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1 Executive Summary

This toolkit was developed on the basis of experience gained through the implementation of EMAS (Eco-Management and Audit Scheme), the European Union's voluntary scheme for organisations willing to assess, manage, continuously improve and report on their environmental performances. EMAS covers environmental aspects such as water, air, soil, material waste, odour and noise as well as energy consumption. EMAS works through first identifying negative environmental effects, then developing a plan to counter these problems, introducing a management system to continuously deal with them, and finally auditing what was done against these self determined targets so that improvements can be verified.

Energy is one of the key issues of EMAS. A systematic and structured analysis of an organisation's energy system provides immediate opportunities for improvement and cost savings. The aim of this toolkit is therefore to explain how to analyse an energy system step-by-step. It helps Small and Medium sized Enterprises (SMEs) to identify current energy consumption for different areas within the company, to set a baseline for continuous monitoring, to identify areas of improvement and to provide guidance on how to eliminate typical weaknesses.

The toolkit gives valuable information for companies to improve energy efficiency whether or not they have an environmental management system. It covers the overall energy review as a step by step process. The technical areas of heating, lighting, ventilation and electric motors will be covered in more detail as they are common to the majority of Small and Medium sized Enterprises in Europe. Typical weak points will be explained and activities presented, aiming at eliminating those weak points and improving the system with 'no cost' and low cost investments.

2 Introduction

The detailed energy analysis proposed in this toolkit is a step by step procedure in which energy consumption and costs in an organisation are evaluated, losses identified and improvements implemented to achieve the highest possible level of efficiency.

The toolkit is particularly targeted at Small and Medium sized Enterprises (SMEs) and takes account of the specific needs of SMEs.

What are the key steps for improving the energy efficiency?

Energy manager

Appoint a person responsible for energy efficiency in the company who will undertake the energy analysis and continuously improve the efficiency of the system.

Goal definition

The energy manager has to clarify the scope of the analysis. This can include a general review, the investigation of unusual losses, and the company's position in relation to benchmarks as well as organisational aspects influencing consumption.

Data collection

Data from invoices, meter readings and measurement must be systematically gathered and documented. This is essential as unstructured or poor data will not be useful for continuous monitoring.

Input-Output Analysis

This analysis helps to get a clear picture about the company's overall position and should contain the main energy inputs, consumption and emissions.

Energy Information System

The information system includes the core data and helps to monitor energy costs and to compare the baseline with improvements.

Data preparation and indicators

Data from the information system will be transferred into appropriate indicators and will help in understanding the various flows and quantities.

Detailed analysis

The detailed analysis and improvement of systems and processes can be undertaken with the help of the technical chapters of this toolkit. Typical areas of improvement will be highlighted, along with an in-depth explanation of technical systems. With this knowledge, it will be possible to increase the efficiency of individual technical systems like heating systems, lighting, ventilation and electric motors.

2 Introduction

The link between EMAS and the Energy Efficiency Toolkit

EMAS, the EU Eco-Management and Audit Scheme, is the most robust and credible environmental management scheme currently on the market, as it adds binding legal compliance, employee involvement, binding annual improvement of environmental performance and the requirement to report on these features to the requirements of the EN ISO 14001 standard.

Detailed information on requirements, performance and how to implement EMAS are available from the website of Environment Directorate-General: http://europa.eu.int/comm/environment/emas/

EMAS aims to continuously improve environmental performance of organisations in Europe. Within EMAS, every organisation has to consider energy as a direct environmental aspect. Therefore the energy review has to identify the main impacts of the energy system on the environment as well as consumption and costs.

The Energy Efficiency toolkit focuses on energy consumption and energy costs in detail. However, to reach continuous improvement in the area of energy a cyclical management process should be incorporated.

The following table shows the ways in which the energy management system lends itself to EMAS implementation.

EMAS	EMAS Definition	Energy management
Initial review	as "an initial comprehensive analysis of the environmental issues, impact and performance related to the activities of an organisation".	Collect energy data Develop an Input- Output Analysis Design a flow chart
Environmental Management System	including procedures, documentation and monitoring systems.	Set the basis for the Energy Information System Prepare data and indicators
Environmental Programme	including objectives and targets, addressing schedules, resources and responsibilities for achieving these	Develop energy related goals for the programme
Environmental Report	as a tool to provide information to the public on the environmental performance of organisations	Present data, indicators and continuous improvement

Additional links which are not covered in this handbook:

Environmental policy	as a statement by an organisation of its principles and intentions in relation to its overall environmental performance.	Guidelines for the responsible use of energy
Environmental Audit	as a "systematic, documented, periodic and objective evaluation of the performance of the organisation, management system and processes designed to protect the environment"	Check predefined energy goals

How can energy management be upgraded to full EMAS registration?

The milestones covered by the Energy Efficiency Toolkit set out the first stepping stones for implementing an environmental management system like EMAS. The principles of goal definition, data collection, input-output analysis, sampling of indicators and definition of measures lead up to implementation when applied to all the relevant direct and indirect environmental impacts of a company. By conducting the EMAS principles outlined above on a company's water consumption, waste water, material consumption, waste, transport, etc. further areas for improvement and cost reduction may be identified.

External auditing by a verifier specifically trained and accredited for the economic activities of the company completes implementation, while government-related institutions check the legal performance of the candidate company, before registering it the to the prestigious EMAS Scheme.

What does the EMAS Energy Efficiency Toolkit add to companies already registered under EMAS?

EMAS organisations tend to have a very high commitment to the environment. Generally, all organisations which do not have an energy manager in place will profit from the procedures outlined in the EMAS Energy Efficiency Toolkit, as they represent best practice in energy management, are cheap in implementation and show a quick return of investment.

3 Framework on how to establish an Energy Management

Irrespective of the company's size, a structured analysis of an energy system is very important because energy systems can be complex. They include factors such as:

- A different number of energy sources such as electricity, natural gas and oil which are all delivered by different companies and measured in different units.
- These sources might have to be converted to a different form before they can be used, e.g. steam, hot water or compressed air.
- A comparison of costs is not easy as the price for individual energy sources is based on different units and composed of various factors.
- There is an interaction between the different energy fluxes within the company. Waste heat from a process, for example, can influence the amount of energy required for space heating.
- Quite often the development of an energy system is linked with the company's development over time, which can result in a complex energy system. This in turn might make the analysis of fluxes more complicated.

For all these reasons, it is of primary importance to get an overview of the total system before undertaking a detailed analysis. Due to the complexity of energy systems, it is recommended to follow a step-by-step approach:

1. Appoint an energy manager
2. Define the goal of the analysis
3. Define the system's boundary
4. Collect data
5. Develop an Input-Output analysis
6. Design a flow chart
7. Set the basis for the Energy Information System
8. Prepare data and indicators
9. Understand the difference between power and energy consumption
10. Evaluate the performance of the energy management

At the end, the organisation should have

- An overview of the current energy system, the energy consumption, the associated costs and emissions,
- Identified the biggest consumers and possible areas of improvement,
- Set a baseline for continuous monitoring.

During or after this process the energy manager might find that it is important to analyse certain areas in more detail. Therefore detailed information about the most common energy systems found in SMEs is given in the technical chapter 4. This technical information can be consulted whenever needed. For instance, whilst carrying out the data collection phase, information about lighting might be needed and is supplied in the relevant technical chapter. If an energy manager notices that the energy consumption for heating is remarkably high, it may check the technical chapter on heating to identify areas of improvement.

3.1. STEP 1: Appoint an energy manager

Irrespective of a company's size, it is necessary to appoint an energy manager, who will act as the responsible person, at least on a part time position, depending on the size of the company. He or she will be responsible for all activities undertaken within the initial review.

If the company does not appoint a specific person for these tasks, nobody will feel responsible and there are chances that the required tasks will not be carried out. In addition, the role and competency of the energy manager must be communicated throughout the organisation.

The energy manager must have the power to ask for support in areas in which he/she has no detailed know-how. Practice has shown that the initial review takes less than a week in very small companies (< 50 employees), at least two weeks in medium-sized companies (50 – 250 employees) and around a month in large organisations (> 500 employees).

One of the first tasks of the energy manager will be to get an overview of the information and data already available in the organisation. Apart from written documents, there will be a lot of knowledge within the workforce. If appropriate, the energy manager should therefore identify people working in energy-intensive areas and in areas which have an influence on energy consumption.

Typically, these areas are

- Production
- Infrastructure
- Maintenance departments

In medium-sized organisations (> 250 employees), the energy manager should constitute an energy team which supports related activities and which acts as a link between the energy manager and other departments.

The energy team consists of people who have a sound knowledge of individual processes and technologies. Their knowledge might be used to influence energy consumption in their departments and to contribute to the development and support of a company-wide strategy. This is necessary as practice shows that individual departments rarely co-operate to increase efficiency. Secluded production processes and a cost accounting system following profit centres act as a barrier to a common strategy to increase the overall efficiency of the energy system. In smaller organisations the energy manager will already be familiar with the organisational structures and co-operate on an informal basis.

3.2. STEP 2: Define the goal of the analysis

For a company that has no understanding of its energy consumption, it is useful to begin with a general review. The aim of the review is to determine the quantities, types and costs of energy used within the company. The following factors are to be considered when determining the scope of an energy study:

- **Intensity of energy consumption**. It is useful to begin the study in areas of high energy consumption. Generally it will suffice to analyse those machines and processes with the highest energy consumption. Experience has shown that 20% of machines or processes use about 80% of the total energy consumed.
- **Structure of energy consumption**. In many areas energy consumption does not have a direct link with production levels. Often this is misinterpreted as having no potential for saving energy. In some areas there is no detailed knowledge about energy consumption. Systems largely influenced by variable factors (e.g. outdoor temperature, daylight), and systems for which no detailed knowledge of fixed and variable factors exists, should be analysed.
- **Maintenance systems or electronic office equipment** are often regarded as fixed factors. Although savings are relatively low compared to those of production processes, they can often be achieved with no or low investment. A change in behaviour does not require investment and can be attained with minimum effort and will add directly to the bottom-line.

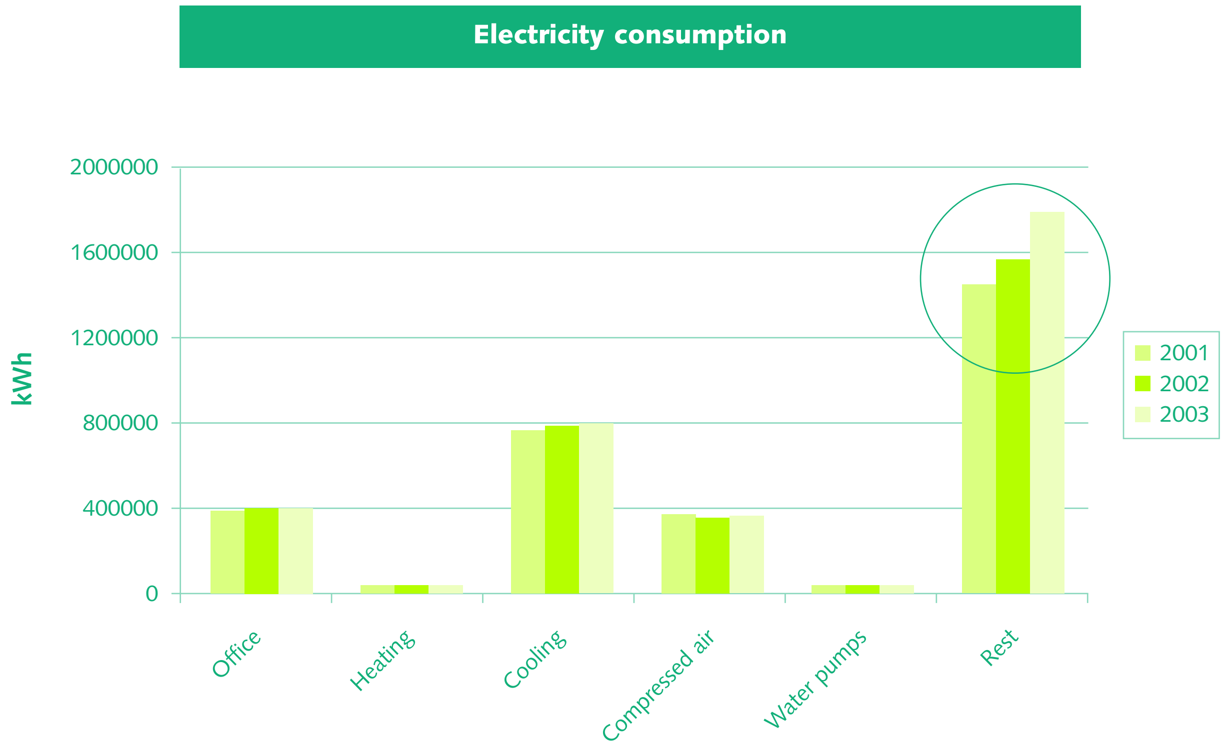


Figure 1: Electricity consumption in a company – Concentrate on main consumers and evaluate areas lacking in knowledge

In the example shown above more than 50 % of the electricity use cannot be allocated to a specific consumer. This energy use should be analysed.

Beside the technical goals, the energy manager should look at both the organisation and at "human factors". Organisational aspects influence the energy consumption due to low co-ordination between the individual departments or unstructured and irregular team work. Human factors should consider

- Motivation,
- Activities already undertaken in the past,
- Opportunities to train in energy conservation.

Therefore one of the goals of the review may be to focus on human factors. An example is competencies and staff motivation for energy conservation in individual areas. The energy manager should identify: staff with appropriate knowledge to support activities during the analysis; staff needing improved awareness; how the team should be organised to increase efficiency.

Best practice

Awareness rising

The energy system of a large office building in Vienna was analysed in 2002 by an external team with the goal to decrease the costs through various activities. The whole building has about 20,000 m^2 in which around 1,000 employees are working during office hours. Beside the technical systems the energy team also developed a strategy on how to motivate staff to participate in the energy efficiency process and to take action to reduce energy.

Posters and leaflets were produced, including information about easy ways to reduce energy consumption. The information included advice about good housekeeping such as switching off lights when leaving rooms, reducing room temperature using thermostats instead of opening windows and switching off office equipment.

Before the campaign the total

- Energy consumption was 9.8 Million kWh per year,
- Costs were € 819,040.

The result of the information campaign was a measured **decrease in energy consumption by 2.5%**, equivalent to 250,000 kWh (€ 20,894) in one year! The

- Electricity consumption could be decreased to 9.55 Million kWh and
- Costs to € 798,154 per year.

Another important factor is green procurement. A goal of the analysis might be to identify areas for which purchase criteria for energy savings can be used. Household appliances, air-conditioning appliances, lighting sources and other equipment may be purchased with reference to the “European energy” label. The label categorises appliances from A (most efficient) to G (least efficient) and shows how much energy is used under standard operating conditions. Higher initial investment in energy saving equipment can be quickly off-set against lower operating costs. Another label which helps to identify energy saving equipment is the “Energy Star” label, often found on office equipment. There are also national labels which help to identify energy saving appliances and which could be used as purchase criteria.

