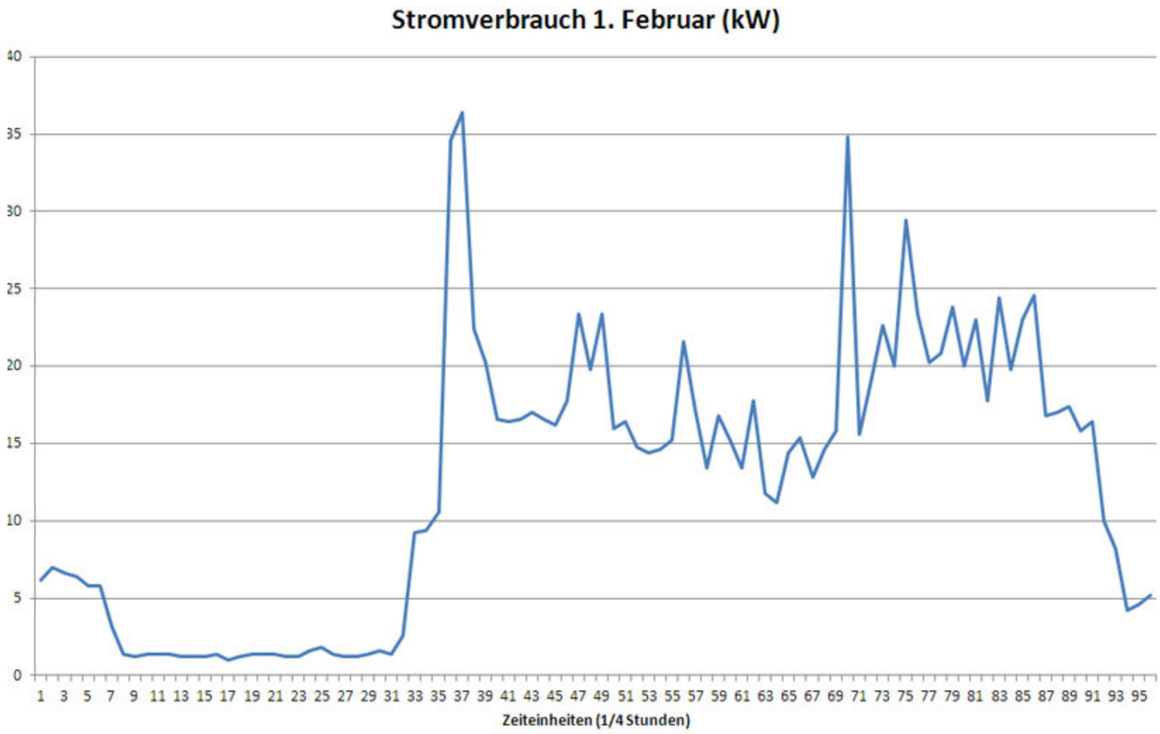


Figure 20: Load profile for typical consumption over one week

	A	B	C	D	E	F	G
1	**Stromlastgang Auswertung**						
2	Datum Uhrzeit	KW	**JDL**	Top 1000	Stundenwerte	**Kenndaten**	
3	01.01. 00:15	0,6	38,4	38,4	38,4	Max-Wert:	**38,4**
4	01.01. 00:30	0,6	38,4	38,4	37,4	Max-Wert in Zeile	**10799**
5	01.01. 00:45	0,6	37,8	37,8	36,2	kWh/a	**89.216**
6	01.01. 01:00	0,6	37,4	37,4	36	VBH/a:	**2323**
7	01.01. 01:15	0,6	37,4	37,4	35,8	Auslastung	**26,52%**
8	01.01. 01:30	1	37	37	35,8		
9	01.01. 01:45	1	36,6	36,6	35,6		
10	01.01. 02:00	0,8	36,4	36,4	35,4		
11	01.01. 02:15	0,8	36,2	36,2	35		
12	01.01. 02:30	1	36,2	36,2	35		
13	01.01. 02:45	0,8	36,2	36,2	34,8		

1 = date and time of measured period (15 minutes)
2 = measured average performance during this period
3 = annual consumption in kWh
4 = maximum measured value over 12 months

Figure 21: Load profile data is provided in Excel sheets by suppliers

Creating and evaluating the load profile helps when planning measures for reducing energy costs.

- If peak consumption rates are considerably lower than the fixed tariff, a lower rate could be selected at lower costs.
- If load peaks exceed the limits of the fixed tariff then higher costs are incurred by the customer. Often, the fixed tariff is raised to the highest load peak for one year (penalty payment). A single peak load per quarter is tolerated by some suppliers. The electricity supply contract and consumption invoices need to be inspected in order to determine this.
- The amount of electricity used outside of operating hours can also be seen in the load profile. If electricity consumption is considerably high during the night or at the weekend, the causes of this need to be explained.

High electricity consumption rates during the evening are a sign that lights are being left switched on in offices because, for example, cleaning staff have forgotten to switch them off. It is also possible that the ventilation system is switched on at full power outside of operating hours although there are only a few people in the building.

Studies on load profiles in office buildings have shown that the greatest savings potential can be made on electricity consumption outside of work hours. Analysing load profile data reveals whether excessive amounts of electricity are being used outside of operating hours. This observation then makes it easier to introduce suitable measures for reducing unnecessary consumption.

2.3.5. Energy consumption of essential electricity consumers

To optimise the operating hours of electrical consumers and lighting, all essential electrical consumers must be listed (electricity consumption balance). Besides containing details on where the consumers are located in the office building, this 'inventory' also includes:

- Type of device/lighting
- Consumption in watts (for fluorescent tubes with control gear)
- Number of electrical consumers per room
- Operating time per week

The Excel form for electricity consumption balance and analysis (Electricity Consumption-Balance-Analysis-1.xls) calculates the estimated actual state of consumption in kWh each year (left half of table, see figure 22a).

In the right half of the table (figure 22b) there is the option of recording improvements (e.g. reduced operating times, no stand-by consumption, more efficient lighting and equipment).

- New equipment with consumption in watts
- New operating times
- Necessary investment (EUR)

The Excel form calculates the new annual rate of electricity consumption in kWh and the savings made in EUR after implementing measures. The payback period is also calculated over on the far right.

To calculate electricity costs, the price for 1 kWh of electricity must be entered.

The Excel form adds up all rates, savings and investments. Consequently, this form is the basis for planning measures to improve energy efficiency and reduce electricity consumption.

Company/department Electricity consumption balance and analysis

Recording data from electronic devices and lighting with analysis								
Room	**Position**	**Device**	**Watt**	**Number**	**Watt (est.)**	**Hours per week**	**kWh per week**	**kWh per year**
Example 1	Lighting	Fluorescent tubes	72	6	432	45	19	1.011
Example 2	Work place 1	PC/tube monitor	120	1	120	45	5	281
Example 2a	Work place 2	Standby PC	5	1	5	123	1	32
Example 3	Ventilation system	Ventilator	3000	2	6.000	80	480	24.960

Figure 22a: Excel form for electricity consumption balance and analysis (left half for the actual state)

Recording data from electronic devices and lighting with analysis											
					Electricity costs:			0,25	EUR/kWh		
Room	**Position**	**Device (new)**	**Watt (new)**	**Number (new)**	**Hours per week**	**Hours (new) per week**	**kWh (new) per week**	**Saving (kWh per year)**	**Saving (EUR per year)**	**Investment (EUR)**	**Payback (years)**
Example 1	Lighting	LED tubes	36	6	45	10	505	505	126	300	2,4
Example 2	Work place 1	PC/LCD monitor	55	1	45	2	129	152	38	150	3,9
Example 2a	Work place 2	Switch off PC	0	1	123	0	0	32	8	0	0,0
Example 3	Ventilation system	Frequency converter	1200	2	60	144	7.488	17.472	4.368	3.000	0,7
						0	0	0	0		#DIV/0!
						0	0	0	0		#DIV/0!
						0	0	0	0		#DIV/0!
						0	0	0	0		#DIV/0!
							8.122	**18.162**	**4.540**	**3.450**	**0,8**

Figure 22b: Excel form for electricity consumption balance and analysis
(right half for the planned state)

The maximum performance of a device in kW can be read from the type label and the electricity consumption rate is measured on the device in kWh.

Depending on the depth of the electricity consumption balance, the calculated amount of electricity consumption ought to be close to the rate that was measured. Ideally, the calculated amount of electricity consumption is identical to the measured amount of electricity consumption.

Practice has shown that the calculated amount of electricity consumption lies considerably below the measured rate of consumption. This may be due to the following reasons:

- The balance is incomplete and only quotes the largest consumers.
- Operating times were considerably underestimated.
- The constant rate of electricity consumption is not easy to estimate because different wattages are in use (e.g. coffee machine, photocopying equipment, refrigerator, ventilation system) and long-term measurements are too difficult.

The calculated rate of electricity consumption does not have to be exactly accurate in order to plan measures to reduce electricity consumption. The savings percentage can be calculated using the electricity consumption balance and by calculating the inferior amount of electricity consumption once electricity consumers have been made more efficient. The saving can be projected roughly onto the actual amount of consumption by using this percentage.

The electricity consumers‘ balance is important for creating a detailed plan of the measures required to save energy. By using the Excel form, a specific saving can be planned for each separate device while taking a potential reduction in operating times into account. Moreover, the cost-effectiveness of the investment can also be estimated.

In reality, businesses are only interested in short payback periods of up to 2 years and periods of up to 4 years in exceptional cases. This must be taken into account when planning the measures so that company management will also give their approval.

The most effective way of making savings is to switch equipment/lighting off when they are not needed. This is the main focus of the measures used to improve the energy efficiency of office buildings.

2.3.6. Measuring electricity consumption

The following measuring equipment is available for measuring energy consumption for individual devices or areas of the building (e.g. rented office floors, business areas and office buildings):

- Electricity meters as main and sub meters.
- Energy monitors with and without data loggers to record electricity consumption.
- Plug-in energy monitors with data loggers (e.g. Plugwise, see figure 23a and chapter 2.3.6.2).
- Current clamp and network monitors with data loggers.
- Counting the increments on the electricity meter.
- Electricity meters integrated into the power distribution (also for the load profile).
- Evaluating the load profile from the electricity meter.

Measuring electricity consumption individually is necessary for the following reasons:

- Only the maximum power input is noted on the device's type label. Electricity consumption can be reduced by controlling the device or by selecting an output level.
- There is no type label including a consumption level.
- It is not known how long periods of high electricity consumption last or if there are pauses.
- Electricity consumption depends on use or on environmental conditions and can not be estimated.

The following figures include an overview of the different kinds of measuring equipment available.

3 electricity consumption monitors without data loggers

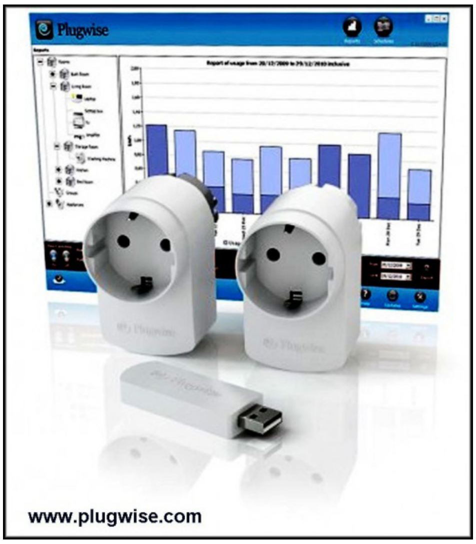
Current clamp

Figure 23a: Electricity measuring devices

Analogue electricity meter with rotating disc (Ferraris)

Digital electricity meter with converter for high connected loads (factor = 40 – arrow)

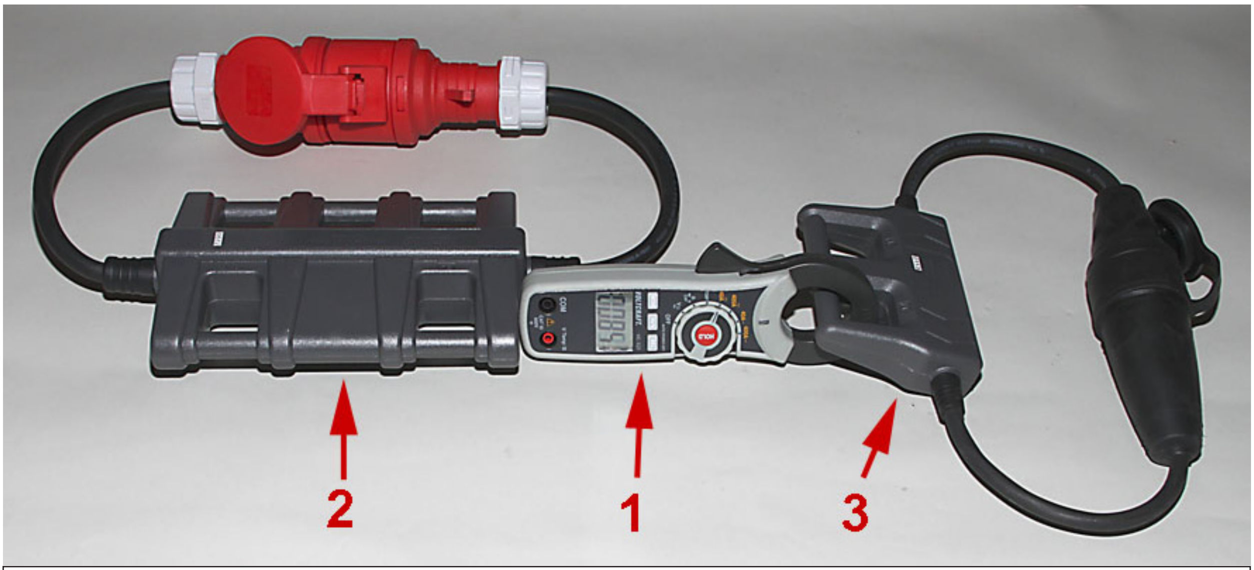
Figure 23b: Electricity measuring devices



Plugwise electricity consumption monitor with data logger and WLAN which transfers the load profile to a USB stick to save it

Consumption data monitor for reading electricity consumption on analogue and digital electricity meters with and without data loggers in order to create the load profile (ELV)

Figure 23c: Electricity measuring devices



Adapter for measuring electricity using the current clamp on supply cables for equipment.
(1) Current clamp – (2) Adaptor for 3-phase power – (3) Adaptor for 1-phase power

Figure 23d: Electricity measuring device

The devices shown on the images are either already present in office buildings (e.g. electricity meters and sub meters) or can be purchased for a reasonable price. Expensive network analysers are required for measuring the load profile on individual devices and in operating zones. There are also alternative, more cost-effective methods available for estimating the amount of electricity consumed by devices which give approximate values. Moreover, it is possible to rent measuring equipment for free for a certain period of time from the city council. These options, however, ought to be examined.

More information is available in the appendix "Measuring Devices".

2.3.6.1. Electricity meters as main and sub meters.

Electricity meters are suitable for measuring electricity consumption over a longer period of time. The amount of electricity consumed is calculated using the difference between the meter readings taken at the start and the end of the period being measured.

Where electricity meters have a current transformer for high connected loads, electricity consumption has to be multiplied by the conversion factor.

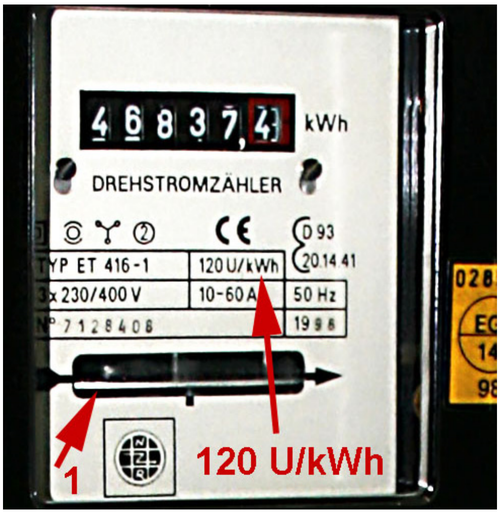
Electricity consumption$_{(effective)}$ = Difference of meter readings x conversion factor

The factor for the current transformer is usually stated on the electricity meter (see image of digital electricity meter). If no factor is provided, then the amount of electricity read from the meter corresponds to the actual amount of electricity consumed (factor = 1).

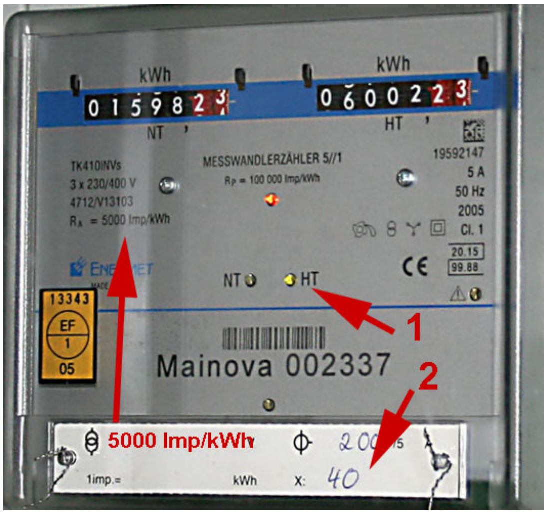
Electricity meters can also be used to confirm the amount of electricity consumed by equipment or systems. First, the so-called 'no-load current' from outside of operating hours is measured. This can be measured by reading the meter, by counting the rotations of the Ferraris disc (analogue meters) or by counting the number of impulses within the time frame (e.g. 15 minutes). Once the additional consumer has been switched on, the same procedure is carried out again. The difference in electricity consumption corresponds to the amount of electricity which the additional consumer uses.

To calculate the average level of consumption, you only need to project the calculated level of consumption to 1 hour.

It is advantageous to install individual sub meters (e.g. for heating/ventilation system) in order to monitor energy consumption more efficiently.



Analogue electricity meter with Ferraris disc (1).
120 rotations per kWh



Digital electricity meter with LED (1).
5000 LED impulses per kWh.
Conversion factor = 40 (2).

Figure 24: Displays on electricity meters

2.3.6.2. Measuring consumption using energy monitors

Energy monitors are compact electricity consumption measuring devices and can be used to measure electricity consumption in watts at one instant and in kWh over a period of time. Additional functions (on expensive energy monitors) for measuring the power supply, active current, cosine-pi factor and operating time are optional.

