Increasing the competitiveness of SMEs through energy efficiency

Best Practices of Energy Efficiency in SMEs

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Introduction

This report presents commercial procedures promoting energy efficiency in small and medium-sized enterprises. The report serves as a source of information for enterprises interested in improving energy efficiency. The report has been written as a part of ENPI CBC project KA 385 “Increasing the competitiveness of SME’s through energy efficiency”

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Contents

1 Introduction

According to Energy Efficiency Directive (EED) 2012/27/EU, all Member States of the European Union are enforced to increase energy efficiency (EE) by 20 % by 2020. EE, as described to be a ratio between performance, service, possession, or energy output and energy input must be improved comprehensively in all sectors. In the EED, it is highlighted that small and medium sized enterprises (SMEs) have a high potential in improving EE. In the EED, EE has been recognized as one of the major factors in fighting against climate change, improving economic growth, and creating employment.

Enhancing energy efficiency in SMEs straightly affects energy costs, as fuel, electricity, and thermal energy is consumed less. Besides the reduced energy bills, operation and maintenance costs of HVAC and lighting systems can be potentially reduced if operating hours of these devices are reduced by a control system. Renewed energy systems and more efficient apparatuses might require less space. Thus, with potentially lower investment costs and longer operating life, improving EE in SMEs can bring significant economic benefits. In addition to economic benefits, environmental benefits include among others decreased greenhouse gas emissions due to reduced fossil fuel consumption and decreased particle emissions. Ultimately, EE solutions in SMEs can contribute to improved indoor air quality (IAQ), whilst improving the image of the SME. (Al-Shemmeri, 2011)

The aim of this report is to present commercial procedures for promoting energy efficiency in SMEs. It must be noticed that presented methods and technologies may not be valid for every situation. For example, a building is always a specific project, in which the building can be constructed in several different ways in very different locations for a specific purpose compared to some other building. This is why generally applicable answers are difficult to give regarding promotion of energy efficiency in SMEs. However, this report is more like a suggestive description of possible procedures, without going too deep into physical and chemical background of technologies.

2 Energy in SMEs

Energy use in SMEs greatly depends on the size and type of the enterprise. Typically, overall electricity costs are usually higher than heating costs. This is especially true in industrial enterprises, where electricity is consumed much more than heat. In service sector, electricity forms a higher cost compared to heating in most cases. A lot of work can be done in SMEs in order to improve energy efficiency. Most of SMEs have not conducted energy inspection analysis, or they are not following the energy efficiency of the enterprise. Industrial sector may be more active in promoting energy efficiency compared to for instance service sector. (EK, 2009)

In order to find out the energy consumption of an enterprise, an energy inspection can be done. Adequate energy inspection can find out where and when most of energy is used. In this way, energy efficiency actions can be allocated to a certain technology or area of SMEs. In other words, possible future investments for promoting energy efficiency can be considered more easily once professionals conduct the analysis. Table 1 illustrates a brief overall procedure for energy efficiency actions in SMEs. (Linna & Nuutinen, 2012)

Table 1. Procedure for energy efficiency action (Linna & Nuutinen, 2012).

Proposal for energy saving actions according to conducted energy inspection
Financing possibilities Investment aid application
Initial planning Ensuring cost savings Assessment of other impacts of installation
Putting the installation into practice
Checking the savings Monitoring the system

Energy can be saved in terms of electricity, heat, and fuels. Energy saving action can be a technological solution, which can be completely new or retrofitted to an existing system. Behavioral based solutions can also promote energy efficiency, but in this report these issues are not discussed in detail. In this report, technological solutions for energy efficiency in SMEs are distinguished to following groups:

- heating and cooling,
- ventilation and air-conditioning,
- compressed air and motors, and
- efficient electric devices.

In addition, case specific issues including agriculture, transportation, construction and industry are introduced.

By improving energy efficiency, SMEs can cut down energy consumption. As energy prices are increasing, energy savings can bring substantial economic savings. Lesser energy use means also less pollution from energy generation. In addition, many energy efficient installations can have better controllability, longer lifetime and they may require less maintenance. Automated energy management systems can also recognize faults. Altogether, the image of the utility can be also improved with more environmentally friendly solutions. In many cases, the payback period of a certain investment might not be very long. Examples of energy efficient installations in bakery enterprises are illustrated in Table 2 below.

Table 2. Energy saving actions in bakery enterprises (Motiva, 2010).

Action	Number of actions	Saving [€/a]	Investment [€]	Payback period [a]
Heat recovery	17	315 400	714 000	2.3
Lighting	13	36 700	148 200	4
Control of ventilation air	12	25 000	1 100	0
Ventilation scheduling	11	131 500	9 600	0.1
Water system	4	49 000	6 000	0.1
Compressed air	8	27 300	28 700	1.1

3 Heating and cooling

Temperature of indoor air is of great importance in any building. Adequate temperature levels in buildings promote healthy indoor air quality. For instance, adequate temperature promotes satisfactory thermal comfort, vitality, and work productivity. By having desired temperature, it is also possible to prevent occupants from diseases. Avoiding overheating, overcooling, and simultaneous heating and cooling can also promote energy efficiency.

3.1 Thermal comfort

One important aspect affecting thermal comfort is dry bulb temperature, which is measured temperature in the space expressed in Celsius degrees (°C) without taking into account other factors that may affect how one senses temperature (for instance, humidity). In addition, operative temperature, which is the overall sensation of temperature, must be considered. Factors affecting the thermal comfort are for instance air velocity and draft, temperature gradients, hot or cold surfaces, humidity, activity level/metabolic rate, and clothing level.

Air velocity can significantly affect the thermal comfort of occupants. If the air velocity and draft increase, the amount of thermally satisfied occupants drop down significantly. This is why for instance too high ventilation rates should be avoided as well as cold surfaces causing draft. If ventilation is required in high rates, it is important that the air is not supplied straight to the face or the neck of the occupant because in these cases the number of thermally unsatisfied occupants are at most. (Seppänen, 2001)

Local temperature gradients can cause thermal discomfort. Temperature gradients can be formed as a result of cold window surfaces and hot radiator surfaces, for instance. Also large vertical difference in temperature can cause discomfort. Preferably, floor temperature should not be too cold. Too large temperature difference between head and feet can also cause thermal discomfort. Moreover, thermal radiation can cause discomfort especially if radiation is asymmetrical. It is important to avoid too dramatic temperature changes. (Amk.fi, 2012)

Humidity levels can affect to the thermal comfort of occupants. As humidity levels rise, the inside air feels warmer and other way around. Humidity level differences can also affect the occupant to feel temperature different between spaces having different humidity levels. (Seppänen, 2001)

Clothing level expressed as clo (m^2K/W) is important factor of the thermal sensation of the indoor air. If clothing levels of occupants vary greatly, there can be a big variety in how occupants feel the indoor air temperature. Thus, it is important to adjust the room temperature into a level, in which indoor thermal comfort is optimized. On the other hand, energy savings can be also reached. Furthermore, individual differences, such as age, metabolic rate, and adaptation to a certain temperature can greatly affect to the sensation of indoor air temperature. (Seppänen, 2001)

Activity level has a great affect to the body temperature and thus to thermal satisfaction of occupants in the space. As we are sleeping, the body releases minimum amount of heat. When the activity level increases, the metabolic rate of the body increases as well, and more heat is produced. Thus, cooler air is required when activity level is high and other way around. (Seppänen, 2001)

Too high temperature may also result building materials to emit contaminants. Human body starts to emit its own emissions as well, if temperature increases. In addition, indoor air may feel stuffy with higher temperature, relative humidity may be too low in the space to satisfy the indoor air requirements. (Seppänen, 2001)

3.2 Preventing heat losses

Preventing building from heat loss plays a very important role in energy efficient buildings in Northern conditions. Excessive heat loss can be prevented by a proper architecture of the building and energy efficient building structures.