At this stage the senior management might be interested in knowing how much an analysis will cost and the savings that can be achieved. Unfortunately there is no general answer, every organisation is unique and every energy system is different. For a preliminary estimate of energy costs, and potential savings only, data available on site or data from the energy supplier should be used. This will not require a cash investment. Subsequently the energy manager will recognise areas where measurement will be needed to get more detailed information. The costs of an analysis must then be balanced against the potential savings that are likely to be generated. However, the reason for undertaking a review is to get an overview of the system and to minimise losses –if the company does not finance the analysis it will never identify its energy losses and potential savings.
Once the scope of the study has been determined, the next step is to decide which areas will be considered and in how much detail.

3.3. STEP 3: Define the system boundary

Defining the system boundaries of a small company should be quite simple. Small companies usually focus on all areas at once and there is no use dividing the company into several separate units. Senior management will be responsible for all areas and all energy sources.

Larger organisations may find this more difficult. At the beginning they should determine areas to be looked at or define and exclude irrelevant areas. It is good practice to define and include production units, storage facilities and office buildings in the initial review and to be aware of energy intensive areas. Care must be taken if energy consumption is not separated for private and company units or where floor space is shared. This might be the case when the owner of the plant lives on the site or two retail outlets trade from the same building, and only one measurement is taken for the whole plant. If appropriate, the company's vehicle fleet should also be considered separately.

Another criterion is the current structure of the company. The specific structure will influence the relationship between departments, profit centres, cost centres, what data are available and hence which should be considered together in a review. It might occur that the structure of profit centres differs from energy consumers. In this case the energy manager should consider that, since data for profit centres is already available, they should try to undertake the analysis following the given structure.

3.4. STEP 4: Collect Data

Structured data collection is fundamental to the energy review. As a first step, only existing data sources should be used. Sources of existing information are:

- Invoices
- Meter
- Test documents
- Manuals
- Measurement documentation, e.g. data output from measuring devices
- Audit reports

INVOICE

G&L Instructions Limited
Abbey Road
Gwellahwaht
XX120GW

charges for the period
23 Mar 2004 to 20 Apr 2004

e.company

Please read the important notice overleaf
Sales Invoice No.: 2426665
A/C No.: 1239123912
Date: 21 Apr 2004

	€
Base rate power 106 kW * 3.02	320.12
Consumption rate - low tariff kWh 4,940 * 2.834 Cent	13.99
Consumption rate - high tariff kWh 20,905 * 4.19 Cent	875.91
Network base rate 106 kW * 2.20	233.2
Network consumption rate 5.7 Cent * 25,845	1473.16
Energy costs	**2916.38**
+ Energy tax	367,75
Subtotal	**3284.13**
+ 20% VAT	656.82
+ Surcharge renewables 0.029 Cent / kWh	7.49
+ Stranded costs 0.041 Cent / kWh	10.72
Total	**3959.16**

Payment terms : 14 Days Net

Figure 2: Example of an energy invoice

A considerable amount of energy information is readily available to an organisation, but it often requires collating and interpreting. By simply gathering appropriate information, a clearer picture of energy use and costs will begin to emerge.

Invoices provide the primary source of energy information. However, data may be available from other areas of the business, which if appropriate, should also be integrated. For example, cost data derived from invoices will in some cases be required by the accounting department.

There are, however, problems associated with data collected from invoices, these might include:

- Invoices not copied for staff reference
- Data illegible, e.g. poor quality copying
- Confusion between accounting and consumption time frame
- Non-consumption billing for account adjustment (e.g. flat rates charged during the year)

Having collected invoice data, the energy manager will need to fill gaps in required data. This step will help to get a better overview of all areas involved. Calculations can be undertaken for areas where the power requirement and the operating hours are known. The following options exist:

- To obtain an estimate for light consumption, count light bulbs and multiply the number by operating hours and wattage.
- A rough estimate for engines and cooling equipment can be obtained by multiplying their power rating by operating hours.

As a next step, the energy manager will identify areas where no or little knowledge about the energy consumption is available. It will then be necessary to think about measuring the energy consumption of individual processes, plant or devices. If so, the following issues should be taken into account:

- The measurement location depends on the structure of the system, what is being measured and should be as close to the energy consumer as possible.
- If it is necessary (e.g. due to high energy costs) to collect data regularly, an automatic system should be installed, e.g. for heating and air condition systems.

Meters

The first point of measurement for electricity consumption is usually the supply meter. The data can be used directly for calculations. Data for gas and district heating can be obtained from meters at the supply terminals. Please note that all consumption measurements should be converted to a common unit i.e. kWh.

The following table shows equivalent unit conversion factors for individual energy sources. Energy suppliers can provide precise figures.

Energy	Units	Calorific value	Units	Calorific value
Heating oil extra light	1 litre	= 10.0 kWh		
Heating oil light	1 l (15°C)	= 10.6 kWh	1 kg	= 11.5 kWh
Heating oil	1 l (15°C)	= 10.6 kWh	1 kg	= 11.4 kWh
Heating oil heavy	1 l (15°C)	= 11.0 kWh	1 kg	= 11.1 kWh
Liquefied gas	1 kg	= 12.8 kWh		
Natural gas	1 m^3 1 therm	= 9.5 kWh = 29.3 kWh		

Table 1: Conversion table

As these data will be important for future comparisons, they must be collected systematically. It must be clear what data will be collected, by whom and at what time. Experience has shown that the person responsible for the process or the department being studied should be in charge of collecting data.

Data quality

The system analysis is only as good as the quality of the data used, information based on the analysis of poor data will be meaningless. The accuracy of data is of considerable importance as is the consistency of data collection methods. There is little point ensuring that a meter is 100% accurate, or that cost data are calculated to five decimal places, if the person responsible for collecting data reads the wrong meter or calculates costs from estimated invoices.

It is highly important that follow-up calculations and the development of indicators are based on real data rather than on estimates.

3.5. STEP 5: Develop an Input-Output analysis

The development of an input-output analysis helps to provide a clear picture about the company's overall position and show the yearly emissions. The analysis should contain

- Energy inputs
- Emission outputs.

Inputs consist mainly of non-renewable energy such as oil, natural gas and electricity. If appropriate, renewable energy such as wood should be mentioned. On the output side, mainly emissions and waste heat will be mentioned. Emissions such as carbon dioxide are directly linked with the company's energy consumption and contribute to negative environmental effects. Staff should be aware of these effects and realise that their activities do not only have an influence on consumption but also the environment.

Input	Output
Coal	Emissions
District heating	
Electricity	
Natural gas	Waste heat
Oil	
Wood	

Table 2: Input-Output analysis

Emissions are directly linked with the combustion of fuels. As emissions will rarely be measured, because it is technically not handy, they should be calculated for use in an Input-Output analysis. UK conversion factors from various energy sources are given in the following table. Emissions from district heating depend on the fuels combusted and will be provided by the plant owner. Emissions for electricity consumption depend on the power plant where electricity is generated and can be requested from the electricity supplier.

Fuel	kg C/kWh	kg CO2/kWh
Gas	0.052	0.19
Oil	0.069	0.25
Coal	0.081	0.30
Electricity	0.127	0.46

Table 3: Emission factors

Waste heat occurs in several industrial processes, machinery and compressors and can be used in other applications including space heating. Recovering this heat can prove highly cost-effective, resulting in a reduction in overall energy bills. However, as it is not easy to identify the available waste heat, an expert should be contacted for detailed advice and analysis.

3.6. STEP 6: Design a flow chart

With the data collected to this point, the energy system should be visualised with an energy flow chart. This is a graphical representation of all relevant energy fluxes in the company.

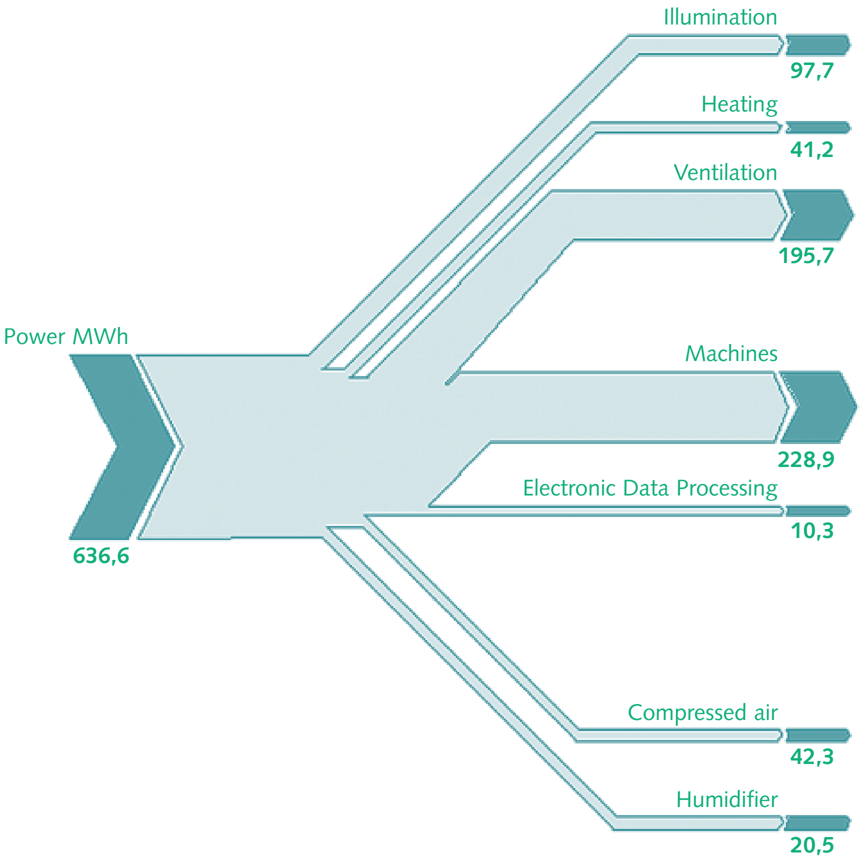


Figure 3: Sankey diagram of the energy system in a joinery

A simple flow chart can be designed to illustrate energy fluxes as shown in Figure 3: Sankey diagram of the energy system in a joinery. This kind of illustration can be prepared using professional software or by hand. The goal is to identify the organisation's energy flows and the associated quantities. The flows must have the same physical units. The width of the flow depends on the energy consumption of the system or machine. The annual input figures can be collected from existing documents, e.g. invoices.

The above example only considers the electricity flow. If other energy sources are used, it is useful to prepare a second flow chart for heat, for instance.

After the preparation of the simple energy flow chart, it is necessary to decide

- Which areas need more analysis due to a lack of data,
- Which machines and processes are responsible for most of the energy consumption and will, therefore, have to be analysed in detail.

3.7. STEP 7: Energy information system

Data should not only be collected and analysed for the initial review but also for continuous monitoring. Consumption and costs should therefore be collected and documented on, at least, a monthly basis. The main advantage of a regularly updated energy information system is that the energy manager can immediately identify areas of unusual and high consumption, to act in time and to avoid losses.

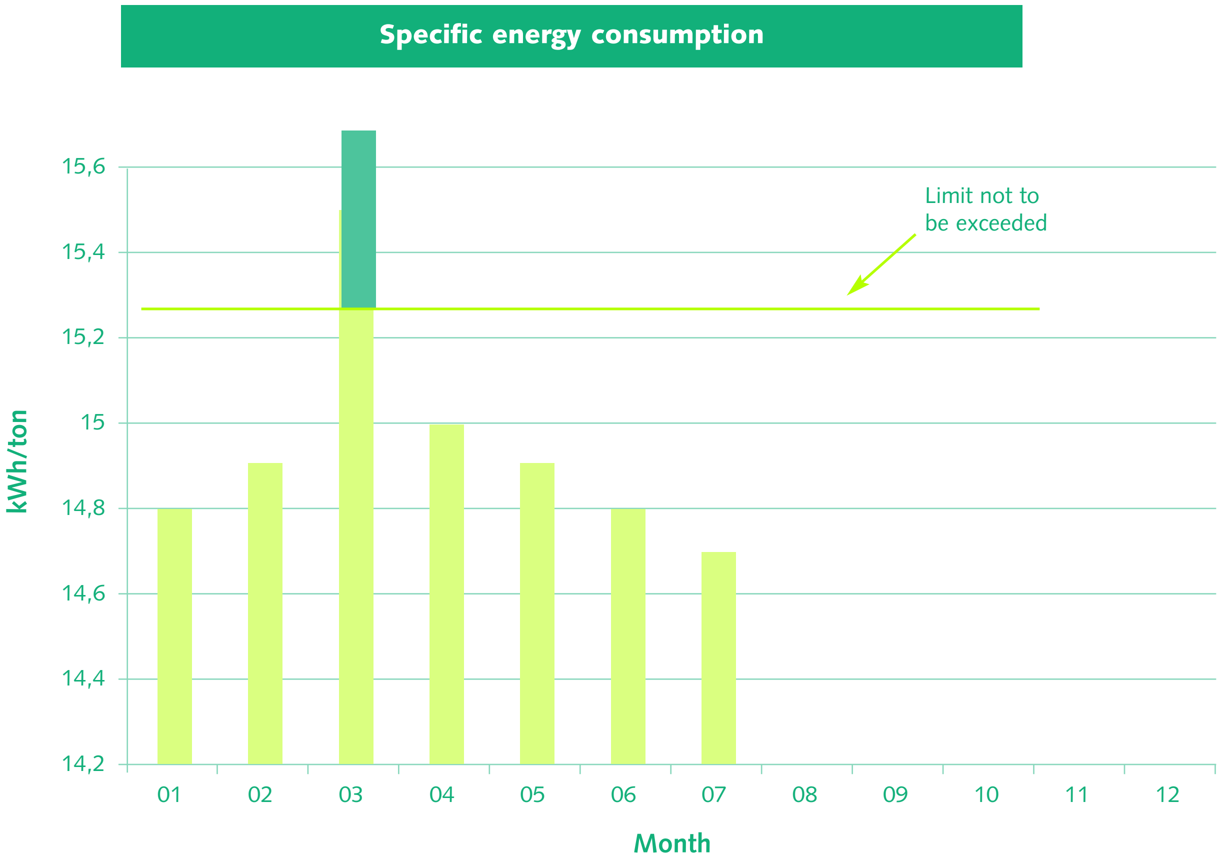


Figure 4: Monthly monitored energy data

In order to compare data over time, it is necessary to always use the same cost basis. In addition, data for each individual energy type should be collected separately. To avoid confusion, only net prices, i.e. costs excluding VAT, should be considered. The following information should be documented:

- Electricity
- Natural gas
- Heating oil
- District heating

Electricity

Electricity consumption often consists of high tariff (HT) and low tariff (LT) times. As there is a different price associated with each and if appropriate, this information should be documented.
The peak load is the highest monthly load the company requires from their energy supplier. This information can normally be found on the invoice and should be documented, as peaks and loads have a significant influence on energy costs.

Electric devices require idle power, the costs can be found on invoices.
The total costs should be given without VAT.

Position	Month	HT kWh	LT kWh	Total kWh	peak load kW	idle power kV/Arh	Total costs €
1	January	25,876	6,887	32,763	129	0	3,604

Table 3: Emission factors

If the company uses more than one electricity supplier, e.g. one for the net use and one for quantity, the costs have to be added up.