The energy monitor is plugged into the socket and the cable on the equipment is plugged into the energy monitor. Different energy monitors designed for up to 3600 watts are available. This means that almost all equipment with a mains lead for a Schuko socket can be connected.

One disadvantage with energy monitors is that the amount of electricity consumed while the equipment being measured is on standby has to be at least several watts for the device's low measuring range to register the measurement. When buying an energy monitor, therefore, you should make sure that the lower measuring range starts at less than one watt.

There are energy monitors available to measure consumption levels of less than 1/10 of a watt when equipment is on stand-by. On these devices, the upper measuring range is often limited to several hundred watts.

Most energy monitors do not have a data logger and so are unable to display a load curve.

2.3.6.3. Socket energy monitor with data logger

Socket monitors which record the consumer's load profile are available for calculating electricity consumption (e.g. products from 'Plugwise'). The system consists of a 'central hub' (circle+) which compiles and saves data from remote-controlled sockets. Data from individual electricity consumers is gathered by socket measuring devices ('circles'). This data can then be transferred via radio waves to the 'circle+ central hub'. Electricity consumption and load profile data can be saved onto a USB stick and analysed on the PC using software.

The Plugwise system (system for calculating electricity consumption on individual electricity consumers with data loggers) can currently only be used for single-phase consumers (230V) which are connected to a Schuko socket via a normal mains cable (live lines with a neutral wire and an earth wire).

Devices and electrical machines which consume more than 400V are connected to a three-phase power supply line (three live lines with a neutral wire and an earth wire).

Data logger systems are available for single and three-phase electricity with current loops. The electricity can be measured using current loops without interrupting the connecting supply line. Plugwise offers a three-phase data logger which can be integrated into the distribution board. The installation must be carried out by an electrical specialist.

2.3.6.4. Current clamps and network monitors with data loggers

Current clamps use the magnetic field created by electricity in the power lines of electrical equipment to measure the amount of power. This allows amperage to be measured without interrupting the supply line. For supply cables that have a connecting plug, an adaptor with 'bridges' is provided for connecting current clamps. The current in supply cables without a plug can only be measured using the cables inside the equipment or in the junction box.

Simple current clamps do not usually have a data logger. They are therefore not suitable for recording the load profile. They can only measure and display electricity consumption at one instant.

Some current clamps do have data loggers which can be used to record the load profile. One disadvantage to this, however, is that the relatively large current clamp has to be connected to the equipment until the measurement has been taken.

Data loggers with current loops for single- and three-phase electricity consumers usually have smaller probe heads which can be fitted to the system better,

Network monitors are also available for more complex tasks (single- and three-phase) with a display for showing the load profile.

Safety notice:

The work described above on how to take measurements using current clamps and current clamp adaptors for network monitors require access to electrical devices by opening the casing and/or the junction box. This work must only be carried out by trained persons who at least have a qualification as an 'electrical specialist for scheduled work'. Measurements may only be taken on medium to high-voltage circuits by qualified personnel.

2.3.6.5. Counting the increments on the electricity meter

Electricity and gas consumption can be measured by taking an electronic reading from the meter. Depending on the type of meter being used (analogue electricity or gas meter, or electronic electricity meter), a sensor is fixed to the glass pane on the meter in order to read the rate of electricity and gas consumption. This sensor 'counts' the rotations of the Ferraris disc on analogue electricity meters or the LED light impulses on digital meters.

The pulses are converted into electrical consumption figures (kWh) in the receiving unit. To calibrate the measuring device, the number of revolutions per kWh (analogue meters) and/or pulses per kWh (digital meters) has to be set. The consumption figures are displayed on an 'energy savings monitor'.

This system can also be expanded using a data logger. The consumption data is displayed periodically. The load profile data can be assessed by a PC by using a micro SD card. This means that the load profile can also be calculated without having to retrieve load profile data from the energy supplier. This is particularly attractive for smaller consumers because suppliers usually do not record electrical connections of below 100,000 kWh/year. This technology can also be used for electricity consumption meters in sub circuits.

As an alternative to the options described above, there are also measuring devices for measuring load profiles which can be integrated into the power distribution.

2.3.7. Inspecting the lighting

Office building lighting often hides a large savings potential for electricity consumption. Causes of unnecessarily high electricity consumption are:

- Lights are not switched off when they are not needed.
- Illumination is too high.
- Defective fluorescent lamps require electricity but are not replaced or removed.
- Light bulbs or halogen bulbs are not replaced with energy saving lights or LED lights.

The lighting is inspected when electricity consumption is recorded (for the electricity consumption balance). The potential saving made by installing alternative lighting and by reducing times when lights are switched on can be estimated by using the Excel table (Energy Consumption Analysis.xls).

2.3.7.1. Minimum luminance levels

Due to technical regulations on safety in the workplace (ASR A3.4 for lighting), a minimum level of luminance must be observed in office buildings. These are illustrated in table 25:

Work room, workplace, work	**Min. luminance (lx)**	**Minimum value Colour reproduction (Index R_a)**	**Measurement in height above floor (cm)**
Office, writing, reading, computer	500	80	75
Technical drawing	750	80	75
Environment of office work places	300	80	<20
Archives	200	80	<20
Entrance halls	200	80	<20
Reception desk, counter, porter system	300	80	75
Thoroughfares without vehicular traffic	50	40	<20
Thoroughfares near steps without vehicular traffic	100	40	<20
Thoroughfares and corridors with vehicular traffic	150	40	<20
Steps, escalators, lifts	100	40	<20
Canteen, tea kitchens, self-service restaurants	200	80	<20
Break rooms, waiting rooms, recreation rooms	200	80	<20
Lavatories, baths, toilets	200	80	<20
Rooms for in-house service facility systems, switchgear	200	60	<20

Table 25: Minimum illuminance and colour reproduction according to work space

Figure 26: Illuminance meter for measuring illuminance

2.3.7.2. Electricity consumption of fluorescent lights with control gear

To calculate electricity consumption, the amount of electricity consumed by the control gear also has to be taken into account. There are three types of control gears for fluorescent tubes:

Type of control gear	Description
CCG	Older lamps with starters have conventional control gear. High electricity consumption. Typical feature is that the tube light flickers slightly. The light flickers a lot when it is switched on.
LLCG	Low loss control gear in modern fluorescent tube lighting. Lower electricity consumption.
ECG	Electronic control gear with low electricity consumption Typical feature is a quicker start-up and no flickering.

Table 27: Control fear for calculating electricity consumption

It has been forbidden to purchase conventional control gear in the EU since 2002/2005 due to high levels of energy loss. They are usually in lights that were installed before 2002.

LLCGs are not deemed very important because in order to improve energy loss they are actually larger than KVGs. Modern fluorescent tube lights have electronic control gears (ECG). Energy saving lamps with small fluorescent tube lights have integrated, electronic control gears already installed.

		Electricity consumption (watts)			
T8 fluorescent tubes	**Length (cm)**	**CCG**	**LLCG**	**ECG**	**Lumen**
18 watt	59	26	24	21	1350

36 watt	120	45	42	39	3350
58 watt	150	71	66	58	5200
T5 fluorescent tube					
14 watt	55	–	–	14	<1350
28 watt	115	–	–	28	<2640
35 watt	145			35	<3320
LED light sticks					
9 watt/120°	60	–	–	–	790
18 watt/120°	120	–	–	–	1730
20 watt/120°	150	–	–	–	2200

Table 28: Connected loads for fluorescent lamps with control gear

With the exception of very old fluorescent lights with so-called 'T12' lights which are 38mm in diameter, the majority of installed lights are fitted with 'T8' tube lights (26mm diameter). T12 tubes can be replaced with T8 tubes which means it is now very difficult to obtain T12 tubes.

Fluorescent tubes available on the market today have good luminous efficiency (approx. 75–90 lumen per watt). 'T5 tubes' with a diameter of 16mm have a higher luminous efficiency and approx. 95 to 100 lumen per watt.

Lights for T8 tubes can be fitted with CCG, LLCG and ECG. A T5 tube can only be operated using an ECG. Due to its smaller socket, it is not compatible with lights for a T8 tube. This means that it cannot be fitted automatically into lights for T8 tubes. Converting a T8 light with ECG to use T5 tubes results in 30% less luminous power than usual. Therefore, before fitting T5 tubes into T8 lights, you must check whether the luminance is still sufficient. Adaptor sets with ECG are available to convert T8 lights with CCG/LLCG to T5 tubes. These adaptors are relatively expensive. Another problem is the low lumen count on a T5 tube in comparison to a T8 tube, since 145cm long T5 tubes only emit approx 3300 lumen (at 35 watts). A T8 tube emits approx 5200 lumen at 58 watts. Using T5 tubes may mean that more lights are required to observe the minimum levels of light intensity. This also means that more investment may have to be made into buying additional lights.

These technical specifications mean that modifying T8 lights into T5 tubes is usually neither technically feasible nor economically viable. When purchasing new fluorescent lights, it is much wiser to buy T5 lights with good reflectors (possible as double lights).

2.3.7.3. Colour rendering index and colour temperature

Besides the luminance of the lights, the colour rendering quality of the fluorescent tubes must also be taken into account. Light from fluorescent tubes, energy saving lamps, high pressure lamps and LED lights is not the result of a smooth progression along the colour spectrum but is simply the product of a number of different wave lengths being emitted. As a result, the quality of colour rendered is affected negatively. This is a particular problem with yellow sodium vapour lamps.

A 'colour rendering index' has been created to assess the quality of the colour rendered. This colour rendering index 'R_a' or 'CRI' indicates what kind of quality the colour of an object will be. The reference is sunlight or daylight with an even distribution of wave lengths with $R_a = 100$.

The lower the value for the Ra index, the poorer the colour rendering. Light bulbs with the highest possible colour rendering index of $R_a = 100$ are therefore provided as a reference value. Example: R_a values of ≥ 80 signify good colour rendering properties, and $R_a = 90$ means there is a very good colour rendering property.

The following R_a empirical values apply for light sources:

Illuminant	R_a	Illuminant	R_a
Light bulb	up to 100	White LED	80 – 90
Fluorescent lamp, 5 bands	> 90	Halogen metal vapour lamp	70 – 95
Fluorescent lamp, 3 bands	80 – 85	Mercury vapour lamp	40 – 55
Old standard fluorescent lamps	60 – 75	Sodium vapour lamps	20 – 35

Table 29: Illuminant and colour rendering R_a

For high-quality graphic work a R_a much greater than 90 is required. A R_a of 80 is sufficient for office work. According to EU guidelines, compact energy saving lamps and LED lamps must have a colour rendering index value of at least 80.

Another physical quantity which affects how illuminants are used in lighting systems is 'colour temperature'. The colour temperature for white illuminants is measured in 'Kelvin' (K=°C + 273). The higher the Kelvin value, the higher the percentage of short waves (blue light) on the light spectrum. The colour temperature for normal light bulbs is between 2600K and 3000K. Light from the light bulb has a continual spectrum. Light from an energy saving lamp is mostly limited to a narrow range of spectral bands.

Mood	Colour temperature	Light source
Comfortable, at ease	2.600 – 2.800 K	Light bulbs and halogen lamps
	2.700 – 3.000 K	Fluorescent lamp (warm white)
	3.000 – 3.200 K	Halogen lamp (extra low voltage)
Technical	4.000 K	Fluorescent lamp (neutral white)
	5.000 K	Morning and evening sun
Similar to daylight	5.500 K	Morning/afternoon sun
	6.500 K	Fluorescent lamp (daylight)

	6.500 – 7.500 K	Overcast sky

Table 30: Light colours according to DIN 503

Fluorescent lamps have a particular coding for colour temperature and for the colour rendering index (R_a). The coding is consists of 3 figures. The first figure stands for the R_a and the last two figures stand for colour temperature.

Code	Colour	Colour rendering	Luminous efficiency (lm/watt) (*)	Use
640	neutral white	moderate	75	often used in offices
740	neutral white	moderate	moderate	often used in offices
827	warm white	good	very good (93)	living room
830	warm white	good	very good (93)	living room
840	neutral white	very good (87)	very good (93)	offices
865	daylight	very good	good (90)	'performance-incre-asing' work light
930	warm white	excellent	moderate (75)	living room
940	neutral white	excellent	moderate (81)	work places with a higher demand for colour rendering quality
954	daylight substitute	whole spectrum (98)	moderate (79)	museums, galleries
965	daylight substitute	excellent	moderate (79)	museums, galleries

(*) Approximate values

Table 31: Typical values for fluorescent lamps

As can be seen from the table, the 8xx series has the best luminous efficiency. Lamps with the code 840 and 865 are particularly good on the colour rendering index.

When fitting fluorescent tubes, you should make sure that the replacement tubes have the same colour temperature as the used tubes. A mixed range of tubes with different colour temperatures can be distracting. Warm white tubes give the subjective impression of being less bright than neutral white tubes.

Fluorescent tubes have a limited life cycle. There is a marked reduction in light intensity after just 2,000 operating hours. Light intensity drops to about 60% by the end of the tube's life cycle. To ensure that the minimum levels of light intensity are maintained, fluorescent tubes should be replaced in good time.

2.3.7.4. Causes of reduced luminance and the maintenance factor

Another cause of reduced luminance at the workplace is when the lights are dirtied, particularly the reflector mirror and acrylic covers. These items should be cleaned regularly so as to maintain the intended level of luminance.

The reduction in luminous efficiency during the service life of the light must be taken into account when working out the desired luminance. This is expressed in the 'maintenance factor'. The maintenance factor provides reduced luminance as a percentage of the as-new condition of the light and lamp at the end of normal operating times. Lights used in offices sustain a loss of 30% during their service life and maintenance periods (e.g. cleaning lights and reflectors). As a result, the maintenance factor for fluorescent lamps, LED lights and halogen spotlights is approximately 70%.

When fitting lights, the luminance in the light's as-new condition needs to be 1.5 times higher than the luminance of the light at the end of its service life. For office workplaces, this means that as-new lights must have at least 750 lux instead of the minimum luminance which is 500 lux.

2.3.7.5. LED fluorescent tubes

LED technology has developed strongly in energy efficiency over the last few years. LED lights reach outputs of over 100 lm/watt. Great leaps have also been made in colour rendering. R_a factors for some products are considerably higher than 90. LED lights are now available for halogen spotlights (extra low voltage and 230 volt), as replacements for light bulbs as well as LED sticks for replacing fluorescent tubes.

Advertisements often claim that LED light sticks lead to considerable savings in contrast to T8 fluorescent tubes. This is only partly true.

Tube light	Electricity consumption (watts)	Lumen	lm/watt
T8 with ECG (150 cm)	58	5.200	90
T5 with ECG (145 cm)	35	3.320	95
20 watt LED (150 cm)	20/30	2.200/3.300	110

A 20 watt LED tube with 2,200 lumen has a considerably lower light intensity than a T8 with ECG. Despite the lower luminous efficiency, it still does not rule out replacing a T8 fluorescent tube with an LED tube. It does not solely depend on the luminous intensity, but on how the light is distributed in the beam angle. If the light from the fluorescent lamp is directed at the work space using a mirror, a higher luminance in lux is achieved with the same luminous power.

Most LED tubes have distinct LEDs. The beam is directed downwards as shown in the following polar diagram.

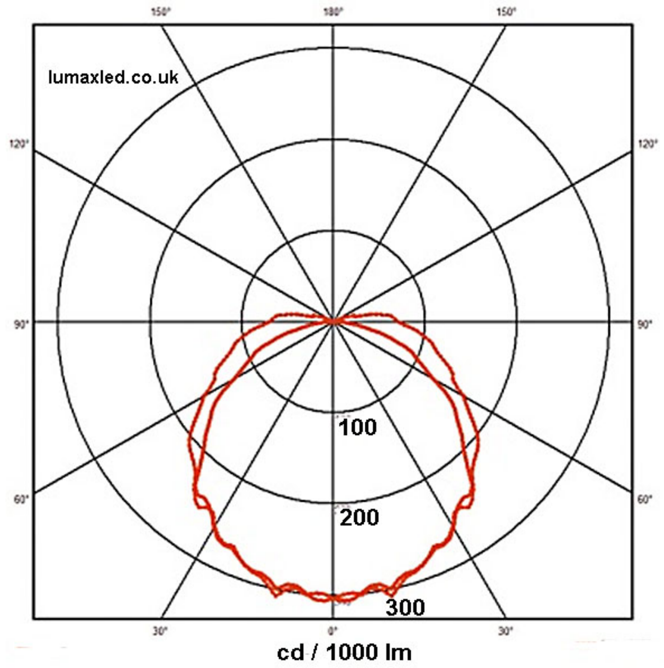


Figure 32: Polar diagram of an LED tube

Luminance in the workplace can be calculated using a polar diagram. Luminance is given in cd/1000 lm. The maximum value on the example diagram is 300 cd/1000 lm. Intensity is reduced to approx. 200 at an angle of approx. 50°.

Luminance is calculated using the following formulae:

$$\text{Illuminance (lx)} = \frac{\text{Luminous flux (lm)}}{\text{Surface (m2)}}$$

$$\text{Illuminance (lx)} = \frac{\text{Luminous intensity (cd)}}{\text{Distance (m)2}}$$

Example for 2,200 lumens, 300 cd/1000 lumens, workplace with distance of 2.15 metres from the ceiling

$$\frac{300 \text{ x } 2{,}2}{2{,}15 \text{ x } 2{,}15} = 143 \text{ lux}$$

Formulae for calculating luminance

In practice, it is sufficient to test the light intensity of lights on a trial basis by measuring the luminance for an application. This saves having to make complex calculations and you are able to get the fastest and most practically-relevant result.

2.3.7.6. Risk groups for Light Emitting Diodes (LEDs)

Health risks which affect the eye (retina) and skin (UV/IR rays) may result from using light fixtures. According to the German DIN EN 62471, light fixtures are divided into 4 risk groups depending on the intensity of the radiation they emit.

Free group:	Lamps/lights present no photobiological danger.
Risk group 1:	Lamps/lights present no risk to the user since normal user behaviour restricts danger.
Risk group 2:	Lamps/lights present no risk due to the user's natural preventative reactions to bright light or due to discomfort from heat.
Risk group 3:	Lamps/lights do present a risk even through brief or short-term exposure. This group must not be used in general lighting.

