Covenant of Mayors
Committed to local sustainable energy

How to develop a Sustainable Energy Action Plan

Part 3

HOW TO DEVELOP A SUSTAINABLE ENERGY ACTION PLAN (SEAP) – GUIDEBOOK

Part 3

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Glossary

Activity Data: Activity data quantifies the human activity occurring in the territory of the local authority.

Covenant signatory: Local authority that has signed the Covenant of Mayors.

Baseline year: Baseline year is the year against which the achievements of the emission reductions in 2020 shall be compared.

Baseline Emission Inventory (BEI): Quantifies the amount of CO_2 emitted due to energy consumption in the territory of the Covenant signatory in the baseline year.

Emission factors: Emission factors are coefficients which quantify the emission per unit of activity.

Certified green electricity: Electricity that meets the criteria for guarantee of origin of electricity produced from renewable energy sources set in Directive 2001/77/EC and updated in Directive 2009/28/EC.

Heating degree days (HDD): Denote the heating demand in a specific year.

Life cycle assessment (LCA): Method that takes into account emissions over the entire life cycle of the commodity. For example, life cycle emissions of oil include emissions from oil extraction, refining, transportation, distribution and combustion.

Local heat production: Production of heat in the territory of the local authority that is sold/distributed as a commodity to end users.

Local electricity production: (Small-scale) production of electricity in the territory of the local authority.

Monitoring Emission Inventory (MEI): Emission inventory that the local authority carries out to measure the progress towards target.

Per capita target: The local authority may decide to set the target as '*per capita*'. In that case, the emissions in the baseline year are divided by the population in that year, and the target for year 2020 is calculated on that basis.

Territory of the local authority: Geographical area within the administrative boundaries of the entity governed by the local authority.

PART III
Technical measures for energy efficiency and renewable energy

Table of contents

Introduction

This chapter is intended to gather a collection of measures to improve energy efficiency and reduce the dependency on fossil fuels by using renewable energies. All measures collected in this chapter have been tested and successfully implemented by several cities in Europe.

As the reader will probably notice, each measure has not been described in depth, but rather a collection of references and links to more specific documents from reliable sources are given in each chapter.

The measures proposed in this document can be applied to the building, public services and the industry sectors. This represents around 65 % of the final energy consumption in the European Union [1]. Measures in the Transport sector, whose final energy consumption share is around 31 %, are described in Part I of these guidelines.

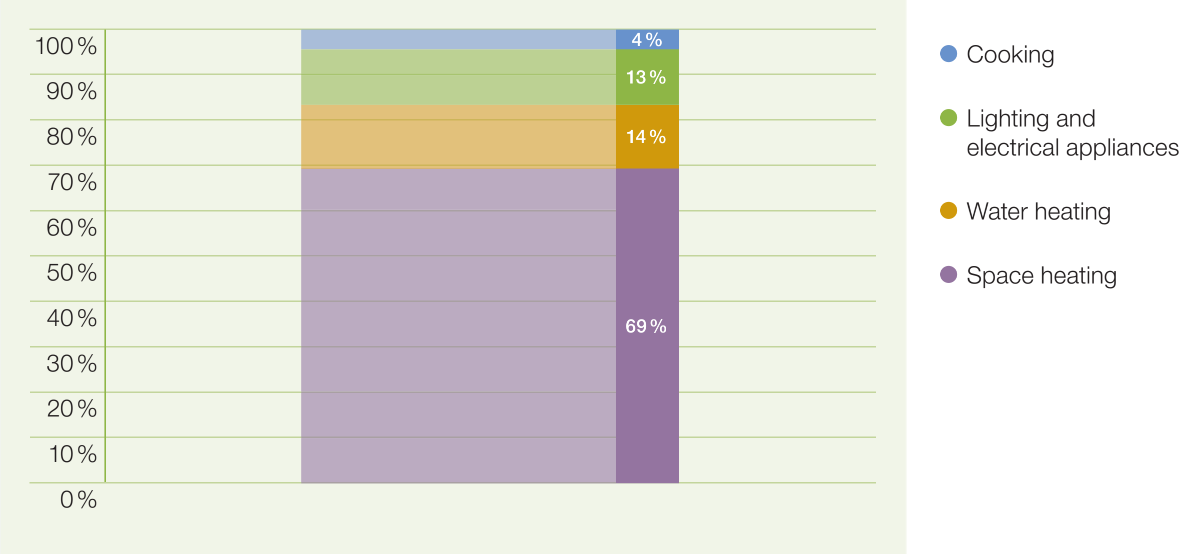
Some cities with a wide expertise in energy management will probably find these measures obvious. Even in this case, we think some measures, or the references provided in this guidebook, will help them to go beyond the objectives of the Covenant of Mayors.

(1) *EU Energy and Transport in Figures 2009. European Commission – DG TREN.*

1. Buildings (²)

In the European Union, the demand for energy in buildings represents 40 % of the whole final energy consumption. The high share of energy consumption, as well as the large potential for energy saving measures (³), implies that it should be a priority for the municipalities to reach the objectives.

HOUSEHOLD ENERGY CONSUMPTION IN EU-27 (2005)



Source: Odyssée database.

The demand for energy in buildings is linked to a significant number of parameters related to constructive design and the usage of the facilities. The variables on which it is convenient to undertake actions to reduce the energy consumption are:

- geometry of the building;
- insulation and functional design of the building;
- equipment, such as type of heaters, air conditioners and lighting;
- usage patterns;
- orientation of the building.

The Energy Performance of Buildings Directive – EPBD – (2002/91/EC) is a key regulatory instrument which is meant to boost the energy performance of the building sector. This Directive has recently undergone some changes after the recent EPBD recast. More information about the main elements of the recast can be found in Annex I.

1.1 Specific considerations related to different kinds of buildings

1.1.1 New buildings

New buildings will generally last 30-50 years before a major refurbishment is carried out. The choices made at the design stage will thus have crucial impact on the energy performance of the building for a very long period of time. This is why making sure new buildings are built according to highest energy efficiency standards is essential in order to reduce the energy consumption in the long term. It is therefore essential that the energy dimension is included as early as possible in the planning and design phases of new buildings.

The reduction of energy consumption in new buildings can be optimised with the use of information and communication technologies (ICT). 'Smart buildings' refer to more efficient buildings whose design, construction and operation is integrating ICT techniques like Building Management Systems (BMS) that run heating, cooling, ventilation or lighting systems according to the occupants' needs, or software that switches off all PCs and monitors after everyone has gone home. BMS can be used to collect data allowing the identification of additional opportunities for efficiency improvements.

(2) *A complete summary of EU legislation can be found on* ***http://europa.eu/legislation_summaries/energy/index_en.htm***

(3) *Further information in the document 'Analysis of Concerto Energy concepts and guidelines for a whole building approach' available on* ***http://www.ecocity-project.eu/PDF/D-2-3-1-1_Concerto_Energyconcepts_Final.pdf***

Note that even if energy efficiency has been incorporated at the start, a building's actual energy performance can be impaired if builders deviate from the plans or if occupants do not operate the BMS according to the plans or specifications. Assuming the building has been designed and built to specification, poor commissioning (ensuring that the building's systems function as specified), constant change of use and poor maintenance can significantly reduce the effectiveness of any BMS. Provide better training to building operators and information to users by simple devices such as visual smart meters or interfaces to influence behavioural change.

The Energy Services Companies' (ESCO) scheme to improve the energy efficiency performance may be applied to all types of buildings of this subchapter. This scheme is explained in Part I (How to Develop a Sustainable Energy Action Plan) financing chapter.

1.1.2 Existing buildings undergoing major refurbishments

When an existing building is subject to a major refurbishment, it is the ideal opportunity to improve its energy performance. In general between 1.5% and 3% of the building stock is renovated each year, so that if energy performance standards are applied to such refurbishments, in a few years the energy performance of the entire building stock shall improve accordingly.

This basic evidence has been translated into the Energy Performance of Buildings Directive and Member States have to set up minimum standards for buildings subject to major renovations. As for new buildings, the local authority could play a role to improve the energy efficiency of renovated buildings.

When considering large investments or refurbishments, it is recommended to make an energy audit in order to identify the best options, allowing the reduction of the energy consumption and preparation of an investment plan. Investments may be limited to a building component (replacement of an inefficient heating boiler) or may be related to the complete refurbishment of a building (including building envelope, windows …). It is important that the investments are planned in a proper manner (e.g. first reducing heat demand by dealing with the envelope and then placing an efficient heating system, otherwise the dimensioning of the heating system will be inappropriate, which results in unnecessary investment costs, reduced efficiency and greater energy consumption).

1.1.3 Public buildings

Public buildings are those owned, managed or controlled by the local, regional, national or European public administration.

The buildings owned, controlled or managed by the local authority itself are those on which the local authority has the greatest control. Therefore, it is expected that the local authority will adopt exemplary measures in its own buildings.

When planning new constructions or renovations, the local authority should set the highest energy standards possible and ensure that the energy dimension is integrated into the project. Energy performance requirements or criteria should be made mandatory in all tenders related to new constructions and renovations (see the public procurement policies point in Part I).

Different possibilities do exist, which can be combined:

- Refer to the global energy performance norms existing at national/regional level [4] and impose strong minimum global energy performance requirements (i.e. expressed in kWh/m²/year, passive, zero energy, …). This leaves all the options open to the building designers to choose how they will reach the objectives (provided they know how to do it). In principle, architects and building designers should be familiar with those norms, as they apply to the entire national/regional territory.
- Impose a certain quantity of renewable energy production.
- Request an energy study that will help to minimise the energy consumption of the building considered by analysing all major options to reduce energy, as well as their costs and benefits (reduced energy bill, better comfort, …).
- Include the building's projected energy consumption as an award criterion in the tender. In this case, energy consumption should be calculated according to clear and well defined standards. A transparent system of points could be included in the tender: (ex: zero kWh/m² = 10 points; 100 kWh/m² and above = 0 points).
- Include the cost of energy consumption over the next 20-30 years in the cost criteria in the tender (do not consider the building construction cost alone). In this case, hypotheses related to future energy prices have to be set and energy consumption should be calculated according to clear and well defined standards.

(4) *In the context of the Energy Performance of Buildings Directive (2002/91/EC), all member States are obliged to set up a method to calculate/measure the energy performance of buildings and to set minimum standards.*

1.1.4 Historical buildings ([5])

The case of buildings that possess a historical (or cultural, aesthetical…) value is complex. Some of them may be protected by law, and options to improve energy efficiency may be quite limited. Each municipality has to establish an adequate balance between the protection of its built heritage and the overall improvement of the energy performance of the building stock. No ideal solution exists, but a mixture of flexibility and creativity may help to find a proper compromise.

1.2 Improvement of the envelope

Space heating and cooling are responsible for almost 70 % ([6]) of the total final energy consumption in European buildings. Therefore effective key actions intended for reducing gains and losses will have a significant influence on the reduction of CO_2 emissions. The losses of energy through the envelope may be reduced through the implementation of the following measures:

Building Shape and Orientation

Building shape and orientation play an important role from the point of view of heating, cooling and lighting. An adequate orientation also reduces recourse to conventional air conditioning or heating.