Oil

Heating oil consumption is more sophisticated as purchase quantities differ month by month. Data therefore cannot be taken directly from invoices. The storage level and the monthly consumption should be documented with the help of either the meter on the tank or with a measuring rod. Light heating oil has an average calorific value of about 10.0 kWh/l, exact data can be requested from the fuel supplier. This data will be needed for on-going comparisons.

Position	Month	Tank filling	Purchase		Consumption		Costs €	Calorific value kWh/l	Heat con-sump-tion kWh
			quantity l	price €	quantity l	price €/l			
1	Jan.	400	4,000	1,320	1,150	0.33	379.5	10.0	11,500
2	Feb.	3,250	-	-	1,250	0.33	412.5	10.0	12,500

Table 5: Example of heating oil documentation

Natural gas

Energy costs and consumption for natural gas can be taken directly from the invoice. However, if gas consumption is measured in m³ or therms, it must be converted to a common unit. Typical calorific values are 10.7 kWh/m³ and 29.3kWh/therm.

Position	Month	Gas consumption m³	Calorific value kWh/m³	Gas consumption kWh	Costs €/kWh	Total costs €
1	Jan.	2,800	10.7	29,960	0.03	898.80
2	Feb.	2,760	10.7	29,532	0.03	886.00

Table 6: Example for natural gas documentation

Summary

The total costs and the total quantities should then be displayed in two summary tables, one for the costs (see below) and one for the quantities to tell apart rising prices and raising consumption. These tables should also contain information on previous periods to allow for comparison.

Position	Month	Electricity €	Natural Gas €	Oil €	Others €	Total €	Total previous year €	Difference
1	Jan.	3,604	899	380	-	4,883	4,320	+13%
2	Feb.	3,840	886	412	-	5,138	4,540	+13%

Table 7: Example of summary sheet

3.8. STEP 8: Data preparation and indicators

In this step, company-related data should be prepared in a way that enables the evaluation of the company's performance. It is helpful to use diagrams to summarise data.

When preparing data, the following items should be taken into account:

- Only data essential for the analysis should be used
- Data should be rounded
- Data must be clearly labelled
- The source of the data used, any assumptions and calculations made during their collection must be described
- The date of collection and preparation of the data must be noted
- The name of the person who collected and prepared the data along with the file name should be indicated

From the data, the energy manager will compile indicators for:

- The entire company
- Departments of the company
- Individual processes

It should be clear from the beginning how the indicators are to be used. Indicators for the entire company will be important for senior management as they show the company's overall development. Indicators for departments and processes should be developed as a tool for staff to monitor processes. They are helpful in case staff can identify opportunities that will improve energy efficiency.

Indicators can be used to compare:

- Machines of different capacities
- Processes which use different technologies
- Machines which produce similar products
- The efficiency of similar machines.

It is important to note that indicators should only be built with real data. Indicators using estimated figures should be avoided as they cannot be related to actual performance.

It is recommended to use relative indicators as they link the company's energy consumption with the output or a unit of reference. It is useful to relate energy consumption to products, employees or, in case of hotels and restaurants, to guests and beds occupied. Energy consumption for heating should be related to the heated square meters. It is then easy to monitor the company's performance over time.

Specific energy consumption	$\frac{\text{total energy consumption}}{\text{production quantity}}$
Energy intensity	$\frac{\text{energy consumption of product in kWh}}{\text{total energy consumption in kWh}}$
Specific energy costs	$\frac{\text{total energy costs in } \textit{Euro}}{\text{total production costs in } \textit{Euro}}$

Table 8: Typical energy indicators to be used at company and departmental level

3.9. STEP 9: The link between energy and power

Energy costs for electricity consist of various factors. Beside taxes and additional charges, the main components of an electricity invoice will be power in kW (kilowatt) and work in kWh (kilowatt hours). Power is normally calculated in kW by adding the maximum power of all machinery and assuming that they are switched on together. The cost of energy is determined by the maximum demand. However, a piece of equipment's maximum power is hardly ever used. Usually an installation operates at partial power or only operates at full power for short periods of time. It is therefore in the company's interest to reduce peak demand and maintain loads as close to the average as possible.

It is possible to plot a power duration curve to determine where peak power consumption occurs. A power duration curve is a diagram presenting data in sequence from the highest power consumption to the lowest. On request, energy suppliers deliver power duration curves.

The following example shows a power duration curve. The maximum power is only used for a brief period of time, in this example for only around 300 hours out of the total working time.

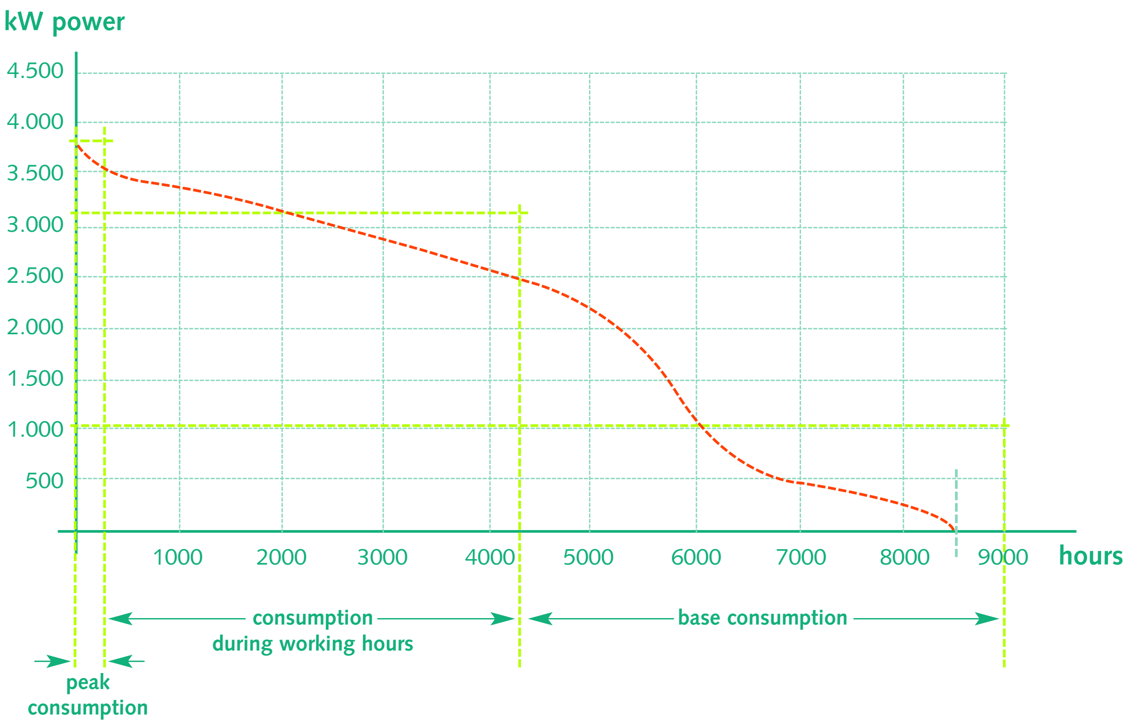


Figure 5: Power duration curve

Power consumption can be divided into three different groups:

- Peak consumption
- Consumption during working hours
- Base consumption

In order to analyse the curve it is necessary to know during which period individual power consumers are operating. It is then up to the energy manager to find out:

- Which consumers are essential for process operation and cannot be switched off and therefore cannot be considered to be part of a power management strategy,
- Which of the necessary consumers may be switched off at different times and, therefore, be used to avoid peak times.

Examples:

- Machinery is normally switched on at the beginning of a shift and therefore causes peaks. Instead they could be switched on one after the other.
- Boilers and warm water containers should not be heated during peaks but during low consumption times.
- Ventilation and air conditioning should not be operated when starting other machines so that the peak power consumption can be reduced.

The aim is to reduce power consumption during peak periods. On a more sophisticated level this can be achieved using electronic load control systems.

Best practice

Load management

A chocolate manufacturer in Germany with about 50 employees paid for a load of 427 kW with a total monthly cost of € 3,397. The senior management of the company decided to monitor energy consumption and costs to identify areas of improvement. The analysis of electricity consumption showed that the agreed power consumption was exceeded once in July, when the peak achieved 437 kW. However, during the rest of the year the limits were never reached. The energy team decided to organise work in a way so that not all machines will be switched on at once. With this power management the connection power could be reduced to 400 kW which saved the company € 215 per month. No investments were necessary to reach a 6 % reduction in load costs.

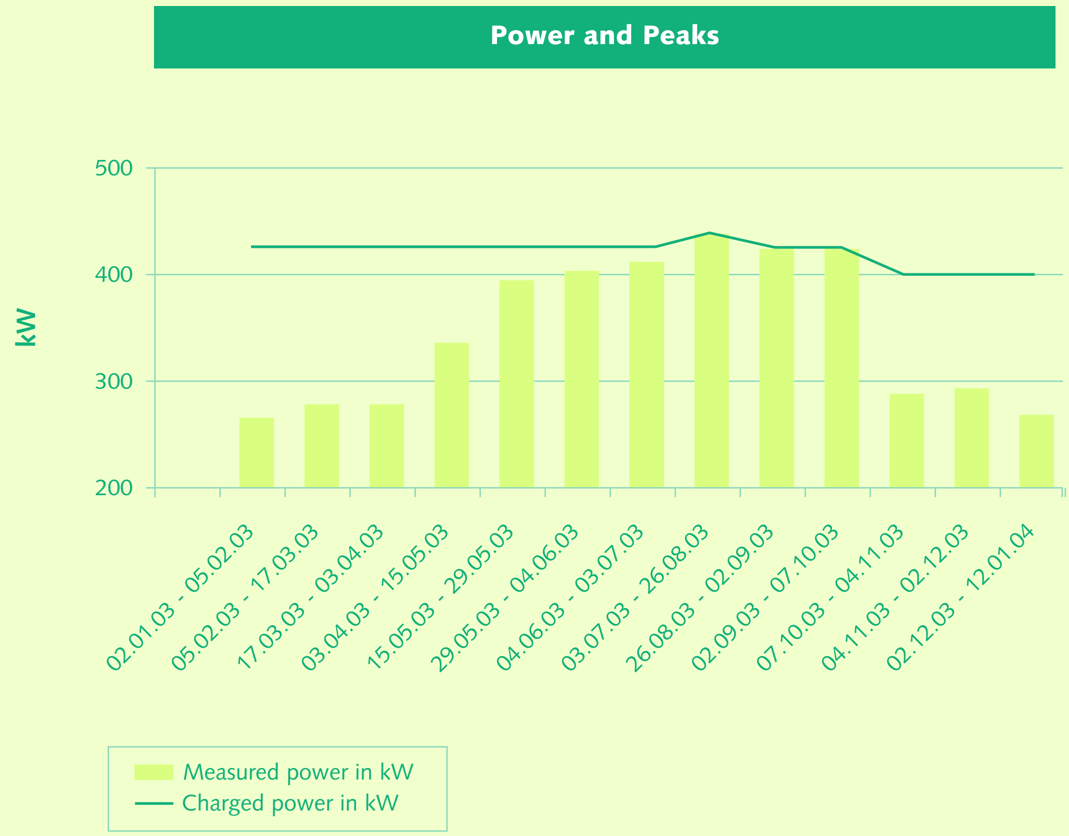


Figure 6: Charged and measured peaks

Best practice

Power management

A large warehouse in Graz, Austria, with more than 22,000m² uses its delivery area irregularly. In 2002 electricity consumption was 1.98 Million kWh and costs € 144,000. During deliveries the heating system peaked. Measurement of power consumption, taken at fifteen minute intervals during the winter (November to March), showed these to be irregular and, at their highest, reaching 970kW. The yearly costs for this power were € 83,808.

A diagram provided by the energy supplier showing peaks during an average day clearly visualised that the maximum peak only occurred during one brief period. Realising that this peak could be reduced by installing a power management system, the management decreased installed power by 270 kW. The energy price for each kW is € 86.4, the total savings therefore amounted to € 22,328 per year! Taking into account that the costs for the load management were € 10,000 the **payback for this investment was <6 month. Savings were equal to 27 % of the yearly costs for power!**

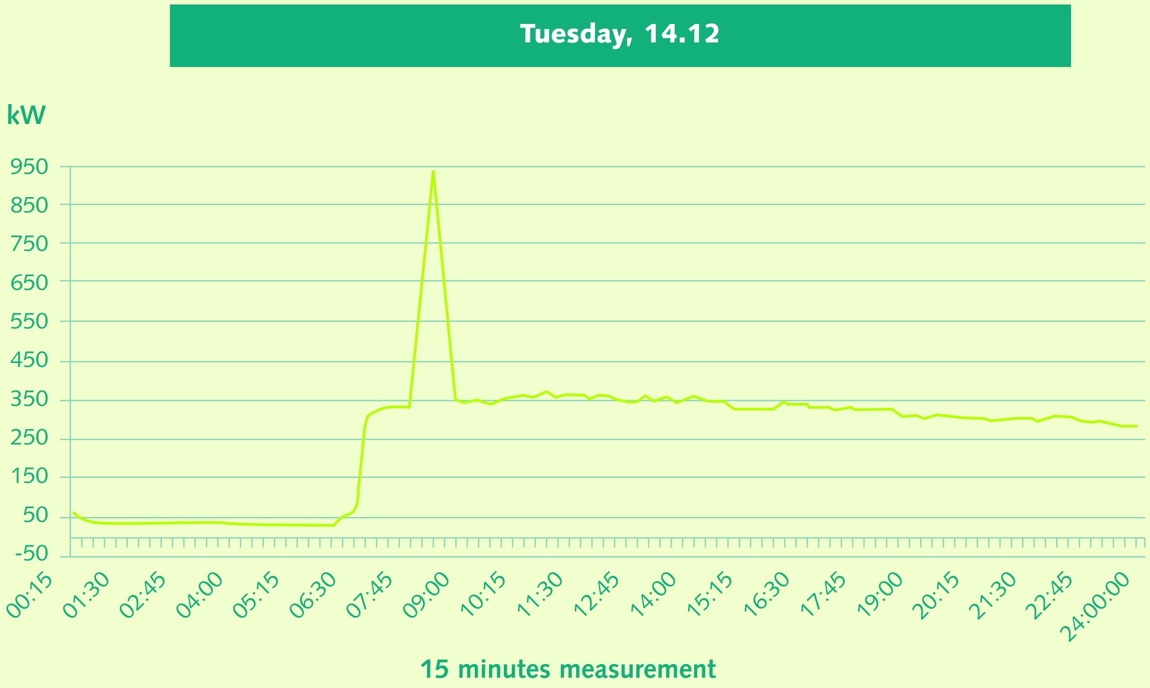


Figure 7: Power duration curve with 1/4 hour measurements

3.10. STEP 10: Evaluate the performance of the energy management

The first 9 steps will now have provided an overview of the organisation's energy consumption and associated costs as well as identified the "main consumers".

The evaluation step consists of a more in-depth approach that will:

- Ascertain performance over time,
- Compare data with benchmarks
- Analyse selected areas in detail

Performance over time

During the evaluation, the energy data from previous years will be summarised. A simple example of how this can be undertaken is given in the following table. The table identifies the fuels used within a company. For each fuel identified in the table, the consumption during the previous three years is evaluated and the total quantity recorded is shown.