Table 33: Risk groups

A label is not required for the free group and risk group 1. A label is required for risk group 2. Risk group 3 is not permitted for use in general lighting. The following symbol is currently often used:	

To avoid health risks, only certified illuminants must be used in office buildings. If uncertified LED lamps are used, there is the danger that

they will not meet the current technical regulations(norms). Complicated measurements are necessary for classifying lamps into risk groups, particularly in regard to photobiological safety. Damage to the eyes is a real risk for LED lamps in risk groups 2 and 3.

2.3.7.7. Alternative lights and converting lighting systems

Some systems can be fitted directly with energy-saving lights. On other systems, the lights have to be converted.

Old illuminant	New illuminant
Light bulb	Use of energy saving lamps or LEDs with a screw base. Does not have to be changed often (approx. 22 year lifespan). It is usually impossible to dim LED and energy saving lamps. Energy saving lamps take a while before they reach their full luminous intensity.
T8 fluorescent tube	Fitting a T5 fluorescent tube using an adaptor.

	It is only possible to fit T5 tubes when there is electronic control gear. The control gear has to be exchanged, if necessary. A T5 tube has a lower luminous intensity (approx. 3,300 lumen in contrast to 5,200 lumen). As a result, it is not possible to exchange the tubes 1:1. There are conversion kits for T8 lights which have an adaptor for T5 tube lights. This adaptor has an integrated control gear. Conversion kits are relatively expensive and may, in certain circumstances, make the tubes' CE certificate in valid. The manufacturer declares with the CE certificate, for example, that they have tested the product in compliance with EU specifications on safety risks.[1] For this reason, we recommend that conversion kits for converting T8s to T5s are only used in certain circumstances.
	Fitting LED light sticks that are plug compatible. When changing this illuminant, you must check whether: • The light will bear the weight of the LED stick. • There is enough space for the LED stick. • The light intensity is sufficient for the workplace.
	Fitting a clamp-on reflector to increase light intensity in the work area.
Halogen spotlights	Fitting LED spotlights with a 230 volt power supply is usually unproblematic. When fitting low-voltage spotlights (12 volt), we recommend using special extra low voltage mains adaptors for LED spotlights. If the alternating current transformers for halogen spotlights continue to be used, this can lead to an overload on the LED spotlights and/or a greater consumption of electricity. There is then no savings effect..
T5 fluorescent tube	Fitting a clamp-on reflector to increase light intensity in the work area.

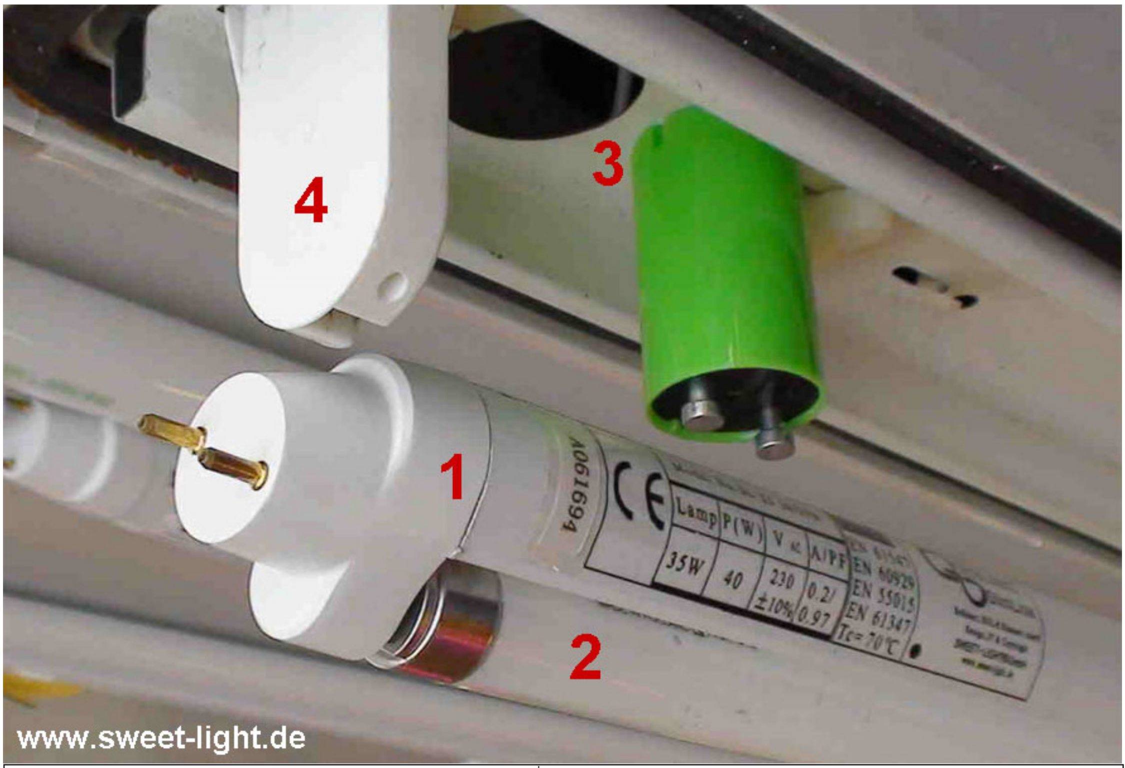
Table 34: Conversion options for different lights

There are now licensed LED light sticks which can be fitted to lights with inductive control gear (CCG, LLCG). Only LED light sticks that have a high luminous power (> 3,200 to 4,000 lumen) can be used to replace T8 fluorescent lamps in the office. They are available from leading brand manufacturers. It is usually unproblematic to exchange T8 fluorescent tubes with a compatible LED light stick. The starter is exchanged for a bypass adaptor.

Lights with electronic control gear can't be used for LED sticks without converting the lights.

T8 fluorescent tubes can be replaced with T5 fluorescent tubes by using the appropriate licensed adaptor.

1 www.din.de/cmd?level=tpl-unterrubrik&menuid=47421&cmsareaid=47421&menurubricid=47429&cmsrubid=47429&menusubrubid=47435&cmssubrubid=47435



1 = T8 on a T5 adaptor 2 = T5 fluorescent tube	3 = Short circuit adaptor 4 = Lights for T8 fluorescent tubes

Figure 35: Permitted conversion adaptor for T5 lights in a T8 light with CCG/LLCG

Plug-on reflectors can be fitted to improve illumination by using fluorescent lamps:

Figure 36: Plug-on reflectors

To ensure that the correct level of lighting in accordance with workplace guidelines is used, we recommend conducting a test installation of new or converted lights. Luminance can be verified by using the relevant measurements.

> **Safety notice:**
>
> Lights of the same type or those that are directly compatible may be replaced by unqualified persons.

Only trained electrical engineers may conduct work on live parts on equipment. This includes exchanging parts, altering switches as well as wiring and testing the equipment.

Making changes to lights so that alternatives can be fitted (e.g. exchanging conventional control gear (CCG) with electronic control gear (ECG), altering wiring for T5 light sticks, etc.) may only be carried out by trained electrical engineers.

When making alterations you must make sure that the lights' certification is not rendered invalid as a result. Additional requirements relating to dust and humidity covers must also be observed when modifying lights.

If the safety certification of electronic equipment is rendered invalid, the manufacturer will bear no liability for the product. Liability then passes to the person who made the alterations.

There are also insurance-legal consequences if the certification of lighting systems is rendered invalid.

LED lighting is attractive for us in compulsory lighting required for emergency exits. They have to remain switched on constantly and have a high usage time.

2.3.7.8. Controlling lighting systems

To reduce electricity consumed by lighting systems, lighting must be switched off when it is not required. This can either be done by hand (manually) or by using electronic control devices. User behaviour also has to be periodically inspected so as to make sure that lighting is then switched off when it is not needed. Awareness should be raised amongst users that they ought to switch off the lights and that users are thereby also contributing towards reducing electricity consumption and energy costs.

Areas that are often neglected are places that are rarely used, i.e. exterior lights, lighting for hallways, storage rooms, toilets and washrooms. There are usually areas in offices and meeting rooms that are well lit by daylight. Lighting is therefore only required during certain periods. Consequently, office lighting should be organised so that it can be switched off in zones. Other savings can be made by installing automatic switches, such as movement sensors, presence detectors, time switches and light intensity detectors (e.g. for sunlight).

Electricity consumption can also be reduced in offices by fitting workstation lights. Work places that need to be brightly lit, can be lit with precision by fitting workstation lights. Workstation lights are also available with integrated light sensors which switch on the lamp when the light in the office is not adequate for the workstation.

Daylight sensors can also be used for fixed, integrated lights to switch off lighting near windows when there is enough daylight. This system then requires investment into a daylight control system.

Movement and presence sensors are usually reasonably priced. They mostly have to be fitted into the mains.

Case study 1:

It is already December and the weather is doing exactly what winter promises. Outside it is cold and dark. Anne has just arrived and has turned on the light in the office. She has a lot do to on this particular day. At 10:30, the sun shines through the window although it is no more than 5°C outside. Since the light from outside is so bright, Anne doesn't even realise that the light is still switched on in the office. Anne goes into the kitchen as it's about time for short coffee break. After 15 minutes, she returns to her work.

Provided that natural light conditions in the office allow, work with daylight! It has been proven that daylight stimulates biological impulses which can influence the quality of work and visual skills in a positive way since periods of natural light are innately recognised by humans as being the most productive periods.

Use every opportunity to make savings. Coffee breaks also count! Don't forget that switching off lights in the office is also part of what it means to work as a team in the office. You can help yourself and others by using post-its, stickers or posters in the office.

Case study 2:

After their lunch break, Anne and Petra meet in the ladies toilets. They have a brief conversation. As they go away they leave the light switched on. Neither the lights in the cubicles nor those in the foyer of the toilets were turned off. Someone is bound to come in later...

We recommend fitting lighting systems with movement sensors and timer functions in communal areas (corridors, toilets, kitchens etc.) However, cooperative, individual user behaviour also affects how much energy is saved. Switch off lighting when leaving the office, in breaks or after finishing times.

2.3.7.9. Planning lighting systems

The quality of lighting in the workplaces, hallways, transport routes and other facilities in office buildings is an essential factor in creating a work-friendly environment in the workplace, and in the productivity of the work done as well as health and safety. Labour regulations on lighting also play an important role here.

Electricity consumption can be reduced easily by first switching off lighting, and secondly by upgrading lights that are less energy efficient (e.g. light bulbs, halogen spotlights, etc.) with compatible high efficient types.

We recommend the optimisation of the lighting system to be conducted by a planning office. This ensures that labour regulations are observed and that the lighting system is safe.

2.3.8. Office and household equipment

A considerable percentage of electricity in office buildings is consumed by equipment used for office communication, PCs, office photocopiers, and household equipment such as coffee machines, heaters, air conditioning systems, etc.

Electricity consumed by PCs, printers, photocopiers, scanners, battery chargers for mobile telephones and wireless telephones is often fairly considerable and should therefore be prevented.

If equipment is not completely turned off, it continues to consume electricity (standby consumption). Given the equipment‘s long operating times, the rate of consumption is not negligible.

If a device uses 2 watts of electricity over 6000 standby hours in one year, this equates to 12 kWh or 3 EUR.

To avoid consuming electricity in this way, all electricity consumers should be switched off completely at socket outlet. Over the last few years, the EU has prescribed very low rates of consumption when equipment is left on standby. This has resulted in new equipment being designed to have low rates of consumption on standby.

Today, PCs, printers and office photocopiers have the option of switching into standby mode after a specific period of time. However, standby mode should only be used during breaks and should be switched off completely after finishing work.

Power saving options on Windows PCs can be set via ‘Control panel – Energy options – Change power saving settings‘.

- Control panel, then
- Power options, then
- Change power saving settings (optional)

We recommend that power saving modifications are set by the IT officer. Once the settings have been selected, they should be locked for the user by using password protection.

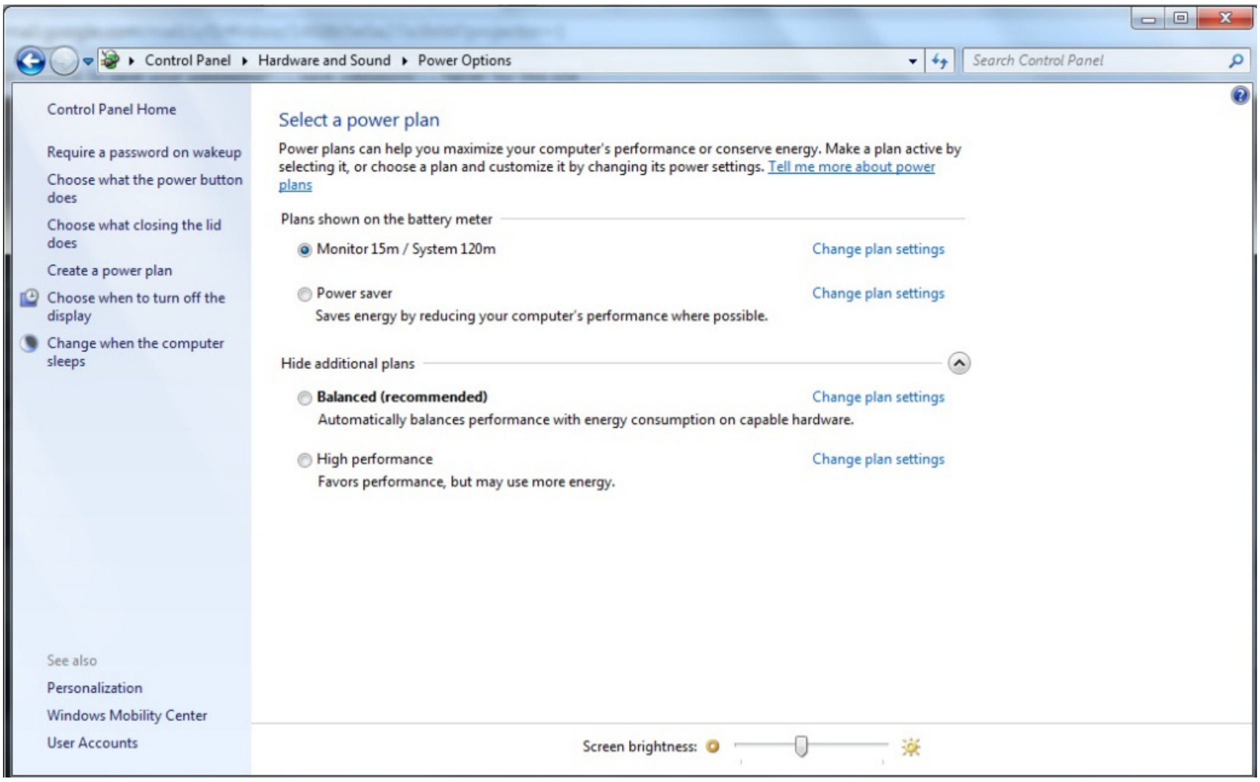


Figure 37: Power settings on Windows PCs

When printing in the workplace, you can print using a central workplace printer which saves more electricity. Printers should be switched off during long periods of inactivity.

Main office equipment should be completely switched off outside of work hours. This can either be done manually by using the switch or by installing a time switch or remote-controlled plug. By installing remote-controlled plugs (e.g. 'Plugwise', ELV, Kopp and other products) along with timers, office equipment in several different offices can be switched on and off from a central point. When using household appliances, such as coffee machines, refrigerators, fan heaters, air conditioning equipment, etc., use them in a way that saves electricity. It is more economical to keep coffee in a Thermos flask than to keep it on a hotplate when using the coffee machine.

Individual fan heaters and air conditioning equipment are not usually necessary on our latitudes. They consume an excessive amount of energy. If individual rooms are not sufficiently heated, then it is considerably more economical to control the heating thermostat settings than to use an electric-powered fan heater. The same applies to mobile air conditioning equipment.

Case study 1:

It is 9 o'clock on Monday. Peter has just arrived at the office and is presently reading his e-mails when he suddenly receives a telephone call from his boss. He now has to leave as there is an impromptu meeting in the meeting room. He takes a few documents with him, grabs a cup of coffee and is then ready for the meeting. But what about the PC? Is it still switched on...?

So that these kind of situations do not arise too often, we recommend setting the computer to go into sleep mode (this saves more energy than standby mode). These breaks can save up to 70% of the power needed by the computer.[2]

The control panel on the computer now provides a balance mode and a power saving mode. Select the option where the screen brightness will not be so high.

Further, avoid using screensavers or desktop pictures whenever possible as these can use up to 50% more power from the computer.[3]

Case study 2:

Peter has had a cold for few days which is quite normal for the winter period. He likes to drink hot drinks while in the office and as much tea as possible. At the moment he has an important event coming up and he needs to be well again for it. This means that he regularly goes to the kitchen, and switches on the kettle every time. He makes coffee in the afternoon and as there is enough left over for his colleagues too he leaves the machine switched on to keep the coffee warm for others after him.

It is quite alright that you are a coffee or tea drinker. You don't have to quit this little indulgence! However, there are two things to watch for. If you are always heating up water, or when you leave the coffee machine switched on, you obviously use more electricity than needed.

How about using a Thermos flask? You just have to heat the water up once and so keep your hot drinks warmer more efficiently and for longer. Often, several colleagues in the office drink one or two cups of tea a day. They could decide together to share a flask. If you prefer coffee, but realise

2 www.office360.de/umwelt/50-tipps-zur-umwelt-im-buero.html
3 www.edv-lehrgang.de/energieoptionen-strom-sparen-mit-energiesparmodus

that the next few cups of coffee are not going to be drunk immediately, do not leave the machine or the hotplate switched on for hours. Only heat the amount of water you need.

It is certainly possible that there are alternatives to using conventional filter machines in the office. Pads and capsules are popular in all kinds of offices but produce a lot of unnecessary waste. Fully automatic machines are the most environmentally-friendly option. However, whatever kind of machine you end up using, please switch the machine off after using it or ask about a standby mode! Electricity costs should not be underestimated in these instances.