3.2.1 Architecture

When choosing a location for an energy efficient building, the possible effect of surroundings should be considered. For instance, if the building would be placed in a slope, the possibility of putting the building facing towards the South should be considered. In addition, surrounding trees can be utilized in shading, especially broadleaved trees allowing solar irradiation to enter the building in winter time and providing shading in summer time. Surrounding buildings should not provide too much shading. Thus, the distance from other building should be adequate. (Sepponen, et al., 2013)

Building shape should be compact in order to prevent from excessive heat loss. In a compact building, the ratio of the building area and volume is important. The compactness of the building is generally described with a shape factor, which can be defined as

$$f = \frac{A}{V},$$

where A is heated building area and V is heated building volume. Figure 1 below illustrates the shape factor. For instance, small shape factor can be obtained for compact cubic shape buildings.

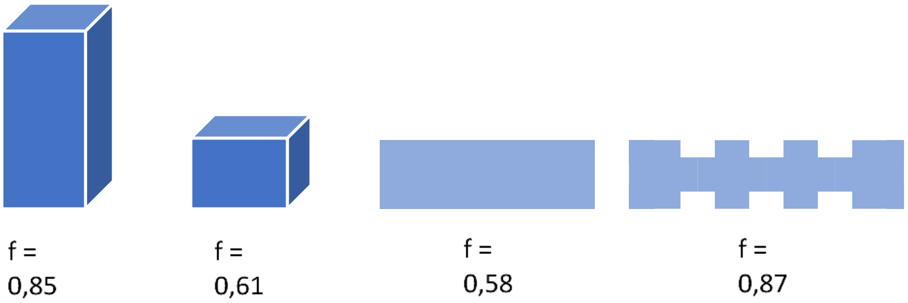


Figure 1. Shape factors ((Sepponen, et al., 2013).

The layout of the building is also important in minimizing heat loss and required heating area/space. Spaces requiring less or no heating can be placed outside the building facing towards the North and spaces requiring more heat and light can be placed towards the South, respectively. In addition, devices supplying heat can be placed in the middle of the building in order to secure efficient supply of heat. Moreover, materials reflecting light can be useful in reducing energy consumption of lighting.

3.2.2 Building envelope

Heat is lost or gained through building envelope by conduction, convection and radiation. These heat transfer phenomena must be taken into account when preventing heat loss. More than one heat transfer phenomenon takes place when building structures are investigated. ***Insulation*** is essential in order to prevent from heat losses. Proper insulation aims at preventing heat loss from building interiors to outside in winter period and the other way around, if the outdoor temperature is higher than the indoor temperature. Thus, less heating is required.

Insulation is greatly depended on insulation material properties, such as heat conductivity and porosity, but also on the thickness of the insulation material. However, it must be considered that heat resistance is not linearly depended on the insulation thickness. Thus, the selection of insulation material is an optimum solution between, at least, heat resistance, thickness and, of course, price. In addition, the air-tightness of the insulation material can be taken into account, for instance.

Heat conductivity is expressed as W/mK. Different materials have different heat resistance for thermal conduction. The lower the heat conductivity of material is, less heat is lost through heat conduction. Heat conductivities for different material are illustrated in Table 3 below. Heat conductivity is expressed with so called normalized heat conductivity taking into account the use and usage conditions, such as moisture.

Table 3. Normalized thermal conductivities of certain building materials.

Material	λ_n [W/mK]
Mineral wool	0.041 – 0.045
Poly styrene	0.041 – 0.055
Poly urethane	0.03
Concrete	1.7
Wood, pine, spruce	0.12

Moisture and excessive pressure can substantially increase the thermal conductivity of insulation material. Thus, vapor barrier is of great importance as it is preventing materials from moisture. Insulation materials or any building material in general should not get wet during the construction phase. Thus, construction and installation quality plays an important role in an energy efficient building. (Seppänen, 2001)

Widely used U-value describes the overall heat conductivity when there is one degree difference in temperature. U-value takes into account the whole building element: heat conductivity, insulation thickness, element area, and heat transfer from air to the inner surface of the material and heat transfer from outer material to the air. U-value is expressed as W/m^{2}K and it can be calculated for the element consisting of several different materials. (Kalliomäki, 2012)

What comes to the thermal conductivity, ***windows*** are generally the weakest part of the building envelope. Thus, glazed area of the total area of building envelope should be set up to 10 – 20 % in order to prevent from excess heat loss. In addition to the glazing area, the U-value of the glazing is important. Triple glazed windows often have lowest U-value. Heat resistance is also depended on the distance of air gas between glazings. In some applications, air between glazings can be replaced with some other gas, such as argon. Typical U-value of the glazing varies from 0.5 – 3 W/m^2K. However, it is also important to consider the total U-value of the window, taking into account the window frame as well. Energy efficient windows can have also an extra coating (semi-conductor coating) allowing short-wave radiation to enter the building but reflecting long-wave radiation coming inside the building back to building interiors. Thus, other properties, such as transmittance and reflectivity are very important, besides U-value. (Seppänen, 2001; Sepponen, et al., 2013)

Besides building walls and windows, floor, roof and doors must have proper U-value. Thermal conductivity of the floor is also depended on the ground type. However, proper insulation of the whole building envelope should always target to minimize local cold areas, thermal bridges, where the temperature of the structure is considerably different compared to surrounding structure. Thermal bridges can be a result of a failure or improper insulation of building structure, such as a pile in the middle of the wall or/and geometrical building structure shape, such as wall and roof corners. (Kalliomäki, 2012)

There is often a pressure difference between outdoor and building interiors, which can be caused by mechanical ventilation system, temperature difference or wind. Due to this pressure difference, air can move from higher pressure to lower pressure, affecting the heat balance of the building. For instance, more heating may be required, if cold air passes through the building envelope from outside. Thus, ***air-tightness*** of the building is very important to avoid these losses. Air-tightness can be expressed, for instance, as air change number n_{50} [1/h] describing the amount of air that changes in the building when there is pressure difference of 50 Pa. Typical values for air-tight residential or office buildings varies around 0.5 to 3, depending on the building type. Here, proper installation of air barrier plays a very important role. (Kalliomäki, 2012; Nieminen & Lylykangas, 2009)

3.3 Heating and cooling processes

Heating is required for comfortable space temperature, hot water, and certain processes. Principally, heating processes can be divided into active and passive heating. The aim of this chapter is to give an insight to some heating solutions, which can promote energy efficiency and the use of renewable energy in SMEs.