	Year 1	Year 2	Year 3
Electricity	720,000 kWh	752,000 kWh	766,000 kWh
Heating oil light	4,500 l	4,550 l	4,800 l
Natural gas	10,800 m^3	10,450 m^3	8,830 m^3

	Year 1	Year 2	Year 3
Electricity	720,000 kWh	752,000 kWh	766,000 kWh
Heating oil light	47,700 kWh	48,230 kWh	50,880 kWh
Natural gas	102,600 kWh	99,275 kWh	83,885 kWh
Total	870,300 kWh	899,505 kWh	900,765 kWh

	Year 1	Year 2	Year 3
Electricity	94.0 %	98.2 %	100 %
Heating oil light	93.7 %	94.8 %	100 %
Natural gas	122.3 %	118.3 %	100 %
Total	96.6 %	99.8 %	100 %

Table 9: From raw data to percentages

The total energy consumption can also be visualised in a graph:

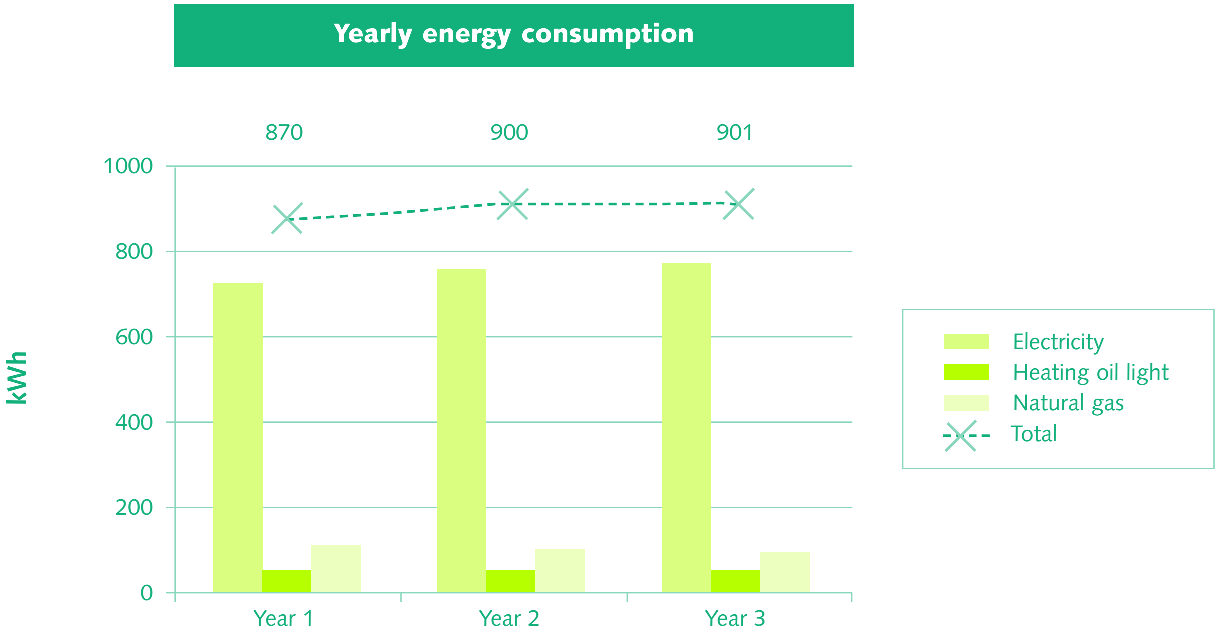


Figure 8: Yearly energy consumption

Consumption figures are likely to have different units depending upon the fuel type. Heating oil, for example, is likely to be indicated in litres and electricity in kWh. It is therefore necessary to use conversion factors to record all fuel sources using the same units. The most common unit is the kilowatt hour.

The conversion table on page 15 provides conversion factors for gas and oil. To identify patterns of consumption over time, it is useful to establish a baseline against which figures can be compared. Year 3 is fixed as the baseline and consumption during Year 1 and Year 2 is expressed as a percentage of the energy consumed in Year 3.

It becomes evident from the example that gas consumption efficiency has improved. There is no clear improvement trend for electricity and heating oil.

In a next step these data must be analysed in detail and interpreted.

Comparison with benchmarks

First of all the data are compared with benchmarks. This can be done using figures from literature relating to heating and lighting.

For certain processes the analysis will require variation patterns including:

- Daily patterns
- Weekly patterns
- Seasonal patterns

The use of these patterns depends on the importance of the data in terms of quantity and costs. A daily or weekly pattern is useful when data are collected automatically, when high costs are at stake or when immediate action is required.

Analyse selected areas in detail

For particular industrial processes, benchmarks and comparison data are unlikely to be available. The only way to identify possible savings is to determine the theoretical energy consumption of the individual production processes from literature and compare these figures with real consumption. If the consumption differs, it is necessary to identify the reason and to try to improve the process. This should only be undertaken by well trained staff or by external experts.

The description of the overall energy review process ends with the detailed analysis of selected areas of energy consumption. A summary is provided by the checklist below. In the next chapter practical detailed examples are listed for the possible improvements resulting from an energy management under EMAS.

Step by step - Checklist

1. Appoint an energy manager with clear competencies and the responsibility to evaluate the current energy system.	
2. Clarify the reasons why you would undertake a detailed analysis and what should be the result (e.g. no knowledge about energy flows and undertake the analysis to get a clear picture about consumption).	
3. State clearly which energy sources and areas to include in the analysis (energy sources such as electricity, natural gas, oil and areas such as production, storage, transportation).	
4.a. Collect invoices for all energy sources of the last 3 years.	
4.b. Document all measuring points and the associated readings over the past year.	
5. Develop an input-output analysis based on invoices, measurements and conversion tables for emissions.	
6.a. Collect data or measure the energy consumption of the major individual consumers (machines, departments) in the departments.	
6.b. Calculate the energy consumption for those consumers where power and operation times are known.	
6.c. Draw a flow diagram of the energy flows inside the organisation.	
7. Write down all figures and indicators which help the organisation to monitor the energy consumption over time. Take care to identify those figures which help staff involved in production processes to realise their influence on the energy consumption.	
8. Determine where data come from, who collects data, how often they should be collected and who receives the information.	
9.a. If you pay for power in kW and for energy in kWh, ask your energy supplier for a power duration curve (yearly and weekly).	
9.b. If appropriate, check in your energy contract what load you are paying for, what peaks really occur and if you could decrease the load.	
10. Having done these 9 steps you will know for sure which areas to analyse in detail and which improvement activities will help you to decrease your energy costs.	

4 Technical details

You may now require additional information about specific technical aspects of your energy system. The next four sub-chapters provide this more detailed information and cover:

- Heating systems
- Lighting systems
- Ventilation systems
- Electric Motors

4.1. Heating systems

Energy consumption and costs for heating are related to both technical and human factors. On the one hand, losses may occur in the heating system itself and may be avoided by adequate technical measures. On the other hand, losses could also occur due to poor user behaviour and ignorance of the effect this behaviour has on heating costs. Therefore measures to reduce heat consumption must consider both technical and human issues. The optimal work place temperature must be balanced against the desire for minimal cost.

Beside human factors, costs for heating depend on the following:

- Heating system – type and efficiency of the heating system
- Level of maintenance – continuous maintenance vs. non-maintained systems
- Building structure – the insulation and the architecture of the building
- Outdoor climate – northern countries obviously require more heating than southern countries, which require more air-cooling
- Fuel price

The systematic collection of data will be needed to analyse the performance of different parts of a building and different buildings on a site and to identify those locations responsible for excessive heat consumption.

Optimisation of the system can be seen as a step-by-step procedure:

1. Learn about your current heating system.
2. Identify fuel consumption and costs for heating.
3. Identify losses and evaluate possibilities to improve efficiency.

4.1.1 Types of heating systems

The following heating systems are typically used within SMEs:

- Individual heating, e.g. separate electric storage heaters for each room,
- Central heating, e.g. one boiler for one building,
- District heating, e.g. community heating with centralised plant.

Individual heating

These systems are well known as they are often used in private households. Individual heating is sometimes used in companies either to heat rooms when the main heating system is not operated or in addition to the main system, for increasing the temperature.

Central heating system

A central heating system consists of a vessel or tank and a boiler, distribution system and the heat emitters. The boiler is used to generate hot water or steam from the combustion of fuels such as natural gas, fuel oil, or coal.

District heating system

Steam or hot water piped in from a central source.

The elements of heating systems are:

- Heat sources
- Distribution systems
- Heat emitters
- Controls
- Fuels

The following table gives an overview of the heating system elements.

Heat sources and boilers	Distribution systems	Heat emitters	Controls	Fuels
Oil/Gas boilers	Hot water	Radiators	Heating valves	Wood, wood chip
Solid fuel boilers	Steam	Convectors	Thermostatic valves	Coal
Electrically heated boilers	Air	Hot air heaters	Zone control	Briquette
Condensing boilers		Panel heating	Timer	Natural gas
Heat pumps		Electric storage heaters		Heating oil
Combined heat and power (CHP) systems		Pipes under the floor		Liquid propane gas
District heating system				Direct electricity

Table 10: Elements of a heating system

Heat sources and boilers

Oil boilers are commonly used and are still installed due to the relatively low investment required in comparison to other technologies. However, the combustion of oil causes very high CO2 emissions and the price of oil rises constantly.

Gas boilers have the advantage that they cause lower CO2 emissions compared to oil boilers and that, when attached to the main gas network, no tank is required onsite. However, investment is higher than for oil boilers.

Solid fuel boilers have been used extensively in private households, they burn coal, briquettes and wood and are only rarely used in companies.

In general, electrically heated boilers are not recommended, since they are the most expensive and least efficient means of generating heat. CO2 emissions depend on the fuel mix of the power plant and are low in countries generating electricity from hydropower.

Condensing boilers represent the most up-to-date heating technology for gas and oil. Energy efficiency is 10 – 20 % higher than for other boilers because they use exhaust emissions with a heat exchanger. The result is that they need less energy and emit considerably less harmful substances than conventional heating boilers. The main disadvantage is investment, the flues of condensing boilers must be fitted with special material.

Heat pumps (Reverse Cycle Systems) absorb heat of a low temperature from the surrounding soil, the outside air or groundwater and transform it to heat at a temperature that can be used for heating applications. Heat pumps are considered to be best available technology and are a form of renewable energy. Apart from very little electricity being needed for the pump, they do not need any fuels and therefore do not cause emissions. Their main disadvantage is the high investment costs and the need for large heat emitters due to relatively low temperatures.

Combined heat and power (CHP) systems produce electricity and heat for use at remote locations with an overall efficiency of above 80 %. They offer optimum efficiency in the transformation of energy with minimum environmental pollution. The main disadvantages are high investment costs and their size, starting from 5.5 kWe (kilowatt electrical).

Distribution systems

In a heat distribution system, hot water, steam or air is transported from the boiler to the heat emitter. Problems could occur when

- the system was not properly constructed to keep investment costs low, e.g. improperly lagged;
- the system does not match its demand requirements e.g. room occupancy has changed;
- the system is not maintained on a regular basis.

The only electrical devices used in a distribution system are circulation pumps. They are required in almost every hot water system to pump the water through the system. Gravity fed systems can be used in some applications.

Best practice

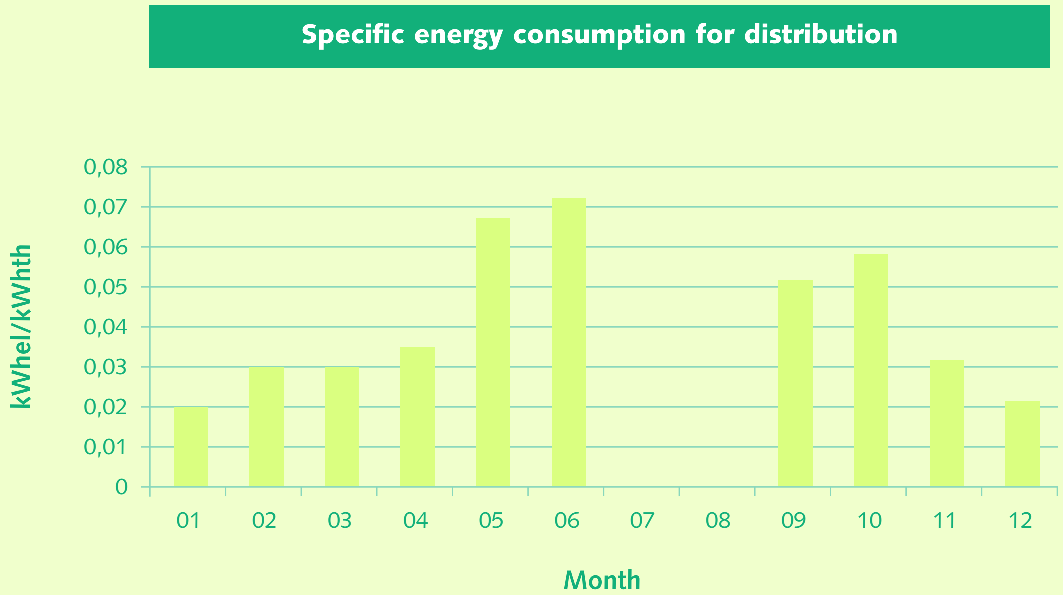
Increasing efficiency of distribution network

A medium sized company in the UK processing synthetic materials for industrial purposes evaluated possibilities to increase efficiency of the heating system. During the review phase therefore the pumps in the heating system were analysed in detail.

The following diagram was developed showing the specific energy consumption for the distribution of warm water through the distribution network. Gas consumption was monitored and documented on a weekly basis. The yearly electricity consumption of the pumps was measured and reached 120,054 kWh.

In cold months, during which a high quantity of heat was needed, the specific energy consumption for distribution was 200 kWh / 1,000 Nm^3. This value can be considered as very good as pumps are used nearly at or actually at full capacity. In higher environmental temperatures, the specific energy consumption rose significantly and specific energy consumption reached 730 kWh / 1,000 Nm^3. This is an indicator of low pump efficiency at low load.

Figure 9: Specific energy consumption for warm water distribution



During service work existing pumps were changed with variable speed driven pumps and the efficiency of pumps at low load could be increased. Pumps are now controlled by the temperature difference of the flow and return temperature. The result of this application is reduced

- Electricity consumption for the pumps
- Losses of the distribution network due to a reduced return temperature.

The total electricity consumption for the distribution network could be reduced by 25% to 90,190 kWh.

Heat emitters

Heat emitters radiate heat into room space. The location and the size of emitters is essential for comfortable working conditions. There are several types of emitters such as radiators and convectors. The exchange of emitters is cost intensive and will not be considered during the early stages of an efficiency programme.

Controls

There are several kinds of controls to regulate the temperature of individual emitters. Heating valves are used to switch heating emitters on and off. Thermostatic valves are used to set the required emitter temperature manually. A timer is used to switch the heating on and off at pre-determined times only. These options are relatively cheap and allow control of individual emitters. Zone control allows the heat regulation of individual areas.

Fuels

The fuels most commonly used for heating are oil, natural gas, coal and coke. Wood is used as a renewable energy source for heating, mainly in central and northern Europe. Electricity is also often used for heating, but is the most expensive alternative.

Although it is well known that fossil fuels are expensive in comparison to other heating systems and their emissions damage the environment, it is hard to change installed capacity due to the high investment involved. Efficiency activities will therefore focus on the improvement of existing systems. However, in the case of new plant acquisition or changes to the heating system, the management should be made aware of alternatives that are both environment-friendly and have low running costs.

