JRC Scientific and Technical Reports

HOW TO DEVELOP A SUSTAINABLE ENERGY ACTION PLAN (SEAP) IN THE EASTERN PARTNERSHIP AND CENTRAL ASIAN CITIES – GUIDEBOOK

PART III

Covenant of Mayors
Committed to local sustainable energy

EUR XXXXX EN - 2013

The mission of the JRC-IET is to provide support to Community policies related to both nuclear and non-nuclear energy in order to ensure sustainable, secure and efficient energy production, distribution and use.

European Commission
Joint Research Centre
Institute for Energy and Transport

Contact information
Address: TP-450 Via Enrico Fermi 2749, 21027 Ispra (Italy)
E-mail: paolo.bertoldi@ec.europa.eu
Tel.: +39 0332 78 9299
Fax: +39 0332 78 9992

http://iet.jrc.ec.europa.eu/
http://www.jrc.ec.europa.eu/

JRC XXXXX

ISBN XXX-XX-XX-XXXXX-X
ISSN XXXX-XXXX
DOI XX.XXXX/XXXXX

Luxembourg: Publications Office of the European Union

Printed in Luxembourg

HOW TO DEVELOP A SUSTAINABLE ENERGY ACTION PLAN (SEAP) IN THE EASTERN PARTNERSHIP AND CENTRAL ASIAN CITIES – GUIDEBOOK

PART III - TECHNICAL MEASURES FOR ENERGY EFFICIENCY AND RENEWABLE

Covenant of Mayors
Committed to local sustainable energy

JRC
EUROPEAN COMMISSION

EUR XXXXX EN - 2013

ACKNOWLEDGEMENTS

This guidebook is a revised version of the guidebook "How to develop a Sustainable Energy Action Plan (2010)" that has been realised with the support and input of many experts, from municipalities, regional authorities, agencies, city networks and private companies. We thank all those who have provided input and contributions and helped to shape the document in the right direction.

TABLE OF CONTENTS

INTRODUCTION....................11

1. BUILDINGS....................12
   1.1. CONSIDERATIONS RELATED TO BUILDING TYPES.................... 13
      1.1.1. New buildings.................... 13
      1.1.2. Refurbishment of existing buildings.................... 14
      1.1.3. Public Buildings.................... 15
      1.1.4. Historical buildings.................... 15
   1.2. IMPROVEMENT OF THE BUILDING ENVELOPE.................... 16
   1.3. BUILDING INSTALLATIONS.................... 18
   1.4. OTHER MEASURES IN BUILDINGS.................... 19

2. LIGHTING....................23
   2.1. DOMESTIC AND PROFESSIONAL BUILDINGS LIGHTING.................... 23
   2.2. INFRASTRUCTURE LIGHTING.................... 24

3. HEATING/COOLING AND ELECTRICITY PRODUCTION IN SERVICE, RESIDENTIAL AND PUBLIC SECTORS....................26
   3.1. SOLAR THERMAL INSTALLATIONS.................... 26
   3.2. PHOTOVOLTAIC ELECTRICITY GENERATION (PV).................... 27
   3.3. BIOMASS BOILERS.................... 27
   3.4. CONDENSING BOILERS.................... 28
   3.5. HEAT PUMPS.................... 28
   3.6. THE REFRIGERATING ABSORPTION CYCLE.................... 33
   3.7. HVAC SYSTEM INDICATORS.................... 33
   3.8. HEAT RECOVERY IN HVAC SYSTEMS.................... 34

4. CHP - COMBINED HEAT AND POWER GENERATION....................35
   4.1. Industrial CHP.................... 36
   4.2. Micro CHP.................... 37
   4.3. Micro Commercial CHP.................... 38
   4.4. Fuel Cells and Trigeneration.................... 38
   4.5. District Heating/Cooling and Cogeneration.................... 39

5. FUEL CELLS....................42
   5.1. Fuel Cells Technology.................... 42
   5.2. Main applications.................... 43
   5.3. Natural Gas Fuel Cells.................... 44

6. ENERGY MANAGEMENT SYSTEMS IN BUILDINGS (BEMS)....................45

7. DISTRICT HEATING AND COOLING TECHNOLOGIES (DHC)....................46
   7.1. Geothermal District Heating with/without absorption heat pump.................... 46
   7.2. Solar district heating.................... 47
   7.3. Absorption heat pump.................... 48
   7.4. Seasonal storage.................... 50
   7.5. District Cooling.................... 51

8. WATERGY: IMPROVEMENT OF OVERALL WATER SYSTEM EFFICIENCY....................54

9. OFFICE APPLIANCES....................58
   10. BIOGAS....................60
   10.1. LANDFILL BIOGAS RECOVERY....................60
   10.2. BIOGAS FROM SEWAGE AND RESIDUAL WATERS....................60

11. ADDITIONAL DEMAND SIDE MANAGEMENT MEASURES....................62

12. ENERGY AUDITS AND MEASUREMENTS....................64

13. SPECIFIC MEASURES FOR INDUSTRY 65
13.1. Electric Motors and Variable Speed Drives (VSD) 65
13.2. The Energy Management standard ISO 50001 65
13.3. Best Available Techniques Reference Document (BREF) in Industry 66
14. NATURAL GAS VEHICLES 67
14.1. Natural gas vehicles 67
14.2. Fuelling 68
14.3. Environmental aspect 69
14.4. Economics and Safety 69
ANNEX I. KEY ELEMENTS OF THE EPBD RECAST 70
ANNEX II: COSTS AND EMISSIONS OF SOME TECHNOLOGIES....................................71