Case study 3:

It is Friday and the end of the month. Peter and Michael have to hand in a monthly report on Monday. They stay longer at work than usual and use the photocopying room where there is also a printer and a scanner. Everything is switched on. Peter and Michael finish their work at about 7pm but neither of them sees when the other goes home as they both sit in different offices. Both of them assume that the last one to use the equipment will switch it off, but no one has...so, see you on Monday!

Everyone who has access to this equipment should consider that they may be the last one to use it, particularly when it is late or when they are working during unusual hours. During the day and in normal work hours, the equipment should be set to standby mode.

A tip would be to plug all the equipment into one multiple socket outlet with a toggle switch. Converting to multiple socket outlets (manual) and/or master-slave plug sockets (automatic) can each save up to 75% or 95% of power consumption.[4]

The savings potential lies in the fact that several pieces of equipment are separated from the mains in just one action, so allowing power consumption to decrease immediately. Automatic multiple socket outlets are popular if you want to set equipment to standby mode. Power consumption is registered electronically on the 'master device' and followed by the subordinate 'slave devices'.

Whether you use manual or automatic multiple socket outlets, electricity is still being consumed. So watch out and make sure you use equipment in a responsible way.

2.3.9. Analysing the heating, ventilation and air conditioning system

Heating costs are a considerable factor in office building operating costs. In old office buildings, heating costs can be at about 10 EUR per m2 every year (140 kWh/m2*a). In new energy-efficient buildings costs can be at 6 EUR per m2 a year.

By optimising and economising on heat energy used, savings can be made on heating costs of up to 25% either without making any investments or by making low-investment measures.

Heating systems in office buildings usually comprise:

4 www.wie-energiesparen.info/stromsparen-im-haushalt/unterhaltungselektronik-und-computer/energie-sparen-manuelle-automatische-mehrfachsteckdosen

Object	Description
Boiler	Boiler for heating the water to heat office rooms and for supplying hot water. Heating substances could be: heating oil, gas, biogas, LPG, firewood, wood-chips, wood pellets and coal. Low temperature and condensing boilers are available for heating oil and gas. Condensing boilers use the condensation heat in the waste fumes once they are condensed. This increases the effectiveness of the heating boiler..
Heat pump	A heat pump heats water for warming office rooms and for supplying hot water. Environmental heat as air, water or geothermal energy is used as a heating substance (in a few cases, gas-driven heat pumps are used).
Thermometer for flow and return	Thermometers show the temperature of the flow into the radiator and the return of cooled water as it exits the radiator. These temperatures are important for optimising the heating system and energy consumption.
Burner	Is used to burn heating oil, gas and wood pellets.
Heating controls	Control the boiler in relation to the outside temperature and heating load. Setting the heating controller to the most efficient setting is important for making savings on energy consumption. The temperature at night and at the weekend can be decreased by programming this using the heating controls.
Recirculation pumps	These pumps circulate water that has been heated by the boiler through the heating circuit with the radiators and also circulates water in the hot water tank for sanitary water. Pumps which do not have electronic controls consume considerably more electricity than modern, RPM-regulated highly efficient pumps.
Buffer storage tanks	Buffer storage tanks are required for heating systems that use solar energy so that the energy can be stored temporarily. They are also used in heat pumps. Storage tanks for conventional heating systems are also practical for reducing the number of pulse firings the burner has to make (on/off switch cycle for the burner).
Hot water storage tank	This is just like the buffer storage tank but with a smaller capacity to store hot water.
Circulation pump	Pump for distributing hot sanitary water to taps. While the circulation pump is working, hot water is constantly pumped to all the taps in the building. This provides hot water without any flow time.
Mixer	Mixers with settings or those which can be regulated help to lower the flow temperature by mixing some of the cooled heating water into the flow water from the heating system. Heat energy loss is lowered by reducing the flow temperature in the heating circuit.
Piping and insulating pipes	Piping is necessary for connecting the boiler to the buffer storage tank, hot water tank and radiators in the building.

	According to the German Energy Saving Act [EnEV], pipes which carry hot water must be insulated in rooms that are not heated in order to reduce heat loss. Equipment that has been recently integrated into the hot water circuit (e.g. pumps, thermometer, mixer) must also be insulated (additional insulation of the building).
Radiators	Radiators convey heat energy to the air inside individual rooms.
Heating coil	Heat exchangers are for conveying heat energy from the water circuit to the ventilation system in order to heat the air being supplied to office rooms.
Thermostat valves and room thermostat	To regulate room temperature, you can either affix a thermostat valve to the radiators and/or a room thermostat which contacts the radiator controller electronically or via remote-control. This controller regulates the amount of water entering the radiators in relation to the heat required to warm the room (depends on the outside temperature).
Solar power system	Uses solar energy through collectors to heat sanitary water and to support the heating system.
Ventilation system	The ventilation system ventilates the building. By using a heating coil, the air is heated and supplied to the rooms in the office building. The heating coil (= heat exchanger) is responsible for heating the air within the ventilation system. One area where energy can be saved is the ventilator performance. It should at least be able to be set at intervals or the revolutions should be regulated so as to keep electricity consumption as low as possible.
Air conditioning system	Air conditioning systems are ventilation systems with additional cooling coils for cooling down the air contained in the room. Part of the air conditioner's job is to regulate the humidity of the cooled air.
Circulation system	Heating and cooling air works most effectively without fresh air from outside. Ventilation systems usually have flaps for returning extracted air from rooms back into the air supply which can then either be heated or cooled. This means that the percentage of fresh air which has to be heated or cooled is reduced. There are ventilation systems which can be set manually or regulated. The circulation control system makes sure that as much fresh air is fed into the ventilation system as is needed for hygiene reasons. This helps to optimise the building's energy efficiency rating.

Table 38: Components of heating systems

Essential factors in heat energy consumption are:

- Setting the room temperature
- Appropriate air exchange rate when ventilating office rooms

- Servicing the heating system
- Setting the heating controller to its most efficient setting
- Lowering room temperatures outside of work hours
- Balancing the amount of water in the radiators
- Electricity consumed by the recirculation pumps
- Electricity consumed by the circulation pumps
- Energy losses from the boiler room and hot water tank
- Electricity consumed by the heating, ventilation and air conditioning system
- Effectiveness of summer heat insulation
- Use of renewable energies, e.g. solar heat
- User behaviour

2.3.9.1. Room temperatures

By setting room temperatures correctly in winter (heating) and in summer (cooling), you can save a considerable amount of energy. The 'Technical Regulations for Workplaces' (ASR 3.5. Room temperature) must be observed.

	Room temperature	Measured at a height of
Seated work at a desk	>20°C	0,6 m
Break rooms, bathrooms, cantines and first aid rooms	>21°C	0,6 m
Work done standing up	>19°C	1,1 m
Washrooms with showers	>24°C	1,1 m

Table 39: Room temperature for certain areas of work (ASR 3.5. Room temperature)

Higher room temperatures lead to additional heat energy consumption of approx. 6% per °C. To avoid high room temperatures during summer, windows, skylights and glass walls must be fitted with suitable sun protection systems. Avoid letting too much sunlight into the work place as this can disturb workers. When the outside temperature is more than 26°C and given that suitable sun protection systems are in place, further measures must be taken when room temperatures exceed 26°C so as to avoid any risk to health.

Room temperature can be set during heating periods by self-regulating room temperature thermostats or radiator thermostats. Outside of heating periods, the room temperature can be set additional ventilation. In office buildings that have a ventilation or air conditioning system, the room temperature can be set by regulating ventilation or the air conditioning. Room temperatures need to be regularly measured during heating and cooling periods to keep room temperature thermostats working as efficiently as possible. If room temperature thermostats and radiator thermostats are inappropriately set by the user, a locked thermostat can also be used. These types of thermostats can only be set using a tool.

Case study:

Petra and Michael sit together in the office. They have been a well-oiled team for years and get on well with each other, except that they don't agree about the heating in the office! While Petra gets cold very quickly, Michael prefers to keep the window open to help the air circulate in the office. Michael says that this helps him to concentrate better. In contrast, Petra says it is more comfortable when it is warm. Up to now, the two colleagues have not found a compromise.

How sensitive one is to temperature always depends on the body's own temperature, clothing and the person's level of activity.

The energy officer or caretaker should make sure that the prescribed level of air circulation as stated in the Work Place Regulations is observed. Windows should not be left tilted for long periods of time. However it is important to ventilate a room in order to maintain an active work atmosphere, particularly if your office does not have a ventilation system.

Are you still cold although the temperature in the office has been checked and the room's thermostat has been set so that the room temperature is at 20 or 21°C? Simply use an old trick: the onion look. Similar to an onion, just wear more layers of clothing. This allows you to either put on or take off layers – a jumper for example – as and when you want to depending on the temperature. This may sound trivial, but saving energy really can be that simple!

Office doors as well as doors into hallways are best kept shut so as to avoid unnecessary drafts.

It's end of business! Great, then please switch the light off and pull the blinds down. This stops the majority of heat being lost through the windows.

Another tip: You can put your office decorations to some good use. Plants are a natural filter. They reduce the concentration of pollutants and improve humidity. You will certainly notice a livelier work place.

2.3.9.2. Heating periods and cooling room temperature in summer

Heating periods depend on seasonal/regional weather conditions. Usually, the heating period begins between September and October and has usually ended by the beginning of May. Outside of heating periods, the heating system (including recirculation pumps) should be switched off. To avoid the pumps remaining stationary, it would be wise to switch on the heating system once a month for a few minutes. When cooling down the room temperature, you must ensure that the heating system is not running at the same time as the cooling system which will cause there to be a higher consumption of power.

2.3.9.3. System efficiency/annual rate of use

The rate of use of heating systems shows how much of the energy, that is saved in the energy carrier, can actually be used. Waste gases, radiation losses through the boiler, downtime losses and convective losses are included in boiler efficiency. Heat distribution loss is mainly a problem in the technical room, piping and during transmission to the radiator.

Typical system efficiency level/annual use factor.

Type of system	System efficiency
Heating oil and gas boiler from before 1980 (constant temperature)	77%
Heating oil and gas boiler from 1980–1990 (low temperature)	90%
Heating oil and gas boiler from 1990 onwards (low temperature)	92%
Heating oil and gas boiler from 1980-1990 (condensing heating technology)	94%
Heating oil and gas boiler from 1980-1990 (condensing heating technology)	96% – 100%
District heating	88%
Wood boiler	ab 50%

Table 40: Level of efficiency according to type of system

High system efficiency levels are achieved by having lower flow and return temperatures (e.g. underfloor heating).

The typical efficiency levels provided in the table show that a constant boiler temperature is considerably less efficient than condensing boilers or low temperature boilers. Boilers built after 1990 have relatively good efficiency values.

A low return temperature is needed in condensing boilers to condense the exhaust gases and recover energy. The degree to which gases are condensed can be easily controlled. If either no water is condensed or only a little in the transition period, then condensing heating technology does not work. In this case, the boiler works as a low temperature boiler.

2.3.9.4. Exhaust gas values and servicing the boiler

In Germany, exhaust gases emitted from boilers must be measured by a chimney sweeper or an authorised company. Measuring values are recorded in the 'Chimney Sweep Protocol'.

Chimney Sweep Protocol for constant temperature boilers

The exhaust gas temperature for gas boilers is between about 60°C and 140°C. For oil heaters the temperature should be between 120°C and 180°C and approx. 40°C to 50°C for condensing boilers. If lower exhaust gas temperatures remain below the dew point temperature, they may cause water vapour in the exhaust gases to condense and lead to damp forming in the chimney breast. High waste gas temperatures signify poor heat transfer to the heat exchangers which can lead to soot being deposited. This can be improved by cleaning the boiler. Maximum exhaust gas values in accordance with the 1st German Federal Emission Protection Ordinance [BImSchV] are:

Boiler output	Maximum permitted loss of exhaust gases
Up to 25kW	11%
Over 25kW up to 50kW	10%
Over 50kW	8%

Table 41: Boiler output and max. permitted loss of exhaust gases

If these values are exceeded, then the boiler must be replaced.

Low temperature boilers lose between 6% and 8% in exhaust gases. This is between 2% and 4% for condensing boilers.

If the values provided in the chimney sweep protocol do not lie within these values then there is probably a maintenance problem. These values can only be corrected by sanitary, heating and air conditioning engineering specialists.

2.3.9.5. Heating circuit in the boiler room

Overall, the temperature shown in the following figure is much too high for an outside temperature of 15°C. This signifies that the heating control is malfunctioning.

As you can see, there is sufficient insulation on the piping.

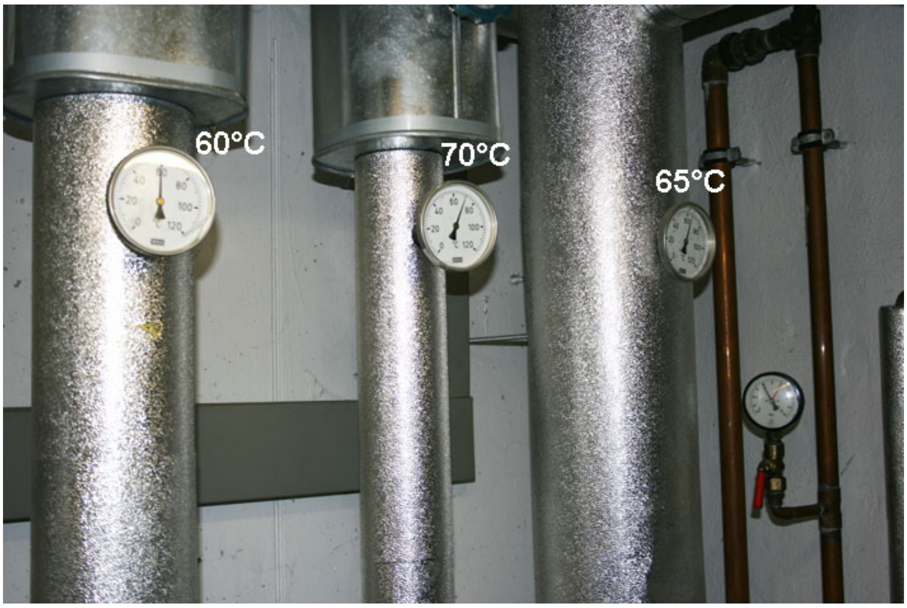


Figure 42: Distribution in the heating circuit in the boiler room with low differences in temperature between the flow and return

The right-hand double pump on the following figure is set to (42°C). The difference between the flow (70°C) and return temperature (65°C) is smaller as a result of the radiator's low rate of heat consumption. In total, the temperatures are much too high for an outside temperature of 15°C.

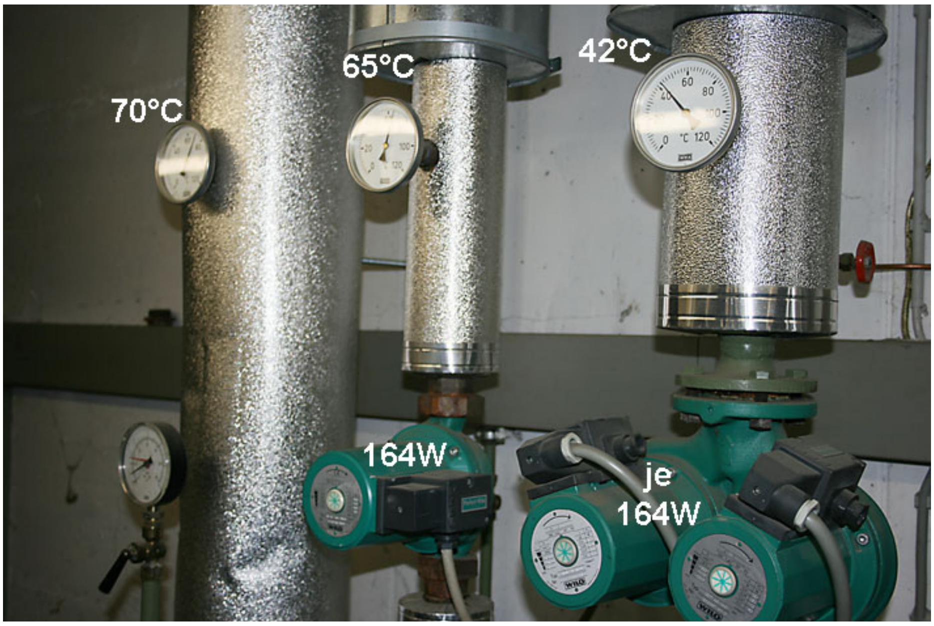


Figure 43: Distribution in the heating circuit using 'old', unregulated recirculation pumps

Most set the switch to the highest pump output setting although this is often unnecessary (see figure below). In many cases, electricity consumption can be greatly reduced by installing a regulated recirculation pump.