4.1.2 Identify fuel consumption and costs of heating

To calculate the cost of any particular investment in heating, running costs, purchase price and fuel costs must be considered. These costs differ according to the location within Europe. However, when evaluating an existing system, the energy manager will mainly look at the fuel costs. As a step-by-step process, it is relatively easy to identify the current costs for heating.

Step 1

As a first step, it is necessary to identify the organisation's heated area. The figure can normally be obtained from floor plans and must not include areas which are not heated, such as storage areas or cellars. The result is necessary for further calculations below and will be represented by the letter A in the formula.

Heated area m^2	A

Step 2

The second step is to identify the heating system's fuel consumption. This is very easy for electricity, natural or liquid gas or distance heating when the energy is exclusively used for heating. The consumption indicated on the invoice in kWh can be used for the calculation. Natural gas may be given in m3 or therms and must be converted to kWh.

- 1 m^3 natural gas multiplied by 9.5 gives the amount in kWh
- 1 therm natural gas multiplied by 29.3 gives the amount in kWh

In some European countries natural gas or oil may also be stated in MJ (Mega Joule) or GJ (Giga Joule)

- 1 GJ = 1000 MJ
- 1 kWh = 3.6 MJ
- 1 GJ = 277.777 kWh.

As a starting point for natural gas, the last 3 years' invoices should be obtained and documented.

In the case of heating oil, the quantities purchased are normally stored and used for a longer period. The daily, weekly or monthly consumption cannot be analysed without detailed documentation. As a first step therefore, only the average consumption for the last 5 years will be taken and converted. 5 years should give you a realistic average without reflecting unusual consumption.

- In case of kg, the quantity is multiplied by 11.5 to get the amount in kWh
- In case of litres, the quantity is multiplied by 10.6 to get the amount in kWh

Detailed figures are provided by the energy supplier.

If in the case that no measurements have been taken and the fuels were not only used for heating purposes, an estimate can be made by comparing costs of summer and winter months. As no heating will be required during the summer months no heating costs will appear on the summer invoice. Therefore the difference on the winter invoice when compared with the summer should show the annual heating demand. This method assumes that there are no large fluctuations in fuel used for the production process.

In this step all yearly costs and quantities for heating are added, resulting in the following:

Energy consumption kWh	B
Energy consumption €	C

Step 3

The energy consumption and the energy costs in kWh/m2/year can be easily calculated:

Specific energy consumption kWh/m²	B/A
Specific energy costs €/m²	C/A

Step 4

In the fourth step, compare the specific energy consumption of a building with benchmarks of the relevant region. The figures will differ within Europe. The following classification for Central Europe should be regarded as a guideline for comparison. In case the annual energy consumption is above 70 kWh/m2, further analysis will be required.

Rating	Heat consumption kWh/m²/year	Comment
A	0 – 30	Best efficiency
B	31 – 50	High energy efficiency
C	51 – 70	Efficient
D	71 – 120	Average
E	121 – 160	Unsatisfying
F	161 – 200	Wasteful
G	201 -	Completely inefficient

Table 11: Benchmarks for heat consumption in Central Europe

4.1.3 Possibilities to improve efficiency

The quantities of fuel used and the costs for heating may be reduced by:

- Awareness raising
- Decreasing the consumption using simple activities
- Improving system efficiency
- Influencing humidity

Awareness raising

It is not recommended to simply start energy saving activities by changing the room temperatures, without informing staff in advance. As comfort at the workplace is a very sensitive area, the level of current satisfaction should be analysed first. In addition, the costs of heating individual departments should be examined. This is necessary as staff is rarely aware of costs, consumption quantities and recommended room temperatures.

Awareness rising should also include informing staff about how to set and manage electronic controls. Experience has shown that users often do not know how to control these devices and therefore set them manually.

Decrease consumption using simple activities

1. Adjust room temperatures

Different areas require different room temperatures. The following table gives an overview of recommended room temperatures for individual areas.

Part of building	(°C)	Part of building	(°C)
Market places	5 – 12	Library; entrance lobby	18
Garage	10	Lecture and study rooms	18
Store, archives	12	Offices, laboratories	20
Cash-desk, buffet	16	Restaurants, canteens	20
Kitchen	16	Theatres, drawing rooms	22
Waiting rooms, toilets	16	Bath, shower	24
Hall	16	Dye-house	25

Table 12: Recommended room temperatures

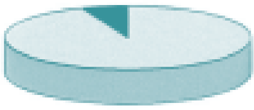
In many cases room temperatures are higher than those recommended. Any adjustment in temperature should involve co-operation with the staff affected if they are to accept the change. As a rule of thumb, turning the thermostat down by 1°C saves about 5 – 7 % of energy costs.

Example: Decreasing room temperature

Did you know that we currently need natural gas worth 380,950 kWh or € 12,470 per year to heat our rooms to a temperature of 22°C.

The recommended room temperature is 20°C for office buildings and a decrease by 1°C would save us about 6% of our heating costs. We therefore ask you to support us in achieving our goal to decrease the room temperature by 1°C.

Achievable energy savings by decreasing room temperature by 1°C



2. Decrease heat losses through windows

Be sure that all windows and curtains are closed during the night; curtains must not cover heating emitters. During heating and cooling periods the windows should be fully opened for a short period of time to provide ventilation. A simple activity is to install draught proof-strips outside doors and windows and to fill the gaps and cracks in floorboards and walls.

3. Keep air change low

Doors between rooms, and areas with different temperature levels, should be closed to retain heat and reduce draughts. Extractor fans should be turned off overnight and during weekends and used only when necessary. It takes about 11 kW power to heat 1000 m^3/hour from 12°C to 20°C, resulting in an energy consumption of approximately 16,000 kWh. This is a hall about 19m wide x 19m long x 3m high. With the energy price of Cent 0.05/kWh, this results in annual costs of € 800, which can be lost if the above measures are not properly considered.

4. Avoid the use of electric heaters

Discourage the use of supplementary electric heaters as they have very high energy consumption. Check if the costs for turning on the heating system during non-heating seasons are more expensive than the use of electric heaters. The running costs for electric heaters can easily be calculated by multiplying the power in kW as given on the motor plate with the daily operating hours (h) and the price per kWh.

5. Check functionality of automatic doors and raise awareness

If automatic doors are used, check that they work properly. In addition, it is useful to advise staff working in the lobby to keep the main door closed, to retain a controlled temperature. It might be useful to place screens in front of doors that are used often.

6. Reduce room temperature at specified times

Heating should be decreased during times of no occupancy. Typically this is during nights and weekends. A reduction of 2°C during nights decreases energy consumption by 2 – 3 %.

However, temperatures must not be decreased too excessively. It is very energy intensive to heat rooms from scratch and possible savings will be eaten up by the extra start-up costs.

7. Switch off heat emitters in rooms not regularly used

Radiators and convectors should only be turned on in occupied rooms. Typical examples of this are unoccupied hotel rooms. If possible, heat emitters should be turned on shortly before the room is used.

8. Ensure good heat radiation

Ensure that heat emitters are not blocked by furniture or curtains as this prevents heat radiation into the room. Make sure that heat emitters are cleaned regularly as dust and dirt further decrease radiation.

9. Check frost detection devices

Frost detection devices prevent the heating system from damage by frost. Thermostats should be adjusted to a temperature of between 4 – 6°C to avoid heat loss and damage.

10. Ensure the heating system is regularly serviced

A regular service includes:

- The measurement of boiler efficiency. In a boiler combustion test, emissions such as CO2 and flue gas temperatures are measured. Although only legally required in some European countries, this test and necessary improvements should be undertaken at least every 3 years by an expert as the outlay is minimal.
- The annual cleaning of oil-burning boilers.
- The cleaning of gas-burning boilers at a recommended interval of 3 years.
- The functionality of temperature controls such as valves.
- Letting air out of radiators; if streaming water can be heard in radiators there is air in the system, which decreases efficiency. To let out air, simply open the radiator valves.
- In forced circulation hot-water panel heating systems, parts can accumulate soot. This should be checked by skilled personnel before the heating season begins.

11. Reduce boiler temperatures

In boilers, water is often heated beyond useful temperatures. To reduce losses, it is necessary to identify the lowest possible temperatures the boiler can be operated at without causing damage. The boiler supplier should have more information about this. The water temperature of a hot water boiler should not be below 60°C. As a rule of thumb, reducing the storage temperature from 65°C to 60°C cuts heat losses by 9%.

12. Switch off circulation pumps when not in use

Water is driven through the heating system with pumps. These pumps are normally operated automatically but can also be switched manually. If the heating system is turned down, the water should not be pumped through the system. This saves pumping electricity whilst maintaining heat.

13. Improve system efficiency

The following section gives an overview of possible opportunities to improve heating system efficiency. As this work needs very technical know-how, it should be undertaken by a skilled employee or external expert.

14. Thermostatic radiator valves

Thermostatic radiator valves allow the individual control of radiators, they do not require high investment and are easy to install on existing radiators. Once installed, it is important to

- advise staff on how to use them and inform them about recommended room temperatures. They should not be used to switch radiators on and off but only be adjusted to control the required room temperature.
- regularly check that they work properly.

15. Thermostats

Thermostats often control the temperature of one large area. It is therefore important that they are installed in areas representative of the general temperature requirements. Experience shows that sensors are often positioned in places that are either too cold or too warm, leading to too much or too little heating. Indoor thermostats should not be placed near windows, near heat emitters or in draughts. Outdoor thermostats must be installed on a north facing wall that is not exposed to direct sunlight.

16. Hydraulic regulation of the heating system

A hydraulically regulated heating system improves the efficiency of a common system by up to 30 %. The pressure differences in a heating network are measured and balanced with special devices. Their main advantage is that room temperatures can be adjusted, saving up to 5 % of the cost for each 1°C. In addition, the water quantity pumped through the system is adjusted and less electricity is needed to run the circulation pumps.

17. Losses caused by heat emitted in exhaust gases

The combustion of fuels in burners produces hot gases which are emitted through the flue. The higher the temperature of the gases, the higher the losses. Gases from oil heating systems should not be above 180°C and those of gas heating systems not above 140°C. In addition, losses could occur due to insufficient burning of carbon-monoxide. The only low cost opportunity for improved efficiency is to reduce hot air emissions and to clean and service the burner regularly. Other opportunities include the re-use of the exhaust gas through a heat recovery system and the installation of variable operating burners.

18. Losses caused by boilers

The two main reasons for losses in boilers are poor insulation and stand-by operation. Insulation of boilers should be at least 20 cm thick, old boilers have to be upgraded to reach this standard.

Standing losses occur because hot water has to be stored for immediate use. Although they cannot be avoided, they can be minimised. The only alternative would be to use boilers that heat the water on demand only. However, for comfort reasons these are rarely used.

As a rule of thumb, replacing boilers older than 10 years has a payback period of 5 years. Replacing them with condensing boilers has a payback period of around 10 years.

19. Distribution losses

Energy loss from heat distribution systems mainly occurs due to non or poorly insulated networks and pipes. When laid in exterior walls, cellars and non-heated areas, losses can be significant. These can be identified simply by walking around these areas. If the surface temperature of space heating pipes is hotter to the touch than ambient, the thickness of thermal insulation and/or its quality is insufficient.

Insulating pipes properly can have a payback period of less than 5 years.

20. Surface temperatures and insulation

Room temperatures also depend on surface temperatures of walls and floors. Obviously, cold floors and walls require a higher room temperature to feel comfortable. This is often caused by poor insulation and it is very difficult to change once the building is in regular use. This makes it important to understand the necessity of good insulation prior to building construction. Improved insulation and changing windows and doors is expensive. If they are an option then an expert should be contacted to confirm potential benefits.

21. Humidity and comfort

A factor influencing comfort is humidity. By optimising humidity, the subjective feeling of a comfortable room climate could be improved. This is caused by warm air evaporating from the skin. Where humidity is too high, the warm air does not evaporate and the room climate feels uncomfortable. This effect is well known in tropical countries. When temperatures decrease, humidity condenses on cold surfaces, consequently comfort decreases. The comfortable range of humidity is between 40 % and 60 % with a room air temperature of 18°C to 23°C. A hygrometer is used to measure humidity. If the air is too dry, a humidifier should be used.

Best practice

Humidity and Cooling

The following example shows that the evaluation of the energy system might not only have a positive effect on the energy costs but also on associated areas.

In a shopping mall near Vienna the energy team analysed the entire energy system including water consumption and costs. The total water and effluent costs were € 52,000. From measurements taken, the team realised that the cooling tower and humidification accounted for 4,300m^3 of water use. Although their sewerage company charged the company for this effluent, it was evaporated and never discharged into the sewerage system.

The company requested a reduction of sewage costs on the basis of the measured evaporated losses. The cost of 1 m^3 sewage is € 1.32. The reduction therefore amounted to € 5,676 or 11%.

In some countries improvement programmes are sponsored by electricity and natural gas utility companies. These may include reviews of equipment and building facilities. Advice on ways to increase the energy efficiency of buildings, including programmes to encourage the use of more energy-efficient equipment, or to improve the thermal efficiency of the building shell, may also be provided.

Best practice

Savings can not only be achieved by decreasing room temperatures but also by improving the heating system itself. This can be done by

- Optimising the amount of hot water running through the system
- Increasing the difference between the temperature of the water leaving the boiler to the warm water network and the water entering the boiler from the supply network. (Flow temperature / return temperature)

In general larger plants should aim to increase this temperature difference (return differential) and reduce the energy input for pumps by minimising water that is pumped through the system. This can be achieved by

- Installing smaller pumps,
- Installing high efficiency motors for pumps,
- Hydraulic regulation of the warm water network,
- Installing devices to control the quantity of warm water running through the network.

An Austrian factory manufacturing machinery equipment analysed its heating system in detail. The heating pumps were listed as follows:

Pumps	Type	Installed power [kW]
Boiler pump 3	LÖWE CNPT 60-0.75/180	0.75
Boiler pump 1	LÖWE CDP 30-3/185	3.0
Boiler pump 2	LÖWE CNPT 120-3.0/180	3.0
Net pump storage hall	LÖWE CNPT 150-5.5/229	5.5
Net pump central heating	LÖWE CDP 40-4/190	4.0
Net pump oil storage	LÖWE CNPT 60-0.55/160	0.55
Transformation pump 1	LÖWE CDP 30-4,0/206	3.0
Transformation pump 2	LÖWE CNPT 80-0,55/148	0.55
Supply pump central heating	LÖWE CDP 40-5,5/205	5.5
Total		**25.8**

Table 13: Heating pumps

The operating time of the pumps are 4,400 hours/year which gives a yearly energy consumption of 113,520 kWh. The energy price is € 0.04/kWh and € 7.2/kW which gives a yearly total of € 6,769.

The current flow temperature from the boiler is 82°C, the return temperature to the boiler was 77°C. The temperature difference (return differential) of 5°C was low.

The implementation of high efficiency motors for pumps allowed for a decreased return temperature of 62°C, the return differential increased to 20°C.

The savings can be identified with the following figure.