As the energy consumption reduction due to the building's geometry may attain 15 %, the proportion between width, length and height, as well as its combination with the orientation ([7]) and proportion of glazed surfaces, should be studied in detail when new buildings are in development. As the energy consumption of heating and cooling systems or lighting will be linked to the amount of radiation collected by the building, the street's width is also a parameter to be analysed during the urban planning phase.

Glazing

A suitable choice of the building's glazing is essential as gains and losses of energy are four to five times higher than the rest of the surfaces. The choice of adequate glazing shall consider both the daylight provision and gaining or protecting from solar radiation penetration.

A typical thermal transmittance value of 4.7 W/(m²•K) for single glazed windows can be reduced to 2.7 W/(m²•K) (reduction of more than 40 % of energy consumption per m² of glazed surface due to heat transmission) when they are substituted by double air-filled glazed windows. The transmittance can be improved with the use of *Low-Emissivity Argon filled double glazing up* to 1.1 W/(m²•K), and up to 0.7 W/(m²•K) for triple glazing. In addition the g-value ([8]) should also be taken into account to select the most suitable glazing or window system.

The replacement of glazing may be avoided by use of a low emissivity (low-e) film that can be applied manually on the window. This solution is less expensive that the glazing replacement, but also achieves lower energy performance and shorter lifetime.

Frames

Frame thermal transmittance affects the global window thermal transmittance proportionally to the rate of frame to glazed area of the window. As this rate is typically 15-35 % of the whole window's surface, gains and losses produced by this part are not negligible. In new types of insulated frames the heat losses has been reduced by help of integrated parts of the construction which breaks the cold bridges.

Due to the high thermal conductivity of metal materials, plastic and wooden frames have always better thermal performance, even if new metal frames designed with a thermal break may be a good cost-effective compromise.

Thermal transmittance of walls

Thermal transmittance of walls can be reduced by applying adequate insulation. This is generally achieved by placing an additional slab or cover of insulating material. Commonly-used types of insulation in building construction include: Fibreglass, Polyurethane foam, Polystyrene foam, Cellulose insulation and Rock wool.

MATERIAL	THERMAL CONDUCTIVITY (W/m•K)
Fibreglass	0.05
Polyurethane foam	0.024
Polystyrene foam	0.033
Cellulose insulation	0.04
Rock wool	0.04

A vapour barrier is often used in conjunction with insulation because the thermal gradient produced by the insulation may result in condensation which may damage the insulation and/or cause mould growth.

(5) *Further information in the document 'Energy and Historic Buildings: Recommendations for the improvement of the energy performance' elaborated by the Swiss Federal Office of Energy available on* ***http://www.bfe.admin.ch/energie/00588/00589/00644/index.html?lang=fr&msg-id=28129***

(6) *ODYSSEE database* ***www.odyssee-indicators.org***

(7) *A. Yezioro, Design guidelines for appropriate insolation of urban squares, Renewable Energy 31 (2006) 1011-1023.*

(8) g-value solar factor *is the fraction of incident solar energy which is transmitted to the interior of the building.* Low values reduce solar gains.

Shading Devices

Shading devices can be used to reduce cooling loads by reducing solar radiation penetration. Different types of shading devices are classified and presented below.

- **Movable devices** have the advantage that they can be controlled manually or through automation, adapting their function to the position of the sun and other environmental parameters.
- **Internal blinds** are very common window protection schemes. They are very easy to apply, but their main effect is to help control lighting level and uniformity. They are generally ineffective in reducing the summer heating load, as radiation is blocked once inside the room.
- **External blinds** offer the advantage of stopping solar radiation before penetrating into the room. For this reason it is an effective strategy in solar control.
- **Overhangs** are relatively widespread in hot climates. Their major advantage is that if correctly positioned, they admit direct radiation when the sun is low in winter, while blocking it in summer. The main limitation of their use is that they are appropriate only for south-facing windows.
- **Solar Photovoltaic Modules** building integration offer the possibility to avoid solar radiation penetration, while producing electricity from a renewable energy source.

Avoid Air infiltration

Air infiltration reduction may account up to 20 % of energy saving potential in heating dominated climates. Windows and doors are usually weak points which need to be well designed. Therefore an air tightness test is recommend is order to trace so as to avoid any uncontrolled airflow through the building. A well controlled ventilation system is necessary in order to ensure suitable internal air quality.

1.3 Other measures in buildings

Here are some simple measures that may reduce energy consumption:

- Behaviour: adequate behaviour [9] of building occupants may also generate significant savings. Information and motivation campaigns could be organised in order to get support of the occupants. In such cases, it is important that a good example is also given by the hierarchy and by the authorities in charge of the building management. Sharing the savings between occupants and the local authority could be a good way of motivating action.

EXAMPLE

In October 1994, it was decided that the schools in Hamburg were using too much energy. In an attempt to conserve some of the energy that was being wasted, the Fifty-Fifty Project was started in a number of the schools.

The key element of the Fifty-Fifty Project [10] is a system of financial incentives that enables the schools to share the saving in energy and water costs that they have achieved themselves. Fifty per cent of the money saved in energy conservation is returned to the school, where it can be reinvested into new energy saving devices, equipment, materials and extra curricular activities. For instance, the Blankenese School bought solar panels with the money they saved on energy consumption and installed them themselves.

- Building management: Great savings can be achieved by very simple actions related to proper operation and management of the technical installations: make sure heating is turned off during week-ends and holidays, make sure lighting is off after work, fine tuning of the heating/cooling operation, adequate set points for heating and cooling. For simple buildings, a technician or an energy manager could be appointed for such tasks. For complex buildings, the help of a specialised company may be necessary. Therefore, it may be necessary to renew or set up a new contract with a competent maintenance company with adequate requirements in terms of energy performance. Be aware that the way the contract is drafted could highly influence the motivation of such a company to effectively find out ways of reducing energy consumption.
- Monitoring: implement a daily/weekly/monthly monitoring system of energy consumption in main buildings/facilities, allowing the identification of abnormalities and taking immediate corrective action. Specific tools and software exist for this purpose.

(9) *Further information on behavioural changes is exposed in chapter 7.*

(10) *This scheme is being used in the Euronet 50-50 (supported by Intelligent Energy Europe) project in development from May 2009 to May 2012.* ***http://www.euronet50-50.eu/index.php/***

- The adaptation and regulation of the technical installations to the current uses and owner's requirement (bring equipment to its proper operational state, improve indoor air quality, increase equipment lifespan, improve maintenance operations…) is called *Retro-commissioning* ([11]). Small investments related to the control and regulation of the technical installations may generate great savings: presence detection or timer for lighting or ventilation, thermostatic valves for radiators, simple but efficient regulation system for heating, cooling and ventilation, etc. …
- Maintenance: good maintenance of the HVAC systems may also reduce their energy consumption with little cost.
- Locations with winter climates are especially suitable to incorporating passive solar heating strategies that will reduce the heating loads. In contrast, buildings located in summer climates will require active protection against solar radiation in order to minimise cooling loads. The specific site behaviour of wind should be studied so that natural ventilation strategies are incorporated into the building design.
- The heat gains from building occupants, lights, and electrical equipment are directly linked to the location, and the type and intensity of the activity to be developed, among others. Therefore, during the early planning of the project, the heat gains anticipated from these sources should be quantified for the various spaces to which they apply. In some cases, such as in storage buildings and other areas with relatively few occupants and limited electrical equipment, these heat gains will be minor. In other instances, such as office buildings or restaurants, the presence of intensive and enduring internal heat gains may be a determining factor in HVAC (Heating, Ventilation and Air Conditioning) systems design. These systems will play an important role in winter for dimensioning the heat installations and in summer for air conditioning. The recovery of heat in this type of buildings is highly recommended as an energy-efficient measure.
- When estimating a building's lighting needs, various spaces shall be considered separately, both quantitatively and qualitatively. Depending on the type of work developed, the frequency of use and the physical conditions of such space, the lighting installations will require different designs. Very efficient electrical lighting systems, use of natural lighting or integrated occupancy sensors and other controls are frequently used tools for the design of low consumption lighting systems. The performance indicators of energy-efficient bulbs are indicated afterwards in this document.
- Hours of Operation are also an aspect to consider. The most energy-intensive building types are those in continuous use, such as hospitals. In these buildings, the balance of heating and heat removal (cooling) may be altered dramatically from that of an office building with typical working hours. For example, the around-the-clock generation of heat by lights, people, and equipment will greatly reduce the amount of heating energy used and may even warrant a change in the heating system. Intensive building use also increases the need for well-controlled, high-efficiency lighting systems. Hours of use can also enhance the cost effectiveness of low-energy design strategies. In contrast, buildings scheduled for operations during abbreviated hours, should be designed with limited use clearly in mind.

Most of these measures, along with renewable energy production, are frequently implemented in low energy buildings (Examples: Building of WWF in Zeist or the Dutch Ministry of Finance building in The Hague). The energy-saving potential for this type of building is in the range 60-70 %.

(11) *Book:* Energy Efficiency Guide for Existing Commercial Buildings: The Business Case for Building Owners and Managers *published by ASHRAE.*

2. Lighting ([12])

2.1 Domestic and professional buildings lighting

Depending on the initial situation of the installation, the most cost-efficient and energy consumption solution may be different for a direct substitution of lamps and a new installation. In the former, initial luminaires will be maintained and only the lamps will be changed. In the latter, designers must consider the type of application. As a side-effect of the energy saving in lighting, designers should take into account the reduction of cooling needs due to the decrease of heat emitted by bulbs.

Direct substitution

INITIAL LAMP	LUMINOUS EFFICIENCY ([13])	RECOMMENDED LAMP	LUMINOUS EFFICIENCY
Incandescent lamps ([14])	11-19 lm/W	Compact fluorescent lamp (CFL)	30-65 lm/W
		LED	35-80 lm/W
		Incandescent Halogen lamp	15-30 lm/W

Example: calculate the amount of electricity saved by replacing a 60W incandescent lamp whose luminous flux is 900 Lumen by a CFL, LED or incandescent. Technical characteristics are supposed to be average values of the typical ones collected in the table above. The luminance distribution diagram of each lamp is supposed to be suitable in all cases of the application studied.