INTRODUCTION

The Part III of the guidebook has presented 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, local mobility solutions and the industry sectors. The technologies available for the heat and cooling are also described along with technologies that optimize energy use in municipal water and wastewater systems through cost-effective efficiency actions. Measures in the local transport sector which is part of mobility solutions in cities 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. BUILDINGS

Energy consumption in buildings is a large share of the world's total end use of energy. Globally, residential and commercial buildings require approximately 40%[1] total end use of energy. Given the many possibilities to reduce buildings' energy requirements, the potential savings of energy efficiency in the building sector would greatly contribute to a reduction of energy consumption. As this reduces greenhouse gas emission, the municipalities should pay a particular attention to the building sector.

Energy is used in buildings for various purposes: heating and cooling, ventilation, lighting and the preparation of hot sanitary water among them. A large part of the energy consumption in residential buildings are used for direct building related use such as space heating, which accounts for more than 50 % in selected IEA Countries (Figure: Energy use in residential buildings**)**.

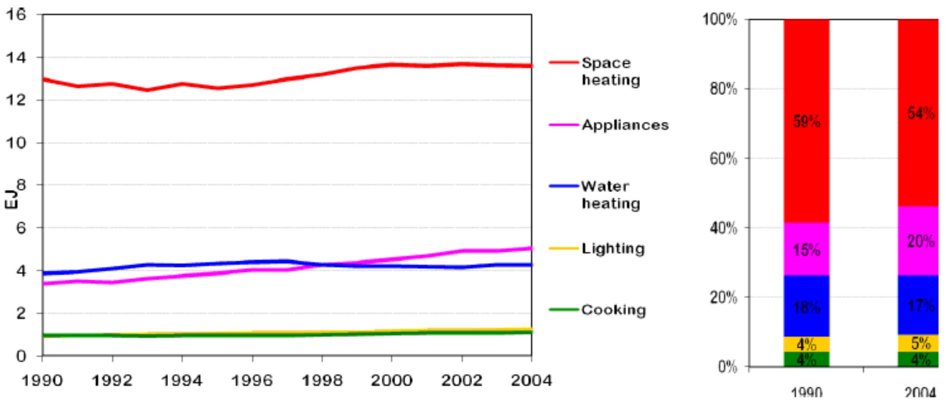


Figure: Energy use in residential buildings

Source: 30 Years of Energy Use in IEA countries. A large part of the energy consumption in residential buildings are used for direct building related use such as space heating, which accounts for more than 50 % in selected IEA Countries.

Building-related end-uses - heating, cooling, ventilation and the preparation of hot sanitary water - require approximately 75% of a residential building's energy demand. For service buildings, the share of energy use for other purposes will often be larger and for some types of service buildings it can be more than 50%.

The demand for energy in buildings is linked to a significant number of parameters related to construction design and the usage of the facilities. It is influenced by the following factors:

- Geometry of the building;
- Performance of building envelope;
- Efficiency of equipment, such as type of heating, air conditioning and lighting systems;
- Usage patterns, management of the building and occupancy behaviour;
- Orientation of the building

The Energy Performance of Buildings Directive – EPBD - (2002/91/EC) [2] 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.

Additional recourses:

1. Report of International Energy Agency "*Cities, Towns and Renewable Energy: Yes in my front yard*" (2009): The report shows how renewable energy systems can benefit citizens and businesses, and it highlights the role of local municipalities that have the power to influence

[1] http://www.iea.org/publications/freepublications/publication/Building_Codes-1.pdf

[2] For countries that are members of Energy Community Treaty. More information on Energy Community Treaty: http://www.energy-community.org.

the energy choices of their citizens. Report includes several case studies chosen to illustrate how enhanced deployment of renewable energy projects can bring benefits, regardless of a community's size or location. http://www.iea.org/publications/freepublications/publication/Cities2009-1.pdf

2. The report *"Analysis of Concerto Energy concepts and guidelines for a whole building approach*" published within the EU-project ECO-City – Joint Eco City developments in Scandinavia and Spain. The objectives of the report is to demonstrate innovative integrated energy concepts in the supply and demand side in three successful Communities in Denmark/Sweden, Spain and Norway: http://www.ecocity-project.eu/PDF/D-2-3-1-1_Concerto_Energyconcepts_Final.pdf

3. The example of legislations developed for EU countries can be found: http://europa.eu/legislation_summaries/energy/index_en.htm

4. The chapter on energy use in buildings of Working Group III of the Fourth Assessment Report (AR4) of the Intergovernmental Panel of Climate Change. The chapter summarises the different strategies, technologies and systems that can be used in order to reduce the energy consumption in buildings. http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch6.html

5. The Sustainable Buildings Centre is an IEA network with focus on policies and measures that lower the energy demand of the buildings sector http://www.sustainablebuildingscentre.org/

1.1. CONSIDERATIONS RELATED TO BUILDING TYPES

1.1.1. New buildings – opportunities in designing, constructing and commissioning

As the lifespan of most new buildings is relatively long, their energy efficiency will influence energy consumption for many years. The decision made at the design stage will thus have crucial impact on the energy performance of the building over decades of building use. It is therefore essential that the energy dimension is included as early as possible in the planning and design phases of new buildings. If energy efficiency is incorporated in the early design phase, it is often considerable less expensive, as the form of the building, its orientation, the orientation of its windows, and its structural materials do not bear additional costs. New buildings can benefit from an integrated design approach, whereby the building performance can be optimised by taking into consideration the interaction of all building components and systems through an iterative process involving all players. An energy performance target can thus be set based on a holistic approach at an early stage of the project, and energy-efficient strategies and technologies can be chosen in view of the climatic conditions and occupant needs. As the energy performance of new buildings decreases, the impact of embodied energy[3] will become increasingly important in relation to the operational energy of the building throughout its lifetime.