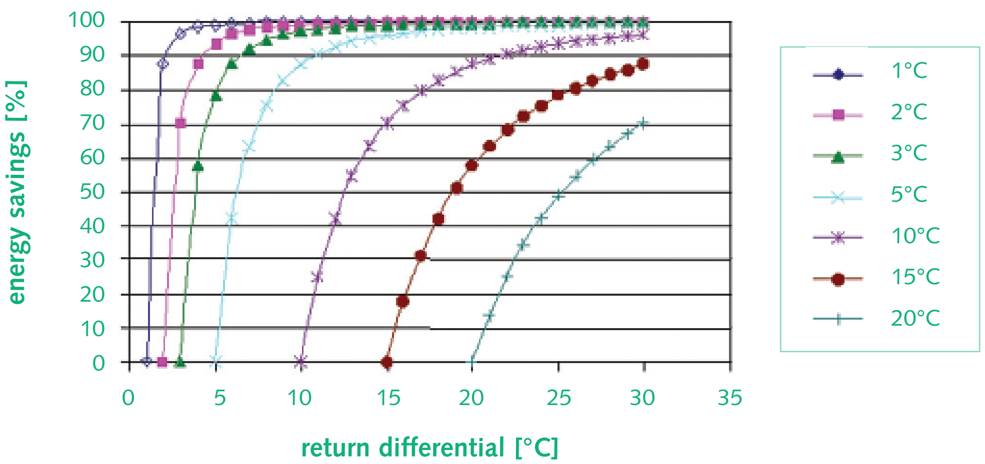


Figure 10: Energy savings due to increased return differential

The figure is read the following way:

1. Start at the horizontal axis which shows the current temperature difference (return differential) at several temperatures.
2. Follow each line upwards. Each point on a line represents one degree of additional temperature difference. The vertical axis shows the energy savings that can be achieved by each additional degree of temperature difference.

In this example the starting point at the bottom scale is 5. As the temperature difference after improvement is 20°C it is necessary to follow the line to the 15th point. This point represents a total energy saving of 98%.

This all shows that due to the installation of High Efficiency Motors, the temperature difference can be increased from 5°C to 20°C, resulting in energy savings of 98 %.

With an energy price of € 0.04/kWh the total savings per year can be calculated as follows:

$$\text{energy savings} = 25.8kW * 0.984 \frac{\text{kW savings}}{\text{kW pump power}} * 4{,}400h/a * 0.04 \frac{\text{Euro}}{\text{kWh}} = 4{,}468 \text{ Euro/a}$$

In addition, savings resulting in a decrease of the total power installed must be included. In this example the total power installed could be reduced by 6 kW. Assuming an energy price of € 7.2/kW the following savings can be generated:

$$\text{energy savings} = 25.8kW * 0.984 \frac{\text{kW savings}}{\text{kW pump power}} * 6 \text{ peaks} * 7.2 \frac{\text{Euro}}{\text{kWh peak}} = 1{,}096 \text{ Euro/a}$$

The total costs for the exchange of the pumps are € 36,340 and € 360 for the installation of each pump.
The payback can be calculated as follows:

$$\text{Pay back} = \frac{\text{cost}}{\frac{\text{savings}}{\text{year}}} = \frac{39{,}580}{5{,}564} = 7.1 \text{ years}$$

Heating - Checklist

1. Decrease consumption simply	
1a. Adjust room temperature	
1.b. Decrease heat loss through windows	
1.c. Keep air change low	
1.d. Avoid the use of electric heaters	
1.e. Check functionality of automatic doors	
1.f. Reduce room temperature at specified times	
1.g. Switch off heat emitters in rooms not regularly used	
1.h. Ensure good heat radiation	
1.i. Check frost detection devices	
1.j. Ensure the heating system is regularly serviced	
1.k. Reduce boiler temperature	
1.l. Switch off circulation pumps when not in use	
2. Improve system efficiency	
2.a Install thermostatic valves	
2.b. Position thermostats properly	
2.c. Regulate heating systems hydraulically	
2.d. Service burners regularly	
2.e. Insulate boiler and heat distribution system	
3. Optimise humidity	

4.2. Lighting

Lighting can be the biggest energy consumer in offices. Experience has shown that quite often simple measures suffice to reduce costs. Good visibility is an important factor in any working environment and minimum requirements for illumination must be met for health and safety reasons. But still, energy for lighting is often wasted because

- The company does not take advantage of new technologies which offer higher lighting levels with lower energy input,
- The lighting system originally installed does not meet the changed working environment and
- Poor user behaviour and knowledge lead to lighting system operating when no-one is in the room.

The aim of artificial lighting should be to provide the necessary level of lighting by using the most energy and cost-effective method. To identify if this is the case, the company must

- Analyse its existing lighting systems and check if they are appropriate for the working environment
- Identify the most appropriate lighting levels,
- Identify types and characteristics of light sources to evaluate if the best solution is in place
- Identify opportunities to improve efficiency.

4.2.1 Types of lighting systems

In general, lighting systems can be classified as follows:

- Direct and indirect lighting
- Single room and large area lighting

Direct lighting can be used to illuminate

- Large areas and
- Individual workplaces.

Direct lighting for large areas will be used where no precise work is done. If lamps are situated at regular intervals, a large area can be illuminated evenly. Direct lighting for large areas may have the disadvantage that the room appears monotonous, it can cause glare and undesirable shadows so that walls not illuminated appear dark.

Direct lighting is also used for individual workplaces in combination with general lighting. The intensity of general lighting can then be reduced. Direct task lighting will be used for precise work, e.g. to light a desk, but may result in strong light-shadow effects.

In indirect lighting, luminaries mainly distribute light upwards, i.e. to the ceiling, the result is that the room appears warmer. However, more energy may be required than for direct lighting.

Lighting systems for single rooms enable the individual control of a lamp or a group of lamps. General direct lighting in large areas is usually combined with direct task lighting in, for example, offices.

Lighting systems for large areas are most often found in conference halls, restaurants, supermarkets and large offices. Often the whole area is illuminated although only a small area is occupied. The typical problem of this system is a lack of flexibility. In addition, these situations often do not have natural light. This can result in the waste heat from lamps being cooled by the ventilation system.

4.2.2 Units of measurement

When talking about lighting, it is necessary to deal with units of measurement and factors influencing illumination. These will be used throughout this chapter and are the basis for identifying the advantages and disadvantages of light sources and task requirements. The most important are:

Illuminance is the luminous flux per unit of surface. Illuminance is measured in lux. Illuminance depends on the square of the distance between the source of light and its receptor.

Luminous intensity is measured in candela.

Luminance is the luminous intensity radiated in a given direction by a source. Luminance can be measured in candela per m2.

Evenness of lighting describes the quality of lighting and its visual comfort.

Colour rendering describes how colours are seen with an artificial light source and influences working conditions. Lamps with very good colour rendering are normally used in areas which require a good level of comfort or where very precise work is performed. This is also known as "warm" or "cold" light.

Only luminance can be detected by the human eye and the level of luminance depends on the quantity of light a lamp provides, the colour of the reflected light and the surface the light shines on. It is well known that a bright surface has a higher luminance than a dark surface when illuminated with a lamp of the same luminance.

Benchmarks for luminance depend on the room, the task or the activity and are laid down in nationally approved standards (for example DIN 5035-2, OENORM O 1040 for Germany and Austria). These benchmarks usually refer to horizontal illumination.

A second variable is vertical luminance. Vertical luminance ensures good colour rendering. As a rule of thumb, vertical luminance of at least 1/3 of horizontal luminance increases the level of comfort in rooms.

Luminance and other variables can be easily measured with an instrument called a lux meter or a light meter.

The following table gives an overview of luminance required for different tasks:

Degree of work delicacy	luminance (lx)	Examples
Limited visual needs	<100	Staircases, corridors, hall
Work of average delicacy	300	Occasional office work
Delicate work	500	Intense office work, computer laboratory, precise machining
Very delicate work	>750	Very precise machining

Table 14: Recommended levels of luminance for different areas

Although there are illumination standards, it is not always necessary to illuminate the whole area to the highest workplace standard. In offices, for example, it might be better to design illumination for a general requirement of 300lx and to light desks with task lights to achieve a higher standard.

4.2.3 Types and characteristics of light sources

Each light source has its own characteristics and its recommended usage areas. With regard to energy efficiency, the main factors are energy usage in W (watt) and the emitted light (lumens). The efficacy is given in lumens/watt. In addition, the following factors should be taken into account when choosing a lamp:

- Illumination system into which the lamp should be integrated
- Life time
- Switching frequency
- Dimming option
- Purchase cost

In general, there are three different types of lamps:

- Electric light bulbs
- Discharge lamps
- Induction lamps

Electric light bulbs include incandescent lamps and halogen lamps. They may be switched frequently and the emitted light can be regulated. The average life time is about 2,500 hours and the efficacy is around 12 lm/W. Halogen incandescent light bulbs are filled with halogen gas and have a higher efficiency.

Discharge lamps have a longer life time than electric light bulbs. They include fluorescent light bulbs, typically known as energy saving light bulbs. Compact fluorescent light bulbs were designed to replace screw-in (or bayonet) incandescent light bulbs, combining the efficiency of fluorescent lighting with the convenience of standard incandescent lighting. In addition, there are metal halide lamps and sodium lamps, both with a very long life time. Although purchase costs are higher than for electric light bulbs, they have a better cost-benefit ratio. The effectiveness of fluorescent lighting is more than twice as high as that of other lighting systems. High frequency fluorescent lighting eliminates flicker and often reduces consumption by 30-60%. The main disadvantages are that the light cannot be regulated and that fluorescent lighting might need some time to reach its full luminance.

Induction lamps have the highest life time of about 60,000 h but are also the most expensive lamps.

The following table gives an overview of the different types of lamps, along with their advantages and disadvantages.

	lm/W	Life time	Colour rendering	Comments
Incandescent lamps	12 - 14	1,000	Excellent	Low purchase cost High life time cost
Halogen lamps	38 - 41	2,000	Excellent	
Fluorescent tubes	65	8,000	Good	Typical energy saving bulb Life time depends on the fre-quency of switching Low purchase and life time costs
Compact fluorescent bulbs	55 - 69	8,000	Good	High efficiency; Low purchase costs, very low life time costs
Metal halide lamps	70 - 100	13,000	Good - Excellent	Some minutes to full operation; High purchase costs, low life time costs
High pressure sodium lamps	65 - 140	25,000	Good - Poor	Very high purchase cost; low life time cost
Induction lamps	65	60,000	Excellent	Very high cost

Table 15: Light sources and their characteristics

Beside the energy consumption of the lamp, the energy consumption of the ballast must also be calculated, it might be considerable. Ballasts are needed to start and run fluorescent lamps. New lamps have electronic ballasts with a high light emitting efficiency, ensuring flicker-free lamp running. Older fluorescent lamps may still have conventional ballasts which cause higher consumption, reactive current and, therefore, increased costs.

The following calculation visualises the advantage of a fluorescent tube in comparison with an ordinary light bulb

Lamp type	Power	Life time	Energy costs for 8000h	Material costs	Total costs
Light bulb	100W	1,000h	46.5 €	3 €	49.5 €
Fluorescent lamp with same luminance	20W	8,000h	9.3 €	11 €	20.3 €

Table 16: Cost comparison of different lamp types

4.2.4 Identify energy consumption for lighting

It is unlikely the energy manager will be able to determine the energy used for lighting directly from bills. But on the other hand it is relatively easy to calculate the energy consumption of a lighting system. The best way to do this is to follow a simple step-by-step procedure:

Step 1: Total power rating of the system

Firstly, it is necessary to identify the total power of all lamps in use. To do this it is necessary to walk around the organisation and to document all lamps, including their power rating. For fluorescent lamps, the power rating of the ballast must also be included. If the power rating of the ballast is not known, add 12% of the power of the lamp.

E.g. Fluorescent lamp 65W + 10W ballast = 75W.

This calculation gives a total power rating for lighting of the whole organisation. Make sure you always use the same unit (1,000W = 1 kW)

E.g. 25 conventional lamps 100W = 2,500W/1,000 = 2.5 kW

Step 2: Yearly operational hours

The annual hours the system is in use will be needed to calculate the total energy consumption. To achieve this figure, calculate how many hours the system is in use. A shop may be open 52 weeks a year with illumination switched on for about 12 hours a day. 52 x 7 x 12 = 4,368 hours

Step 3: Annual energy consumption for illumination

The total power rate is multiplied by the operating hours to achieve the annual energy consumption.

2.5kW x 4,368 = 10,920 kWh

It is useful to do this calculation one room at a time.

4.2.5 Identify opportunities to improve efficiency

There are several ways to improve efficiency:

- Primarily, choose activities that do not require investment.
- Secondly, undertake activities that increase the efficiency of the current system.
- Thirdly, carry out changes to, or restructuring of, the system itself.

Use of daylight

The consumption of artificial lighting can be reduced by increasing the use of natural daylight. For this to be effective, a constant level of sunlight must be available throughout a room without leaving shaded areas, which again require illumination. Practice has shown that energy savings may often be achieved by simply ensuring constant daylight throughout a room. This can be achieved by regular cleaning of windows, avoiding too many plants in front of windows, lifting blinds if they are not needed. In addition, desks should be placed in a way that optimises the use of daylight.

Good housekeeping

Switch off lamps if they are not needed. This is especially the case in offices where the lights are switched on in the morning and remain switched on, even when there is enough sunlight.

Switch off lamps in unoccupied areas. Typical examples of this are restrooms, storage halls and corridors. Awareness raising campaigns can help.

Clean the surfaces of lamps and lampshades regularly. As access to fittings is not normally easy, practice shows that often this is ignored. In addition, lampshades should not be coloured but transparent.

Exchange fluorescent lamps when they start to flicker as this can raise the energy consumption by up to 30%. If thick fluorescent lamps (38 mm diameter) are still installed, replace them with new fluorescent lamps that have a 26mm diameter. They have a higher light intensity and an approx. 8% lower energy consumption. Please note that new lamps might not fit in old fittings.

In premises where lighting is necessary for long periods of time, it is economical to use long-life fluorescent tubes.

If the work demands a high illumination level, then use task lighting, preferably halogen lamps, which allow you to reduce general lighting.

4.2.6 Lighting control

Control systems are effective in reducing the energy consumption of lighting. The main disadvantage is that they are very costly if installed after the lighting system is already in place. The installation of lighting control systems should therefore be considered when renovating or constructing a building.

Light switches

Existing switches should be labelled so that it is clear which lights they control. In the case of new systems, it is very important to install more switches so that lighting can be zoned. This mainly applies to areas parallel, and near, to windows which can use available daylight. One switch should not control too many lights.

Time controllers

Automatic lighting control is an effective additional tool to reduce energy consumption. Time controllers are used if illumination is needed for a short period. They allow lights to be turned on and off automatically at predetermined intervals.

This type of control is only suitable for large areas with low occupancy, for example, storage rooms. Experience shows that the installation of motion detectors reduces energy consumption by up to 70% in very big warehouses.

Installation requires high investment costs. Practice shows that these systems are only economical in buildings with high energy consumption or if installed during construction.

Daylight control

Another very effective option for reducing energy consumption is the installation of daylight detectors. However, installation could require considerable costs and may only be cost effective in bigger buildings.