3.3.1 Active heating

Conventional furnaces and stoves can be fed with wood. Wooden fired stoves are commonly use in residential sector, but can be also utilized in agriculture, industrial sector, and so on. In Finland, most areas can be also connected to the district heating network. SMEs joining to the district heating system should check the efficiency of the heat distribution system inside the building in order to improve energy efficiency. (Seppänen, 2001)

Pellets can provide considerable amount of heat when combusted. Pellets are generally cylinder shaped wooden “capsules” consisting of wood. The energy density of pellets is large compared to wood chips and it easier to store them as less space is needed and dust is not formed. Pellets have usually very uniform quality and low moisture content. That is why pellets are well suited for stove or furnace in order to produce heat. Automated solutions with integrated pellet storage are also available. (Obernberger & Thek, 2010)

Heat pumps can provide an energy efficient and renewable solution for heating purposes. Heat pumps can use ground, air or water as heat source or sink. Coefficient of performance (COP) for the annual use of heat pumps generally varies between 2 and 3, depending on the type of the application and usage. Heat pumps can usually operate also the other way around, producing cooling energy. Thus, cooling energy can be produced in summertime and heating during colder periods. Heat pump may not always be able to provide enough heating, so auxiliary heating should be considered. (Motiva, 2009)

Active use of solar thermal collectors can produce renewable heat when sufficient amount of solar radiation is available. Solar collectors can be basically divided into flat plate collectors, evacuated tube collectors, and parabolic collectors. The position of the collector can be fixed, or it can follow the sun in order to maximize the amount of absorbed heat. However, the basic idea of the collector is to absorb as much heat as possible, and transfer absorbed heat to circulating working fluid, which can be water, air or some other compound. Solar collectors can provide space and water heating, thermal energy for drying processes and other unit processes requiring heat. (Kalogirou, 2004)

Combustion engines producing heat can run with liquid or gasified fuel, depending on the technology. Thermal efficiency of the heat recovery should be maximized. One possibility is also to have combined heat and power (CHP) system providing heat and electricity. Combustion engines can be fed with renewable produced fuels such as syngas, biogas and bio ethanol. In future, fuel cells may be also a considerable choice for heating. (Sørensen, 2011)

In heating processes, it is important to minimize pressure losses in pipes and other devices so that energy in pumping can be saved. Pipes and storage tanks must be also insulated properly so that heat is not substantially lost to the surrounding environment. In addition, efficient heat distribution method can play an important role in efficient heating. The method for heat distribution can be very case specific. However, local heating for instance in industry by using radiators can be useful because heat is not delivered to the whole factory, but rather where it is needed. In spaces that require high comfort, floor heating can be considered. (Motiva, 2012a)

In energy efficient active heating, overheating should be always avoided as well as simultaneous heating and cooling. Thus, control of the systems can play a very important role in heating systems. Heating devices can be also scheduled according to the occupancy or according to the use of space. For instance, if the space is not occupied during weekends, the temperature inside the building can be lowered in order to gain energy savings. Active heating should be used only when passive heating cannot provide enough heat. (Motiva, 2012a; Nieminen & Lylykangas, 2009)

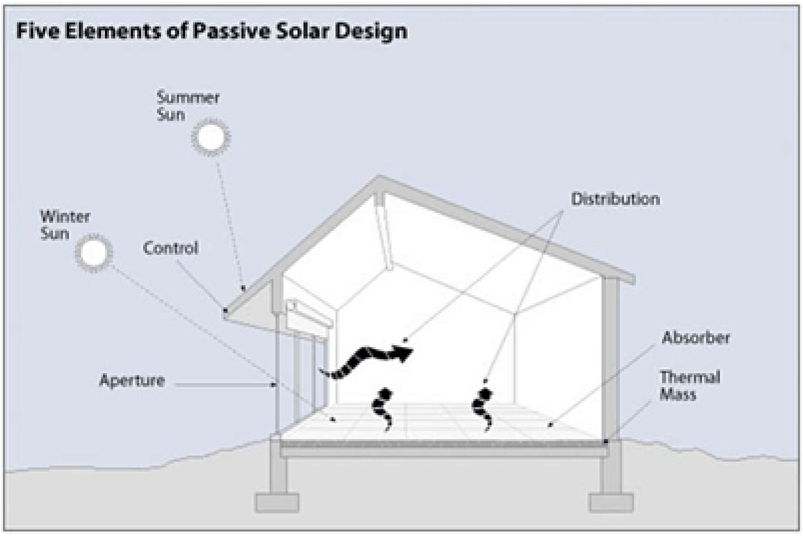
3.3.2 Passive heating

In passive heating, solar irradiation is used in building without utilizing any electric or mechanical power. Solar irradiation can enter building interiors directly through transparent building components, such as windows or through opaque building structures collecting irradiation. In energy efficient building, passive use of solar energy should be considered in order to cut down energy use of heating devices. (Stevanović, 2013)

Windows can play an important role in passive heating. Nowadays, energy efficient windows can allow short-wave radiation from the Sun to enter building interiors. At the same time, a special coating on of the window at the building interior side prevents long-wave thermal radiation from building to escape. Thus, solar energy can be used in more efficient way. The amount of obtained heat from the radiation depends greatly on the transmittance properties of the glazing. (Seppänen, 2001)

The orientation of windows and other building structures can also play a very important role in passive heating. Still, it is important to remember that even though building can be substantially heated up with solar thermal radiation from the Sun, over-heating can occur in summer-period. Thus, shading should be considered in order to protect from over-heating, especially if large windows are facing towards the South. Proper external shading, such as overhang, can block out substantial amount of heat. Moreover, window blinds and curtains can also prevent from heat gain, even though it may not be as efficient as external shading. (Seppänen, 2001)

Thermally heavy building structure can be very beneficial in passive heating. The mass of the building can store heat during day time, whilst releasing heat during colder nighttime. Thus, thermally heavy building structure can prevent also from overheating. Overheating or – cooling peaks can be thus avoided. Thermally heavy structure depends, among others, on the heat capacity and density of the structure.



Passive heating can be also used for pre-heating the incoming ventilation air, for instance. In addition, some special structures, such as solar walls can be used in order to absorb more solar energy. Instead of thermally heavy building structure, phase change materials can be used. (Seppänen, 2001)

3.3.3 Cooling processes

As mentioned earlier, efficient cooling method is to prevent heat to enter building interiors by using shading, thermally heavy building structure, insulation, and air-tightness. Thus, less electricity in active cooling processes is needed. Proper architecture can also substantially decrease the need of cooling, bringing thus energy savings.

Still, cooling may be required in warmer periods and in spaces having processes emitting substantial amount of heat and requiring cooling. Energy efficient solutions in cooling devices should be also considered. An option for instance for offices can be a heat pump operating with refrigeration cycle, when cooling is required. Cooling coils in the air handling unit can be also used in order to supply cool air. In addition, night cooling supplying cooler air in nighttime can be utilized, if possible. Chapter 5 discusses more about process cooling by using compression.

4 Ventilation and air-conditioning

Ventilation is required to supply fresh air to occupants and keep adequate oxygen levels in the room. At the same time, ventilation should provide the feeling of satisfactory thermal comfort. On the other hand, the aim of ventilation is to remove all unwanted odors, humidity, CO_2, particles and other harmful chemical and biological compounds. Thus, the importance of ventilation in providing comfortable indoor air quality and satisfactory thermal environment is extremely important. Still, it is important to notice that inadequately operating ventilation can lead to bad indoor air quality for instance if the air is supplied with undesired temperature or too high velocity. Also noise caused by ventilation system can be very disturbing. This is why ventilation air velocities and temperatures must be always optimized between heating and cooling systems, thermal comfort, and contaminant removal.