Optimising the orientation can maximise daylight, minimise heat gains summer and heat losses in winter, which can have a significant impact on heating, cooling and lighting needs. Great opportunity lies in simple design solutions of buildings that respond to location and climate. For instance, for most North American sites [[4]], simply facing the long side of a building within 15 degrees of true south (and using proper shading to block summer, but not winter sun) can save up to 40% of the energy consumption of the same building turned 90 degrees.

Making the building envelope (exterior walls, roof, and windows) as efficient as possible for the climate can also significantly reduce heating/cooling loads, especially in small buildings (the so-called skin dominated building). For such buildings, optimal insulation, high performance windows, ceiling, radiant barriers and reflective insulation systems, combined with heat-recovery ventilation, can reduce heat losses to the environment. Passive solar and internal heat gains can be harnessed in order to offset the remaining heat losses. For warmer climates, reducing the cooling load is possible through various measures such as self-shading through clustering of buildings, highly reflective building materials, improved insulation, night-purge ventilation, installation of fixed or adjustable shading systems etc.

[3] Embodied energy refers to the energy consumed by all processes related to the construction of the buildings (e.g. mining and processing of natural resources to manufacturing, transport and product delivery).

[4] http://www.iea.org/publications/freepublications/publication/Building_Codes-1.pdf

1.1.2.Operation and maintenance of new and existed buildings

The reduction of energy consumption in new and old 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 Energy Management Systems (EMS) 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. EMS can be used to collect data allowing the identification of additional opportunities for efficiency improvements. More information on Energy Management Systems can be found in **chapter 5** of this report.

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 building level EMS according to the plans or specifications[5]. 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 EMS. It is therefore needed to organise daily monitoring energy performance, calculate, set up and control daily energy targets for actual schedule of building use, provide better training to building operators and awareness raising information and behaviour tips 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~~

1.1.3.Refurbishment of existing buildings

Major renovations or refurbishment, occurring at 30-50 year intervals during a building's lifespan, aim to replace or repair parts of a building, such as windows, doors and outdated equipment in the context of new technology and requirements for functionality.

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. The energy consumption of existing buildings can be reduced by upgrading the windows (e.g. using double or triple glazed technology), adding internal or external insulation (if feasible) to walls during renovations, upgrading the heating and cooling systems, insulating the roofs and reducing the air leakage of the building envelope and ductwork. The cost of different technologies is usually a key factor when choosing the preferred measures. This can be determined through a lifecycle analysis, taking into account investment costs, maintenance and operating costs, earnings from energy produced and disposal costs (if applicable). Energy efficient measures will typically have higher investment costs compared to conventional ones but will result in reduced energy costs, hence are more profitable in the long term.

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).

Additional resources:

1. Prefabricated Systems for Low Energy Renovation of Residential Buildings, Energy Conservation in Buildings and Community Systems Programmes, IEA

   http://www.ecbcs.org/docs/ECBCS_Annex_50_PSR.pdf

[5] In some cases, unrealistic input parameters regarding occupancy behaviour and/or energy management in building energy models may be an additional cause of discrepancies between designed and actual energy performance

1.1.4.Public Buildings

The local authority should provide an example to a community by implementing and adapting measures of energy efficiency in public buildings, because the sector of public buildings falls under municipality control. In addition to promoting energy efficiency to the broader public, a leading role for the public sector can help kick start the energy efficiency market for renovation and subsequently bring costs down for private households and businesses. The sector of public buildings considers all buildings that are owned, rented, managed or controlled by the local, regional, national or public administration.

When planning new constructions or renovations, the local authority (if such power is confirmed by national legislation) 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 and impose strong minimum global energy performance requirements (i.e. expressed in kWh/m^2/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; The example of such norms can be found in the Energy Performance of Buildings Directive (2002/91/EC)[6], where EU countries are obliged to set up a method to calculate/measure the energy performance of buildings and to set minimum standards.

- Impose a certain quantity of renewable energy production while preparing new construction site and object;

- 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.

Additional resources:

1. IT-Toolkit for energy efficient retrofit measures in government buildings http://www.annex46.de/tool_e.html

1.1.5.Historical buildings

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.