	INCANDESCENT LAMPS	INCANDESCENT HALOGEN LAMP	CFL	LED
Luminous efficiency	15	22.5	47.5	57.5
Luminous flux (lm)	900	900	900	900
Power (W) = Energy consumption per hour (kWh)	60	40	18.9	15.6
Energy saved (%)	-	-33.3 %	-68.5 %	-74 %

(12) *The Greenlight project's webpage contains wider information about lighting* ***http://www.eu-greenlight.org/index.htm*** *Further information on lighting technologies and policies in OECD countries can be found in the document 'Lights Labour's Lost: Policies for Energy-Efficient Lighting'. Can be downloaded from* ***www.iea.org/textbase/nppdf/free/2006/light2006.pdf***

(13) *Only the luminous efficiency has been included as this is the parameter that allows an evaluation of the energy efficiency of the lamp. However, this parameter is not the only one to be taken into account to choose a lamp. Other characteristics like the Colour Temperature, the chromatic rendering index, the power or the type of luminaire will be essential to decide the more suitable lamp.*

(14) *As part of the implementation process of the Directive 2005/32/EC on Ecodesign of Energy Using Products, on 18 March 2008, the Commission adopted the regulation 244/2009 on non-directional household lamps which would replace inefficient incandescent bulbs by more efficient alternatives between 2009 and 2012. From September 2009, lamps equivalent in light output to 100W transparent conventional incandescent bulbs and above will have to be at least class C (improved incandescent bulbs with halogen technology instead of conventional incandescent bulbs). By the end of 2012, the other wattage levels will follow and will also have to reach at least class C. The most commonly used bulbs, the 60W will remain available until September 2011 and 40 and 25W bulbs until September 2012.*

New Lighting Installation

CRI ([15]) REQUIRED	RECOMMENDED LAMP	LUMINOUS EFFICIENCY
Very important 90-100	26 mm-diameter (T8) linear fluorescent lamp	77-100 lm/W
Very important 90-100 e.g: Art Galleries, precision works	Compact fluorescent lamp (CFL)	45-87 lm/W
	Very-low voltage tungsten halogen lamp	12-22 lm/W
	LED	35-80 lm/W
Important 80-89 e.g: Offices, schools…	26 mm-diameter (T8) linear fluorescent lamp	77-100 lm/W
	Compact fluorescent lamp (CFL)	45-87 lm/W
	Fitting-based induction lamp	71 lm/W
	Metal halide lamps	65-120 lm/W
	'White sodium' high pressure sodium lamp	57-76 lm/W
Secondary 60-79 e.g: workshops…	26 mm-diameter (T8) linear fluorescent lamp	77-100 lm/W
	Metal halide lamps	65-120 lm/W
	Standard high pressure sodium lamp	65-150 lm/W

CFL (Compact Fluorescent Lamps) have attracted great interest in households as they can easily be adapted to the existing installation. Due to their Mercury contents, this kind of lamp requires well-planned recycling management.

Lighting controls are devices that regulate the operation of the lighting system in response to an external signal (manual contact, occupancy, clock, light level). Energy-efficient control systems include:

- localised manual switch;
- occupancy linking control;
- time scheduling control;
- day lighting responsive control ([16]).

Appropriate lighting controls can yield substantial cost-effective savings in energy used for lighting. Lighting energy consumption in offices can typically be reduced by 30 % to 50 %. Simple payback ([17]) can often be achieved in 2-3 years.

2.2 Infrastructure lighting

2.2.1 LED ([18]) Traffic Lights

The replacement of incandescent halogen bulb traffic lights by more energy-efficient and durable LED yields a significant traffic light energy consumption reduction. Compact LED packages are available on the market so that the replacement of incandescent traffic balls can easily be done by the LED one. A LED array is composed by many LED unities. The main advantages of these traffic lights are:

1. The light emitted is brighter than the incandescent lights, making them more visible in adverse conditions.
2. A LED's lifespan is 100 000 hours, which makes 10 times more than incandescent bulbs that will reduce maintenance costs.
3. The energy consumption reduction is higher than 50 % with respect to incandescent bulbs.

(15) *Colour Rendering Index (CRI): ranging from 0 to 100, it indicates how perceived colours match actual colours. The higher the colour rendering index, the less colour shift or distortion occurs.*

(16) *Further information in the book 'Daylight in Buildings' published by the International Energy Agency Task 21 Daylight in Buildings. Available on* ***http://www.iea-shc.org/task21/source_book.html***
Determination of the energy saving by daylight responsive lighting control systems with an example from Istanbul. S. Onaygil. Building and Environment 38 (2003) 973-977.

(17) *Besides the payback time, the Internal Interest Rate (IRR) of the investment should also be taken into account.*

(18) *LED – Light Emission Diode.*

2.2.2 Public lighting (19)

Energy efficiency in public lighting presents a high energy-efficiency potential through the substitution of old lamps by more efficient ones, such as low pressure, high pressure lamps or LED. Here are some values of energy efficiency.

Direct substitution

INITIAL LAMP	LUMINOUS EFFICIENCY	RECOMMENDED LAMP	LUMINOUS EFFICIENCY
High pressure mercury lamps	32-60 lm/W	Standard high pressure sodium lamp	65-150 lm/W
		Metal Halide Lamp	62-120 lm/W
		LED	65-100 lm/W

New Lighting Installation

CRI REQUIRED	RECOMMENDED LAMP	LUMINOUS EFFICIENCY
Less than 60	Low pressure sodium lamp	100-200 lm/W
	Standard high pressure sodium	65-150 lm/W
More than 60	LED	65-100 lm/W

Changing lamps is the most effective way to reduce energy consumption. However, some improvements, such as the use of more efficient ballast or adequate control techniques, are also suitable to avoid the excess of electricity consumption.

In the choice of the most suitable technology, luminous efficiency, as well as other parameters such as CRI, duration, regulation or Life Cycle, must be included in the set or design parameters. For instance, when in a public-lighting project a high CRI is required, the use of LED technology is recommended. This technology is a suitable solution to reach a well-balanced equilibrium CRI versus Luminous efficiency. If CRI is not essential for a given installation, other technologies may be more appropriate.

Arc discharge lamps, such as fluorescent and HID (High Intensity Discharge) sources, require a device to provide the proper voltage to establish the arc and regulating the electric current once the arc is struck. **Ballasts** also compensate voltage variation in the electrical supply. Since the electronic ballast doesn't use coils and electromagnetic fields, it can work more efficiently than a magnetic one. These devices allow a **better power and light intensity control** on the lamps. The energy consumption reduction caused by electronic ballasts has been estimated around 7 % (20). In addition, LED technology not only reduces the energy consumption, but also allows an accurate regulation depending on the needs.

Electronic photo-switches can also reduce the electricity consumption in public lighting by reducing night burning hours (turning on later and turning off earlier).

A **Telemanagement system** enables the lighting system to automatically react to external parameters like traffic density, remaining daylight level, road constructions, accidents or weather circumstances. Even if a Telemanagement system doesn't reduce the energy consumption in lighting by itself, it can reduce traffic congestion or detect abnormalities. Telemanagement systems can be used to monitor failed lamps and report their location. Maintenance expenses can be reduced by considering the remaining life of nearby lamps that might be replaced during the same service call. Finally, data collected by the Telemanagement system that tracks the hours of illumination for each lamp can be used to claim warranty replacement, establish unbiased products and supplier selection criteria, and validate energy bills.

(19) *Further information available at* ***www.eu-greenlight.org and www.e-streetlight.com*** *(European project supported by Intelligent Energy Europe).*

(20) *E-street project* ***www.e-streetlight.com****. Supported by Intelligent Energy Europe.*

3. Heating ([21])/cooling ([22]) and electricity production

This chapter sets out some energy-efficient measures for the production of heat, cold or electricity. Further information is available in the GreenBuilding programme webpage **www.eu-greenbuilding.org**

Note that when significant renovation works are foreseen, it is important to plan the measures in a proper sequence, e.g. *first* reduce heating/cooling/electricity needs by means of thermal insulation, shading devices, daylight, efficient lighting, etc. , and *then* consider the most efficient way to produce the remaining heat/cold/electricity by means of properly dimensioned installations.

3.1 Solar thermal installations ([23])

Solar thermal technology brings a significant CO_2 emission reduction as it entirely substitutes fossil fuels. Solar collectors can be used for domestic and commercial hot water, heating spaces, industrial heat processes and solar cooling. The amount of energy produced by a solar thermal installation will vary depending on its location. This option may be taken into account in most of the European countries due to the increase of fossil fuels and decrease of solar collector prices.

The performance of solar thermal collectors represents the percentage of solar radiation converted to useful heat. It can be calculated when the input and output average temperature ($T_{average}$), environment temperature ($T_{environment}$) and solar irradiation (I) are known. Coefficients a_0 and a_1 depend on the design and are determined by authorised laboratories. I is the solar irradiation at a given moment.

$$n = a_0 - a_1 \frac{(T_{average} - T_{environment})}{I}$$

At a certain environmental temperature, the lesser the average input/output temperature is, the higher the whole performance will be. This is the case of low temperature installations (swimming pools) or low solar fraction (30-40 %) installations. In these cases the energy production per square metre (kWh/m^2) is so high that the simple payback of the solar installation is significantly reduced. Designers must consider that for a given energy consumption, the energy yields per square metre (kWh/m^2) will decrease as the total surface of the collector is increased. As in this case the cost of the whole installation will go up, it will be required to estimate the most cost-efficient size.

Considering the positive effect on the profitability of low solar fraction and the effect of economies of scale in large plants, these installations might be implemented using an ESCO scheme ([24]) in swimming pools, district heating and cooling, laundries, car washing and industries ([25]), among others.

The JRC has created a database that contains solar radiation data all over Europe. These data may be used by the designers for the evaluation of the necessary collector's surface by using, for example, an f-chart or direct simulation model. The database is focused on the calculation of photovoltaic installations, but data linked to the solar radiation may also be used for solar thermal installations designs. **http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php#**

3.2 Biomass boilers ([26])

Sustainably harvested biomass is considered a renewable resource. However, while the carbon stored in the biomass itself may be CO_2 neutral ([27]), the cropping and harvesting (fertilisers, tractors, pesticide production) and processing to the final fuel may consume an important amount of energy and result in considerable CO_2 releases, as well as N_2O emissions from the field. Therefore, it is imperative to take adequate measures to make sure that biomass, used as a source of energy, is harvested in a sustainable manner (Directive 2009/28/EC Art 17, Sustainability Criteria for Biofuels and Bioliquids).

As explained in Part II of this guidebook, biomass is considered as a renewable and carbon-neutral energy source when the territorial approach is used for the CO_2 accounting.

(21) *Technical and behavioural information about boiler and installations are available on the Ecoboiler webpage.* ***http://www.ecoboiler.org/*** *This project has been funded by the European Commission – DG TREN. Technical and economical information about the implementation of solar thermal energy in swimming pools can be found in* ***www.solpool.info*** *which is supported by Intelligent Energy Europe.*

(22) *Further information on renewable heating and cooling on the European Technology Platform on Renewable Heating & Cooling webpage* ***www.rhc-platform.org***

(23) *Further information on solar thermal strategies on European Solar Thermal Technology Platform webpage* ***www.esttp.org***

(24) *Further information on Solar Thermal ESCOs is available at* ***www.stescos.org*** *– Project supported by Intelligent Energy Europe.*

(25) *Minimizing greenhouse gas emissions through the application of solar thermal energy in industrial processes – Hans Schnitzer, Christoph Brunner, Gernot Gwehenberger – Journal of Cleaner Production 15 (2007) 1271-1286.*

(26) *Further information on Biomass Installation is available at* ***www.biohousing.eu.com*** *– Project supported by Intelligent Energy Europe. The project's webpage offer a tool aimed at comparing costs of biomass and other fossil fuels. Moreover a catalogue of product for the use of biomass is also available. See also* ***www.aebiom.org***

(27) *In some cases CO_2 emissions may be replaced by GHG (Greenhouse Gases) emissions which is a more general term that refer not only to CO_2 but also to other gases with greenhouse effect.*

If the LCA ([28]) approach is chosen for the CO_2 emissions inventory, the emission factor for biomass will be higher than zero (differences between both methodologies in the case of biomass may be very important). Following the criteria established in the 2009/28/EC Directive on the promotion of the use of energy from renewable energy sources, biofuels will be considered as renewable if they fulfil specific sustainability criteria, which are set out in paragraphs 2 to 6 of Article 17 of the Directive.