4.1 Ventilation strategies

Ventilation can be organized naturally, mechanically or combining natural and mechanical aspects together. The main strategies for ventilation can be basically divided into three groups: mixed ventilation, displacement ventilation, and natural ventilation

In mixed ventilation, the supply air is usually distributed from ceiling or wall diffuser. The supply air is introduced to a room with high velocity. In this way, the room air is circulated. One of the main advantages of mixed ventilation is that it fits well for both heating and cooling purposes. However, it must be kept in mind that too high supply air velocities can lead to discomfort and excess noise. In addition, short circuit of supply and exhaust air may occur. (Lindab, 2011)

In displacement ventilation, the supply air is introduced at floor level with rather low temperature and low velocity. Heat sources in the room make cold air to warm up and rise up to the ceiling, by removing pollutants simultaneously. This ventilation strategy is very efficient in very high rooms and can lead to very high comfort at the occupied zone in the room. However, displacement ventilation cannot be used for heating purposes and it can cause large vertical temperature difference in the room. (Lindab, 2011)

In natural ventilation, the air supply is organized trough building envelope openings, such as windows. In this way, no fans are needed, and energy savings can be brought. Natural ventilation can, however, if controlled improperly, bring too cold or warm air to building interiors. At the same time, contaminants from outside, including also noise, can enter the building and affect thus to indoor air quality and comfort. (Heimonen, et al., 2012)

4.2 Energy efficient ventilation

Energy consumption of the ventilation unit is often related to the ducting system. Pressure loss in ducts is essentially related to fan electricity consumption. Thus, pressure loss should be minimized in energy efficient air handling units (AHU). Common strategies for this are for instance over sizing the duct and choosing a diffuser with low pressure loss. In addition, duct bends should be avoided as much as possible. Bends should be also designed to have small local pressure loss. Furthermore, duct length and material can play an important role. It is also important the duct is insulated properly in order to avoid unnecessary heat transfer to surrounding environment. (Kreider, 2001)

In addition to ducts, pressure loss over different heat exchangers, filters and heating coils should be also considered. In energy efficient ventilation system, maintenance plays also an important role in order to avoid excess pressure loss over for instance filters. This is of a great importance especially in places where lots of air pollutants are produced. Checking leakages is also one important main maintenance routine. It is also important to ensure proper fan operation. (Kreider, 2001)

Variable air volume (VAV) ventilation can be used in order to control the supplied amount of air according to occupancy density or for instance according to office rooms occupied. In VAV, fans are having variable speed motors. In this way, fans are not running with full power all the time. By using this kind of technology, significant energy savings can be reached. (Siemens, 2013)

In the exhaust air there might be considerable amount of heat. In the most energy inefficient situation this air is just discharged to outdoors. In order to avoid this, heat recovery can be used. In this technology, a plate or rotating heat exchanger is transferring heat from the exhaust air to the supply air. In this way, the supply air can be pre-heated and less energy (or none) is needed in the heating coil in order to raise the temperature of the supply air. This technology can be utilized widely in dwellings, offices, swimming pools, retail and in industrial sector. Furthermore, the heat exchanger unit can include also a bypass (or in case of rotating heat exchanger, the heat exchanger can be turned off) in order to enable cooling air to flow to building interiors. This can be utilized efficiently in summertime, and especially in nighttime, when it can be called also as night cooling. Typical efficiency of heat recovery device in energy efficient building is around 50 – 80 %. (Carbon Trust, 2012)

In high buildings, the utilization of stack can lead to decreased pressure loss in the ventilation system. Similarly, the utilization of wind can provide additional pressure for supply air and under pressure for exhaust air. Thus, this pressure difference can be taken into account in ventilation design, if possible. (Kreider, 2001)

Control engineering can play a major role in energy efficient ventilation. For instance, scheduling can be efficiently used in offices, where ventilation is not required during unoccupied periods. Control engineering can also enable the use of VAV ventilation efficiently and reliably, including also step control where the fan can have e.g. four different operating modes (off, slight, medium, high). Moreover, some systems may include CO_2 and temperature sensors in order to take care of adequate ventilation level in the room. Control system can also efficiently take care that right amount of ventilation air is supplied. In this way, excessive air supply, and excessive energy consumption, can be avoided. (Siemens, 2013)

As discussed before, natural ventilation can lead to energy savings, but affect also to indoor air quality and general comfort in the building. However, in situations where indoor air quality does not have to be very high, natural ventilation can provide a good option. Such situations may include for example storages, where mechanical ventilation may always not be necessary. Ventilation can be also organized in a way that supply air is brought in mechanically and exhausted naturally. On the other hand, supply air can be brought in naturally and exhausted mechanically. (Heimonen, et al., 2012)

5 Compression and motors

Pumps, fans, and compression devices are widely required in SMEs. In pumps and fans motors enable the conversion of electricity into useful mechanical work of the fan or pump. In energy efficient compression and motors, the whole system should be considered: pipes, control devices, end-use, and so on. When supplying for instance air or water from one place to another, it is important to minimize pipe losses, pressure loss over filters and other devices, and minimize leakages. In this chapter, motors and compression are discussed by letting out detailed information of pipe losses etc. Still, it must be remembered that holistic system approach is the best approach when considering compression and motors. Besides energy efficiency for instance noise, cost, lifetime, safety, and maintenance are of great importance when considering compression and motors. Correct sizing of systems is also important.

5.1 Motors

Motors running by electricity are widely required in pumps and fans. In motors, largest costs are generally related to energy consumption, being higher than investment costs. This is one of the main reasons why attention should be paid on energy efficient motors. (Heikkilä, et al., 2008)

Electric motors can be divided, among others, into direct current (DC) and alternating current (AC) motors. The advantage with AC motors is usually higher efficiency, less maintenance and lower price. DC motors tend to have better controllability. However, the motor efficiency is essential when considering an energy efficient motor. The motor should be also optimally sized and run with the optimal operating area, if possible to cut down energy consumption. (Motiva, 2012a)

Control devices in motors can cut down energy consumption significantly. For instance, the motor can be turned off it is not required. In addition, motors with frequency converter can reduce significantly energy consumption by reducing the rotational speed of the motor. In this way, the motor is not running with full speed in situations, when less rotation would be required. The relationship between rotation, power and energy can be aimed to be demonstrated by affinity laws (there can be also different affinity laws):

$$\frac{P_1}{P_2} = (\frac{n_1}{n_2})^3,$$

where P is power and n is the shaft rotational speed of the motor. From the equation it can be seen that if the motor rotation increases, the power consumption raises by cubic. Moreover, control devices are important in order to ensure motors operating in their optimal operating area. (Heikkilä, et al., 2008)

Maintenance of the motor is also necessary. Power transmission losses can be significant. Hence, importance must be paid on installing and choosing low loss belts, cogwheels, and shafts. Table 4 illustrates typical saving potential of earlier described procedures in motors. (Heikkilä, et al., 2008)

Table 4. Energy saving actions and typical saving potential in motors (Heikkilä, et al., 2008).