Additional resources:

1. The report "Renovation of Historic and Protected Buildings in Geneva" published by Swiss Federal Office of Energy in 2009. It depicts how to achieve thermal renovation of buildings

[6]For countries that are members of Energy Community Treaty. More information on Energy Community Treaty: http://www.energy-community.org.

with architectural and historical value. It describes technical solutions and building details of a selected range of projects, and exploring the limits of possible thermal improvements for various kinds of buildings.
http://www.bfe.admin.ch/php/includes/container/enet/flex_enet_anzeige.php?lang=en&publication=10385&height=400&width=600

2. Report "Sustainable Renovation of Historical Buildings" published by Swiss Federal Office of Energy in 2011. It describes advanced and well tested insulation methods applicable for historical buildings.
http://www.bfe.admin.ch/php/includes/container/enet/flex_enet_anzeige.php?lang=en&publication=10713&height=400&width=600

1.2. IMPROVEMENT OF THE BUILDING ENVELOPE

Common factors of the effectiveness of a building envelope include physical protection from weather and climate (comfort), indoor air quality (hygiene and public health), durability and barrier to the transfer of heat or air between the interior and exterior. Energy efficiency is associated not only with heating, ventilation, and air-conditioning systems but also heat losses through a building envelope to environment as well as exchange between indoor and exterior air. Thus, reducing heat losses from a building, increasing air-tightness and deploying passive heating techniques, can have a major impact on the amount of energy consumed by a building. Therefore effective key actions intended for reducing gains and losses will have a significant influence on the reduction of CO_2 emissions. The performance of the building envelope may be improved through the implementation of the following measures:

Building Shape and Orientation

Building shape, orientation, height-to-floor and window-to-wall area ratios play an important role for determining the heating, cooling and lighting needs. 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/(m^2·K)[8] for single glazed windows can be reduced to 2,7 W/(m^2·K) (reduction of more than 40% of energy consumption per m^2 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/(m^2·K), and up to 0,7 W/(m^2·K) for triple glazing. In addition the g-value[9] 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,

[7] A. Yezioro, Design guidelines for appropriate insolation of urban squares, Renewable Energy 31 (2006) 1011-1023.
[8] From 4.7 W/m2K to 5.7 W/m2K
[9] *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.

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. Solid walls can be insulated either externally or internally for buildings with complex facades. Insulation can also be used to fill cavity walls. 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. Condensation of water vapour may occur when internal insulation is applied and may cause mould growth, indoor air quality problems (sick building syndrome) and in certain cases even lead to structural failures. Avoidance of thermal bridges is also important when a building is insulated as they can significantly increase heat losses and hence heating or cooling demands. Thermal bridges occur through elements which have a much higher conductivity than surrounding material. (e.g. junctions between walls and windows or doors).

Roofs

Insulation measures can also be applied in roofs in order to reduce heat losses through the roof which may account for up to 30% of the total losses through the envelope. Conventional roofs have low solar reflectance levels of 5-15%, which means that they absorb the remaining solar energy during summertime and thus increase the cooling demand of buildings. Cool roofs, on the other hand, help minimise solar absorption and maximise thermal emission, and therefore reduce the heat flow into and energy used for cooling a building. There are two main cool roof types: (1) low-slope roofs which are flat or have a gentle slope and typically used for commercial or office buildings and (2) steep-sloped roofs found in many residential buildings. Cool roof coatings can be applied to a large range of roof materials in low-slope roofs while asphalt shingles are mostly used on steep-sloped roofs. Depending on the climate and length of day in winter months, cool roofs have the drawback of increasing the need for heating in certain regions.

In contrast to cool roofs which use highly reflective and emissive materials to deviate the heat from the sun, green roofs, an alternative environmentally friendly option, refer to rooftop gardens, which can be used to reduce the heat flow into the building, while at the same time provide rainwater management. Green and cool roofs also help to mitigate the urban heat island effect.

Shading Devices

Shading, shutters and reflection can greatly reduce sun penetration of windows and other glass areas. 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.

Air infiltration

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

1.3. BUILDING INSTALLATIONS

New buildings should be equipped with the most energy efficient building installations, while in existing buildings, installations may require replacement during the building's lifetime and therefore offer a good opportunity to significantly improve their energy efficiency through new technologies. The main technologies for heating, cooling and hot water installations are discussed below. Further information can be found in chapter 3, while chapter 2 cover technologies for lighting systems. In general, the energy use for lighting can be significantly reduced through, e.g. proper use of daylight and use of more efficient lighting systems.

Heating and hot water systems

In addition to high-performance envelope and passive heating techniques, installing efficient heating systems to cover the remaining heating needs can ensure that the energy consumption and fuel bills remain low. The same applies for hot water needs. There are various types of heating & hot water systems that can be used. In general, energy efficient heating should include a highly efficient generation system, an effective and efficient distribution system as well as effective controls on both generation and distribution systems.

A **condensing boiler** – most commonly gas fired, although oil fired condensing boilers also exist – is an efficient heat generation system which use an additional heat exchanger to extract extra heat by condensing water vapour from the combustion products. Condensing boilers offer a high thermal efficiency (at least 85%) compared to non-condensing boilers. **Biomass boilers**, using CO_2 neutral products such as wood logs, pellets, etc., may offer an alternative option but have higher installation costs. **Solar thermal** uses a solar collector, which absorbs the incoming solar radiation, and converts it into heat. The heat is then carried from the circulating fluid either to the space heating or hot water equipment or to a thermal energy storage tank for later use at night and/or cloudy days. Solar thermal can cover 50–90% of hot water needs in a year, depending on climatic conditions. **Heat pumps**, whose main operating principle is to absorb heat from a cold place and release it to a warmer one, can also be used for space heating and hot water purposes. More information on these systems can be found in **chapter 3**.In general, integration of heating and hot-water systems leads to higher energy savings.