Biomass boilers ([29]) are available on the market from 2 kW onwards. During a building refurbishment, fossil fuel boilers can be replaced by biomass boilers. The heat distribution installation and radiators are the ones used with the previous installation. A biomass storage room must be foreseen for the accumulation of pellets or wood chips. The performance of the combustion and the quality of the biomass are critical in order to avoid the emissions of particles to the atmosphere. Biomass boilers must be adapted to the type of biomass to be used.

3.3 Condensing boilers

The advantage of condensing boilers is that they are able to extract more energy from the combustion gases by condensing the water vapour produced during the combustion. A condensing boiler's fuel efficiency can be 12 % higher than that of a conventional boiler'. Condensation of the water vapour occurs when the temperature of the flue gas is reduced below the dew-point. For this to occur, the water temperature of the flue gas exchanger must be below 60 °C. As the condensation process depends on the returning water temperature, the designer should pay attention to this parameter so as to ensure it is low enough when it arrives to the exchanger. In case this requirement is not fulfilled, condensing boilers lose their advantages over other types of boilers.

When a conventional boiler is replaced by a condensing one, the rest of the heat distribution installation will not undergo major changes. Regarding the price of a condensing boiler, it is not significantly different from that of a conventional one.

3.4 Heat pumps and geothermal heat pumps ([30])

The use of heat pumps for heating and cooling is very well known. This way of producing heat or cold is particularly efficient.

Heat pumps are composed by two heat exchangers. In winter the heat exchanger located outdoors will absorb heat from the environmental air. The heat is transferred to the indoor exchanger to heat the building. In summer the role of each part is inverted.

As the outdoor unit must transfer heat in summer and absorb it in winter, the performance of the heat pump is highly influenced by the outdoor temperature. In winter/summer, the lower/higher this temperature is the more the heat pump's performance will decrease.

As the performance of heat pumps depends on both the indoor and the outdoor temperatures, it is convenient to reduce the difference between them as much as possible to increase the performance. Accordingly, in winter season an increase of temperature in the heat pump's cold side (outside) will improve the performance of the cycle. The same reasoning can easily be applied to the hot (outside) part in summer.

A possible solution to increase typical performance value is to use the ground or ground water as a source of heat in winter and of cold in summer. This can be done due to the fact that, at a certain depth, the ground temperature doesn't suffer significant fluctuations throughout the year. Generally speaking COP or EER ([31]) values can be improved by 50 %. Seasonal Performance Indicators (SPF ([32])) can be improved by 25 % ([33]) with respect to an air-water cycle. This leads to the conclusion that the electricity consumption in this case could be 25 % lower than the case of an air-water conventional heat pump. This reduction is higher than the case of an air-air cycle for which general data is not available.

(28) *LCA – Life Cycle Analysis.*

(29) *Further information about biomass fuels, storage and maintenance is available in the GreenBuilding programme webpage* ***www.eu-greenbuilding.org***

(30) *Further information available at* ***www.egec.org*** */* ***www.groundreach.eu*** *project supported by Intelligent Energy Europe / Heating and Cooling With a Heat Pump, Natural Resources Canada's Office of Energy Efficiency* ***www.oee.nrcan-rncan.gc.ca*** */* ***www.groundmed.eu*** *Seventh Research Framework Programme /* ***www.groundhit.eu*** *Sixth Research Framework Programme.*

(31) *COP (Coefficient of Performance) and EER (Energy Efficiency Ratio) are both heat pumps performance indicators.*

(32) *Defined in 3.8.*

(33) *Further information about calculation principles for renewable heat is available on the webpage of the ThERRA project* ***www.therra.info*** *– project supported by Intelligent Energy Europe – Information about training on the Geotrainet project webpage* ***www.geotrainet.eu*** *and IGEIA project* ***www.saunier-associes.com*** *supported by Intelligent Energy Europe.*

The heat transfer process between the Ground Heat Exchanger (GHE) and surrounding soil is dependent on local conditions such as the local climatic and hydro-geological conditions, the thermal properties of soil, soil temperature distribution, GHE features, depth, diameter and spacing of borehole, shank spacing, materials and diameter of the pipe, fluid type, temperature, velocity inside the pipe, thermal conductivity of backfill and finally the operation conditions such as the cooling and heating load and heat pump system control strategy.

Geothermal energy systems can be used with forced-air and hydronic heating systems. They can also be designed and installed to provide 'passive' heating and/or cooling. Passive heating and/or cooling systems provide cooling by pumping cool/hot water or antifreeze through the system without using the heat pump to assist the process.

Example:
Let us compare the primary energy saved with a conventional boiler, a condensing one, a heat pump and a Ground Heat Exchanger Heat Pump to produce 1 kWh of final energy.

TECHNOLOGY	FINAL ENERGY KWH	PERFORMANCE RATIO (34)	COP (35)	PRIMARY ENERGY FACTOR (36)	PRIMARY ENERGY (kWh)	PRIMARY ENERGY SAVED (%) (37)
Conventional Boiler (natural gas)	1	92 %	-	1	1.08	-
Condensing Boiler (natural gas)	1	108 %	-	1	0.92	**-14.8 %**
Heat Pump (electricity)	1	-	3	0.25 – 0.5	1.32 – 0.66	**+22 % to -38.8 %**
Ground Heat Exchanger Heat Pump (electricity)	1	-	5	0.25 – 0.5	0.8 – 0.4	**-25.9 % to -62.9 %**

3.5 CHP – Combined heat and power generation (38)

A cogeneration plant, also known as Combined Heat and Power (39) (CHP) plant, is an energy production installation that simultaneously generates thermal energy and electrical and/or mechanical energy from a single input of fuel.

As CHP plants are usually very close to the electricity consumer, they avoid network losses during the transport and distribution to end-users. These plants are a part of the distributed generation scheme in which several small power plants are producing energy being consumed nearby.

The cogenerated heat may also be used to produce cold through absorption refrigeration chillers Other types of thermally driven chillers are commercially available although their market presence is more limited than that of absorption chillers. The plants that simultaneously produce electricity, heat and cooling are known as trigeneration (40) plants. A part of the trigeneration units offer significant relief to electricity networks during the hot summer months. Cooling loads are transferred from electricity to gas networks. This increases the stability of the electricity networks especially in Southern European countries that undergo significant peaks in summer (41).

(34) *Based on the Lower Heating Value (LHV).*

(35) *This ratio is a function of the outdoor or temperature or the ground temperature.*

(36) *The primary energy factor is 1 for a fossil fuel and 0.25-0.5 for electricity. This range represents the electricity generated in a coal cycle with a performance of 30 % or a combined cycle with a performance of 60 %. The transport and distribution losses have been estimated around 15 %.*

(37) *Seasonal effects are not considered in this calculation. (-) is saving and (+) is wasting in comparison with the first case of the table.*

(38) *The European GreenBuilding Programme* ***http://re.jrc.ec.europa.eu/energyefficiency/index.htm*** */* ***www.cogen-challenge.org***

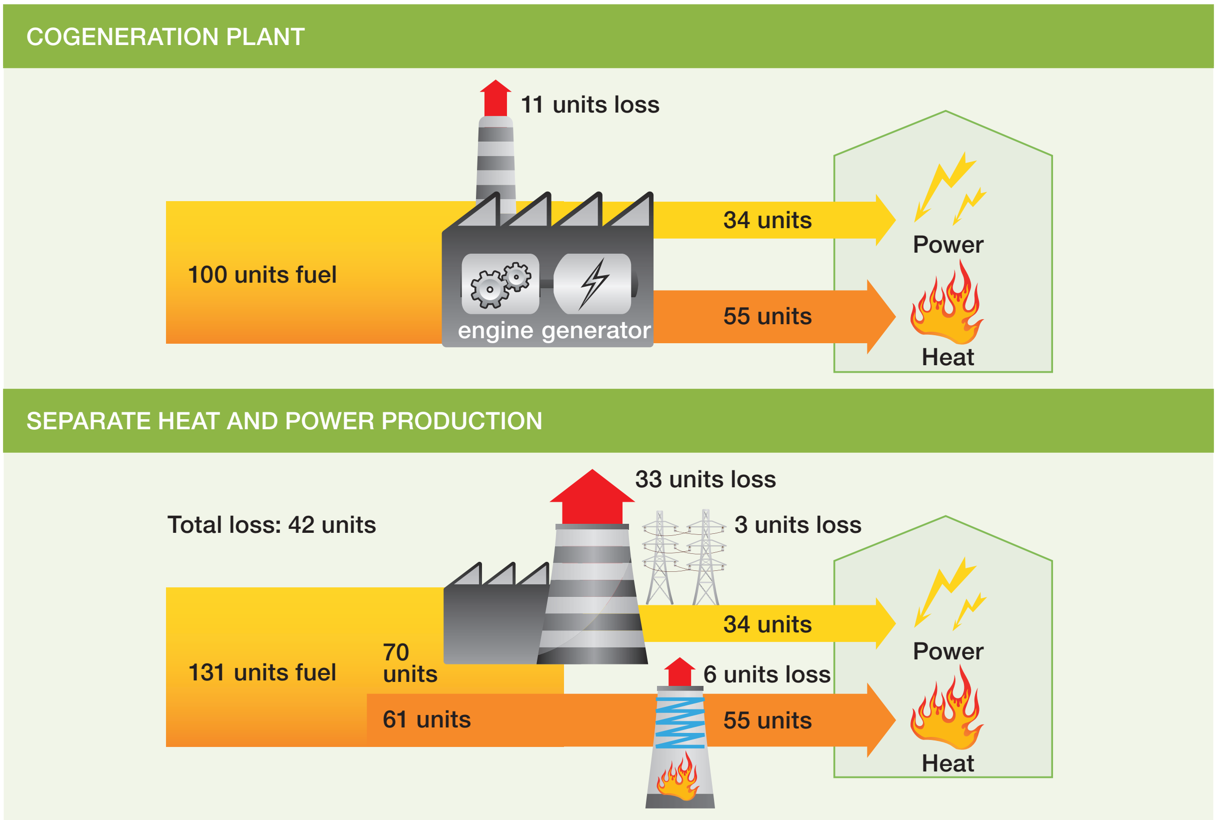
(39) *DIRECTIVE 2004/8/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC.*

(40) ***www.eu-summerheat.net*** *project supported by Intelligent Energy Europe –* ***www.polygeneration.org*** *and* ***www.polysmart.org*** *are financed by the 6th Framework Programme of the European Union.*

(41) *Project CAMELIA Concerted Action Multigeneration Energy systems with Locally Integrated Applications* ***www.cnam.fr/hebergement/camelia/***

CHP leads to a reduction of fuel consumption by approximately 10 - 25 % compared with conventional electricity and separate heat production. The reduction of atmospheric pollution follows the same proportion.