Energy saving action	Typical saving potential [%]
Energy efficient motor	2 – 8
Correct motor sizing	1 – 3
Motor maintenance	0.5 – 2
Speed adjustment	4 – 50
Energy efficient power transmission	2 – 10
Power quality control	0.5 – 3
System control and maintenance	1 – 5

5.2 Compression of air

Air compression plays a very important role in industry since it is required for supplying air to processes, to move items, cool down processes and enabling adequate control of processes. Thus, energy efficient air compression procedures are important in industry in order to save energy. Air compression devices require electricity in order to operate, and in an inefficient device, lot of compression work is actually lost as heat. In the Finnish industry, air compression is commonly the most energy inefficient unit process as the electricity to work -efficiency can be less than 10 %. Generally, what comes to compressors, energy related costs are much higher than investment costs. Thus, especial attention should be paid on air compression in industry. (Motiva, 2013a)

In the energy efficient compression of air the optimal design of the device plays an important role. Especially, the nozzle design is important in order to avoid excess losses. The pressure loss in pipes should be also minimized. This can be done for instance by having large pipe diameter, smooth inner surface of the pipe and having proper insulation and air-tightness procedures, especially in pipe joints. In addition, excess turnings should be minimized as well as pressure losses in down-stream unit processes, such as filters and dryers. Corrosion protective pipe material can be also considered. (Motiva, 2012b)

Air compressors should not run more than it is required. Thus, defining minimum pressure that the compressor have to produce is of a great importance. This can be done for instance after the installation of a compressor by doing measurements and optimizing the operation of the system. Dropping down pressure by 1 bar can already greatly contribute to energy savings. Providing less compressed air than required have to be avoided. Moreover, compressors should be also run within the optimum operating area in order to promote energy efficiency and ensure the proper quality of compressed air. Turning off compressors when not needed saves essentially the operating hours, and thus energy. (Motiva, 2013a)

The control of compressors can also promote energy efficiency significantly. For instance, frequency changer compressors can adapt to different loads and reduce thus electricity consumption. In addition, the maintenance of the system is essential. In this case, the system includes not only the compressor, but also for instance pipe network and down-stream processes. Inspection for possible leakages should be also included. (Motiva, 2013b)

6 Artificial lighting

Electromagnetic radiation at wavelengths between 350 – 780 nm, referred as visible light, is required in all occupied spaces in order to reach comfortable indoor environment. Adequate lighting can improve our health, comfort and performance considerably, besides making the environment to feel safer. For instance, sufficient lighting can considerably improve working performance in an office, but also contribute to the accuracy of the work. Therefore, sufficient light quantity (expressed as lux), but also quality (expressed e.g. in Kelvins) must be considered as well as energy consumption of the lighting system. Energy efficient lighting can be a result of well-made design or retrofit operation. Besides energy savings, healthy and comfortable indoor environment can be achieved.

6.1 Lamp types

Artificial lights can be basically distinguished to incandescent, discharge and solid state lamps. Incandescent lamps are the most conventional existing lamp type. These lamps operate by allowing electric current to flow through a wire placed inside a lamp. As a result, light (and some heat) is produced. Incandescent lamps provide pleasant light quality, but often come with a short lifetime and high energy consumption. (Carbon Trust, 2013)

Discharge lamps based on gas filled envelope are commonly in use. The basic characteristic of discharge lamps is that the light does not shine with full power immediately, which means that there is some kind of starting time, or strike time. However, discharge lamps are more energy efficient compared to incandescent lamps. Discharge lamps can be divided into following groups: fluorescent, low pressure sodium, high pressure sodium, metal halide, ceramic metal halide, and high pressure mercury.

Different discharge lamps are used in different applications. Low and high pressure sodium lamps are used in street lighting and aside of motorways. Metal halide lamps are often utilized in shops and sport applications. Discharge lamps are rather energy efficient compared to incandescent lamps, but can often come with poor light quality and long starting time. Long starting time can affect to the controllability of lighting system. (Carbon Trust, 2013)

Light emitting diodes (LED) produce light when electric current is passed through the semi-conductor. The technology has been developing, and will continue to develop in the future significantly. At the moment, LEDs are a highly energy efficient solution for energy efficient lighting with good dimming properties. In addition, the service time can be very long, even 100 000 hours. On the other hand, the price of LEDs can be considerably higher compared to other lamp types. Moreover, the problem with LEDs is that efficacy may not be high enough to produce enough light to surroundings. However, the technology is developing and improving fast. (Taloon.com, 2013; LightingEurope, 2013)

Based on the fact that different light types have very different properties, lamp types are used in different applications, as seen from Table 5.

Table 5. Application of different lamp types (Electric-installation.org, 2013).

Lamp type	Application
Standard incandescent	Domestic use, localized decorative lighting
Halogen incandescent	Spot lighting, intense lighting
Fluorescent tube	Shops, offices, workshops, outdoors
Compact fluorescent lamp	Domestic use, offices
HP mercury vapor	Workshops, halls, hangars, factories
High-pressure sodium	Outdoors, large halls
Low-pressure sodium	Outdoors, emergency lighting
Metal halide	Large areas, halls with high ceilings
LED	Signs, decorative, emergency

6.2 Energy efficient lamps

Besides a lamp light quality and amount, one important aspect when choosing energy efficient lamp is to check the lamp efficacy, which is described as how much light expressed in lumens one watt of electricity can produce (lm/W). In addition, lamp life time expressed in hours should be also considered. Based on these two characteristics, lamps can be divided into energy efficiency classes from A to G, where A is the most energy efficient choice and G the worst, respectively. However, by checking the lamp efficacy and lifetime, it is possible to compare solutions in the same energy efficiency class. The final parameter is to check the price and compare the overall economic solution between different lamps. Table 6 illustrates the characteristics of different commonly used lamp types. In addition, it is important to point the light source towards the intended area. Thus, for example desk lighting can be energy efficient solution to an office. (Taloon.com, 2013)

Table 6. Lamp characteristics (IEA, 2010; Schneider Electric, 2008).

Lamp type	Power [W]	Efficacy [lumen/W]	Service time [h]
Standard incandescent	3 – 1 000	10 – 15	1 000 – 2 000
Halogen incandescent	5 – 500	15 – 25	2 000 – 4 000
Fluorescent tube	4 – 56	50 – 100	7 500 – 24 000
Compact fluorescent lamp	5 – 40	50 – 80	10 000 – 20 000
HP mercury vapor	40 – 1 000	25 – 55	16 000 – 24 000
High-pressure sodium	35 – 1 000	40 – 140	16 000 – 24 000
Low-pressure sodium	35 – 180	100 – 185	14 000 – 18 000
Metal halide	30 – 2 000	50 – 115	6 000 – 20 000
LED	0.05 – 0.1	10 – 120	40 000 – 100 000

The easiest way of saving lighting energy is to turn lights off. Thus, several control techniques can be applied to energy efficient lighting. Commonly used techniques can be divided into occupancy sensors, timers, and light sensors

Occupancy sensors indicate whether the space is occupied or not and turns lights on/off according to the fact if the space is occupied or not. Thus, lighting energy savings can be reached when turning lights off when the space is not occupied. Another way of controlling light is to use timers/schedulers, where lights are turned on/off according to scheduled period of time. An example could be a scheduler putting lights on only during working hours between 8.00 am to 17.00 pm. (Carbon Trust, 2013)

Lighting sensors and dimming can be utilized in energy efficient lighting when daylight is available. For instance, daylight can be used in order to illuminate the room and artificial lighting in order to illuminate the remaining luxes to the room, when daylight is insufficient. Daylight can be also used next to windows and artificial lighting in deeper parts of the room. Dimming saves energy, when the lamp is not illumining with full power. However, this kind of design must take into account the room architecture, window size, glare effect, and optimization between the amount of daylight and heat loss/gain through the window. Still, daylight as "free" and qualitatively comfortable is an important aspect to consider in energy efficient lighting design. (Taloon.com, 2013)

7 Efficient electric devices

Electric devices, such as fridge, television, and dishwasher make our life more convenient. There are several small, medium, and large size devices everywhere. Indeed, these devices consume energy when operating. It may feel like these devices individually do not consume significant amount of energy, but when there are several different devices, energy efficiency can bring large energy savings. It is also important to remember that devices consume some amount of energy also when having stand-by mode on.