The **distribution systems** also have an important impact on performance of the overall system. Correct sizing and positioning is important as well as insulation of the pipework in order to minimise heat losses. The ratio between convective and radiant heat is a key feature for heating distribution systems, where radiant systems heat occupants directly – without heating the air to full comfort temperatures – and convective systems transfer heat by convection and raise the ambient temperature to a comfortable level. Radiant systems are more appropriate in buildings with high air change rates, such as warehouses and factories. Radiators, with a convective component of between 50% and 70% are frequently used, while natural convertors are less efficient as they result in steep ambient air temperature gradients. Underfloor heating uses a low temperature warm water distribution system and, therefore operates on reduced energy requirements compared to radiators. A boiler connected to an underfloor system is typically set at 45-60°C whereas the boiler temperature for radiator systems is set at around 80°C.

Central and de-central heating systems offer different benefits and therefore suit different needs. De-central heating may be preferable in multi-family buildings with different occupancy patterns between the housing units, while centralised systems may be a suitable option for buildings with large heating needs. The advantages of de-central heating include reduced capital cost per unit with increased capacity of the generation system as well as operation of generation system at higher efficiencies. On the other hand, decentralised systems may suffer from high investment costs in terms of distribution systems and higher distributional heat losses. Decentralised systems offer flexibility in operational periods, less specialised maintenance and low overall investment cost but tend to have a shorter operational life and may require more control systems.

A **district heating or cooling system** distributes hot water, steam or chilled water through underground pipes to several buildings connected to it. District heating can make use of renewable energy sources, such as biomass, geothermal and solar thermal. Many district heating systems are based on cogeneration (CHP) plants which recycle surplus heat produced from electricity production for heating and hot water purposes in buildings.

Besides large scale cogeneration plants used in district heating, micro-generation plants (compact systems) also exist and are used in individual households and small businesses. More information on CHP can be found in **chapter 3.4.**

Ventilation, cooling and HVAC systems

Energy efficient building designs should aim to provide sufficient health comfort levels through natural means where and when possible. If natural ventilation is not a feasible option, mechanical ventilation and/or air conditioning systems can be installed which, however, will increase the overall energy consumption. In certain cases, it may be even possible to apply mixed-mode ventilation, which allows the use of mechanical systems (in replacement to natural ventilation) only if necessary.

In addition to heat pumps as previously discussed, remaining cooling needs which cannot be met through natural means can be covered by air conditioners which employ the same operating principles with refrigerators. An air conditioner provides cool air through a cold indoor coil (evaporator) connected to a hot outdoor coil (condenser), which in turn releases the collected heated air to the exterior environment. Depending on operating conditions, air conditioners have a nominal coefficient of performance (COP) of 2.2-3.8. As transport and heat losses in ducts in air conditioners, or heat pumps can waste a lot of energy, taking measures such as insulating and air sealing the ductwork can improve the efficiency of the cooling system by 20% or more.

Chillers, on the other hand, are larger cooling devices than air conditioners and produce chilled water rather than cooled air for use in large residential and commercial buildings. Compared to typical air conditioners, chillers' performance can be better by a factor of 3. A chiller can use a liquid via a vapor-compression or absorption refrigeration cycle. For more information on the concept of absorption refrigeration cycle, see **chapter 3**.

HVAC systems provide an air flow at a sufficiently warm or cold temperature in order to maintain the desired thermal conditions. Measures such as heat recovery systems can reduce the energy consumption of HVAC systems as they use heat exchangers to recover heat or cold air from the ventilation exhaust and supply it to the incoming fresh air.

1.4. OTHER MEASURES IN BUILDINGS

Here are some simple measures that may reduce energy consumption:

- Behaviour: adequate behaviour 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. The formation of energy conservation behaviour is required constant steering efforts from the building energy management. It was proven that average durability of one time action energy conservation action is approximately 9 months. It seems to be completely disappearing if building energy management staff will not refresh and restore positive element in behaviours of building users. Further information on behavioural changes of building occupants is exposed in **chapter 10** of this guidebook.

Example from Hamburg: 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.

Example from Tbilisi (Georgia). In the framework of Affordability of Utility Services in Urban Housing in Georgia (2008), energy efficiency (EE) measures were implemented in the common spaces of the residential buildings and in an apartment in Tbilisi. Prior to project implementation, the air temperature in the entrances of the building as well as the internal air temperature in the apartments was very low (-4 ^{o}C, when the outdoor temperature was -6 ^{o}C). Cold air was constantly blowing through the entrance, thus increasing the heating costs for the residents. The following energy efficiency measures were implemented:

- Replacement of wooden single glazed window with the modern metal-plastic window and also replacement of the incandescent light bulbs with compact fluorescent bulbs in the apartment
- Repairing the wooden window frames and glazing in the building entrance,
- Repairing and thermal insulation of the entrance door and installation of a spring system for keeping the door shut,
- Painting of the entrance door and windows.

The budget for this project comprised $1,279, of which:

- Entrance doors and windows - $409,
- Apartment 24 - $870, of which $830 was spent on replacement of the windows, and $40 on the CFLs.

Results of implementing EE measures were monitored. According to the monitoring results the internal air temperature in the building entrance as well as in the apartments has increased by around 3÷4 ^{o}C. Besides the temperature increase, there was also a decreased electricity and natural gas consumption reported by the residents, compared with the pre-project months. According to the analysis of the electricity and natural gas consumption for two heating seasons of 2006-2007 and 2007-2008 there was an aggregate 3% electricity consumption decrease and 12% natural gas consumption decrease in the entrance households.