Daylight detectors generally work in three different ways:
- by on/off
- by gradual switching (for example 100% – 60% – 30%)
- by continuous control

In practice, switching off the artificial light bulb by bulb is unlikely to be accepted by the user. Continuous adaptation is the most comfortable solution for the human eye and is most likely to be accepted by the user.

Occupancy control

These sensors detect the occupancy of a room and switch lights on and off. Occupancy controls reduce energy consumption significantly, however they require high investment if not installed during the building's construction.

Additional factors influencing energy consumption for lighting

Interiors and colours have an influence on luminance. It is clear that a bright ceiling, floor or wall reflects the light more than a dark one. This also applies for furniture. It is therefore not only important to paint walls and ceilings in bright colour, but also to clean them regularly.

Best practice

A clothes shop opens from Mon-Fri 9.30 a.m. to 7.00 p.m. and Sat 9.30 a.m. to 5.00 p.m. The shop is open for 2,765 hours a year. The cleaning service starts at 7.15 a.m. and finishes at 8 p.m. This means a work period of 3,822h per year, 1,057h longer than the actual opening hours.
Total connection power of the lighting system in the shop is 60 kW. Following an analysis of the lighting system, the management decided to turn off special lighting (e.g. shop window lamps, spots) during secondary activities (e.g. cleaning) using a time switch. This led to a reduced connection power of 20 kW (1/3 of the original power). In one year 42,280 kWh energy (~€ 3,100) can be saved by this simple, low-cost measure.

Lighting - Checklist

1. Decrease consumption simply	
1.a. Increase use of daylight	
1.b. Switch off lamps if they are not needed	
1.c. Switch off lamps in unoccupied areas	
1.d. Clean the surfaces of lamps and lampshades regularly	
1.e. Exchange fluorescent lamps when they start to flicker	
1.f. Use long life fluorescent lamps	
2. Decrease consumption using control systems	
2.a. Label light switches to control them more easily	
2.b. Install time controllers	
2.c. Install daylight controllers	
2.d. Install occupancy controllers	

4.3. Ventilation

Ventilation and cooling have a big influence on the energy consumption of a building. Practice shows that it might account for up to 50 % of the total energy costs of office buildings. In principle, ventilation means to exchange used and conditioned air with fresh air to control temperature, humidity and odour. One of the main goals is to reduce the quantity of this exchange rate while keeping a good quality indoor air.

Another purpose of the ventilation system is to heat and cool the air to achieve thermal comfort. A significant amount of energy is needed for this. A survey undertaken in France shows that the energy required for ventilation represents 10% of the heating load for an existing house and up to 30 % for a newly built one[1]. One of the goals therefore is to reduce the energy loss within this air transfer.

It is not easy to evaluate the extent to which it is possible to decrease the amount of air. Of most importance is that there is a strong link between the required air quality and the energy used for ventilation. Both factors have to be taken into account when identifying opportunities for improving the efficiency of a ventilation and cooling system.

4.3.1 Ventilation methods

Ventilation can be achieved in different ways. The two main types are natural and mechanical ventilation.

Natural ventilation

Natural ventilation is based on two driving forces: wind pressure and stack effect (lift due to temperature difference of air), on which the ventilation rate and air flow strongly depend. The air flows in and out through specified openings such as open windows, small air vents in windows, trickle ventilators located in the window frame, air inlets, vertical ducts. Careful design is required for a satisfactory ventilation process. Natural ventilation is mainly used for buildings located in mild climates, away from inner city locations.

Mechanical ventilation

Mechanical ventilation relies on the use of one or more fans to extract and/or introduce air from/to a space. In general, the incoming air is filtered and some systems recover the heat from the exhaust air stream and reuse it for heating purposes. The exhaust and/or supply systems may be decentralised or centralised. In the latter case, air is conducted out of and/or into spaces through a network.

Mechanical ventilation systems have an advantage in that the air flow rate can be controlled. This means that the flow rate may be constant or vary according to demand. The user of the system can control the amount of fresh air depending on individual preferences or based on the level of airborne contaminants (water vapour, volatile compounds). Mechanical systems that are used in cold climates are often combined with a heat recovery system.

[1] *http://europa.eu.int/comm/energy_transport/atlas/homeu.html*

4.3.2 Cooling systems

Illumination, computing and other electrical devices as well as direct sunlight result in high heat loads, which require cooling. In general, passive and active cooling methods are used to achieve a comfortable working environment.

Passive cooling systems

In many parts of the world, passive cooling design and techniques were abandoned until they gained renewed interest during the last couple of decades, in connection with energy and environmental concerns.

Passive cooling includes systems such as

- Night ventilation
- Evaporate cooling
- Heat exchange using cold air
- Plate cooling with water or air
- Ground cooling with water

Passive cooling systems do not use a refrigerant. They can be used as stand-alone cooling systems or combined with other active cooling systems. Passive cooling systems lead to a substantial decrease in energy consumption for cooling and a decrease of the total load. They are therefore low-energy.
Passive cooling systems should be taken into consideration during the construction planning phase, as subsequent installation is very expensive.

Active cooling systems

Active cooling systems use energy for a refrigerant or cooling system to cool warm air. In general, compressors are used. The efficiency of such systems is indicated with the "performance figure". A performance figure of 3 means that for an output of 3 KWh cold energy, an input of 1 kWh electricity is needed.

The following table gives an overview of compressors typically used for water cooling:

Compressor type	Cooling capacity	Performance figure	Advantages	Disadvantages
Piston compressor	10 – 800 kW	3 - 4	for small cooling capacity cheap system	high service costs
Screw compressor	200 – 4,000 kW	3 – 4.5	only rotating parts no valves good control characteristics	more expensive than piston compressor
Turbo compressor	400 – 8,000 kW	3.5 – 4.5	high efficiency	more expensive than screw compressor
Adsorption machine	10 – 6,000 kW		less electricity for pumps needed	large space required

Table 17: Compressors used for cooling

4.3.3 System components for ventilation

A ventilation system consists of various components. All components are important when discussing energy efficiency. Although the components are selected during the design phase of the system, it is necessary to understand their efficiency, why maintenance is an important factor for energy efficiency and the opportunities available when replacing parts.

A ventilation system consists of the following components:

- Fans
- Filters and air-cleaning system
- Distribution
- Control system
- Heating batteries
- Heat recovery systems

Fans

Fans transport air from the air intake, through the system to the required area. The required power of a fan will be influenced by the resistance it has to overcome, through ducts and other ventilation parts for example. There are 4 types:

Type	Use	Efficiency
Backward curved blades	Less suitable for contaminated air	Up to 80%
Backward angled blades	Suited for contaminated air	Up to 70%
Straight radial blades	Prevents contaminants from sticking to the impeller	Up to 55%
Forward curved blades	Air volume is affected very little by changes in air pressure	Up to 60%

Table 18: Types and efficiency of fans

Filter

There are two reasons for using filters in an air-handling unit:

- To prevent impurities in the outside air from entering the building
- To protect the unit's components from contamination

The filter's capacity to trap particles is called "dust holding capacity" and filters are often divided into three classes depending on this capacity:

Coarse filter	EU 1 to EU 4
Fine filter	EU 5 to EU 9
Absolute filter	EU 10 to EU 14

It is important to protect the filter from moisture as this can alter the characteristics of the filter fibres and impair its dust holding capacity.

Distribution

Channels and pipes transport air into areas where air is needed or remove air from polluted areas. It is important to have filters and service openings in the system, since the system gets dirty quite easily.

Controls

- The best control strategy allows occupants to directly manipulate simple and understandable building features, such as windows or shades.
- Controls should provide immediate feedback on their effects.
- Controls should not require occupant attention for safe, healthy indoor conditions, low energy consumption and operating costs.
- Automatic building controls must ensure that the building operates efficiently regardless of occupant behaviour.

In general, the regulation of a ventilation system allows to control:

- room temperature
- pressure in air channels
- volume of exhaust air
- supply air conditions

Heating batteries

When the outside air is colder than the temperature required for the supply air, it is necessary to warm the air before it enters the building. The air can be warmed using a heating battery, either an electric heating battery or a hot water battery.

Heat recovery systems

Ventilation systems often exhaust warm air together with pollutants. During the heating season, the use of a ventilation system significantly increases the energy needed for the heating system. Therefore, heat recovery systems are installed to use the energy of the exhaust air and, consequently, to reduce energy cost.
The following table gives an overview of the various methods:

Type	Efficiency	Advantage	Disadvantage
Rotary heat recovery	75 – 90 %	The degree of heat recovery can be regulated by increasing or decreasing the rotary speed.	Impurities and odours will be transferred from the exhaust to the supply air.
Plate heat recovery	50 – 85 %	Impurities and odours will not be transferred from the exhaust to the supply air.	Due to condensation, there is a serious risk of ice formation.
Battery heat recovery	45 – 60 %	Impurities and odours will not be transferred from the exhaust to the supply air.	Lower efficiency than a rotary heat exchanger
Heat pipe	50 – 70 %	There can be no transfer of impurities.	Expensive system

Table 19: Heat recovery systems

Another possibility is the recirculation of indoor air. Recirculation systems are usually found when the ventilation system is combined with the heating system. The main problem is that good air quality is difficult to obtain. Therefore these systems need air cleaners as well as continuous inspection and maintenance.

4.3.4 Ventilation rates

The quantity of ventilation needed depends on the amount and nature of contamination present in a specific space. To determine the overall ventilation needed, it is useful to identify the dominant pollutant. This is the pollutant that requires the greatest amount of ventilation for removal.
In the table below there are examples of minimum ventilation rates:

Air flow for humans	25.2 m^3/h per person
Air flow to ventilate emission from construction materials	2.5 m^3/h per m^2 floor area

Table 20: Ventilation rates

4.3.5 Evaluating energy consumption

To evaluate the electricity cost of ventilation, it is necessary to measure the energy consumption of the

- ventilation system
- cooling / heating system

The following data are needed to calculate the cost:

- Load (in kW) of the electric devices
- Electricity consumption (in kWh)

Based on the cost for peak load and electricity, it is possible to calculate the energy cost of ventilation and cooling.

Typical industrial sites do not meter the energy consumption of the ventilation system as they only have one meter. In this case, the energy consumption and the related costs have to be calculated using the:

- Power load as indicated on the type plate or in the manual
- Operating hours of the ventilation system based on the working hours

In the following step, the load and the consumption are multiplied by electricity tariffs.

Example:

Power load for ventilation	: 10 kW
Operating hours	: 1.000 h
Electricity consumption	: 10 kW*1,000 h = 10,000 kWh
Load cost	: 10 kW * € 50 /kW = € 500
Consumption cost	: 10,000 kWh* € 0.12 /kWh = € 1,200
Total cost for ventilation	: € 500 + € 1,200 = € 1,700

The energy consumption and energy cost of the heating battery have to be analysed either with the help of a meter or, where no consumption data is available, using a calculation.

For example:

Heat consumption	: 10,000 kWh
Specific heat cost	: 0.05 €/kWh
Cost for heat consumption	: 10,000kWh*€ 0.05/kWh = € 500

4.3.6 Reducing energy consumption

There are several ways to reduce the energy consumption of a ventilation system. Energy consumption depends on the power of the system as well as on the operating time. The main goal therefore is to reduce these variables.

4.3.7 Energy optimisation with simple activities

The first step should be to evaluate the ventilation cost for individual areas. This is necessary because ventilation costs are normally calculated as a lump sum for all departments and staff. This results in staff:

- not realising the cost of ventilation
- not caring about efficiency as cost reductions are not visible on departmental level.

Such an evaluation helps to identify areas of poor efficiency.

Switch off

The easiest way to reduce energy consumption is to switch off equipment and systems when not needed.

There are several ways of controlling the switching off:

- Manual switching off of the fan or the ventilation system, e.g. during lunch times and breaks. This is the cheapest method as it does not require any investment.
- Time switch on the fan or ventilation system (for example meeting rooms).
- Demand-controlled ventilation by a presence sensor.
- Program the building control system so as to turn off the system during the periods it is not needed.

Best practice

Ventilation

An energy analysis was undertaken in a small hotel in Italy with 50 beds. The total monthly energy consumption was 38,530 kWh.

The energy manager started to monitor the energy consumption of the kitchen which was only used at breakfast times. Ventilation quantities and costs were documented on a monthly basis and presented in a graph. It was immediately visible that the consumption rose after June 2003. Before this date the average energy consumption was 3,800 kWh (€ 266) per month. After this date the average consumption was 7,900 kWh (€ 553), an increase of more than 100%. The energy manager discussed the figures with his boss and realised that the ventilation system was operated automatically before June 2003 and manually after this date. The reason was construction work, during which the system operation was changed from "automatic" to "manual". Staff were not trained to switch the ventilation correctly and because there was no monitoring system in place the **average losses per month were 10% (€ 208)!**

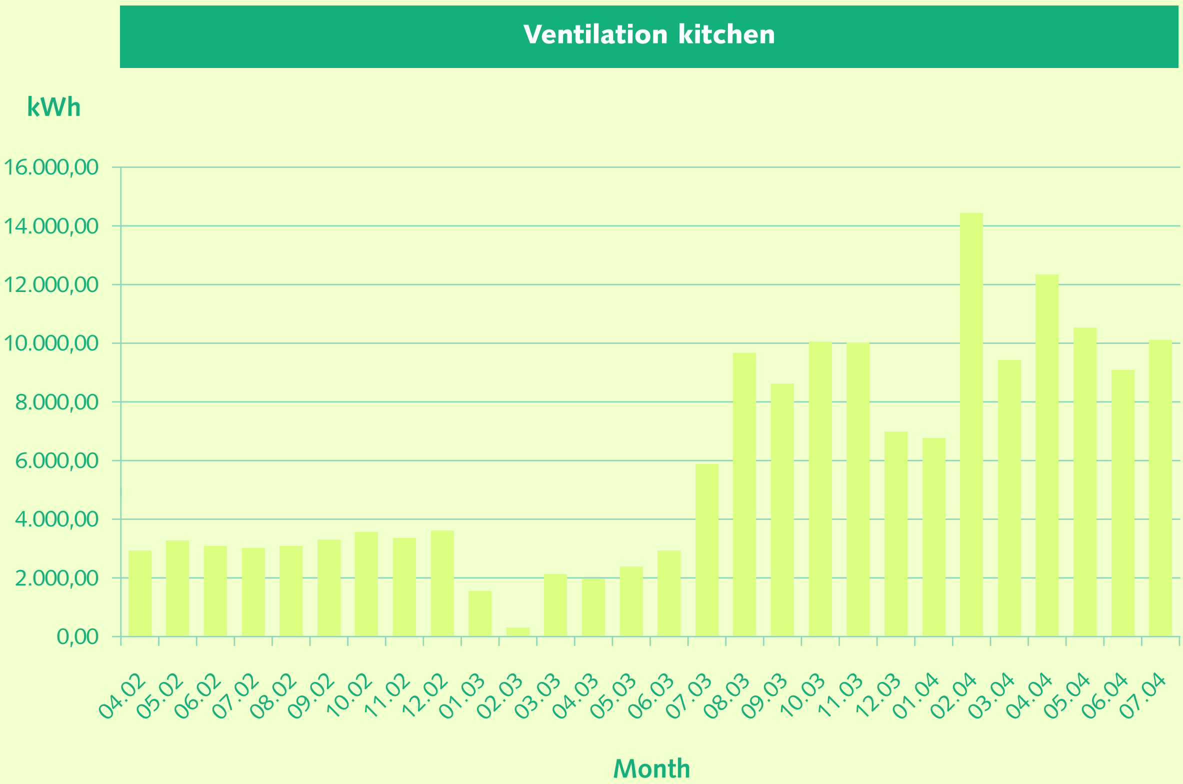


Figure 11: Energy consumption for ventilation in a kitchen

Reduce ventilation rate

Instead of switching the system off, the ventilation system rate can be reduced without a noticeable change to the indoor climate. As an indication, reducing the air rate by 30 % can save up to 60% of energy.