TECHNOLOGY	POWER RANGE	ELECTRIC EFFICIENCY	GLOBAL EFFICIENCY
Gas turbine with heat recovery	500 kWe – >100 MWe	32 – 45 %	65 – 90 %
Reciprocating engine	20 kWe – 15 MWe	32 – 45 %	65 – 90 %
Micro gas turbines	30 – 250 kWe	25 – 32 %	75 – 85 %
Stirling engines	1 – 100 kWe	12 – 20 %	60 – 80 %
Fuel Cells	1 kWe – 1 MWe	30 – 65 %	80 – 90 %



Source: COGEN ([42]) Challenge Project – Supported by Intelligent Energy Europe.

CHP may be based on a reciprocating engine, a fuel cell or a steam or gas turbine. The electricity produced in the process is immediately consumed by the users of the grid and the heat generated might be used in industrial processes, space heating or in a chiller for the production of cold water.

Small-scale heat and power installation can play an important role in the energy efficiency improvement in buildings such as hotels, swimming pools, hospitals and multi residential dwellings, among others. As compact systems, they are extremely simple to install. The system might be based on engines or gas micro-turbines.

The dimensioning of the micro-cogeneration installation will depend on the heat loads. Combined electrical and thermal efficiency varies between 80 and well above 90 %. Similar to electrical efficiency, capital costs per kW_{el} depend on the electrical capacity of the system. A significant decline of capital costs, due to scale effects, can be observed particularly as systems reach the 10 kW_{el} range ([43]). CO_2 emissions of micro cogeneration systems are in the range 300-400 g/kWh_e.

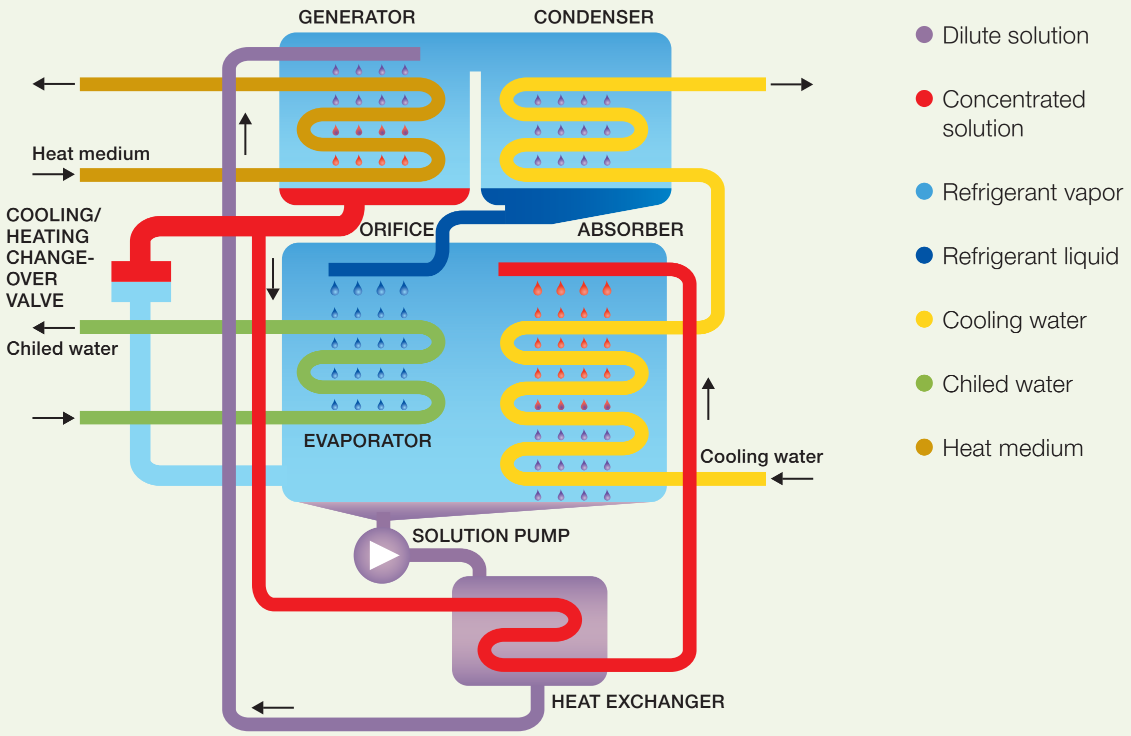
(42) ***www.cogen-challenge.org*** *project supported by Intelligent Energy Europe.*

(43) *Micro cogeneration: towards decentralized energy systems. Martin Pehnt, Martin Cames, Corinna Fischer, Barbara Praetorius, Lambert Schneider, Katja Schumacher, Jan-Peter Voss – Ed. Springer.*

3.6 The refrigerating absorption cycle

The main advantages of absorption chillers are that they use natural refrigerants, have a low decrease of performance at part load, nearly negligible electricity consumption, low noise and vibration and very few moving parts.

FIGURE 1: REFRIGERATION ABSORPTION CYCLE



In the absorption chiller the refrigerant is not compressed mechanically like in conventional chillers. In a closed circuit, the liquid refrigerant that turns into vapour, due to the heat removed from the circuit to be chilled, producing chilled water, is absorbed by a concentrated absorbent solution. The resulting dilute solution is pumped into the generator onto a higher pressure, where the refrigerant is boiled off using a heat source. The refrigerant vapour, which flows to the condenser, and the absorbent get separated. In the condenser, refrigerant vapour is condensed on the surface of the cooling coil. Subsequently the refrigerant liquid passes through an orifice into the evaporator, while the reconcentrated solution returns to the absorber to complete the cycle. Electric energy is only needed for pumping the dilute solution and for control units.

A simple effect absorption chiller will need at least an 80°C energy source and an energy sink under 30-35°C. Therefore the energy can be provided by solar thermal collectors (44) or residual heat. In order to maintain low electricity consumption, the sink of energy should be a cooling water tower, geothermal exchanger, a lake, river… A double-effect absorption chiller, that must be fed by a 160°C energy source, may be coupled to a cogeneration system (trigeneration) that will be able to offer this level of temperature. In both cases the electricity consumption is almost negligible.

Absorption cycle devices that are available from 5-10 kW to hundreds of kW can also be used to produce cold for industries (45), buildings and the tertiary sector. For this reason, simple effect absorption cycle can easily be installed in households. In this case the heat can be obtained from a renewable energy source like solar thermal collectors or biomass. The heat dissipation of the condensing circuit has to be foreseen during the designing phase (this is an essential aspect of this type of installation). There are some typical possibilities to dissipate the heat, like using it for sanitary water, to use a lake or swimming pool or a ground heat exchanger (GHE).

(44) *www.iea-shc.org/task38/index.html*

(45) *POSHIP The Potential of Solar Heat in Industrial Processes www.aiguasol.com/poship.htm*

3.7 Photovoltaic electricity generation (PV)

Photovoltaic modules permit the conversion of solar radiation to electricity by using solar cells. The electricity produced has to be converted from direct current to alternating current by means of an electronic inverter. As the primary energy used is the solar radiation, this technology does not emit CO_2 to the atmosphere.

According to an International Energy Agency study (46) the PV solar collectors´ lifespan is estimated at around 30 years. During the lifetime of the modules the potential for CO_2 mitigation in Europe can reach in the specific case of Greece 30.7 tCO_2/kWp in roof-top installations and 18.6 tCO_2/kWp in façade installations. If we focus on the life-cycle period of the module, the energy return factor (47) (ERF) varies from 8.0 to 15.5 for roof-top mounted PV systems and from 5.5 to 9.2 for PV façade installations.

The integration of solar modules has been improved by manufacturers over the past few years. Information about PV building integration can be found in the document 'Building integrated photovoltaics. A new design opportunity for architects' in the EU PV Platform webpage **www.eupvplatform.org**

3.8 HVAC system indicators

The aim of this point is to stress the need to choose HVAC systems, not only according to their instantaneous performance, but also the yearly average.

HVAC systems are those devices aimed at heating, ventilating and producing air conditioning. Performance Ratio may basically be divided into 2 groups. The Energy Efficiency Ratio (EER) measures the amount of electricity required by an A/C unit to provide the desired cooling level in the 'standard' conditions. The higher the EER, the more energy efficient the unit will be. When the whole cooling period is considered, the ratio is called seasonal performance factor (SPF).

$$EER = \frac{P_{cooling}}{P_{electric}} \qquad SPF = \frac{E_{cooling}}{E_{electric}}$$

$P_{cooling}$: cooling power (kW)
$P_{electric}$: electrical power (kW)
$E_{cooling}$: cooling energy during a period (kWh)
$E_{electric}$: electricity consumption during a period (kWh)

The same calculation may be performed for the heating season and/or the whole year. EER is provided under specific environmental conditions by the manufacturer of the A/C unit. The EER depends however on the load and environmental conditions of the operation. This means that a certain unit will have different performances depending on the location and demand of the building. Due to frequent start/stop and losses, SPF will necessarily be lower than EER. This indicator can be improved by ensuring long-working periods and minimising start/stop switches.

3.9 Heat recovery in HVAC systems

A Heat Recovery Ventilator (HRV) consists of two separate systems. One collects and exhausts indoor air and the other heats outdoor air and distributes it throughout the home.

At the core of an HRV is the heat-transfer module. Both the exhaust and outdoor air streams pass through the module and the heat from the exhaust air is used to pre-heat the outdoor air stream. Only the heat is transferred, therefore the two air streams remain physically separate. Typically, an HRV is able to recover 70 to 80 percent of the heat from the exhaust air and transfer it to the incoming air. This dramatically reduces the energy needed to heat outdoor air to a comfortable temperature.

3.10 Building energy management systems (BEMS)

BEMS are generally applied to the control of systems such as heating, ventilation, and air-conditioning (HVAC). It uses software to control energy-consuming plant and equipment, and can monitor and report on the plant's performance. The performance of the BEMS is directly related to the amount of energy consumed in the buildings and the comfort of the building's occupants. BEMS are generally composed by:

- controllers, sensors (temperature, humidity, luminance, presence…) and actuators (valves, switches…) for different types of parameters;
- HVAC central system with local controllers for each area or room in the building (zoning) and central computer assisted control;
- central control management software for areas or rooms;
- monitoring through energy consumption measurement devices.

According to scientific experiences (49), the energy saving achieved after the installation of a BEMS can reach at least 10 % of the whole energy consumption.

(46) *'Compared assessment of selected environmental indicators of photovoltaic electricity in OECD countries' report of the International Energy Agency PVPS task 10.* ***www.iea-pvps-task10.org***

(47) *Energy Return Factor (ERF): ratio of the total energy input during the system life cycle and the yearly energy generation during system operation.*

(48) *Low-energy cooling and thermal comfort (ThermCo) project –* ***www.thermco.org****. Inspection and audit of an air conditioning facilities document* ***http://ieea.erba.hu/ieea/fileshow.jsp?att_id=3638&place=pa&url=http://AUDITACTrainingPackP_V.pdf&prid=1439*** *of the AUDITAC project. Both projects are supported by Intelligent Energy Europe.*

(49) *Intelligent building energy management system using rule sets. H. Doukas. Building and Environment 42 (2007) 3562-3569.*

4. District heating ([50]) and cooling ([51]) (DHC)

District heating and/or cooling consists in using a centralised plant to provide thermal energy for external customers. Energy may be supplied by fossil fuel or a biomass boiler, solar thermal collectors, a heat pump, cooling systems (thermally driven or compression chillers) or from a combined heat and power plant (CHP). A combination of the mentioned technologies is also possible and may even be advisable depending on the technologies, the fuel used and other technical issues.