The results of the EE measures implemented in the apartment were even more significant. According to the monitoring results when comparing the pre- and post-project energy consumption in the aforementioned apartment there was 40% (116 m^3) less natural gas consumed for heating purposes and around 20% (32 kWh) less electricity consumed on a monthly basis.

Example from Khidistavi (Georgia). A project on improving the indoor environment was implemented in Khidistavi School (municipality Gori). The building, constructed in 1973, was heated with 22 inefficient wooden stoves and with five electric space heater with 2,2 kWh capacity. School used inefficient bulbs for lighting. School had no heating, ventilation and etc. systems, and therefore unhealthy indoor microclimate prevailed with very low indoor temperature in winter periods.

Energy Audit suggested improving existing condition in the building by implementing the following energy efficiency measures:

- Change one glass wooden frame windows by double glass plastic frame windows in the classrooms
- Installation wooden burning boiler and heating systems in the classrooms.
- Installation 125wt PV and 400wt wind generator for electricity supply of heating system circulation pumps.

The building consumed totally 262278 kWh/ per year prior implementation of energy efficient measures. According to the monitoring results, energy consumption in the school was reduced by 22% (58776 KWh/year) when comparing the pre- and post-project periods. Implementation of small-scale energy-efficiency measures can lead to significant energy and costs savings combined with relatively short payback for some EE measures.

[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/

- Building energy management: Great savings can be achieved by very simple actions related to proper operation and management of the technical installations and by periodical reminding useful tips in behaviour to building occupants: 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. Further information on behavioural changes is exposed in **chapter 10** of this guidebook.

- Energy monitoring and targeting: implement a daily/weekly/monthly monitoring system of energy consumption in main buildings/facilities, allowing the identification of abnormalities and taking immediate corrective action on one hands on other – to set up and control optimal level of consumption of all kinds of energy sources.. Specific tools and software exist for this purpose, but their applicability is subject of availability of energy meters installed and dedicated users trained.

- 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, and 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: energy efficient 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. The light reflecting characteristics should be taken into consideration when colours for painting walls, sealing or furniture are selected.

- 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

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

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%.

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%

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

[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.

[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.

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.Light Emission Diode (LED) Traffic and Street 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:

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

2.2.2.Public lighting[18]

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

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

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%[19]. 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] E-street project www.e-streetlight.com . Supported by Intelligent Energy Europe

3. HEATING/COOLING AND ELECTRICITY PRODUCTION IN SERVICE, RESIDENTIAL AND PUBLIC SECTORS

This chapter is dedicated to the description of technical measures for the production of heat, cold or electricity that can be implemented service, residential and public sectors

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. Further information is available in the GreenBuilding programme webpage www.eu-greenbuilding.org

3.1. SOLAR THERMAL INSTALLATIONS

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 countries due to the increase of fossil fuels and decrease of solar collector prices. Further information on solar thermal strategies can be found on European Solar Thermal Technology Platform webpage www.esttp.org.

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.

$$\eta = a_0 - a_1 \frac{\left(T_{average} - T_{environment}\right)}{I}$$

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[20] in swimming pools. For the examples of technical and economical project for swimming pools, an interested reader is refereed to website supported by Intelligent Energy Europe www.solpool.info. Solar thermal energy is also applied in district heating and cooling, laundries, car washing and industries[21].

The JRC has created a database that contains solar radiation data for European and other countries. 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/apps4/pvest.php

Additional resources:

- IEA Report on Solar Heating and Cooling (2012) that aims to identify the primary actions and tasks that must be addressed to accelerate solar heating and cooling development http://www.iea.org/publications/freepublications/publication/Solar_Heating_Cooling_Roadmap_2012_WEB.pdf

[20] Further information on Solar Thermal ESCOs is available at www.stescos.org – Project supported by Intelligent Energy Europe

[21] 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

3.2. 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[22] 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[23] varies from 8,0 to 15,5 for roof-top mounted PV systems and from 5.5 to 9.2 for PV facade 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

3.3. BIOMASS BOILERS

Sustainably harvested biomass is considered a renewable resource. However, while the carbon stored in the biomass itself may be CO_2 neutral[24], 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. The example of such definition can be found in Directive 2009/28/EC Art 17[25], Sustainability Criteria for Biofuels and Bioliquids. The national directives or standards can also be applied for definition of sustainability criteria for biofuels and bioliquids in countries of Eastern Partnership and Central Asian Countries.

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.

If the Life Cycle Analysis (LCA) 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. The national directives or standards can also be applied for definition of sustainable biomass usage in countries of Eastern Partnership and Central Asian Countries.

Biomass boilers are available on the market of various thermal capacities starting with 2 kW [26]. 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. Further information about biomass fuels, storage and maintenance is described in the GreenBuilding programme webpage www.eu-greenbuilding.org.

The examples of installations of biomass boilers are indicated at webpage www.biohousing.eu.com supported by Intelligent Energy Europe. The project's webpage offer a tool aimed at comparing costs of biomass and other fossil fuels. In addition, a catalogue of product for the use of biomass is also available from www.aebiom.org

[22] "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

[23] Energy Return Factor: ratio of the total energy input during the system life cycle and the yearly energy generation during system operation.

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

[25] For countries that are members of Energy Community Treaty. More information on Energy Community Treaty: http://www.energy-community.org.