Energy efficient devices can have an energy efficiency label describing how energy efficient the product is. In European Union, energy efficient products are labeled with A – G, where A is the most energy efficient and G is most energy inefficient. In some products, labels A+, A++ and A+++ can be also found. Here, A+++ is given to the most energy efficient product. Energy efficiency label must be found from all common electric devices, such as television, vacuum cleaner, fridge and oven. Computers and imaging devices promoting energy efficiency can also get an energy star label. (Ekosuunnittelu.fi, 2013; TEM, 2013)

The energy consumption level of electric devices is greatly depending on the number of devices. In addition, usage time is also affecting significantly to the energy consumption of devices. This is why for instance dishwasher should be run with a full load. Finally, the installed power capacity in Watts affects to the energy consumption, besides stand-by energy consumption. Hence, energy efficient devices (energy efficiency class of A) should be considered and usage time minimized in order to cut down the energy consumption of electric devices.

Average energy consumption of typical electric devices can be seen from Table 7. Values are indicative.

Table 7. Average energy consumption of typical electric devices (Vattenfall, 2013).

Device	Electricity consumption	Device	Electricity consumption
Refrigerator	0.01 – 0.03	Dishwasher	0.5 – 1.5 kWh/occasion
Fridge-freezer	0.03 – 0.05	Laundry (40 °C)	0.5 – 0.8 kWh/occasion
Freezer	0.02 – 0.06	Laundry (60 °C)	0.6 – 1.9 kWh/occasion
Picture tube TV 32"	0.12 – 0.19	Laundry (90 °C)	1.8 kWh/occasion
LCD TV 32" – 37"	0.08 – 0.19	Tumble dryer	3 kWh/occasion
LCD TV 42"	0.14 – 0.20	Drying cabinet	4.5 kWh/occasion
Plasma TV 42" – 46"	0.31 – 0.41	Sauna (1.5 hours)	8 kWh/occasion
Computer	0.13 – 0.17		
Air humidifier	0.06 – 0.32	Microwave oven	0.02 kWh/min
1 Stove	0.50 – 1.00	Coffee machine	0.01 kWh/min
2 Stoves or oven	1.50 – 2.00	Electric water boiler	0.02 kWh/min
Vacuum cleaner	1.00		
Digibox	0.03	Water heating	1.0 – 1.2 MWh/a/person
Laptop	0.03		
Hood	0.20		

Distribution and transfer of electricity causes some electric losses. Energy losses from electricity distribution can be decreased by having sufficient cable size and minimizing cable distances. Transformers should be also energy efficient and run with designed loads.

8 Sector specific issues

Energy efficient solutions described earlier are very general and those may not be applied in every situation. For instance, a buildings or processes can be very different compared to each other. In addition, the design of energy efficient building, for instance, can be different in different buildings. However, the aim of this chapter is to give an insight to sector specific issues with some case studies. Case studies may not be SMEs, but presented technologies and methods can be applied in different scales.

8.1 Agriculture

Efficient heating, cooling and lighting are essentially important in agriculture. For instance, air heat recovery, recycling of washing water and utilizing of natural ventilation can lead to considerable energy savings in both heating and electricity. Intelligent lighting with occupancy sensors can also cut down electricity consumption significantly. Farmers in Finland have managed to install well operating, energy saving technologies without compromising the quality of production and living. (Motiva, 2011)

Energy in agriculture is required to heat up and cool agricultural buildings and warm up hot water. However, larger portion of energy is usually consumed by machines, motors and transportation. Also crop drying and storage can share substantial part of energy consumption in a farm. In agriculture, machines and production can consume up to 60 % of overall energy in Finland, whilst crop drying shares 20 % and residential buildings at farms 19 %. (Motiva, 2011)

Energy consumption of machines, such as tractors, can be reduced by having an energy efficient engine. It is also important not to put full load or too small load on the machine. For instance, tractors should be loaded down about 60 – 70 % of the maximum power in order to maximize efficiency. Similarly, other machines should be also energy efficient. Moreover, one important aspect is to drive machines economically in order to save energy. Minimizing driving distances and maintaining machines can also save substantial amount of fuel. (Motiva, 2011)

8.1.1 Renewable energy from own resources

Local agricultural resources can be utilized in order to produce renewable energy. Sludge and other biodegradable waste can be introduced into an anaerobic digester producing methane (CH_4), which can be utilized in CHP plant in order to produce heat and electricity. Pellets and wood chips can be utilized efficiently in space and water heating. Extra heat for drying can be obtained by using solar thermal collectors, for instance. Electric appliances can be powered, at least partly, by wind mills or solar photovoltaic cells. (Sørensen, 2011)

8.1.2 Natural ventilation

Many cow houses in Finland use natural ventilation, or fan assisted natural ventilation instead of mechanical ventilation. Natural ventilation in a cow house operates in a way that cows or other animals are emitting heat, which as lighter than surrounding colder air is rising up to the ceiling, where the air is exhausted outside. Fresh and colder air from outside replaces exhausted air by passing through a curtain wall structure. During summertime, the curtain walls of the cow house are fully opened so that air can freely pass through the house. There might be assisting fans in order to provide the cooling effect. However, good air quality and energy savings can be reached. The efficiency of the system depends on the amount of heat released by animals, temperature difference and the height of the cow house. (Heimonen, et al., 2012)

8.1.3 Case: Cattle farm Nousiainen

Nousiainen’s farm has 120 cows and 120 calves. All together, the energy efficient farm is consuming around 120 MWh of energy annually. The farm is recycling washing water so that the first washing water from milk machines are going straightly to a sludge tank and secondary washing water is recycled. About 60 – 70 % of washing water is actually recycled washing water, so approximately 1m^3 of purchased water can be saved daily. (Motiva, 2011)

The cow house has water circulating heating system, where part of the heat is acquired from recovering heat from milk cooling. Substantial energy savings can be reached in heating energy of the cow house. The price of the heat recovery system was about 3 000 euros. (Motiva, 2011)

8.1.4 Chicken farm Yli-Soini

At Yli-Soini’s farm 85 000 broilers are being grown up in very accurate thermal conditions, with proper moisture content of the air. Newly born chicks require special conditions, about the temperature of 34 °C. However, when chicks grow, more heat, moisture and pollutants are being removed. Thus, the farm has installed an automated ventilation system, where a frequency changer motor takes care of the amount of supply air to the space. The frequency changer is controlled according to the temperature, moisture and air requirement. Thus, high quality can be guaranteed. On the other hand, the automated system stops supply air fans when needed, resulting to considerable energy savings in electricity. (Motiva, 2011)

8.2 Industry

In industry, the magnitude of energy consumption depends greatly on type of the industry. Generally speaking, heating, cooling, air compression, pumping, hot water heating, ventilation and lighting can all form a substantial part of the energy consumption of certain industrial factory. Thus, there may not be a straightforward way to suggest a technology that can apply to each situation. The aim of this chapter is to discuss about energy consumption in different industrial applications, where energy efficiency has been promoted. Figure 2 below illustrates the typical consumption of electricity in industry.

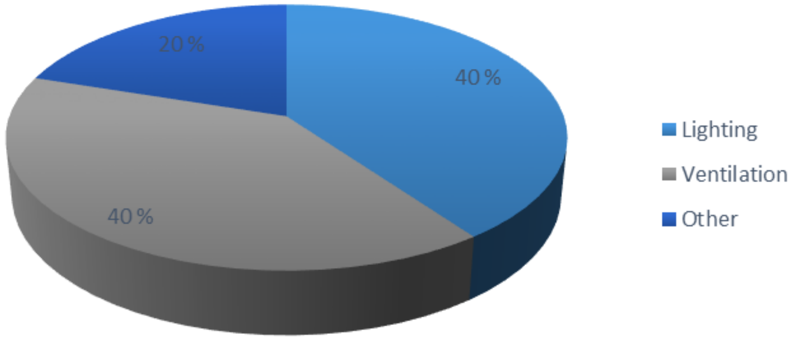


Figure 2. Typical share of electricity consumption in industry (Motiva, 2012a).