Energy-efficiency characteristics´ advantages of DHC are based on high SPF (Seasonal Performance Factor) due to an intensive operation of the installation, introduction of highly efficient equipment, proper insulation of the distribution network, and on efficient operation and maintenance. As an example, the seasonal performance (defined as the total amount of supplied heat over the total primary energy consumption) can be improved from 0.615 for individual heat pumps to 0.849 for district heating heat pumps. Absorption chiller seasonal performance can be improved from 0.54 for an individual absorption chiller and boiler to 0.608 for the same type of installation in a district heating network ([52]). As each installation is operating under different conditions, detailed engineering studies will be necessary to evaluate the percentage of distribution losses in the network and overall efficiency. In addition, the use of environmentally-friendly energy resources such as biomass or solar energy allows the emissions of CO_2 ([53]).

DHC open the possibility to better exploit existing production capacities (use of surplus heat not only from industries, but also from solar thermal installations used in winter for heating), reducing the need for new thermal (condensing) capacities.

From an investment perspective, the specific production capacity (€/kW) that has to be invested in it is radically reduced in a large-scale district cooling system compared to individual systems (one per household). The investment reduction is due to the simultaneous factor and avoided redundancy investments. Estimations from cities where district cooling has been introduced indicate up to 40 % reduction in total installed cooling capacity.

District Heating systems offer synergies between energy efficiency, renewable and CO_2 mitigation, as they can serve as hubs for surplus heat which otherwise would be wasted: for instance, from electricity production (CHP) or industrial processes in general.

District Cooling can make usage of alternatives to conventional electricity cooling from a compression chiller. The resources can be: natural cooling from deep sea, lakes, rivers or aquifers, conversion of surplus heat from industry, CHP, waste incineration with absorption chillers or residual cooling from re-gasification of LNG. District Cooling systems can greatly contribute to avoiding electricity peak loads during summer.

([50]) *SOLARGE project database contain good examples of large solar district heating. Most of them are located in Denmark and Sweden.* ***http://www.solarge.org/index.php?id=2***

([51]) *ECOHEATCOOL project* ***www.euroheat.org****. Supported by Intelligent Energy Europe / Danish Board for District Heating* ***www.dbdh.dk***

([52]) *These data that reflect the real operation of 20 district heating networks in Japan have been extracted from the article: Verification of energy efficiency of district heating and cooling system by simulation considering design and operation parameters – Y. Shimoda et al. / Building and Environment 43 (2008) 569-577.*

([53]) *Some data about CO_2 emissions from district heating are available on the EUROHEAT project webpage.*

5. Office appliances ([54])

Energy savings in office appliances are possible through the selection of energy-efficient products.

Only an assessment of the systems and the needs can determine which measures are both applicable and profitable. This could be done by a qualified energy expert with IT experience. The assessment conclusions should include hints for procurement of the equipment, via purchase or leasing.

The definition of energy-efficiency measures in IT in the early planning stage can result in a significant reduction of loads for air conditioning and UPS, and thus, can optimise the efficiency for both investments and operation costs. Additionally the duplex printing and paper saving in general are important measures for saving energy for paper production, as well as reducing operation costs.

The following tables show the potentially significant energy savings measures which might be applicable to your IT landscape. In each table the measures are presented, beginning with those that have a large potential impact and are the easiest to implement.

Step 1: Selection of energy efficient product – Examples

DESCRIPTION OF MEASURE	SAVING POTENTIAL
Flat-screen monitors (LCD) replacing equivalent conventional monitors save energy	About 50 %
Centralised multi-function devices replacing separate single-function devices save energy, but only if the multi-function is used	Up to 50 %
Centralised printer (and multi-function devices) replacing personal printers save energy, when well dimensioned for the application	Up to 50 %

Step 2: Selection of energy-efficient devices in a defined product group – Examples

DESCRIPTION OF MEASURE	SAVING POTENTIAL
The specific appliance dimension for the realistic application is the most relevant factor for energy efficiency	Not quantified
Use of Energy-Star criteria as a minimum criterion for call for tender will prevent the purchase of inefficient devices	0 – 30 % compared to state of the art
Make sure that the power management is part of the specification in the call for tender and that it is configured by installation of the new appliances	Up to 30 %

Step 3: Check power management and user-specific saving potentials – Examples

DESCRIPTION OF MEASURE	SAVING POTENTIAL
The power management should be initiated in all devices	Up to 30 %
Screensavers do not save energy and thus, should be replaced by a quick start of standby/sleep mode	Up to 30 %
Use of a switchable multi-way connector can avoid power consumption in off-mode for a set of office equipment for night and absence	Up to 20 %
To switch off monitors and printers during breaks and meetings reduce energy consumption in stand-by mode	Up to 15 %

The label ENERGY STAR ([55]), available for energy-efficient office equipment, covers a wide range of products from simple scanners to complete desktop home computer systems. The requirements and specifications of a product to be labelled can be found at **www.eu-energystar.org**. A product-comparison tool is available that allows the user to select the most energy-efficient equipment. For instance, it can be seen that depending on the choice of monitor, the power consumption varies from 12W to 50W. In this case the energy consumption in 'on' mode is reduced by ~75 %.

([54]) *The European GreenBuilding Programme* ***http://re.jrc.ec.europa.eu/energyefficiency/index.htm***, ***http://www.eu-energystar.org/*** *and the Efficient Electrical End-Use Equipment International Energy Agency Programme* ***www.iea-4e.org*** *Information on Office Equipment procurement available on* ***http://www.pro-ee.eu/***

([55]) *Further information available at* ***www.eu-energystar.org*** *According to the Regulation (EC) 106/2008, central government authorities shall specify energy-efficiency requirements not less demanding than the Common Specifications for public supply contracts having a value equal to or greater than the thresholds laid down in Article 7 of the Directive 2004/18/EC.*

6. Biogas [56]

Biogas is a naturally occurring by-product of the decomposition of organic waste in sanitary landfills or from sewage and residual waters. It is produced during the degradation of the organic portion of waste.

Biogas essentially contains methane (CH_4), which is a highly combustible gas. Therefore, biogas is a valuable energy resource that can be used as in a gas turbine or a reciprocating engine, as a supplementary or primary fuel to increase the production of electric power, as a pipeline quality gas and vehicle fuel, or even as a supply of heat and carbon dioxide for greenhouses and various industrial processes. The most usual ways to obtain biogas are from landfills or from sewage and residual waters.

In addition, methane is also a greenhouse gas whose global warming is 21 times higher than carbon dioxide (CO_2). Therefore, biogas recovery is also a valid option to contribute to the reduction of greenhouse gas emissions [57].

6.1. Landfill biogas recovery [58]

Waste disposal in landfills [59] can generate environmental problems, such as water pollution, unpleasant odours, explosion and combustion, asphyxiation, vegetation damage, and greenhouse gas emissions.

Landfill [60] gas is generated under both aerobic and anaerobic conditions. Aerobic conditions occur immediately after waste disposal due to entrapped atmospheric air. The initial aerobic phase is short-lived and produces a gas mostly composed of carbon dioxide. Since oxygen is rapidly depleted, a long-term degradation continues under anaerobic conditions, thus producing a gas with a significant energy value that is typically 55 % methane and 45 % carbon dioxide with traces of a number of volatile organic compounds (VOC). Most of the CH_4 and CO_2 are generated within 20 years of landfill completion.

Landfills comprise an important source of anthropogenic CH_4 emissions, and are estimated to account for 8 % of anthropogenic CH_4 emissions globally. The Directive 1999/31/EC states in Annex I that 'Landfill gas shall be collected from all landfills receiving biodegradable waste and the landfill gas must be treated and used. If the gas collected cannot be used to produce energy, it must be flared'.

6.2. Biogas from sewage and residual waters

Another possibility to produce biogas is through the installation of a biodigester in a sewage an residual waters facility. The residual waters are conducted to the sewage plant where the organic matter is removed from the waste water. This organic matter decays in a biodigester in which the biogas is produced through an anaerobic process. Around 40 % to 60 % of the organic matter is transformed in biogas with a methane content of around 50 % to 70 % [61]. The biodigester can also be fed by vegetable or animal wastes. Therefore, it can be used in the food industry such as in big municipal sewage facilities.

Modern plants can be designed to reduce odours to a minimum extent. Biogas plants may be designed to fulfil the prerequisites for approval by the food industry to use the bio-fertilizer in agriculture.

(56) *Some examples of biogas projects may be found in the webpage* **http://ec.europa.eu/energy/renewables/bioenergy/bioenergy_anaerobic_en.htm**

(57) *See chapters 2 and 3 of the part II of this guidebook.*

(58) *Study of the energy potential of the biogas produced by an urban waste landfill in Southern Spain. Montserrat Zamorano, Jorge Ignacio Pérez Pérez, Ignacio Aguilar Pavés, Ángel Ramos Ridao. Renewable and Sustainable Energy Review 11 (2007) 909-922 // The impact of landfilling and composting on greenhouse gas emissions – A review. X.F. Lou , J. Nair. Bioresource Technology 100 (2009) 3792-3798 // International Energy Agency Bioenergy – Task 37 Energy from Biogas and landfill gas.* **www.iea-biogas.net**

(59) *The information given may not be relevant for countries where landfills are no longer allowed.*

(60) *Further information in the document 'Feasibility study sustainable emission reduction at the existing landfills Kragge and Wieringermeer in the Netherlands Generic report: Processes in the waste body and overview enhancing technical measures' available online at* **http://www.duurzaamstorten.nl/webfiles/DuurzaamStortenNL/files/R00001_Final_generic_report.pdf**

(61) *Joan Carles Bruno et al. Integration of absorption cooling systems into micro gas turbine trigeneration systems using biogas: Case study of a sewage treatment plant. Applied Energy 86 (2009) 837-847.*

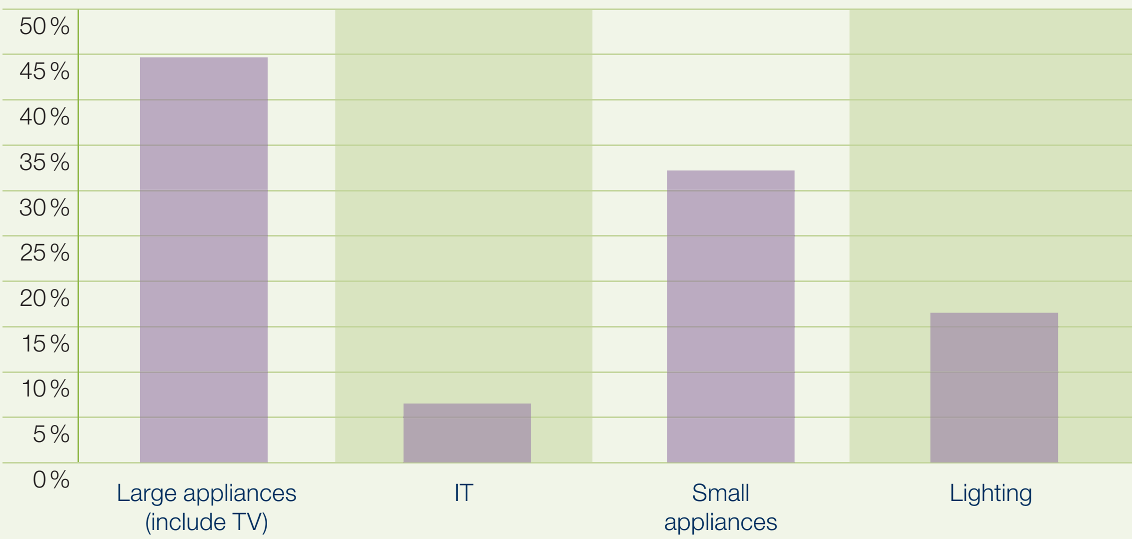
7. Additional demand side management ([62]) measures

The purchase of Green Electricity ([63]) (as explained in Part I, chapter 8.4, point 3) by the Public Administration, Households and Companies, is a great incentive for companies to invest in the diversification of clean energy generation power plants. There is some experience of municipalities buying Green Electricity from power plants owned by a municipal company.