[26] Further information on Biomass Boiler Installation is available at www.biohousing.eu.com supported by Intelligent Energy Europe. The project's webpage offer a tool aimed at comparing costs of biomass and other fossil fuels.

Additional resources:

- IEA report on Bioenergy for Heat and Power (2012): http://www.iea.org/publications/freepublications/publication/name,27281,en.html
- Examples on heat production from biomass in Ukraine can be found from http://biomass.kiev.ua/en/ and http://www.uabio.org/img/files/docs/position-paper-uabio-6-en.pdf

3.4. CONDENSING BOILERS

A condensing boiler is a high efficiency modern boiler that incorporates an extra heat exchanger so that the hot exhaust gases lose much of their energy to pre-heat the water in the boiler system. Condensing boilers 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 ºC. 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. Technical and behavioural information about boiler and installations are available on the Ecoboiler webpage. http://www.ecoboiler.org/ funded by the European Commission - DG TREN.

Additional resources:

1. Practical guidance for application low temperature hot water boilers from the Carbon Trust, which is an organisation helping to accelerate the move to a low carbon economy through carbon reduction and energy-saving strategies http://www.carbontrust.com/media/7411/ctv051_low_temperature_hot_water_boilers.pdf
2. National Energy Foundation provides guidance on Condensing Boilers. http://www.nef.org.uk/energysaving/boilers.htm
3. Energy Efficiency Best Practice in Housing on Domestic Condensing Boilers (by Energy Saving Trust) http://www.west-norfolk.gov.uk/pdf/CE52.pdf
4. Practical guidance for application renewable energy, including biomass heating and heat pumps from the Carbon Trust: http://www.carbontrust.com/resources/guides/renewable-energy-technologies/renewable-energy-and-combined-heat-and-power-(chp)

3.5. HEAT PUMPS

The heat pumps can be applied for space heating systems (i.e., hydronic heating systems) and domestic hot water. A heat pump is able to transfer heat form one fluid at a lower temperature to another at a higher temperature. A heat pump consist of a closed circuit through which a special fluid (refrigerant) flows. This fluid takes on a liquid or gaseous state according to temperature and pressure conditions. This closed circuit consists of:

- A compressor;
- A condenser;
- An expansion valve;
- An evaporator.

The condenser and the evaporator consist of heat exchangers, where tubes with the refrigerant are in contact with service fluids, which may be water or air. The former transfers heat to the condenser (the high temperature side) and takes it away from the evaporator (the low temperature side). Heat is typically transported through engineered heating or cooling systems by using a flowing gas or liquid. In HVAC applications, a heat pump is typically a vapor-compression refrigeration device that includes a reversing valve and optimized heat exchangers so that the direction of heat flow (thermal energy movement) may be reversed. Some systems are reversible and can also be used for cooling purposes.

The heat pumps are classified by the use of:

- Heat transport medium: water or air;
- Heat source: ambient air, exhaust air or ground source.

The most common types of the heat pump are presented below according to the heat/cold source:

Heat source for the heat pump with water as the heat transport medium: ambient air (Figure: Illustration of an ambient air/water heat pump). The efficiently of such pumps depends a lot on an outside temperature, and deceases with the decrease of an ambient temperature. For outside temperature around or lower the freezing point, air-source heat pumps needs a defrost cycle due to the moisture in ambient air, that will condensate and freeze on the outdoor heat exchanger. The ice on the outdoor heat exchanger will decrease the efficiency of the heat pump and it must be removed by an additional heating of the outdoor heat exchanger. The average efficiency of such system ranges from 250 to 440% for heating and cooling, while for heating in Northern European climates the efficiency ranges from 250 to 300 %[27]. (see below Table: Technology and cost characteristics of heat pumps for heating and cooling in single family dwellings in 2007). The average cost of a heat pump covering only space heating is 3000 €, and 10000 € for a heat pump covering both domestic hot water preparation (with a storage tank) and space heating (for the prices in 2012) [28].

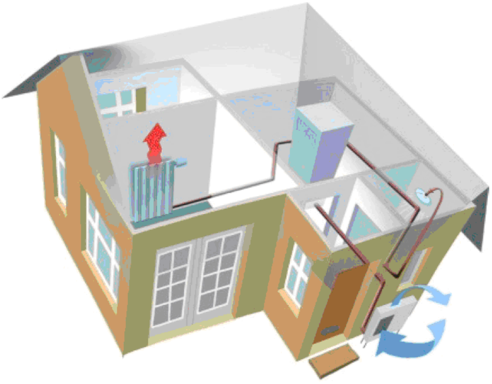


Figure: Illustration of an ambient air/water heat pump (*Reference: Dansk energi, 2011, Den lille bla om varmepumper. www.danskenergi.dk)*

Heat source for the heat pump with water as the heat transport medium: exhaust air (Figure: Illustration of an exhaust air/water heat pump).The system uses exhaust air from a mechanical ventilation extraction system, which limiting the flow rate of exhaust air, and can therefore cover not more than 50 to 60 % of the maximum load for heating in the house. Another heating source (for example electric source) must therefore be available and used in a parallel mode. Such heat pumps are used either as a water heater or combined space and domestic hot water heating. The efficiency is comparable to other heat pump due to the relatively high temperature of the exhaust air. The efficiency for heating the incoming air with an exhaust air constitutes 310 %, as reported in [29]. The average cost of a heat pump covering only domestic hot water preparation ranges from 2000 to 3500 €, and 6000 € for a heat pump covering both domestic hot water preparation and covering space heating (for the prices in 2012) [30].