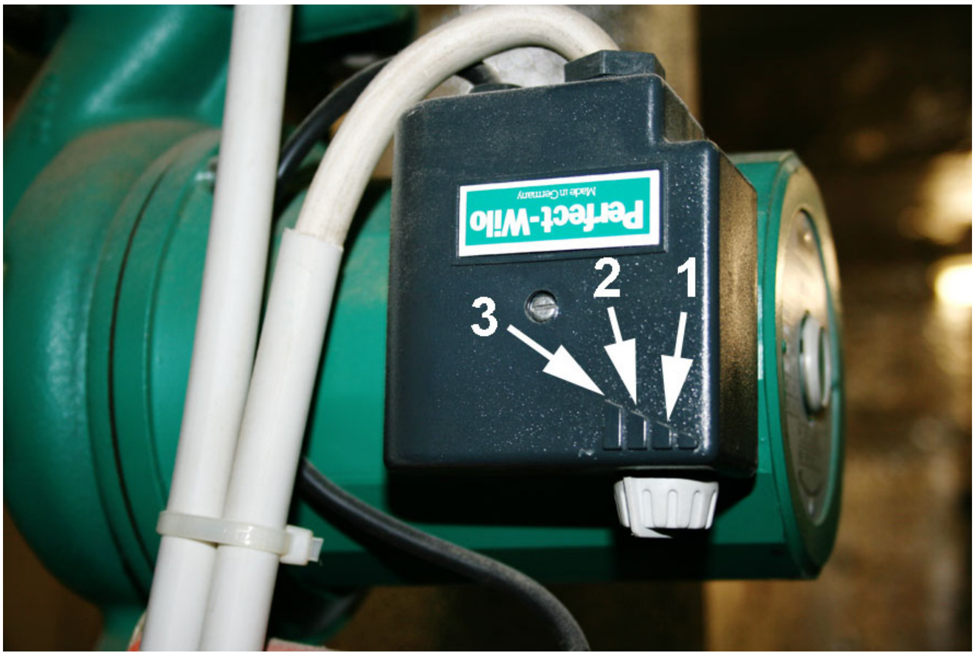


Figure 44: Recirculation pump with adjustable pump output

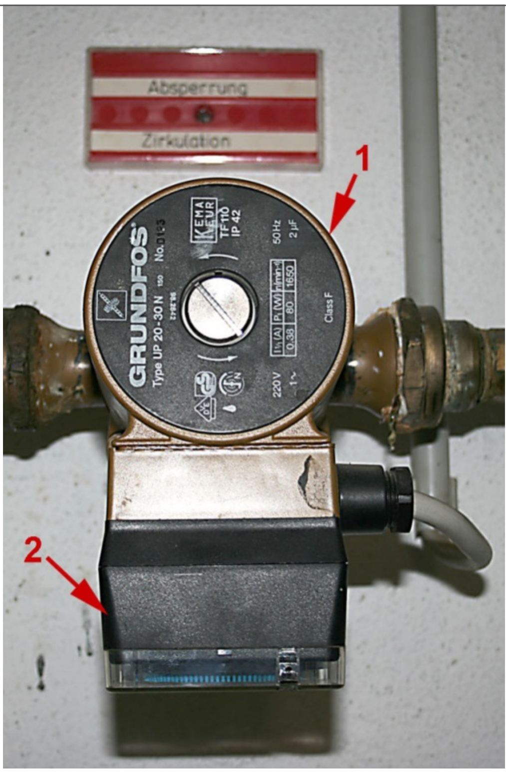
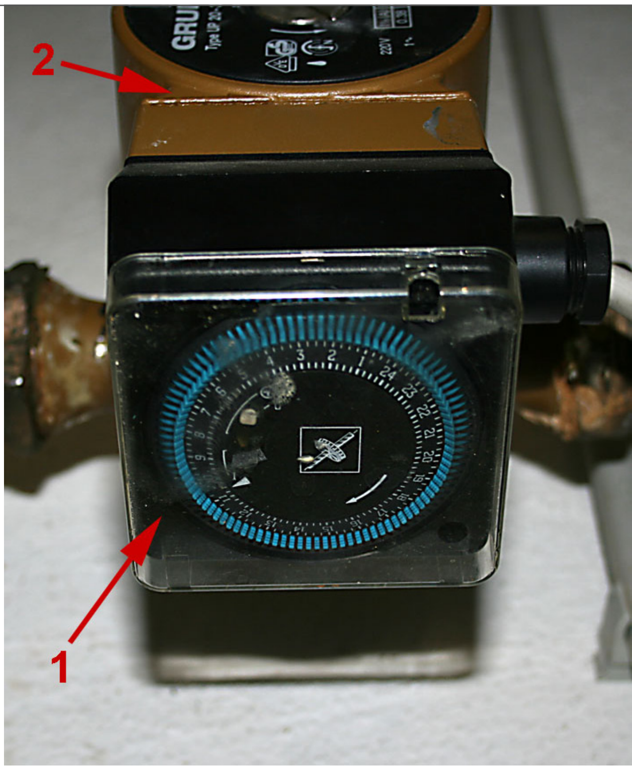
 Circulation pump (1) Pump (2) Time switch	 Circulation pump (1) Time switch (2) Pump

Figure 45: Circulation pumps

Figure 46: Ventilation system with part for supply and exhaust air.
(1) Display for air circulation (see next image)

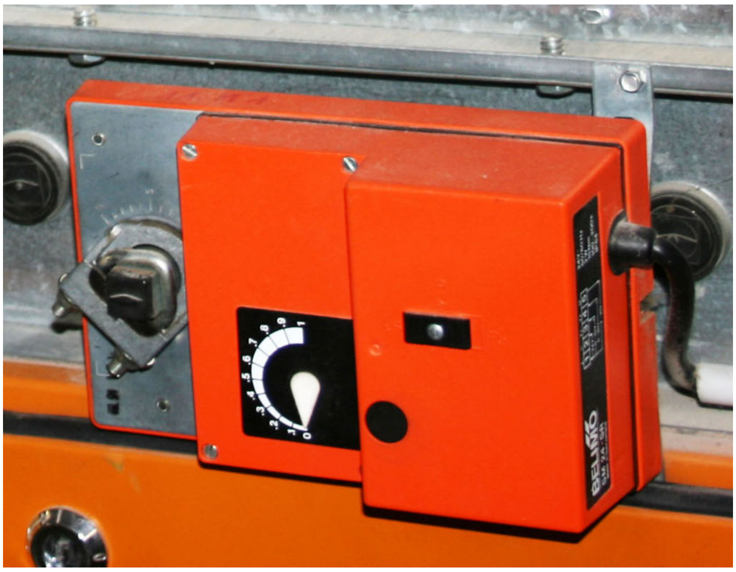


Figure 47: Display for the position of the air circulation flaps

In figure 47, you can see that the percentage of fresh air is at 100% and circulated air is at 0%.

2.3.9.5.1. Boiler

The chimney sweep protocol is the first source to be used in analysing the boiler's energy status. If the data lies outside of the values provided for exhaust gases and heating system maintenance, then a specialist in sanitary, heating and air conditioning engineering should carry out the necessary maintenance work and settings. Exhaust gas condensation in condensing boilers should also be tested. The condensed liquid should be emitted from the outflow on the condenser when the boiler is in operation provided that outside temperatures are not very low.

The condensation temperature for exhaust gases emitted from a gas condensing boiler is 55°C. It is 46°C for heating oil boilers. The heating return temperature has to be considerably lower than this temperature for the exhaust gases to be condensed. The aim is to keep the flow and return temperatures in the heating system as low as possible. This not only allows energy to be recovered from exhaust gases but also keeps energy loss in the heating circuit low.

2.3.9.5.2. Heating controller

The heating controller keeps the room at a set temperature even when outside temperatures fluctuate.

Well-placed, correctly set heating controllers allow you to save energy while running your heating system. They are also able (depending on the design) to regulate system temperatures (flow temperature, return temperature) according to need. This prevents there being an excessive supply of heat and also minimises loss in energy distribution.

By activating/programming switching times, heating controllers enable you to control how the heating system runs during periods of absence. They also allow you to switch off the system or reduce operation at night as well as switch off the heating system when it reaches the heating limit. The heating controller basically regulates water temperatures supplied to the heating circuit and to sanitary water in the hot water tank. In the simplest of cases, the flow temperature of the heating circuit is regulated in relation to the outside temperature. A thermistor which is fixed to the north side of the building in the shade is used to do this. The flow temperature is regulated by the heating controller in relation to the outside temperature. The colder the outside temperature is, the higher the flow temperature has to be because of heat loss.

There are also controllers available which use room temperature instead of the outside temperature as the reference variable for the flow temperature. Consequently, the flow temperature is set in relation to the temperature of the room and the return temperature.

Typical design temperatures for heating systems:

Heating system	Flow temp. (°C)	Return temp. (°C)	Spread (difference) (K)
Low temperature boiler (gas or heating oil)	55 – 75	45 – 60	10 – 15
Condensing boiler (gas or heating oil)	45 – 65	35 – 40	10 – 25
District heating/local heating	55 – 80	30 – 50	25 – 30
Heating pump/underfloor heating	35 – 45	30 – 35	5 – 10

Table 48: Design temperatures for heating systems

The spread is the difference between the flow and return temperature.

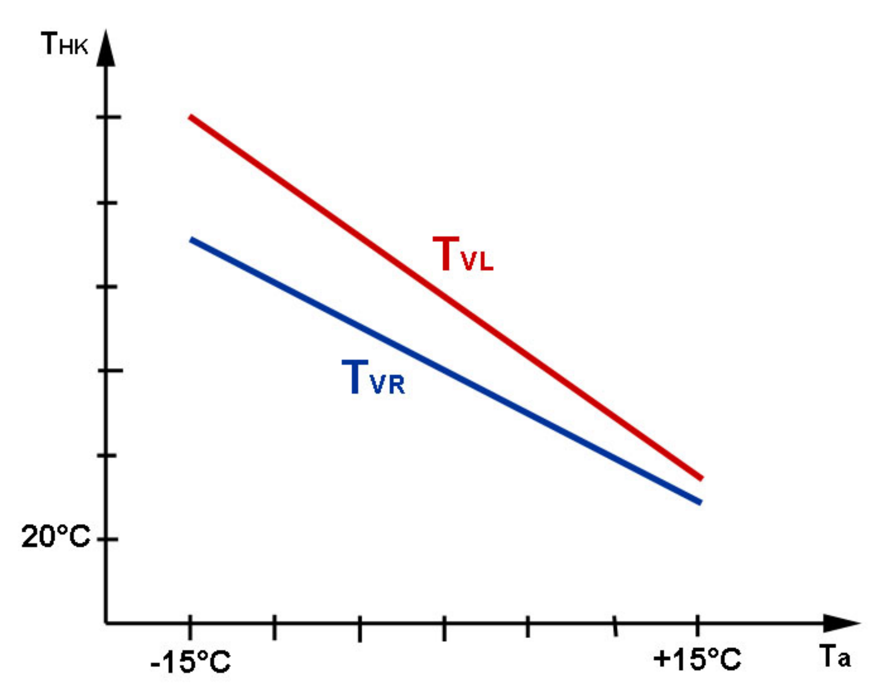
90/70°C: Heating systems with design temperatures of 90/70°C used to be built into old office buildings. These systems were usually set to lower temperatures by replacing the boiler.

70/55°C: These are the standard types of heating systems which you will find in old properties with radiators.

60/40°C oder 65/40 °C: Design temperatures for condensing boilers. A lower return temperature ensures that exhaust fumes are condensed. As a result, a greater spread (difference) is usually necessary.

35/28 °C: Design temperatures for condensing boilers, heating pumps with underfloor heating or surface heating. Low temperatures ensure that exhaust fumes are condensed in condensing boilers.

Typical temperature ratios for flow/return temperatures (spread) depend on the outside temperature:

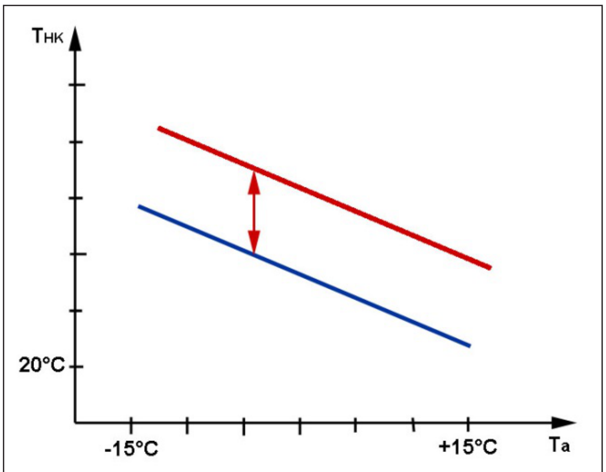


T_a = outside temperature | T_{HK} = temperature in the heating circuit

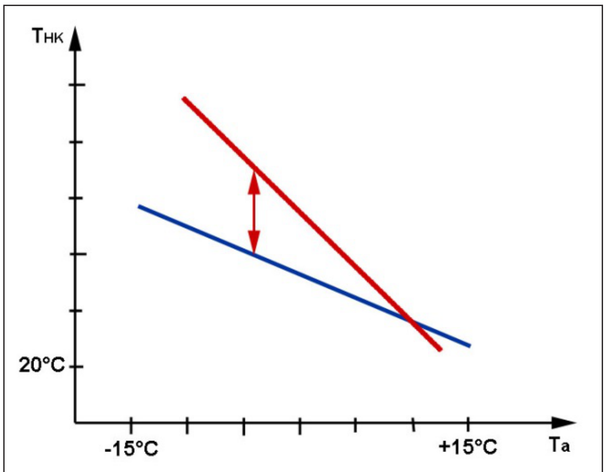
T_{VL} = flow temperature | T_{RL} = return temperature

Figure 49: Temperature ratios for the spread (difference) in relation to the outside temperature

Flow and return temperatures must be checked regularly. If they are too high when compared to the outside temperature the heating controller is not working well and energy consumption increases. It might also be that the heating controller has been set to maintain a constant temperature. This means that the controller is no longer regulating the temperature. The heating circuit runs at a maximum flow temperature. If the flow and return temperatures are too low then this problem usually becomes apparent in that the temperature of the radiators is too low and the rooms are too cold.



Parallelverstellung der Heizkurve für die Vorlauftemperatur in Abhängigkeit von der Außentemperatur

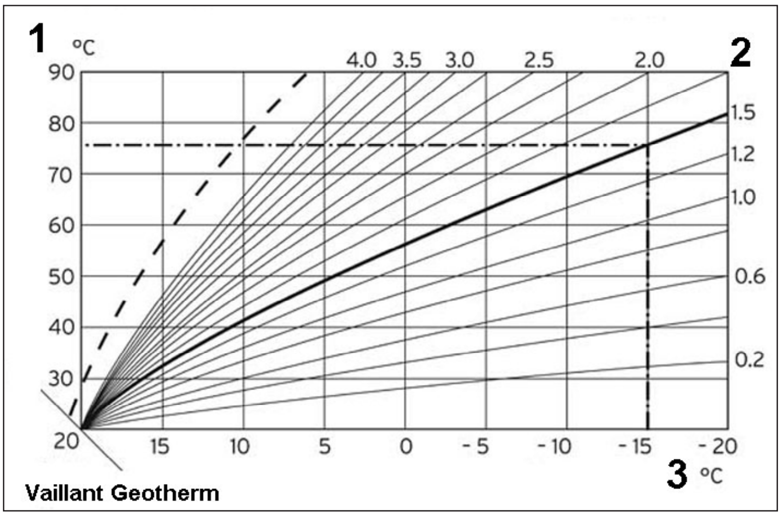


Änderung der Steilheit der Heizkurve für die Vorlauftemperatur in Abhängigkeit von der Außentemperatur

Figure 50: Temperature ratio when flow and return temperatures are too low

The heating controller regulates the flow temperature in relation to the outside temperature and/or the flow temperature on controllers that are regulated by room temperature which depend on the spread (difference) shown on the 'heating curve'. The controller can be set since the heating curve can be shifted vertically in parallel and because of the heating curve's gradient. The heating curve, for example, can be moved lower in order to make the heating controller more efficient. If there are no complaints about room temperatures being too low when the outside temperatures are high, then no further changes are necessary. If rooms are not warm enough when outside temperatures are low, then the gradient of the heating curve needs to be increased. If the rooms are heated sufficiently when outside temperatures are low but are too cold when the weather turns warmer, then the heating curve is too steep.

The heating curves shown in the following figures are also displayed in the instruction manual provided with heating controllers.

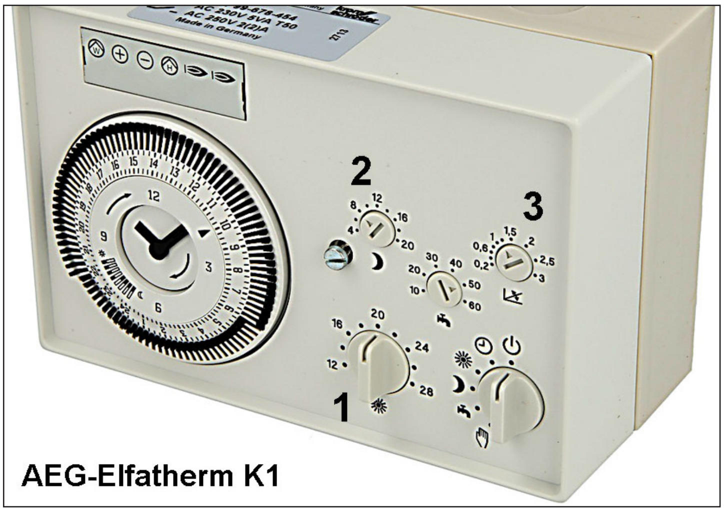


(1) Flow temperature (2) Heating curve (3) Outside temperature

Figure 51: Heating curve for a Vaillant geothermal heating controller

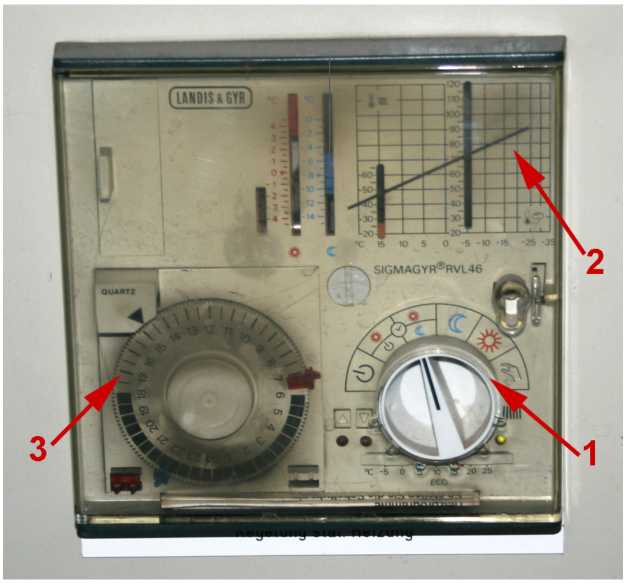
The figures provided in the diagram above on the right are the values which are entered in order to activate the corresponding gradient on the heating curve shown on the switch.

Figure 52: Setting the gradient of the heating curve on the heating controller.
The setting for moving the curve in parallel is on the right.



(1) Parallel shift tag (2) Decrease at night (3) Gradient of heating curve

Figure 52: AEG Elfatherm K1 heating controller with time switch for reducing the heating at night



(1) Operating mode (2) Gradient and parallel shift of heating curve (3) Time switch

Figure 53: Landis & Gyr heating controller with traditional setting for heating curve

The heating controllers shown in these images are old models. Modern, digital heating controllers can be programmed and have additional functions such as regulating the temperature of the hot water tank, or an additional solar power system, etc.