Decrease operation time

Use cooling and ventilation systems only when and where required. Optimise the start up and shut down times so that the building is only being air conditioned when people are present.

4.3.8 Select components with the best efficiency

The following components are important when discussing energy efficiency and savings:

- **Fans:** The efficiency of fans can be 80% to 85%, but inappropriate choice and/or dimensioning of a fan can result in an efficiency of below 50%.
- **Air-cleaning and filtration:** Dirty filters will decrease efficiency of heat recovery units from 80 % to 20 %.
- **Heat recovery equipment:** Depending on the system, the efficiency of heat recovery equipment is between 40 % and 80 %.

4.3.9 Regular maintenance

Maintain ventilation and cooling equipment regularly according to the manufacturer's instructions. Make sure that all filters and heat exchangers are kept clean.

Best practice

Ventilation

An energy team analysed the system of a large office building in Berlin with 550 employees. The total energy consumption for ventilation and cooling could be identified by multiplying the power of the system and the operating times and was 357,000 kWh (€ 18,228) per year.

During the initial review of the energy system, staff complained that the cooling system did not work properly and that they had to switch the system manually. On summer mornings, staff realised that room temperatures at the east side of the building were higher than the outside temperature. The result was that the system was operated at full load in the morning. The energy team found out that the cooling system did work properly during predefined times, but that blinds were open all day when they should have been closed. This resulted in rooms being heated in the afternoon. The following morning staff realised that the temperatures inside the heated rooms were higher than outside. Staff was asked to close blinds in the afternoon to protect the room from natural sunshine and to avoid an increased operation of the cooling system.

The result was a 7.4 % decrease in cooling energy. Savings achieved through this simple measure were 26,440 kWh (€ 1,350 per year).

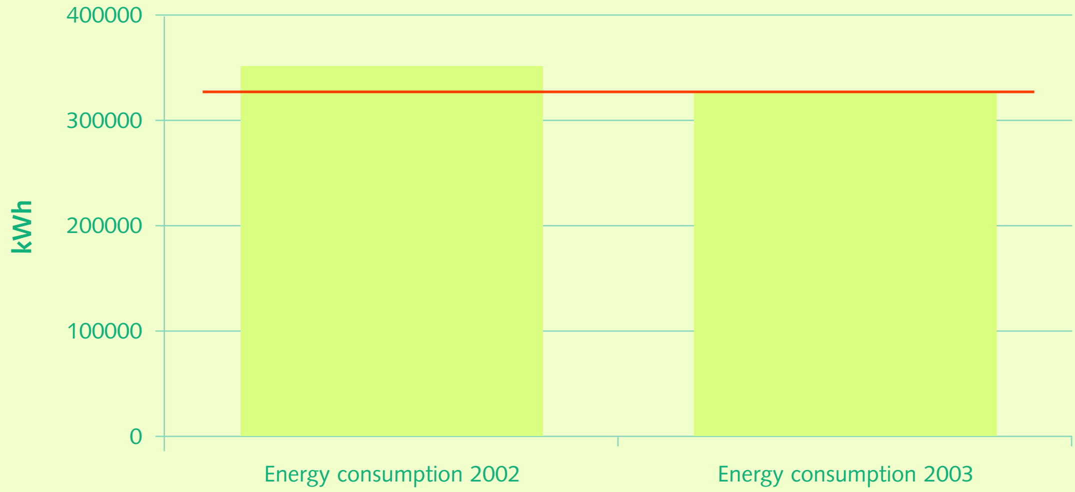


Figure 12: Energy consumption for ventilation before and after a simple improving measure

Ventilation - Checklist

1. Decrease consumption simply	
1.a. Switch off system manually when not needed	
1.b. Install time switches for ventilation system	
1.c. Install presence sensors to demand control the system	
1.d. Establish ventilation zones	
1.e. Reduce ventilation rates	
1.f. Regularly maintain and clean the system	
2. Chose efficient components	
2.a. Chose efficient and appropriately dimensioned fans	
2.b. Consider the use of heat recovery systems	

4.4. Electric motors

More than 50 % of electricity used in industry is for electric motors. In addition, only part of the electricity consumed is used for motor operation, the majority of consumption is in losses. Therefore, electric motor systems are an important element in every energy management system.

Electric motor drives are used in all industry types. They convert electricity to rotational energy. The motor is then used to drive a variety of machinery. It is essential to understand that a 'motor system' consists of more parts than the motor itself. The motor system can be as simple as a press or as complex as a conveyor system in a printing house.

A motor system consists of the following components:

- Power supply
- Motor-drive package
- Process system

The components are closely interdependent, but classifications are not rigid.

4.4.1 End-user applications

Motor systems usually fall within one of the three major application groups:

- Generic applications; pumps, fans and compressors
- Material handling
- Material processing systems

The following table gives an overview of the main applications:

Category		Application
A. Generic application	Pumps	Pumps are mainly used for pumping warm or cold water, for the movement of various liquids. Pumps normally do not need very much attention as they are reliable. However, with the use of high efficiency pumps and variable speed drives there is a high saving potential.
	Fans	Fans are mainly used for the supply of clean, warm and cool air. Main savings can be gained by adapting the air supply to the real need.
	Compressors	Compressors compress air or liquid gases which are then used to spray, clean and move. Compressed air is one of the most inefficient mediums and significant savings can be achieved by optimising and reducing its usage.
B. Material handling		Electric motors are used in conveyors, cranes and assembly lines. These systems are often over-dimensioned and savings can be achieved by intelligent transport of goods and intermediate products. However, material handling with the help of electric motors is more efficient than the use of compressed air and hydraulic systems.
C. Material processing		Electric motors are used for various material processes such as stamping, forming, casting, spinning, dyeing, rolling… The saving potential for the processing step is low, however the entire process often bears a high saving potential. This includes the transport to and from the processing plant, electricity consumption when idling etc.

Table 21: Applications of electric motors

4.4.2 Identify energy consumption for electric motors

The energy consumption for electric motor systems cannot be identified using the energy bill but can be using the following information:

- kW
- Annual running hours
- Energy price per kWh

The power (kW) of a motor can normally be found on the motor nameplate itself or in the motor's technical specifications. The annual hours of running may be available from the machine itself or, if this is not an option, from skilled staff working in the area.

Multiplying the power with the annual running hours gives the annual energy consumption of the device in kWh. If it is not possible to calculate the energy consumption, it will be necessary to take measurements. The measurements are neither difficult nor expensive (approx. € 2,500 for the purchase of a data logger, they can also be rented) and can be undertaken by staff. Once the data logger is obtained the energy consumption will only need to be measured for a limited period of time, e.g. a week representing the usual working conditions. Collecting this information for the entire organisation gives the total energy consumption of all electric motors combined.

The following information should be gathered:

Motor reference	Motor type	Power kW	Annual running hours	Yearly consumption kWh
Water Pump	A.N.O 223	5	7,700	38,500

Table 22: Main information to collect for electric motors

For plants with extensive motor drive end-uses, an appropriate system to support maintenance, inventory management, and system redesign might need to take account of all the following information:

- Nameplate information, including motor type, power, synchronous speed, voltage rating and efficiency rating
- Location and application history (use in plant)
- Date of purchase and initial cost
- Installation benchmark record (initial vibration, full-load current)
- Maintenance records (lubrication, filter replacement, belt replacement, etc.)
- Repair / rewind records
- Load and duty cycle measurements

Compiling this list in detail and for the entire organisation has the advantage that

- a comprehensive database gives a good overview of the current state of technology
- in case of a breakdown, there is already a decision basis for repair or exchange.

4.5. Possibilities to improve efficiency

The energy efficiency of electric motor systems can be improved using a step-by-step process:

1. Collect motor data
2. Identify motors using most energy
3. Decide on best action for each case

The following actions could take place:

- Switch off
- Reduce motor load
- Proper motor repairs and maintenance
- Use motor control systems
- Select motor with best efficiency
- Minimise distribution losses
- Reduce idle power

Switch motors off

The simplest method to decrease energy consumption for motors is to switch them off when not required. Manual switching off will only work with the close co-operation of staff, e.g. during breaks or lunchtime. Detailed instructions should be developed. The production manager will need to be involved and be responsible for any system developed.

A second opportunity is to interlock the motor with the process, e.g. the ventilation fan and saw in a timber manufacturer. In this case, the saw and the ventilation system operate at the same time.

Motors can also be switched off using a time switch. There are several applications which do not need continuous operation and which are not directly connected with production. For these applications, a time switch might be appropriate, e.g. ventilation systems.

Reduce motor load

Electric motors are designed to operate efficiently within a small range of load. Motor efficiency decreases significantly when the motor is operated below 50% of the rated power. One of the main reasons for losses in motors is that they are too large for the specific task. Another problem is that factories reconfigure production machinery regularly to respond to customer demands and changing technologies. As a result, systems may end up handling very different volumes of materials over time. They may even perform quite different tasks that are unrelated to those they were initially designed and installed to perform.

To reduce motor load, the following issues should be considered:

- Identify process load requirements and adapt the motor power to the need. The most common type of industrial motor is designed to operate at a fixed speed under a wide range of loads. Standard motors tend to reach maximum efficiency at 80-100% of full load, while energy efficient motors achieve maximum efficiency between 65% and 75% of full load.
- If materials are being transported, the quantity of the materials should be decreased or even eliminated.
- When several motors are used in one process, an analysis should be undertaken to evaluate if all motors are required or if the task could be fulfilled with fewer motors.

Motor system repairs and maintenance

Correct operation and maintenance of motor systems offer many benefits, including lower operating costs, less unplanned downtime and increased equipment life. For most types of industrial motor systems, proper maintenance involves a continuous cycle of inspection, diagnosis, maintenance and repair. The potential energy savings are substantial if all components are properly maintained, they are particularly high in the case of compressed air systems, where leaks can contribute significantly to efficiency losses.

If older motors have to be repaired, replacement should be considered. This could be important since high-efficiency motors have a very good payback in comparison to older motors.

Motor control systems

Variable Speed Drives (VSD) control the speed at which an alternating current (AC) induction motor runs. VSD are electronic devices which can be easily programmed to control the speed and torque of a motor depending on the load requirements.

A second control system is soft starting. This is a method to reduce the high starting current that occurs when a motor is first switched on by applying a reduced adjustable voltage. The voltage is then increased over a period of time to a value which allows the motor to accelerate smoothly to full speed. Electronic "soft starters" can reduce wear during start-up and can allow the motor to be switched on 2-4 times more often. Soft starters should be considered if frequent starting takes place.

Select motor with the best efficiency

In continuous operation, losses depend on the kind, the rated power and the load of an electric motor. In general, small motors have bigger losses than large motors. Motors with a rated power of between 1 – 22 kW have efficiencies of 90 – 93%.

In addition, losses in increased waste heat will occur. This could lead to waste heat being cooled down with a separate cooling system or the need for space ventilation. The result is that losses are doubled.

High-efficiency motors (Efficiency class EFF1) are about 2 – 3 % more efficient than standard types. This sounds small but over the life-time of the motor this will mean a significant reduction in energy use. In the first 5-6 weeks of use, motors generally consume energy equal to their purchase price. The purchase price of high-efficiency motors is only a little higher than that of standard motors.

Best practice

Motor size	15 kW
Annual runtime	4,500 hours
Energy costs	0.07 €/kWh

	Efficiency	Purchase cost	Power required
HIF motor	0.95	600	15 kW * 0.95 = 14.25 kW
Normal motor	0.92	460	15 kW * 0.92 = 13.80 kW
Difference			0.45 kW
0.45 kW *4,500 hours *0.07 = € 141.75			

Buying a less efficient cheaper motor will not always be cost efficient: Savings from the lower investment costs of a normal motor will be eaten up after one year by the higher operating costs. Buying a device with very small operating costs will be the cost efficient solution in most cases.

The smaller the motor the greater the savings will be when using high-efficiency motors. High-efficiency motors below 1 kW save about 14%, 1-10 kW save about 6.5% and motors larger than 10 kW save about 2 % of the cost in comparison to normal motors.

If motors are only loaded at about 40 % of their rated power, the reconnection to star is one way of increasing efficiency. Star describes how the windings of a three phase induction motor are connected. In the star connected configuration, one end of each winding is connected to a common point. Connecting a motor in star reduces the voltage, the starting current and the torque. Competent industrial electrical engineers can easily perform this task and achieve significant savings.

Minimising distribution losses

Variable conditions in pipes and ducts that carry fluid can lead to system-level losses as the pressure drops and energy losses occur. In this case, the system must be hydraulically regulated by an expert.

An example of this is leakage in compressed air systems. Compressed air is one of the most intensive (and expensive) of all energy using applications, enormous costs can occur when there is no systematic control. The air, produced in an air compressor, is conducted through a network to its place of use. The overall efficiency of compressed air plant is about 10%. Where leakage occurs, losses are very costly.

Idle power

Idle power is the amount of electrical power required to keep an inverter ready to produce electricity on demand. A certain amount of idle power (usually 50 % of electricity consumption) is free of charge, the rest (> 50 %) will be charged by the energy supplier. If the company has to pay for this, an electrical device should be installed to compensate idle power.

Electric Motors - Checklist

1. Decrease consumption simply	
1.a. Switch motors off when not required	
1.b. Reduce motor load	
1.c. Maintain motor systems regularly	
2. Chose efficient components	
2.a. Install Variable Speed Drives (VSD)	
2.b. Select the most efficient motors	
2.c Minimise idle power	

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Recknagl Sprenger:Taschenbuch für Heizung -und Klimatechnik 2001, Oldenburg

6 Useful links

http://europa.eu.int/comm/environment/emas/index_en.htm
The official European EMAS website provides information about EMAS.

http://www.inem.org/new_toolkit/
Step-by-step easy to read toolkit on the implementation in SMEs of an environmental management system leading to EMAS registration. Contains best practice examples of the EU 25.

http://www.actionenergy.co.uk
Action Energy, a government-funded programme, helps businesses and public sector organisations save money through energy saving. From simple tips to free publications for UK based organisations this site can help you when dealing with energy topics.

http://www.caddet-ee.org
Caddet is a network; the multi-lingual website covers various energy efficiency and renewable energy topics.

http://www.energy-efficiency.org
The Scottish energy efficiency office provides information on energy and waste topics. Case studies and publications are provided.

http://www.energyoffice.org
This website provides simple information in 4 languages on how to save energy in offices.

http://www.energystar.gov
This site gives you an overview about energy efficient equipment in more than 40 categories.

http://www.managenergy.net
ManagEnergy is an initiative of the DG Energy & Transport and promotes co-operation between local and regional energy actors in Europe through workshops, study tours and online events on energy saving and renewable energy.