8.2.1 Heat recovery

Heat recovery can be widely used in any industrial sector. Heat can be recovered from ventilation air, as discussed before. Still, there might be some other raw-material flows having very high temperature. Heat can be generated for instance through combustion reactions or as a side product of mechanical work. Recovering heat from such sources can bring substantial savings. Heat can be recovered also from wastewater or other liquids from industrial processes. In heat recovery, the heat exchanger efficiency and pressure loss over the heat exchanger plays an important role. It is also possible to integrate a heat pump into a heat recovery system, especially if the heat source is relatively low temperature. (Heikkilä, et al., 2008)

8.2.2 Unit processes

Energy efficient unit processes can be also considered. For instance, instead of conventional separation processes, low pressure loss membrane processes can be used, if possible. In addition, energy efficient drying processes can be utilized. Here, auxiliary heat can be obtained from heat recovery, for instance. Proper control and the driving of unit processes in the economical and energy efficient operating area can save energy significantly, whilst making the process to be safer and more productive. (He & Hägg, 2012)

8.2.3 Cleaning and maintenance

Cleaning and maintenance of unit processes in industry is important in order to enable as efficient and safe operation of processes as possible. In order to enable easy access to the process, the location and position of the process must be considered beforehand. Cleaning and maintenance has to be followed according to given schedule and actions. Cleaning and maintenance must be always done by a trained specialist.

All unit processes must be taken into account in cleaning and maintenance procedures in industry. Pipes, ducts, valves, pumps, fans and filters, for instance, require cleaning in order to operate efficiently. Processes having a significant impact on energy efficiency, such as lighting, air compressors, motors, ventilation system and heating units must be cleaned and maintained with care. Automation system taking care of reporting on maintenance and cleaning can be also considered. (Motiva, 2012a)

Case: Brief checklist of maintenance and cleaning of compressors (TUKES, 2004)

- Check that the compressor has CE mark and maintenance instructions
- Locate the compressor so that it has easy access and safe operation
- Check the operation of safety valve and pressure meter
- Check paintwork, knocks and other possible damage
- Check the attachment (is it attached properly and does trembling occur)
- Remove water from compressor
- Check the inner side of the compressor (moisture, purity (sediment, rust), corrosion, scuff marks)

8.2.4 Storage

Raw-materials in industry are often stored in a storage, especially if batch processes are involved. As storage may not require lighting, or for instance ventilation all the time, a control system may be implemented in order save energy by shutting down these systems when not needed or decreasing the level of usage according to for instance load or occupancy. A cold storage may be also considered in order to cut down heat consumption.

In construction industry, especially at the construction site, building materials have to be stored properly. For instance, insulation materials exposed to rain and snow can decrease the insulation material properties significantly and expose the material to for instance mold. Building materials should be stored in a covered storage rather than left outside. Materials should be also stored in a way that the storage minimizes safety risks. (FISE, 2008)

8.2.5 Work safety

Work safety in industry is essential to take into account already in the design phase. Insufficient work safety may result to industrial accidents. Risks may be associated with such as chemicals, electric equipment, machines or compressors. Minimizing and identification of risks plays a very important role in industry. In practice, work safety can be improved by training and informing working personnel about possible risks. Safety rules must be also followed accurately. If accidents happen, these have to always be reported. Risk assessment analysis is also important to conduct in industry. Safety automation can significantly improve the safety of industrial processes. Safety automation system is a separate system from other automation systems monitoring process safety in real time. If a certain process is driving towards risk limits, safety automation system can recognize the situation and start actions to eliminate these risks and drive the process back to the safe stage. In a high risk situation, safety automation system can automatically shut down the process in order to prevent from risks. (TUKES, 2007)

8.2.6 Machine and metal industry

One Finnish machine and metal industrial company has achieved substantial energy savings. Initially, the company consumed 9.1 GWh of electricity and 2.8 GWh of heat. Electricity was mainly consumed by ventilation, lighting, compressed air and machines. Heat was mainly consumed in order to warm up space and hot water. A Finnish company, Motiva Oy, made an energy suggestion to the machine and metal industrial company, and came up with 15 different suggestions in order to improve energy efficiency. Many of these suggested technologies were calculated to have payback periods less than one year. According to the inspection, 5 % saving in electricity and 29 % saving in heating could be achieved. (Heikkilä, et al., 2008)

One suggestion in order to improve energy efficiency was by installing an occupancy sensor controlled lighting system in to storage halls. By doing this, 60 % of lighting electricity could be saved annually. In addition, the ventilation was inspected to run 7 days a week, even though the company was running only during weekdays. The system stopping the ventilation system during weekend would save 2 % of electricity and 20 % in heating, respectively. (Heikkilä, et al., 2008)

The company has two ***compressed air systems.*** Both systems were inspected to have significant air leakages, and by repairing these, 11 kW saving in power could be achieved. In addition, the pressure level could be possible to drop down by 0.2 – 0.5 bar and the intake air of the other compressor could be taken inside of the building (not outside). By utilizing these improvements altogether, and driving compressors optimally, 28 % saving in electricity usage of compressors could be achieved. (Heikkilä, et al., 2008)

In this case, ***cooling water*** to unit processes of the company is taken from a sea located nearby. It was inspected by Motiva Oy, that there was no adequate control of cooling water system, and that cooling water in some cases was controlled by required temperature. In order to improve the system, especially pumping energy, the system could be controlled according to the required amount of cooling water. In this kind of system, the pump motor would have also a frequency changer. In addition, if the sea water was colder, less water would be required. As a result, 30 % reduction in pumping power could be achieved. (Heikkilä, et al., 2008)

8.2.7 Construction industry

Construction industry is conducting actual construction or preparing materials for construction. For instance, industry preparing concrete or wood materials aiming to be used in construction, is defined as construction industry. Moreover, construction industries can undertake building construction, maintenance and demolish.

Construction industry producing materials should pay attention on energy consumption of the material fabrication processes. Moreover, the energy consumption related to obtaining raw-materials for a certain end-product should be considered. For instance, transportation of raw-materials can share a large portion of fuel consumption. So, the total energy needed from acquiring raw-material and obtaining the end-product, also called as gross energy requirement, can be defined. Materials having low energy input should be promoted. (Kojo & Lilja, 2011)

In construction phase, material efficiency is very important from energy point of view. For instance, the amount of waste generated from building materials should be minimized. If waste is generated, part of energy is lost as it is embodied in waste and more energy is required to handle and transport waste. Not only the material should be done in energy efficient manner, but also the lifetime of the material should be also proper. In addition, materials should be durable. This is of a great importance since maintenance and demolishing of buildings require energy as well. Efficient construction machinery and minimizing of transport cost can also save substantial amount of energy, especially fuels. Buildings, which can be constructed of readily made materials in factors, such as ready-to-install walls and roofs, may cut down energy consumption of construction phase. (Kojo & Lilja, 2011)

8.2.7.1 *Energy efficient construction materials*

Energy efficient construction materials can be very different in different building applications. For instance, energy efficient window may not be only depended on thermal insulation (U-value) but also light transmittance and other optical properties blocking out or allowing in thermal radiation. Depended on the target in terms of thermal gain, windows may utilize different coatings. However, there are common goals for energy efficient building materials used in building envelope, as illustrated in Table 8. (IEA, 2013)

Table 8. Performance goals for building envelope materials (IEA, 2013).