Besides monitoring measured values, the time switches and the settings on the heating controller should be checked regularly to see if they are set correctly.

2.3.9.5.3. Regulating room temperature

Room temperature is kept at a constant value in compliance with the German Energy Saving Act [EnEV] by using independent temperature controllers in each room. These controllers may be a radiator thermostat or a room temperature thermostat. By way of exception, several different rooms in office buildings can also be regulated by a room temperature controller. The valves on the room temperature controller regulate the supply of warm water to the radiators depending on the heating required.

On convection air heating systems or air conditioning systems, the air temperature and the amount of air supplied in relation to the heating required are controlled instead. Radiator thermostats and room temperature thermostats used in the household are frequently altered by users in order, for example, to increase the room temperature. As a result, more heat energy is consumed. To avoid this happening, room temperature controllers can be used which the user is unable to alter. The room temperature can then only be set by using a tool.

For radiator thermostats, there are so-called ‘locked thermostats‘ which can only be set using a tool. There are two kinds of radiator thermostat. The older kinds of thermostats require there to be a temperature difference of 2 K (2°C) before an open valve is fully closed.

New radiator thermostats close when there is a temperature difference of 1K (1°C). These thermostats work in a much more precise way and contribute towards saving energy. For this reason, old radiator thermostats should be replaced. Although a radiator thermostat is able to greatly reduce the volume flow rate in the radiator in order to keep the set room temperature constant, the valves only work efficiently if the flow temperature (e.g. in relation to the outside temperature) is adjusted to suit the amount of heating required by using a heating controller.

The room heating works most efficiently when the radiator is supplied with as low a flow temperature as possible. To do this, the largest possible volume flow rate and the largest possible convection surface (hot radiator) are needed. Since this ideal situation of adjusting the flow temperature to the current amount of heating required in single rooms is not possible in practice, a higher flow temperature is then set. To adjust the heat given off by the radiator to the room when a higher flow temperature is being used, the volume flow rate of the radiator is curbed using the radiator thermostat valve. As a result, the radiator cools down at the bottom.

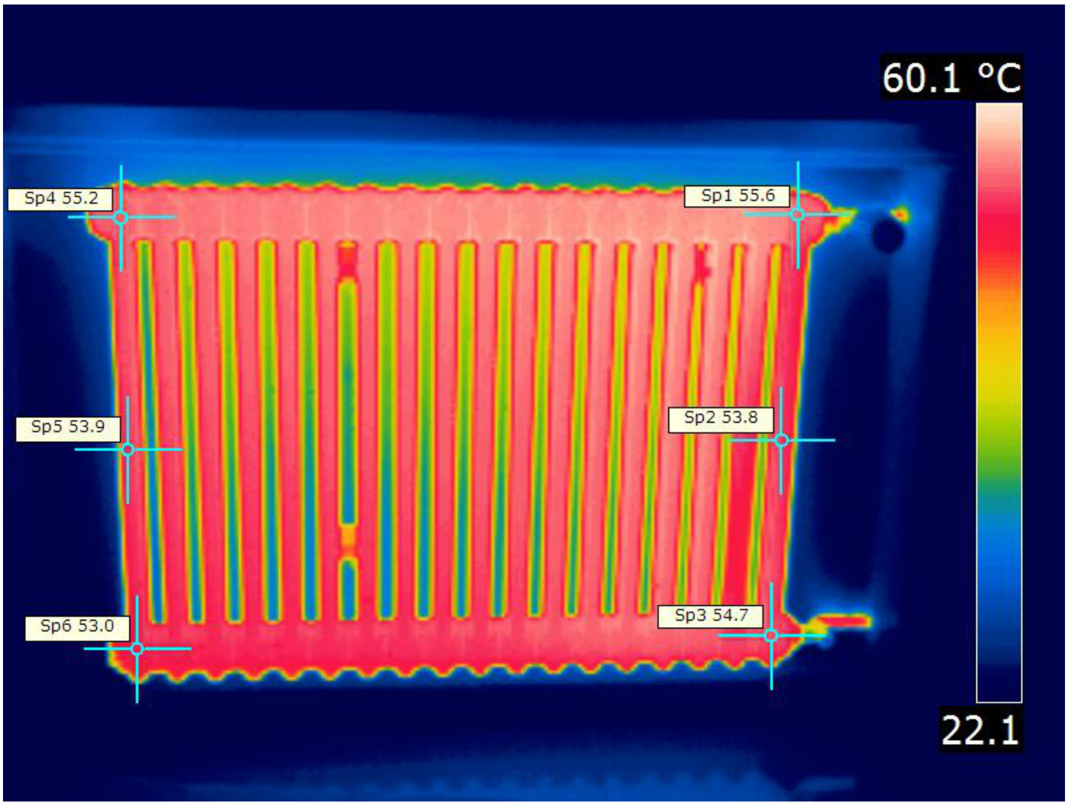


Figure 54: Radiator with maximum heat output. The surface temperature at the top and at the bottom is almost the same. The flow temperature is too low for the heating required.

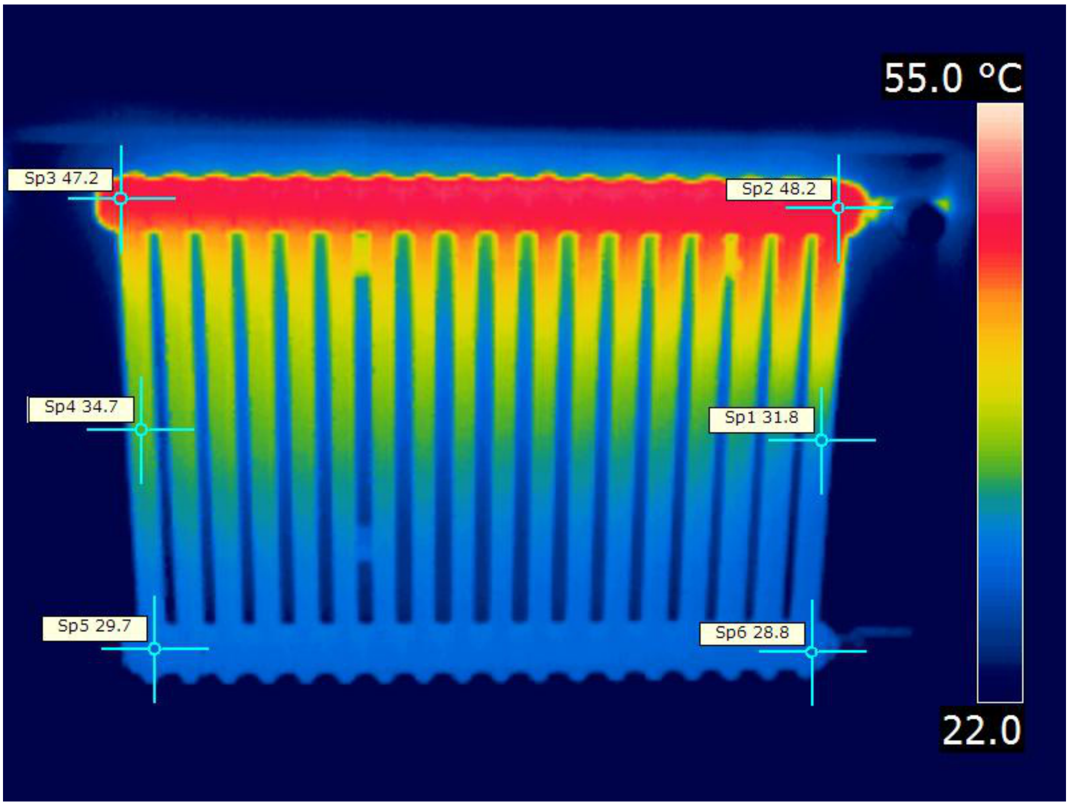


Figure 55: Radiator with greatly reduced heat output. The surface temperature decreases considerably in the top half. The flow temperature is too high for the heating required.

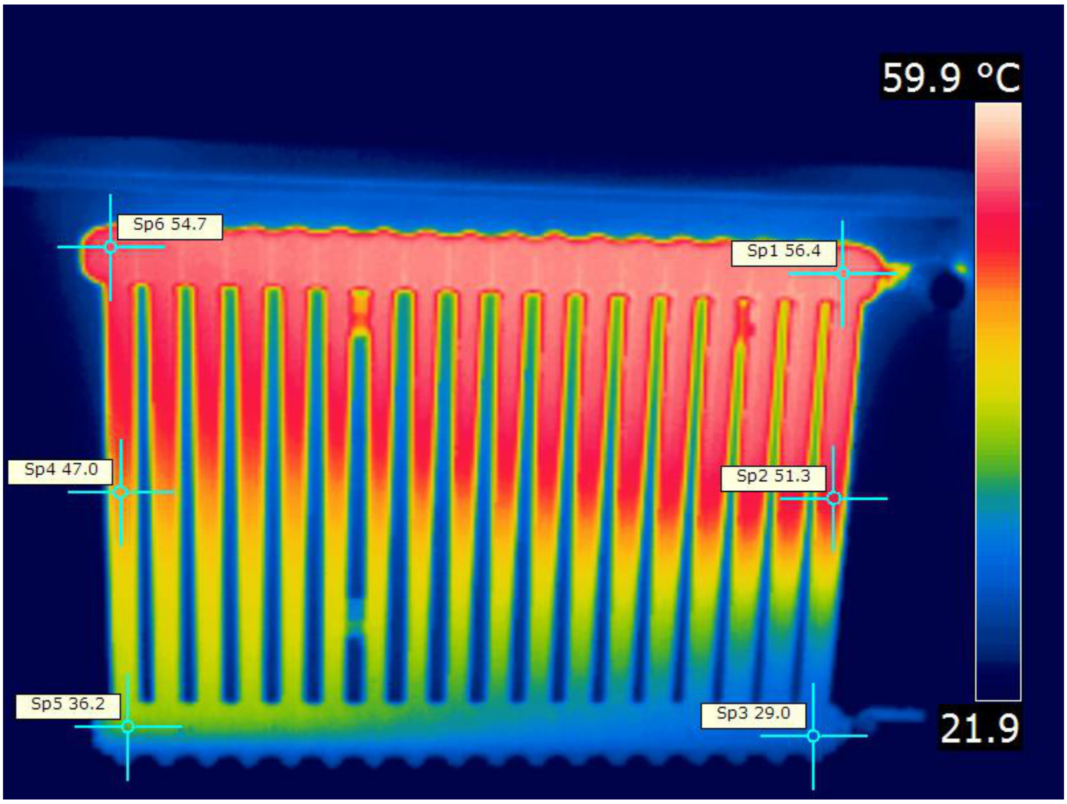


Figure 56: Radiator with partly reduced heat output. The surface temperature decreases equally across the radiator. The flow temperature is well adjusted to the heating required.

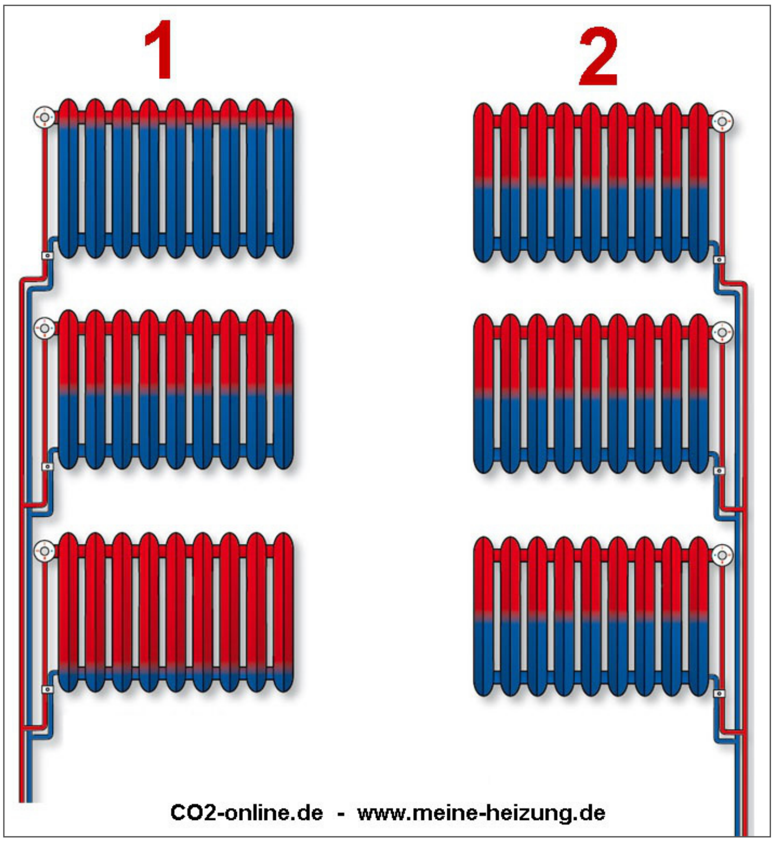
2.3.9.5.4. Hydraulic balancing in the heating cycle

Hydraulic balancing describes a process where each radiator within a heating system is set to have a particular flow rate of hot water. As a result, each radiator is supplied with exactly the right amount of hot water required to reach the desired room temperature while maintaining a particular flow temperature. In this way, the flow temperature can be decreased in an efficient way without leaving some rooms without sufficient heating. The return flow of each radiator should have the same temperature, if possible.

In practice, mistakes are often made when the water flow is not balanced hydraulically.

Instead of a hydraulic balance of the flow of water, considerably larger radiators are sometimes installed and/or the amount of water supplied to heat the radiator is increased. These measures cause more heat energy and electricity to be consumed.

Particularly when there are several radiators in the same room which are all regulated by their own radiator thermostat, the radiators are often not balanced. It is also difficult to set the radiator thermostats so that they are more or less balanced due to a lower temperature range. To avoid people resetting the radiator balance in the same room, a ‚locked thermostat' should be used.



Hydraulic balancing in the heating cycle with (1) an unbalanced and (2) a balanced heating cycle

Figure 57: Surface temperature of radiators

Image 57 shows the surface temperatures of radiators in a balanced and an unbalanced heating circuit (see section on hydraulic balancing in the heating circuit).

The hydraulic balance of the heating system must be taken into account when deciding which radiators to use for the heating load and what cable lengths and supply volumes are needed in the heating circuit. Heating technicians will do this for you. Any changes made to the hydraulic balance in the circuit should be carried out by a heating technician.

Hydraulic balancing can be useful for optimising the heating controller and for setting the gradient of the heating curve to be more efficient. If individual radiators are identified during the process which require a considerably higher flow temperature in order to reach the desired room temperature, then you may want to consider whether to fit a larger or an additional radiator. However, it is expensive to carry out a proper hydraulic balancing process with specialist planning involved and there is a long return period.

2.3.9.5.5. Recirculation and circulation pumps

Recirculation pumps in heating systems consume a lot of power due to the long periods of time they are in use. We recommend the following measures for reducing electricity consumption:

- Switch off the heating system outside of the heating period.
- Switch off the recirculation pumps when you do not need them for a time.

- Reduce the times when you use the circulation pumps to your daily work hours.
- Set the recirculation pump output to the required level of output on the step switch.

These points must be checked regularly.

Further improvements can be made by making small investments:

- Exchange the recirculation pumps with highly efficient pumps that have an electronic controller in order to optimise the difference in pressure and volume flow rate.
- Take the central hot water supply from the heating system out of operation and install decentralised hot water undercounter units. This allows the hot water tank and the circulation pump to be shut down and means that the heating system can be switched off completely in summer.

This allows you to make considerable savings in heat energy, heating costs, maintenance costs, electricity consumption and electricity costs for the pumps.

The payback period for savings made on electricity costs alone is between 3 and 8 years when you replace recirculation pumps with highly efficient pumps. Another considerable saving is usually made on heat energy.

Regulated, highly efficient, recirculation pumps cannot be fitted to heating systems that are designed to provide a constant volume flow rate (e.g. one pipe heating systems).

Figure 58: Controlling recirculation pumps using a time switch (1)

2.3.9.5.6. Supplying hot water

In many office buildings, hot sanitary water is generated centrally in the boiler room using the heating system and is stored in a tank. Hot water is supplied at the taps whenever it is required. However, the amount of heat that is lost is immense due to the water having to be transported. Another problem which occurs when storing drinking water is the development of legionella (bacteria). Consequently, the Drinking Water Act specifies that hot water should be stored at a minimum temperature of 60°C. Enormous amounts of energy are lost as a result.

Point-of-use water heaters are a practical alternative especially when there is a small number of taps. The heater only heats the quality of water needed. The advantage is that there is no loss of storage space and only a very small amount of heat is lost in transporting the water.

2.3.9.5.7. Insulating hot water pipes

Water pipes which carry hot water to unheated rooms must be insulated to reduce heat loss.