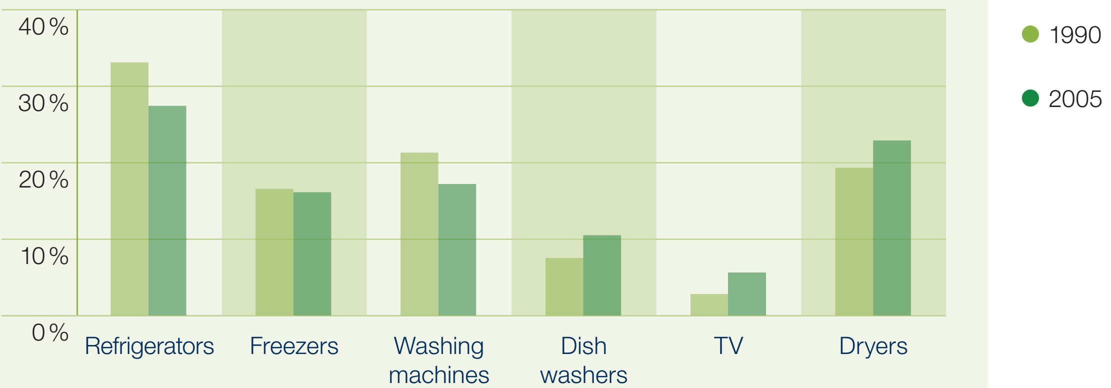
Directives 1992/75/EEC and 2002/31/EC oblige domestic appliance producers to label their products, offering to the customers the possibility to know the energy efficiency of these devices. The appliances included in these regulations are: refrigerators, freezers and their combinations, washing machines, driers and their combinations, dishwashers, ovens, water heaters and hot-water storage appliances, lighting sources, air-conditioning appliances. It is highly recommended to choose A+ or A++ labeled appliances.

The combination of behavioral changes and the implementation of straightforward energy efficient measures (this does not include refurbishment) at homes can reduce the energy consumption by up to 15 % after the second year ([64]).

CONSUMPTION OF HOUSEHOLD ELECTRICAL APPLIANCES PER DWELLING PER TYPE OF APPLIANCES (EU-15) – 2005



CONSUMPTION OF LARGE ELECTRICAL APPLIANCES BY TYPE



Source: Odyssée database – **www.odyssee-indicators.org**

(62) *Demand Side Management Information available on the International Energy Agency Demand Side Management webpage* ***www.ieadsm.org***

(63) *The Topten websites provide a selection of best appliances from the energy point of view* ***www.topten.info*** *(project supported by Intelligent Energy Europe).*

(64) *Further information in the document 'Green electricity – making a different' by PriceWaterhouseCoopers.* ***http://www.pwc.ch/de/dyn_output.html?content.cdid=14918&content.vcname=publikations_seite&collectionpageid=619&backLink=http%3A%2F%2Fwww.pwc.ch%2Fde%2Funsere_dienstleistungen%2Fwirtschaftsberatung%2Fpublikationen.html***

Raising citizens' levels of awareness is a powerful way to reduce the energy consumption at work and at home. A 2006 scientific study has proved that positive behaviour at home may significantly reduce power consumption ([65]). This study made a quantitative analysis with an on-line interactive 'energy consumption information system' that was installed in nine residential houses. The main findings were:

- installation of the system led to a 9% reduction in power consumption;
- comparisons of daily-load curves and load-duration curves for each appliance, before and after installation, revealed various energy-saving forms of behaviour of the household members, such as the reduction of stand-by power and better control of appliance operation;
- energy-conservation awareness affected not only the power consumption of the appliances explicitly shown on the display monitor, but also other household appliances.

Some student-oriented projects ([66]) aimed at teaching them good practices have been developed or are now under development. These projects propose including positive-energy patterns in curricula in order to make students aware of the benefits of energy-efficient behaviour. These initiatives are not only focused on students, but also on parents. In fact, the idea is to bring energy efficiency to the home from school.

EXAMPLE

Significant energy saving reduction through motivation and information in a citizen competition can be seen from the IEE Project Energy Neighbourhood **http://www.energyneighbourhoods.eu/gb/**

Water supply ([67]) is also a field in which the municipality can actively reduce the fossil fuels-based energy consumed through the implementation of two groups of measures:

- Those oriented to the energy consumption reduction of the water supply. Typical measures are the reduction of leaks, control of pumps with frequency inverters, or the water consumption reduction.
- Due to the scarcity of water, some European regions are obliged to use desalination. As this process requires a considerable amount of energy, the use of renewable energy technologies in which relevant progresses have been made over the last years is an alternative to be considered by the technical staff.

([65]) *Effectiveness of an energy-consumption information system on energy savings in residential houses based on monitored data – Tsuyoshi Ueno, Fuminori Sano, Osamu Saeki, Kiichiro Tsuji – Applied Energy 83 (2006) 166-183.*

([66]) *Further information on energy efficiency at school available on* ***www.pees-project.eu****. Project supported by Intelligent Energy Europe. A Scientific research on energy efficiency at school has been performed in Greece. Results can be found in the article: Effective education for energy efficiency – Nikolaos Zografakis, Angeliki N. Menegaki, Konstantinos P.Tsagarakis. Published in Energy Policy 36 (2008) 3226-3232.*

([67]) *Further information on DG Environment webpage* ***http://ec.europa.eu/environment/water/quantity/scarcity_en.htm#studies***

8. Energy audits ([68]) and measurements

The purpose of Energy Audits is to perform an analysis of energy flows in buildings or processes that allows understanding how efficient the use of energy is. In addition, it should propose corrective measures in those areas with poor energy performance. The characteristics of the building or equipment to be audited, as well as the energy consumption and performance data, are collected by means of surveys, measurements or energy consumption bills provided by utilities and operators or simulations performed, using validated software. As measurement and data acquisition are an important issue in energy-efficiency projects, the way to do it has to be planned in advance. More information on energy measurements can be found on the IPMVP webpage **www.evo-world.org**. Once these data are collected and correctly analysed, it is possible to propose corrective measures aimed at improving the energy efficiency of the building/installation. The outcomes of energy audits should at least be:

- identification and quantification of energy-saving potentials;
- energy-efficiency corrective/improvement measure recommendations;
- quantification of investments to improve energy-efficiency effectiveness;
- a plan/programme to implement measures.

The energy audit is the first step before taking the final decision on which type of measures will be taken in order to increase the energy efficiency. Regardless of measures, an energy audit can reveal bad energy consumption practices.

From the point of view of energy efficiency, showing energy consumption and progress to people has an awareness effect that can lead to additional saving, due to the change of behaviour.

During the decision process of the financing scheme (i.e. programmatic carbon crediting – financing schemes chapter), the method used to measure savings or energy produced plays an essential role. In fact, this can be a requirement from the bank or fund to access financing. Moreover, when a project is based on an ESCO scheme, the contract should clearly specify how the energy will be measured (heat, electricity or both) and the payment deadlines and penalisation are based on these measurements. In addition, monitoring the energy consumption/savings allow investors and engineering offices to check the accuracy of forecasts and implement corrective measures in case of non-expected deviations.

(68) *Further information and guidelines are available on the GreenBuilding Webpage* ***http://re.jrc.ec.europa.eu/energyefficiency/greenbuilding/pdf%20greenbuilding/GBP%20Audit%20Guidelines%20final.pdf***

9. Specific measures for industry

9.1. Electric Motors ([69]) and Variable Speed Drives (VSD)

Motor driven systems account for approximately 65 % of the electricity consumed by EU industry. A significant amount of energy is consumed by electric motor in cities. In addition, they are used in buildings to pump water to end-users, in water treatment and distribution or in heating and cooling installations among others. This chapter is addressed to all sectors of activity in which electric motors are present.

A label used by the main European Manufacturer is available for electric motors. This label proposes 3 level of efficiency: EFF1, EFF2, and EFF3. It is recommended to use the most efficient motors which are labelled with EFF1. The efficiency value of two motors labelled with EFF1 and EFF3 with identical electrical power may be at least between 2 % and 7 %.

When a motor has a significantly higher rating than the load it is driving, the motor operates at partial load. When this occurs, the efficiency of the motor is reduced. Motors are often selected that are grossly under-loaded and oversized for a particular job. As a general rule, motors that are undersized and overloaded have a reduced life expectancy with a greater probability of unanticipated downtime, resulting in loss of production. On the other hand, motors that are oversized and thus lightly loaded suffer both efficiency and power factor reduction penalties.

The adjustment of the motor speed through the use of Variable Speed Drives (VSD) can lead to better process control, and significant energy savings. However, VSD can have some disadvantages such as electromagnetic interference (EMI) generation, current harmonics introduction into the supply and the possible reduction of efficiency and lifetime of old motors. The potential energy savings produced by VSD in electric motors have been estimated around 35 % ([70]) in pumps and fans and 15 % in air compressors, cooling compressors and conveyors.

9.2. The Energy Management standard EN 16001

The European standard for Energy Management Systems – EN 16001 – is a tool for all kinds of companies to review their energy situation and improve their energy efficiency in a systematic and sustainable way. This standard is compatible with and complements other standard such as ISO 14001. It is intended to apply to all types and sizes of organizations and industries, including transport and buildings.

The norm doesn't define specific performance energy criteria. Its aim is to help companies to organize their process so as to improve energy efficiency. This standard follows the Plan-Do-Check-Act (PDCA) approach.

9.3. Best Available Techniques Reference Document (BREF) ([71]) in Industry

The Best Available Technology (BAT) Reference Document (BREF) aims to exchange information on BAT, monitoring and developments under the article 17(2) ([72]) of the IPPC Directive 2008/1/EC. These documents give information on a specific industrial/agricultural sector in the EU, techniques and processes used in this sector, current emission and consumption levels, techniques to consider in the determination of BAT, the best available techniques (BAT) and some emerging techniques.