Technology	**Performance goal**
Insulation	Average U-value walls and roof ≤ 0.15 W/m^{2}K
Advanced insulation	Thermal conductivity of ≤ 0.015 W/m^{2}K
Air sealing	Retrofit ≤ 0.3 ACH or 50 % reduction; new ≤ 0.5 ACH with mechanical
Reflective surfaces	Long-lasting SR of ≥ 0.75 for white surfaces and SR ≥ 0.4 for colored surfaces
Windows	Whole-window performance, U-value ≤ 1.8 W/m^{2}K
Highly insulating	U-value ≤ 1.1 W/m^{2}K
Energy-plus windows	Highly insulating U-value ≤ 0.6 W/m^{2}K and variable SHGC 0.08 – 0.65

Designers of energy efficient buildings can utilize Table 8 as a basic tool when considering energy efficient building materials for building envelope. In the end, material properties, not only thermal and optical properties, but also thickness, price, availability and durability are important to take into account. (IEA, 2013)

8.2.7.2 Housekeeping

Good housekeeping is essential in energy efficient buildings. Using energy efficient devices correctly is of great importance. Maintenance of system according scheduled times enables better operation of any system and prevents from malfunctions. For instance, ventilation filters in the air handling unit can be changed, and in this way, pressure loss over filter can be reduced whilst taking care of better indoor air quality. Thus, it is important to familiarize with the usage and maintenance guidebook in any case. In more advanced systems, automation system can take care of maintenance scheduling and report also alarms and malfunctions of the system by monitoring in real time.

8.2.7.3 Construction phases of building one-family house

The aim of this chapter is to illustrate typical construction stages of a one-family house. It must be remembered that proper design of the building is as important as construction. The construction work must be also scheduled and designed beforehand so that construction stages are as safe and fast as possible. (Puuinfo Oy, 2009)

At first, a construction site must be implemented. Logical and proper routes must be organized in order to reach the site. At the site, WC, waste bins, material storage, rest rooms and a place to store land mass must be considered. The actual construction phases of typical one-family house include following: (Puuinfo Oy, 2009)

- Ground construction (cutting down trees, excavation work, fillings)
- Foundations (pile driving, footing, foundations, frost insulation, underdrain
- Frame (wood frame, facing the base floors, air barrier facing for exterior walls, frames for inner walls, flue etc., eaves, grating)
- Roofing
- Insulation
- Windows and doors
- External cladding
- Metal sheeting
- Ventilation
- Heating, cooling and water
- Electric work
- Inner wall work
- Finishing and furnishing
- Painting exterior walls
- Garden work

Stages described are general, and may vary in different building projects. There can be also a possibility construct building materials inside a factory, and then construct building from readily made blocks.

8.2.7.4 Resource efficiency in construction

Resource efficiency is involved to the efficient use of water, energy and other resources in building materials. The target is also to minimize the amount of produced waste and embodied carbon in materials. Following list suggests basic actions towards resource efficient construction. (WRAP, 2014)

- Material consumption reduction
- Reduction and proper handling of waste
- Re-use and recycling
- Durability and life time of products
- Scarcity and security
- Products with low embodied water and carbon
- Reducing energy and water use in construction.

8.3 Transportation

In transportation enterprises, a lot of attention can be paid on the energy efficiency of vehicles, as can be concluded from Figure 3. This is of great importance also in a global scale since transportation is major energy end-user in the world. Mainly fuels are needed to supply energy required for vehicle nowadays, even though electric cars are also emerging. In this chapter, the energy efficiency of road transportation is discussed, and some ideas of cutting down energy efficiency of vehicles are introduced. (Kojima & Ryan, 2010)

Energy (100 %)
Useful energy (10-15 %)
Losses:
Power transmission (5-7 %)
Gearing (1-2.5 %)
Cooler (27-33 %)
Exhaust gases (30-35 %)
Motor friction losses (8-10 %)
Motor throttling losses (5-7 %)
Auxiliary devices (2-4 %)

Figure 3. Typical energy losses of a passenger car (Laurikko, 2007).

8.3.1 Engine

Engine efficiency plays important role in energy efficient transportation. Less fuel is required when the engine can produce more useful work. Moreover, engine sizing and having optimal load on vehicle can greatly affect to fuel consumption. This must be kept in mind especially in truck companies having different loads. In addition, aerodynamics can affect to fuel consumption. Good aerodynamics of a vehicle can reduce fuel consumption in vehicles. (Kojima & Ryan, 2010)

8.3.2 Tires

In vehicles, tires can affect to energy consumption. For instance, tires can have a certain coefficient in slowing down the vehicle. Indeed, tires made from different material and size and having different grooves can have different friction factors, causing rolling resistance. Thus, for instance in buses, energy efficient tires can be considered. It is also important to maintain adequate pressure in tires so that fuel can be saved. (Mutanen, 2006)

8.3.3 Route management

Transportation enterprises should consider minimizing driving distances and the number of drives if possible. Furthermore, vehicle driver can significantly contribute to fuel consumption. Thus, so called eco-driving should be promoted in transportation enterprises. In order to promote eco-driving, driver training can be organized. Moreover, feedback and monitoring systems about driving habits and fuel consumption can be implemented. (Kojima & Ryan, 2010)

There are software available for route management, for instance from Siemens. Route management software can define the most energy efficient, cheapest and fastest route, for instance. The software can accept new orders and can automatically change the route plan. These software often come with digital maps and navigation tool. (Siemens, 2009)

8.3.4 Alternatives

Cutting down fuel consumption can be reached by using hybrid cars, which have two different energy sources, electric motor and internal combustion engine, for instance. Hybrid cars can load electric batteries by utilizing the friction and breaking energy. Electric batteries can be used to deliver useful work in order to move the hybrid car, so the delivered work would be additional work besides the work delivered by the internal combustion engine. Some hybrid cars can also reverse by using the electric motor only, for instance. (Honkola, 2007)

Different fuels can have different energy properties. Nowadays the selection can be done for instance between gasoline, diesel, ethanol, mixed fuels and so on. For instance, the octane number of biogas and ethanol are higher compared to gasoline. Still, in this work it may be challenging to distinguish the most energy efficient one since fuel properties and end-use may be very different in different cases. In future, electric motors having much higher efficiency may provide a considerable choice. (Lampinen, 2009)

9 Conclusions

Being energy efficient saves energy – and money – which is beneficial from economic point of view. Energy efficient solution is about providing similar service with less energy. Thus, the quality of service, for instance ventilation air flow rate, is not suffering because of being energy efficient. The same than before is done by using less. This is becoming even more important when the price of energy is increasing. At the same time, the value of SME buildings may improve as energy efficiency is improved.

At its best, energy efficient solutions can even contribute to better indoor air quality, happiness and work productivity in SMEs. For instance, energy efficient windows may not cause as much draft as inefficient windows. Allowing more daylight into building and having adequate temperature will lead to higher satisfaction of occupancy. Thus, development towards being energy efficient can provide social benefits. By developing SMEs towards energy efficiency can also improve the image of SMEs

Consuming less energy means also less stress on environment. Pollutants origin from energy production to air, ground, water and biosphere can be reduced. Resource efficiency may also contribute energy efficiency and straightly to the amount of produced waste. Possibilities to reduce noise as well may improve working environment. Saving energy is definitely future. As shown earlier, small actions may already contribute to significant economic savings.

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