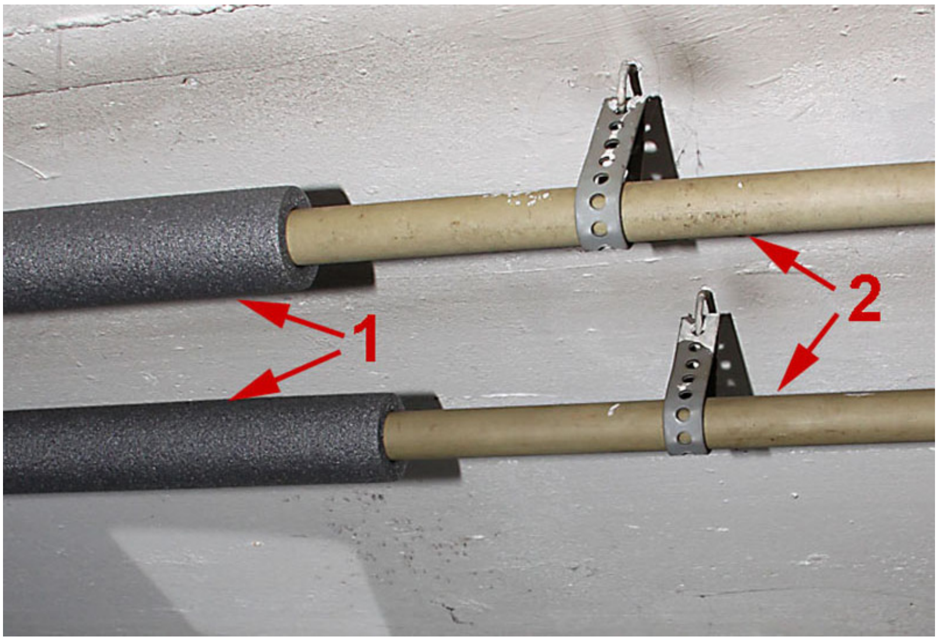
Minimum insulation thicknesses for pipes are in accordance with the German Energy Saving Act 2009 [EnEV], appendix 5:

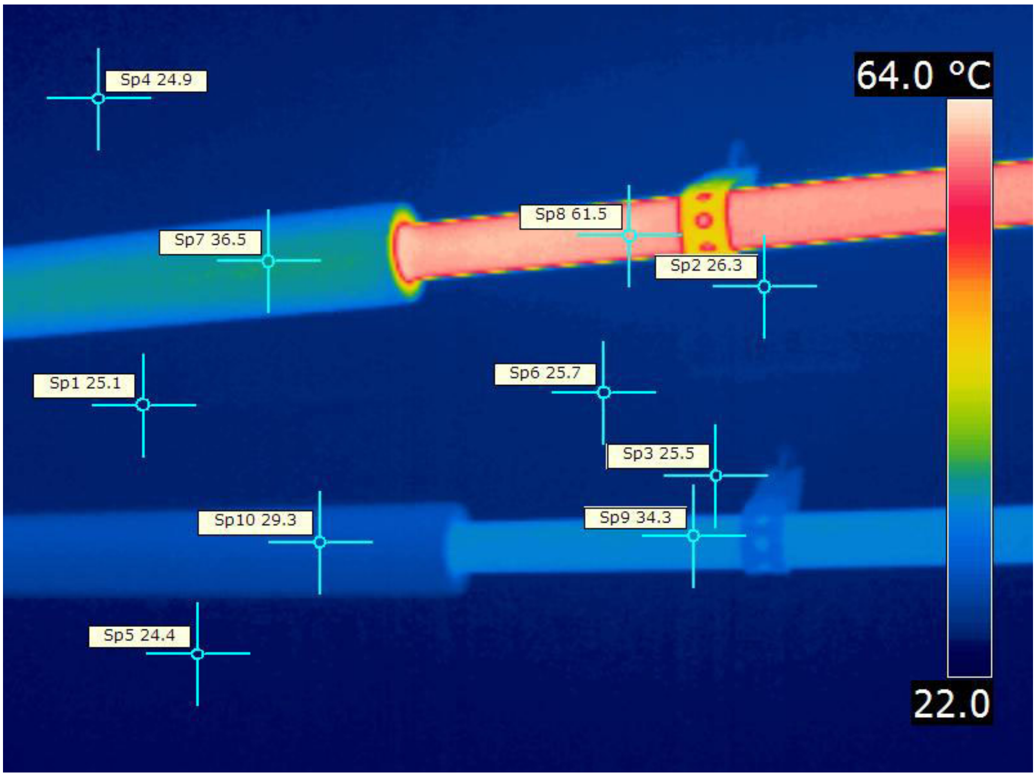
Kind of piping	Minimum thickness of insulation
Interior diameter of up to 22 mm	20 mm
Interior diameter of over 22 mm and up to 35 mm	30 mm
Interior diameter of over 35 mm and up to 100 mm	Equal to the interior diameter
Interior diameter of over 100 mm	100 mm

Table 59: Minimum insulation thicknesses for pipes in accordance with the German Energy Saving Act 2009 [EnEV]

These minimum insulation thicknesses are mandatory in accordance with the German Energy Saving Act 2009 [EnEV]. If hot water pipes are not insulated or do not meet the minimum thickness requirements, then they must be fitted with the proper insulation.

The effect of heat insulation on hot water pipes in unheated rooms can be seen in the following thermal imaging.





Surface temperatures on insulated and uninsulated hot water pipes
'1' = insulated pipe - '2' = uninsulated pipe
(room temperature = 24°C – flow above – return below)

Figure 60: Insulated and uninsulated hot water pipes, thermal imaging

2.3.9.5.8. Ventilation and air conditioning systems

An air conditioning system is a system for creating a balanced room temperature in offices. The air conditioner regulates room temperature, relative humidity levels and air quality. Central air conditioners are available for the whole building and decentralised air conditioners for single rooms (room air conditioning systems) or server rooms. In contrast, a ventilation system exchanges used air in the room. The room can only be somewhat cooled using special ventilation systems that are built into the floor.

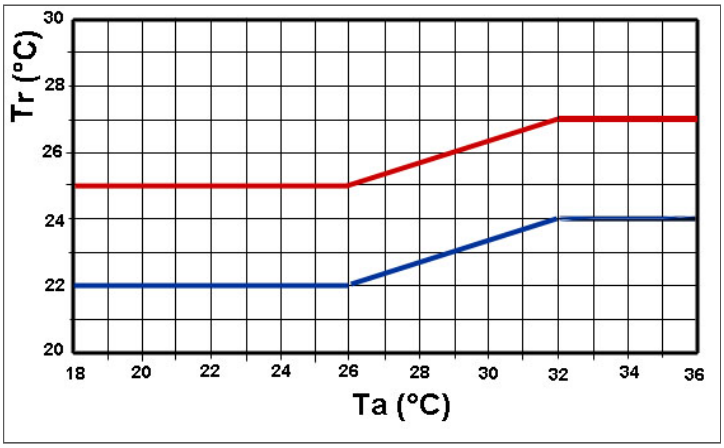
Ventilation and air conditioning systems mostly consume a lot of energy. For this reason, the settings used to operate these systems must be inspected so that energy can be saved.

The following factors influence energy consumption of ventilation and air conditioning systems:

- Room temperature for heating and cooling the room in summer
- Relative humidity level, primarily when cooling rooms in summer
- Air exchange rate or air exchange volume in rooms
- CO_2 concentration in the air in the room

As has already been discussed in chapter 2.3.9.1, the room temperature in offices should be between 20°C and 21°C during the heating period. Higher temperatures are possible outside of the heating period. Once the room temperature reaches 26°C during summer, measures must be taken to reduce an increase in room temperature.

The following diagram displays the ranges of room temperatures permitted outside of the heating period (between the two lines) in accordance with the German DIN 1946-2 and the ASR 3.5 (Technical Regulations for Workplaces [Technische Regeln für Arbeitsstätten]).



Ta = outside temperature Tr = room temperature

Figure 61: Room temperature permitted in relation to the outside temperature in summer

The room temperature may occasionally exceed the norm if measures are taken to reduce room temperatures.

- Activate facilities used to reduce the amount of sunlight entering the building.
- More ventilation in office buildings (opening windows).
- Increase the ventilation volume on ventilation systems.
- Air office buildings overnight.
- Shift work hours to another time.
- Activate room cooling system (if one is available).

As soon as the room temperature exceeds 30°C, further measures must be taken. The following steps can be implemented to reduce room temperature:

- Control sun protection effectively (blinds).
- Control the ventilation system effectively (e.g. night cooling).
- Reduce the thermal loads (only switch on electrical devices when needed).
- Ventilate during the early morning hours.

You should first try to work within the permitted temperature ranges for room temperature without using a cooling system. The heating controller must ensure that offices are not able to be heated at the same time as they are being cooled. The relative humidity in offices should be between 30% and 65%. If relative humidity decreases in winter to below 30%, then we recommend that you humidify the air in the rooms. To avoid mould forming, the relative humidity of the rooms should not exceed 70% for any extended period of time.

When the outside air is cooled, the relative humidity of the air in the room increases. If necessary, the air in the room must be dehumidified to limit relative humidity. This can be done by quickly cooling the room and then heating the air by using the air conditioner. This method uses a lot of energy. To cool the air in a way that saves energy, the room temperature controller and relative humidity must be monitored. Low relative humidity leads to high energy consumption when using the system to cool the air temperature. In this respect, the air conditioner controller (cooling) should be set so that the relative humidity level in the offices is not too low.

In accordance with ASR 3.6 (ventilation), the following values for relative humidity must not be exceeded.

Temperature of air in room	Maximum relative humidity
20°C	80% (*)
22°C	70%
24°C	62%
26°C	55%

(*) To avoid mould forming, a humidity level of 75% should not be exceeded.

Table 62: Temperature of air in room and maximum relative humidity level

Mobile air conditioning systems should be avoided since they consume lot of energy. If there is no container available for the condensate, the air is also not dehumidified.

Ventilation and air conditioning systems are also considerable factors in making sure that the air in rooms remains free of harmful substances. Besides the room temperature and the relative humidity level, CO_2 concentration levels are also relevant for energy consumption. Air containing CO_2 is fed into the air in the room when you breathe. As a result, the CO_2 concentration rises in offices and common areas when there are people present. CO_2 concentrations are between 400 ppm and 500 ppm (depending on location) in the environment. 1,500 ppm is the permitted limit of CO_2 concentration for schools.

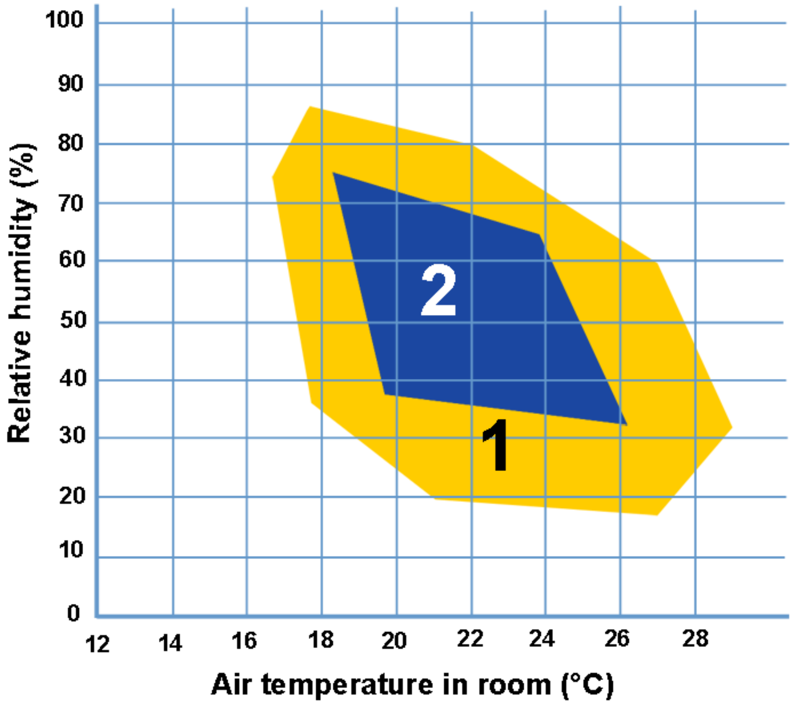
According to ASR 3.6 (ventilation), the following information is cited regarding permitted CO_2 concentrations in the workplace:

CO_2 concentration	Measures
Up to 1.000 ppm	No other measures are necessary as long as 1,000 ppm are not expected to be exceeded.
1.000 – 2.000 ppm	Inspect and alter the ventilation ratio or air volume flow rate and air circulation settings on the ventilation system accordingly.
Over 2.000 ppm	Further measures to improve ventilation ratios are required.

Table 63: Measures to take against increased CO_2 concentrations

Measures taken to save heating and cooling energy (e.g. by a higher percentage of recycled air) must not lead to concentrations of CO_2 that are not permitted.

To make it comfortable in the office and living areas, the following standard values apply:



(1) still comfortable indoor climate (2) comfortable indoor climate

Figure 64: Comfortable temperature range according to Leusden and Freymark

The German DIN 1946-2 provides the following standard values for the amount of outside air required for each person present in one room:

Single room office	40 m^3 per hour
Large office	60 m^3 per hour
Conference rooms, break rooms, cantines	30 m^3 per hour

Table 65: Standard values for the amount of outside air required for each person present in one room

When outside temperatures are below 0°C and over 26°C, the air exchange rate can be halved.

Recommended air exchange rates for rooms used for commercial purposes:

	Air exchange rate (per hour)
Office rooms	1,5 – 3
Meeting rooms	2 – 3
Laboratories	3 – 5
Workshops – low air pollution	1,5 – 3

Table 66: Air exchange rate according to room use or type of room

The air exchange rate shows how often the air inside a room is exchanged with fresh air from outside per hour.

To control the indoor climate in relation to air quality and energy consumption, the following measurements and measures should be carried out.

In order to determine the amount of air which is supplied to offices by the ventilation and air conditioning system, the quality of the air inside the room can be altered. If an unnecessarily large amount of air is being supplied to offices, this leads to greater consumption of electricity. If the percentage of fresh air is high, then more energy is also used to heat the air supplied from outside. The volume flow rate for supplying offices can be roughly calculated as follows:

$$V = 0{,}36\ v \cdot A$$

V = air volume flow rate (m^3 per hour)
v = air speed (m per second)
A = exit plane (cm^2)

Flow velocity can be measured using a hot-wire anemometer or a rotating vane anemometer. The exit plane for the air supplied from the air conditioning or ventilation system can be calculated using these measurements.

Air volumes calculated per hour are only estimate values since the flow velocity in the middle of the outlet and at its edges is unequal.

2.3.9.5.9. Special case: server room

Larger server rooms have to emit large amounts of heat into the environment caused by electrical power dissipation. Since they are usually located in windowless cellars, they are air-conditioned. This leads to more electricity being used in order to cool these server rooms. Since the computers have a high heat output, server rooms mostly only have to be cooled and not heated. Modern computers work more reliably at higher environmental temperatures than older models. They also give off less heat. As a result, cooling systems for the air in the room are put under less strain.

During the cold period in the year, the cooling system is mostly not required because the heat given off by the computers can be emitted along with the outside air.

The following questions should be answered when analysing energy consumption in server rooms.

- Is the light in the server room switched by a movement and/or presence sensor (saves up to 90% on electricity costs)?
- What room temperatures have been set (the Bavarian state government has prescribed a room temperature of 25°C for all server rooms)?
- Is the server room ventilated using air from outside?
- Can the room be cooled sufficiently using outside air or is a cooling system occasionally necessary?

Server rooms are sensitive areas. Changes made to the air conditioning must only be carried out in agreement with the head of IT systems. In this regard, all safety systems responsible for continuous operation must remain. Ventilation and temperature controls must still function even when there is a power cut.

2.3.10. Analysis of user behaviour (ventilation, electricity consumption)

User behaviour has a considerable influence on energy consumption in office buildings. For this reason, user behaviour must be monitored in the detailed analysis and then at regular intervals during work hours (also at different times of the year).

The results can be recorded in the form, 'Checklist-Circuit-User Behaviour', and then assessed.

The following information can be obtained using this form:

• Building • Storey • Room (number) • Room temperature • Relative humidity • CO_2 concentration	• Ventilation (OK?) • Lighting switched on/off • Light intensity • Can standby devices be switched off? • Eco mode switched on for PC/monitor • Eco mode switched on for printer/photocopier

2.3.11. Using checklists

Several checklists are provided for your own use as part of this handbook:

- Checklist for the initial assessment of a building
- Checklist for planning 'on site inspections'
- Checklist for assessing a building
- Checklist for circuit/user behaviour with data acquisition

Using these checklists makes it easier to acquire data to be used in the detailed analysis.

2.4. Step 4: Prioritising measures and action plan

The detailed analysis identifies areas in office buildings where energy can be saved. The inspections carried out as part of the detailed analysis should document the 'actual status' and describe the most energy efficient 'target status'. This chapter is about determining measures in order to reach these goals.

Measures for saving energy range from switching off lights as soon as they are not needed (without investment) to adding more heat insulation to the exterior walls and installing a solar power system (large investment). Each measure must be planned and listed by importance so as to ascertain whether they are cost-effective enough.

The form entitled 'Planning form, improving efficiency' can be used to plan and list measures.

Those measures which make the largest saving using the lowest amount of finance should have the highest priority. These kinds of measures are changes to user behaviour, heating and ventilation system settings, replacing light bulbs with energy saving lamps, installing multiple socket outlets with a switch. Areas with energy saving potentials – user behaviour:

Area	Measure
Lighting	Switch lights on and off as needed.
Heating and ventilation	Set room temperature to 20°C to 21°C.
Heating and ventilation	Balanced ventilation in the rooms (e.g. no extended periods of ventilation during heating periods).
Heating and ventilation	Set air circulation to provide optimum air quality and save energy.
Heating and ventilation	Use equipment to keep out the heat and avoid high room temperatures during the summer.
Heating and ventilation	Air the offices during the night in summer.
Heating and ventilation	Set times for the heating to be reduced in temperature out side of work hours (at night and at the weekend).

Area	Measure
Office equipment	Use power-saving settings on PCs, monitors, printers and photocopiers (power management).
Office equipment	Avoid leaving equipment on standby for long periods of time, switch the equipment off completely.
Office equipment	Switch off plug-in power supplies and chargers when not using them.
Office equipment	Keep coffee in a Thermos flask and not on a hotplate.
Office equipment	Regularly defrost the refrigerator.

Table 67a: Measures affecting user behaviour amongst office workers

Areas with energy saving potentials – organisational measures:

Area	Measure
General energy consumption	Regularly read the meters, check energy consumption in voices, inspect contracts for energy supply.
Lighting	Reduce the number of lamps in areas where light levels are too high.
Lighting	Clean reflectors on fluorescent lamps.
Lighting	Replace defective fluorescent lamps (defective tubes still use electricity without emitting light).

Lighting	Use light colours on the walls when renovating.
Lighting	Set delay times on the motion sensor to the most efficient setting.
Heating and ventilation	Regularly service the heating system.
Heating and ventilation	Optimise the heating controller for the operating temperature in the flow and return (by using the outside temperature).
Heating and ventilation	Switch on the ventilation valves when needed and set the number of revolutions for the ventilation valves.
Heating and ventilation	Set circulation in ventilation systems to suit demand.
Heating and ventilation	Set cooling settings to suit demand.
Heating and ventilation	Set the ventilation controller for the relative humidity level during cooling (air conditioner) to suit demand.
Heating and ventilation	Set the revolutions/output of the recirculation pumps to the most efficient setting.
Heating and ventilation	Set reduced temperatures for nights and weekends (temperature and work times).
Office equipment	Use power management on office equipment.
Office equipment	Consider buying energy-saving equipment when purchasing new devices.
Office equipment	Switch off drinks machines at night and at the weekend.