(69) *The Motor Challenge Programme – European Commission* **http://re.jrc.ec.europa.eu/energyefficiency/motorchallenge/index.htm** *and the Electric Motor System Task of the Internation al Energy Agency* **http://www.motorsystems.org/**

(70) *From the report: VSDs for electric motor systems. These data have been estimated for the industrial sector. The report is available on* **http://re.jrc.ec.europa.eu/energyefficiency/motorchallenge/index.htm**

(71) *Energy Efficiency BREF is available on:* **ftp://ftp.jrc.es/pub/eippcb/doc/ENE_Adopted_02-2009.pdf**

(72) *'The Commission shall organise an exchange of information between Member States and the industries concerned on best available techniques, associated monitoring, and developments in them.'*

ANNEX I
Key elements of the EPBD recast

- Elimination of the **1 000 m² threshold** for the renovation of existing buildings: minimum energy performance requirements are required for all existing buildings undergoing a major renovation (25 % of building surface or value).
- Minimum energy performance requirements are required **for technical building systems** (large ventilation, AC, heating, lighting, cooling, hot water) for new built and replacement.
- Minimum energy performance requirements have also to be set **for renovation of building elements** (roof, wall, etc.) *if technically, functionally and economically feasible*.
- A **benchmarking methodology** framework for calculating **cost-optimal levels** of minimum requirements shall be developed by the Commission by 30 June 2011.
- Cost-optimal level mean minimised lifecycle cost (including investment costs, maintenance and operating costs, energy costs, earnings from energy produced and disposal costs).
- Benchmarking methodology shall help MS in setting their requirements.
- In case of >15 % gap between cost-optimal and the actual national standard, Member States will have to justify the gap or plan measures to reduce it.
- Better visibility and quality of information provided by **Energy Performance Certificates**: mandatory use of the energy performance indicator in advertisements; recommendations on how to improve cost-optimally/cost-effectively the energy performance, it can also include indication on where to obtain information about financing possibilities.
- Certificates to be issued to all new buildings/building units and when existing buildings/building units are rented/sold.
- Public authorities occupying office space of > 500 m² will have to display the certificate (lowered to > 250 m² after 5 years).
- Commission to develop a **voluntary common European certification scheme** for non-residential buildings by 2011.
- MS to establish **regular inspection** of accessible parts of heating system (> 20kW) and of AC system (> 12kW).
- Inspection reports issued after each inspection (includes recommendations for efficiency improvement) and handed over to owner or tenant.
- Certificates and inspection to be carried out by independent and qualified and/or accredited experts.
- MS to set up **independent control system** with random verification of certificates and inspections reports.
- MS to establish penalties for non-compliance.
- Requirement to consider **alternative systems** for new buildings (such as RES, district heating and cooling, CHP…).
- All new buildings in the EU as from December 2020 (2018 for public buildings) will have to be **nearly zero energy buildings**.
- The ***nearly zero or very low*** amount of energy required should to a very significant level be covered by energy from renewable source.
- MS to **take measures**, **such as targets**, to stimulate the transformation of buildings that are refurbished into nearly zero energy buildings.
- EPBD recast **underlines crucial role of financing for EE**.
- MS have to draw up lists of national (financial) measures by 30 June 2011.
- MS to take into account cost-optimal levels of energy performances in funding decisions.

ANNEX II
Costs and emissions of some technologies

TABLE 2-2: ENERGY TECHNOLOGY FOR POWER GENERATION – HIGH FUEL PRICE SCENARIO (a)								
	PRODUCTION COST OF ELECTRICITY (COE)			NET EFFICIENCY 2007	LIFECYCLE GHG EMISSIONS			FUEL PRICE SENSITIVITY
Power generation technology	State of the art 2007 €2005/MWh	Projection for 2020 €2005/MWh	Projection for 2030 €2005/MWh		Direct (stack) emissions kgCO2 (eq)/MWh	Indirect emissions kgCO2 (eq)/MWh	Lifecycle emissions kgCO2 (eq)/MWh	
ENERGY SOURCE: NATURAL GAS								
Open Cycle Gas Turbine (GT)								
-	80 + 90 (b)	145 + 155 (b)	160 + 165 (b)	38 %	530	110	640	Very high
Combined Cycle Gas Turbine (CCGT)								
-	60 + 70	105 + 115	115 + 125	58 %	530	70	420	Very high
CCS	n/a	130 + 140	140 + 150	49 % (c)	60	85	145	Very high
ENERGY SOURCE: OIL								
Internal Combustion Diesel Engine								
-	125 + 145 (b)	200 + 220 (b)	230 + 250 (b)	45 %	595	95	690	Very high
Combined Cycle Oil-fired Turbine (CC)								
-	115 + 125 (b)	175 + 185 (b)	200 + 205 (b)	53 %	505	80	580	Very high
ENERGY SOURCE: COAL								
Pulverised Coal Combustion (PCC)								
-	40 + 55	80 + 95	85 + 100	47 %	725	95	820	High
CCS	n/a	100 + 125	100 + 120	35 % (c)	145	125	270	Medium
Circulating Fluidised Combustion (CFBC)								
-	50 + 60	95 + 105	95 + 105	40 %	850	110	960	High
Integrated Gasification Combined Cycle (IGCC)								
-	50 + 60	85 + 95	85 + 95	45 %	755	100	855	High
CCS	n/a	95 + 110	90 + 105	35 % (c)	145	125	270	Medium
ENERGY SOURCE: NUCLEAR								
Nuclear fission								
-	55 + 90	55 + 90	55 + 85	35 %	0	15	15	Low
ENERGY SOURCE: BIOMASS								
Solid biomass								
-	80 + 195	90 + 215	95 + 220	24 % + 29 %	6	15 + 36	21 + 42	Medium
Biogas								
-	55 + 125	50 + 200	50 + 190	31 % + 34 %	5	1 + 240	6 + 245	Medium
ENERGY SOURCE: WIND								
On-shore farm								
-	75 + 110	55 + 90	50 + 85	-	0	11	11	nil
Off-shore farm								
-	85 + 140	65 + 115	50 + 95	-	0	14	14	nil
ENERGY SOURCE: HYDRO								
Large								
-	35 + 145	30 + 140	30 + 130	-	0	6	6	nil
Small								
-	60 + 185	55 + 160	50 + 145	-	0	6	6	nil
ENERGY SOURCE: SOLAR								
Photovoltaic								
-	520 + 880	270 + 460	170 + 300	-	0	45	45	nil
Concentrating Solar Power (CSP)								
-	170 + 250 (d)	130 + 180 (d)	120 + 160 (d)	-	120 (d)	15	135 (d)	Low

(a) *Assuming fuel prices as in DG TREN 'Scenarios on high oil and gas prices' (barrel of oil 54.5$$_{2005}$ in 2007, 100$$_{2005}$ in 2020 and 119$$_{2005}$ in 2030).*
(b) *Calculated assuming base load operation.*
(c) *Reported effiencies for carbon capture plants frefer to first-of-a-kind demonstration installations that star operating in 2015.*
(d) *Assuming the use of natural gas for backup heat production.*

Source: COMMISSION STAFF WORKING DOCUMENT. AN EU ENERGY SECURITY AND SOLIDARITY ACTION PLAN. Energy Sources, Production Costs and Performance of Technologies for Power Generation, Heating and Transport. European Commission. ***http://setis.ec.europa.eu/***

TABLE 2-4: ENERGY SOURCES FOR HEATING – HIGH FUEL PRICE SCENARIO (a)						
EU-27 MARKET SHARE BY ENERGY SOURCE (RESIDENTIAL SECTOR) (b)	FUEL RETAIL PRICE (INC.TAXES)	PRODUCTION COST OF HEAT (INC.TAXES)		LIFECYCLE GHG EMISSIONS		
		Running cost	Total cost	Direct (stack) emissions	Indirect emissions	Lifecycle emissions
	$€_{2005}$/toe	$€_{2005}$/toe	$€_{2005}$/toe	tCO_2 (eq)/toe	tCO_2 (eq)/toe	tCO_2 (eq)/toe
ENERGY SOURCE: FOSSIL FUELS						
Natural gas						
45.4 %	1 010	1 125 + 1 400	1 425 + 1 750	2.5	0.7	3.2
Heating oil						
20.0 %	1 030	1 200 + 1 600	1 775 + 2 525	3.5	0.6	4.1
Coal						
3.1 %	590	975 + 1 025	1 775 + 2 100	5.4	0.7	6.1
ENERGY SOURCE: BIOMASS, SOLAR AND OTHER						
Wood chips						
11.6 %	410	725 + 925	1 575 + 2 675	0.0	0.3	0.3
Pellets						
11.6 %	610	925 + 1 350	1 700 + 4 175	0.0	0.7	0.7
Solar						
11.6 %	-	275 + 300	1 350 + 9 125	0.0	0.3	0.3
Geothermal						
11.6 %	-	650 + 1 100	1 150 + 3 775	0.0	0.2 + 5.9	0.2 + 5.9
ENERGY SOURCE: ELECTRICITY						
12.3 %	1 875	1 925 + 1 975	2 025 + 2 900	0.0	0.7 + 15.2	0.7 + 15.2

(a) *Assuming high fuel prices as in DG TREN 'Scenarios on high oil and gas prices' (barrel of oil 100$$_{2005}$).*
(b) *District heating has an additional share of 7.6 % of the market.*

Source: COMMISSION STAFF WORKING DOCUMENT. AN EU ENERGY SECURITY AND SOLIDARITY ACTION PLAN. Energy Sources, Production Costs and Performance of Technologies for Power Generation, Heating and Transport. European Commission. ***http://setis.ec.europa.eu/***

TABLE 2-5: ENERGY SOURCES FOR TRANSPORT – MODERATE AND HIGH FUEL PRICE SCENARIO			
ENERGY SOURCE FOR ROAD TRANSPORT	COST OF FUEL TO THE EU		LIFECYCLE GHG EMISSIONS (c)
	Moderate fuel price scenario (a) $€_{2005}$/toe	High fuel price scenario (b) $€_{2005}$/toe	tCO_2 (eq)/toe
Petrol and diesel	470	675	3.6 + 3.7
Natural gas (CNG) (d)	500	630	3.0
Domestic biofuel (e)	725 + 910	805 + 935	1.9 + 2.4
Tropical bio-ethanol	700 (f)	790 (f)	0.4
Second-generation biofuel (e)	1 095 + 1 245	1 100 + 1 300	0.3 + 0.9

(a) *Value are given for 2015, assuming oil prices of 57.9$$_{2005}$ /barrels as in 'Europe Energy and Transport: Trends to 2030 – Update 2007'.*
(b) *Value are given for 2015, assuming oil prices of 83.3$$_{2005}$ /barrels as in DG TREN 'Scenarios on high oil and gas prices'.*
(c) *Data subject to revision pending on an agreement on an appropriate methodology for calculating indirect land use change.*
(d) *Require a specially adapted vehicle, which is not accounted for in the reported values.*
(e) *Ranges is between cheapest wheat-ethanol and biodiesel.*
(f) *Values are based on an assumed competitive market price of biofuels imported in the EU.*

European Commission

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