Table 67b: Organisational measures for the caretaker or energy officer

Areas with energy saving potentials – low investment measures:

Area	Measure
Lighting	Replace light bulbs, halogen floodlight and halogen spot lights with energy-saving lamps or LED lamps.
Lighting	Install movement and presence sensors in areas which are lit occasionally.
Lighting	Install lighting controllers for partial lighting when there is sufficient daylight.
Lighting	Install workstation lamps with reduced luminance for the office.
Heating and ventilation	Air rooms at night during summer (if ventilation systems are installed).

Heating and ventilation	Time switch for under-counter hot water boilers.
Heating and ventilation	Settings of the time switch for the circulation pump.
Office equipment	Install energy-saving equipment.
Office equipment	Install time switches/radio plugs for office equipment.
Office equipment	Use power strip for office equipment.

Table 67c: Low-investment measures

Areas with energy saving potentials – technical measures:

Area	Measure
Lighting	Integrate electronic control gear into fluorescent lamps.
Lighting	Integrate daylight dependent controls for regulating room lighting in different areas.
Heating and ventilation	Add blinds and/or sun protection foil for heat and sun protection during the summer.
Heating and ventilation	Integrate efficient (RPM-regulated) motors for valves on the air conditioning and ventilation system.
Heating and ventilation	Reduce the amount of generated cooling required by server rooms, use air from outside.
Heating and ventilation	Integrate RPM-regulated highly efficient recirculation pumps.
Heating and ventilation	Install under-counter hot water devices with the option of shutting down the central hot water supply system.
Heating and ventilation	Integrate regulators for circulation pumps.

Table 67d: Technical measures

The plan of measures required to reduce energy consumption is submitted to the management for approval. When taking low-investment and technical measures, planned savings on energy/energy costs must be evaluated in regards to how cost-effective they are. An essential factor in approving low-investment and technical measures is how economical they are. In practice, there is a simple way to consider the cost-effectiveness of an investment with short payback periods:

How long will the payback period of this investment last?

The following formula can be used to do this:

$$\textbf{Return time} = \frac{\textbf{Investment (EUR)}}{\textbf{Energy saving (EUR per year)}}$$

This is a simplified formula for smaller investments. For larger investments, interest also has to be taken into account in certain circumstances. The accounts department usually calculates a more exact figure.

Payback periods for investments with energy-efficient measures should be as short as possible. Payback periods of 2 years (up to 4 years in exceptional cases) are usually deemed acceptable by the management.

When carrying out general renovations/refurbishments in offices, the cost-effectiveness of additional costs needed to improve the energy efficiency of systems and equipment can be considered in the buyer decision process or when deciding upon measures. In this case, it just depends on the cost-effectiveness of the additional measures or costs spent.

As a tool for doing this, you can use:

- Form: 'Planning form, improving efficiency'
- Excel tables for energy consumption

2.5. Implementing and inspecting measures for reducing energy consumption and regular statistics on success rates

2.5.1. Step 5: Carrying out measures to reduce energy consumption and compiling a regular record of energy consumption

Planned measures are carried out in accordance with the approval given by the management. These measures are based on the rough and detailed analysis and are carried out in order of importance prioritising using the plan created to increase energy efficiency.

- Revising energy supply contracts and inspecting the purchasing conditions for planned levels of energy consumption.
- Taking meter readings on a regular monthly basis and compiling a record, conducting an annual assessment to monitor the effectiveness of the measures and compiling a report for the management.
- Implementing planned measures that have been approved by the management using own and/or external personnel.
- Inspecting the measures carried out by using the plan created for the measures.

2.5.2. Step 6: Inspecting measures and compiling a report for the management

Once the measures for improving energy efficiency have been carried out, the planned savings must be verified by measurements as far as possible. If individual measures are unable to be carried out, then regular meter readings must be taken to ascertain the effectiveness of the measures.

The result of the inspection into how effective the measures have been must be documented in a report and submitted to the management. Further details may be added as part of the 'Annual report on energy consumption and implemented measures'. We recommend compiling additional intermediary reports once further measures have been carried out.

As a tool for doing this, you can use:

- Form: 'Planning form, improving efficiency'
- Excel tables for energy consumption

The amount of energy used and how energy consumption has changed over the past year in comparison with previous years should be presented to the management as a report and with assessments of the Excel tables on energy consumption. If areas are noted where planned goals have not been attained, then a plan of additional measures to be taken should be created in order to reach these goals.

2.5.3. Step 7: Carrying out additional measures in order to reach planned savings goals

If these savings goals for energy consumption are either not reached at all or only in part, then additional measures must be taken to reach these goals.

Additional measures are decided based on the extent of the planned energy savings, on the measures approved by the management and on the outcome of the measures once they have been implemented.

Usually, further measures required to meet savings potentials must be agreed with the management.

Steps for planning and implementing these measures follow the same pattern as described in this handbook.

3. Factors of success and case studies on problem solving in energy management

To conclude this handbook, we would like to focus on the central keys of success for establishing energy management processes.

Continual improvement

One of the most important keys of success in energy management is the principle of continual improvement. This means that once the described measures have been carried out, the planning stage is then repeated in order to develop additional energy saving measures, and the whole process starts all over again. Consequently, the process becomes routine. This is important for monitoring energy consumption. Experience has shown that the building's users – mainly office workers – only learn to adjust their behaviour and consciously save energy over long periods of time.

As previously mentioned, if this process is only carried out once then you will often have to go right back to the start. By continually repeating the measures previously described, a PDCA cycle ensues which enables energy to be managed professionally.

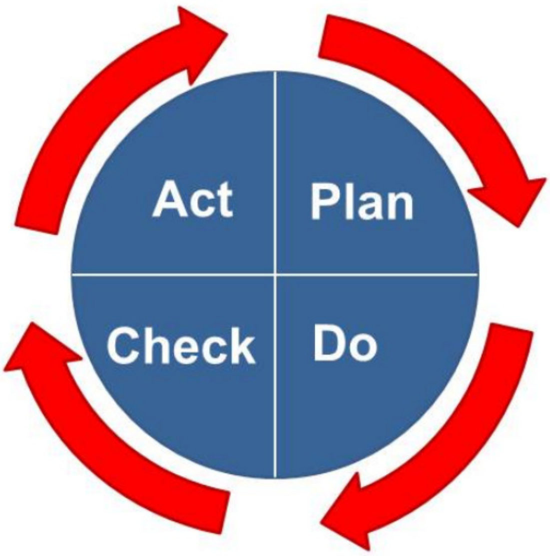


Figure 68: PDCA cycle for continual improvement based on ISO 9001

The effectiveness of the measures must also be monitored over the course of analysing the actual state of the office building, while planning measures to improve energy efficiency and while implementing these measures.

If the planned goals to save energy are not attained by carrying out these measures then additional measures also have to be planned and implemented in order to reach the set goals.

This process is illustrated using the following diagram:

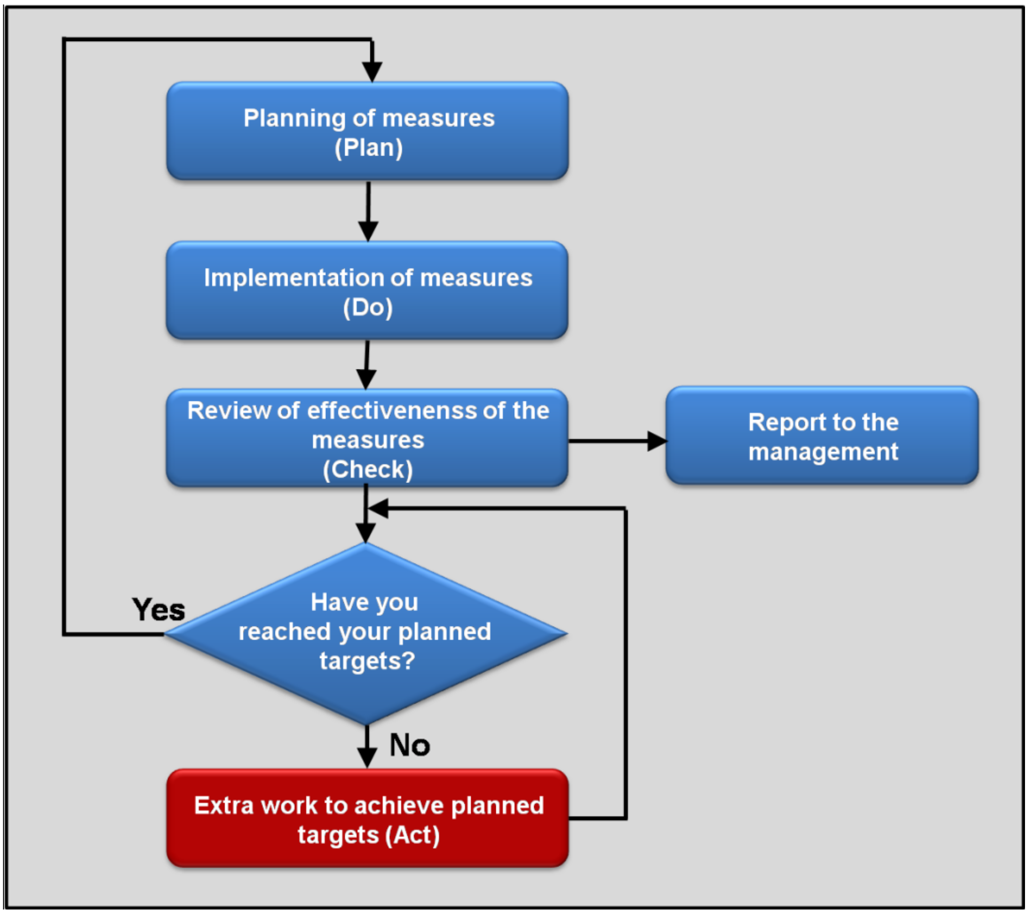


Figure 69: Process diagram of PDCA cycle where planned goals have been reworked or corrected

Appointed person

Long-term results are not possible without there being an appointed person who is responsible for continuing to implement energy saving measures.

This handbook is mainly aimed at the person appointed to do this, that is, an energy officer or caretaker. Their task is to independently analyse the actual status of energy consumption, plan measures for reducing energy consumption and energy costs, and to monitor how effective these measures are by compiling relevant documentation on meter readings and by using statistics.

An energy officer is specialised in giving advice on the energy used in commercial settings and may be useful for conducting a rough and a detailed analysis. However, an energy officer is not essential. An energy advisor should be consulted when planning to make large investments into replacing systems or renovating the building envelope. Their job is to evaluate the efficiency of planned systems/measures and to calculate their cost-effectiveness.

Communicating the aims of energy management

An essential factor in making energy management a success in office buildings is to motivate employees (buildings' users) to change their behaviour in order to save energy. Communicating aims and giving practical advice and rules on saving energy in the office are highly important for doing this. This may be verbal or written communication in the form of notices, newsletters or brochures. Moreover, it would be practical to stipulate energy saving targets in the company's guidelines and to integrate related themes into employee training.

Recognition and displaying success

Communicating the outcome of measures implemented to reduce energy consumption in office buildings and compiling statistics on this can encourage user behaviour to be more 'energy-saving friendly' in the long term. Verbal recognition given by a supervisor, for example, is also one aspect of this. We would also particularly recommend publishing success stories and statistics on energy consumption in employee newsletters and on notice boards. Employees who make a particular contribution towards saving energy can be given an award, e.g. as employee of the year.

Monetary rewards system

Hard work has to pay off. To encourage employees to participate in energy management alongside doing their regular work, we recommend introducing a rewards system based on targeted savings (in kWh and/or energy costs in EUR).

Incentive systems for saving energy costs are already practised in companies and communal facility management. The city of Frankfurt has introduced the following profit-sharing rewards system for reaching its targets. After implementing energy saving measures, the profit which results from the costs saved is distributed as follows:

25%	Facility user or office with several users
25%	Energy officer/caretaker
50%	Facility management for implementing measures which includes making investment in order to reduce energy consumption (comparable with office building's operating company)

Table 70: Distributing savings made on energy costs based on the city of Frankfurt

If, for example, 100 euros are saved over one year by implementing energy saving measures, then 25 euros are paid to the company based in the building, that is, the management, who can then use the profit in whatever way they see fit. The energy officer or caretaker receives 25 euros. The other 50 euros saved in energy costs can be used to invest in measures for improving energy efficiency, that is, to elevate further savings potentials.

A starting point for calculating savings made on energy costs is to use a reference value either for each energy consumer meter or for the total amount of energy consumption. The reference value is calculated by using the average amount of energy consumption from the last 3 years. A weather adjustment is made to the reference value for heat energy consumption.

At the end of each calendar or fiscal year, the differences in annual consumption are calculated in relation to the reference value. This provides the savings made in kWh which can be used to calculate profit-sharing. If technical measures or organisational measures are carried out which lead to a reduction in energy consumption, then the reference value needs to be recalculated accordingly.

Function	2009	2010	2011	Reference	2012	2013
Electricity consumption (MWh)	152	163	149	155	142	136
Saving (MWh)					13	19
Saving (%)					8%	12%
Electricity price (EUR/MWh)	140	148	152		162	175
Electricity costs (EUR)	21280	24124	22648		23004	23800
Electricity saving (EUR)					1884	2872
Heat energy consumption (MWh)	760	782	731		698	623
Climate factor	1,08	1,05	1,12		1,07	1,13
Heat energy consumption (MWh)	821	821	819	820	747	704
Saving (MWh)					73	116
Heat energy saving (%)					9%	14%
Heating price (EUR / MWh)	55	57	59		65	69
Heating costs (EUR)	41800	44574	43129		45370	42987
Heating savings (EUR)					4057	6091
Savings on electricity costs (EUR)					1884	2872
Savings on heating costs (EUR)					4057	6091
Total savings (EUR)					5941	8963
Bonus for energy officer (EUR)				25 %	1485	2241

Table 71: Example calculation for profit shared with the energy officer (with heating costs adjusted according to climate)

Including employees in optimising energy management

Company employees are the best acquainted with work processes in the office and are therefore able to make very helpful suggestions on how to reduce energy consumption by using office equipment differently according to measures implemented in the workplace.

This means that they should certainly be included in the energy management process. One way of encouraging employees to add their own suggestions for improvement is to create competitions in which individual employees or groups (e.g. teams, departments) can take part. The prize for the idea which brings about the greatest energy savings may, for example, be a staff outing or a bonus.

You can also create fixed work groups made up of members from different departments which are responsible for improving user behaviour and reporting to the management with the incentive of a bonus, for example.

The keys to success listed here are a guide as to how you can introduce sustainable energy management processes, particularly those which can be further developed and supported by company management.

Summary

Five members came together to compile this handbook on 'Energy management for office buildings made easy' as part of the 'Pioneers in Practice' programme. This handbook provides a detailed and practical introduction into implementing energy efficiency measures in office buildings.

At the start, the authors introduce the reader to the subject of energy management. Important figures who are required in order to carry out energy saving measures are identified and their jobs are discussed.

Seven stages for increasing energy efficiency are discussed in the next section. This section presents a step-by-step guide as to how to ensure that savings measures are implemented efficiently. First, a rough analysis is conducted. This analysis provides an initial estimation of how energy-efficient the building is. Moreover, energy supply contracts are reviewed in order to see whether the present tariff is suitable for the consumer (the building's users in this case).

Once an initial assessment has been made, the first targets are created for measures to reduce energy consumption. This is then followed by the third and most difficult stage: conducting a detailed analysis. In this stage, the building is thoroughly inspected. First, energy consumption is continually monitored by reading the meters to get a better overview of the situation. Then the measured heat energy consumption is calculated based on the weather by using a climate factor. This is followed by conducting an analysis of the load profile of the building. These measures enable an assessment to be made regarding the present electricity tariff and particularly regarding electricity consumption outside of working hours. An inventory is then taken which is aimed at providing a statement on the consumption levels of key energy consumers. The next point relates to inspecting the lighting. Here in particular, there is a high savings potential which can be achieved by making small investments.

The measures are usually very easy to implement. Simply switching of the lights after work hours can lead to large savings, as can exchanging defective fluorescent lamps. Heating, ventilation and air conditioning systems can be optimised by implementing low-investment measures which alone lead to cuts of up to 25% in expenditure. This means that increasing the room temperature by just 1°C leads to an increase of 6% in energy consumption. One way to remove this problem is to prevent thermostats from being altered manually by users in the room. Two other aspects for consideration are first that of hydraulic balancing in the heating system and second that of optimising operating times for recirculation and circulation pumps since these increase electricity consumption.

Ventilation and air conditioning systems are major causes of energy consumption during summer. Before any such systems are put into operation, less energy-intensive measures should first be implemented, e.g. an automatic dimming system for rooms. If it is absolutely necessary to switch this on then you need to make sure that it is on an efficient setting. The CO_2 concentration of the air in the room, the air exchange rate and relative humidity are especially important here.

Once the detailed analysis has been conducted, the measures are listed in order of importance. This is especially practical if you have a prescribed budget so that the cost-effective measures can be adopted first of all. In general, measures should first be adopted which can be implemented in the fastest and most cost-effective way (e.g. switching off equipment). Immediate savings are made particularly when carrying out these measures.

The fifth stage consists of carrying out complex measures and of regularly recording energy consumption levels. In the sixth stage, these measures are reviewed in order to evaluate their effectiveness. In

the last stage in the ‘seven stages towards increasing energy efficiency‘, additional measures should be adopted for saving energy. This is also about continuing with the process so that efficiency steadily increases.

The last chapter of this handbook concerns itself with key factors for successfully introducing energy management. The PDCA cycle is explained here as well as the significance of using this instrument. Further, the handbook discusses the importance of having a member of staff (‘appointed person‘) who is responsible for coordinating and structuring how measures are implemented. What is more, communicating all of this to employees is very important, as is the introduction of a monetary rewards system. Incentives are created by using these measures in order to encourage employees and officers to participate in carrying out energy saving measures.

Table of figures

The images and graphics which have not been specially labelled in the handbook have been provided by Thomas Möller. Furthermore all attachments, and the images and graphics contained in it, have been created by Thomas Möller as well.

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