[27] Dansk energi, 2011, Den lille bla om varmepumper. www.danskenergi.dk

[28] JRC study on "Best available technologies for the heat and cooling market in the European Union" (2012) http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26689/1/eur%2025407%20en%20-%20heat%20and%20cooling%20final%20report-%20online.pdf

[29] Dansk energi, 2011, Den lille bla om varmepumper. www.danskenergi.dk

[30] JRC study on "Best available technologies for the heat and cooling market in the European Union" (2012) http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26689/1/eur%2025407%20en%20-%20heat%20and%20cooling%20final%20report-%20online.pdf

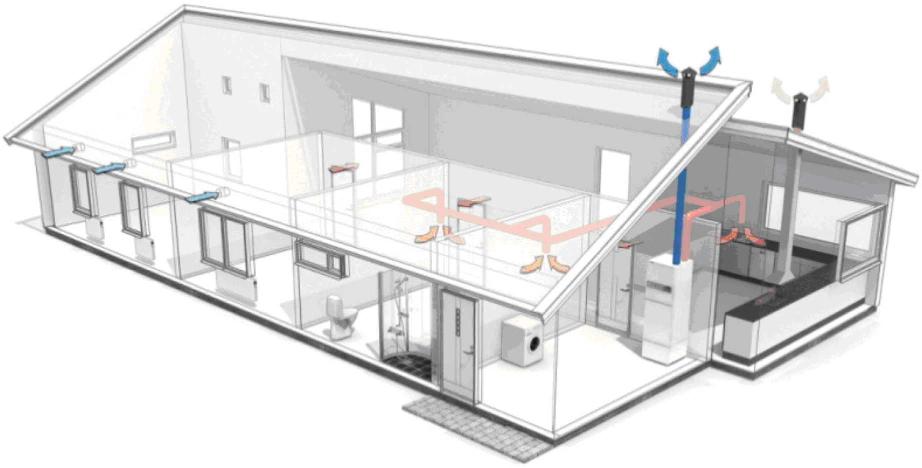


Figure: Illustration of an exhaust air/water heat pump (*Reference: Dansk energi, 2011, Den lille bla om varmepumper. www.danskenergi.dk).*

Heat source for the heat pump air as the heat transport medium: ambient air (Figure: Illustration of an ambient air/ air heat pump) The ambient air–to-air heat pumps are the most widely used due to relatively low costs and simple installation. It can be served as reversible air to air heat pump that has a cooling and a heating function, which particularly useful for the regions that predominantly used cooling and a limited amount of space heating. Even though the COP (Coefficient of Performance, that is a ratio of the amount of heat energy provided for each unit to electricity used to run the pump) in heating modes of these systems drops at low temperatures (and with defrosting cycles) these systems have a high market share in Central and Northern Europe. The average efficiency of such system has the range between 250 and 350 % for heating and cooling, while for heating in Northern European climates the efficiency ranges from 260 to 340 %[31]. The average costs are from 2000 to 3000 € for a compact system excluding costs for the heat distribution system (for 2012) [32].

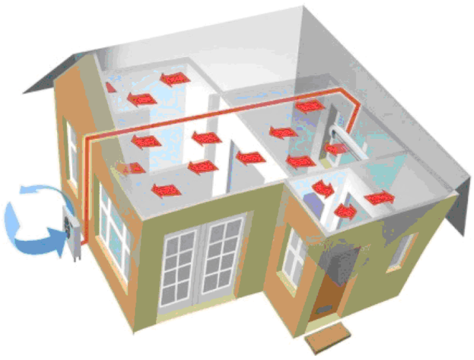


Figure: Illustration of an ambient air/ air heat pump (Reference Dansk energi, 2011, Den lille bla om varmepumper. www.danskenergi.dk)

Heat source for the heat pump with water as the heat transport medium: ground source closed loop brine (Figure: Illustration of a ground source closed loop brine/water heat pump). The most common type of ground source heat pump boiler is the vapour compression heat pumps, including horizontal or vertical collectors in the ground. Ground source horizontal collectors, the pipes are buried in the soil at depth of between 1-2m. Vertical collectors may be used where land area is limited. They are inserted as U-tubes into pre-drilled boreholes generally 100-150mm diameter, 5 m apart and between 15-120m deep. About 30m of pie is necessary per KW installed. Vertical collectors, in some cases, can have a length of up to 250 m. Vertical collectors are more expensive

[31] Dansk energi, 2011, Den lille bla om varmepumper. www.danskenergi.dk

[32] JRC study on "Best available technologies for the heat and cooling market in the European Union" (2012) http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26689/1/eur%2025407%20en%20-%20heat%20and%20cooling%20final%20report-%20online.pdf

than horizontal one but have higher efficiency and require less overall pipe length and pumping energy.

Another possible solution to increase typical performance is to use the ground water (or in some cases surface 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 does not undergo significant fluctuations throughout the year. The temperature levels of the space heating system is typically 55/45 °C (supply and return temperatures) for existing buildings in which the existing radiators often are used. For new buildings lower temperature levels are common, e.g. 35/28 °C, which can be achieved with well-insulated buildings and the application of floor heating systems. These heat pumps are often used for both space heating and domestic hot water and designed to cover 50 to 60 % of the maximum required heat/cold demand. As for the rest of the energy demands a backup system is required (which might be electrical or fuel).

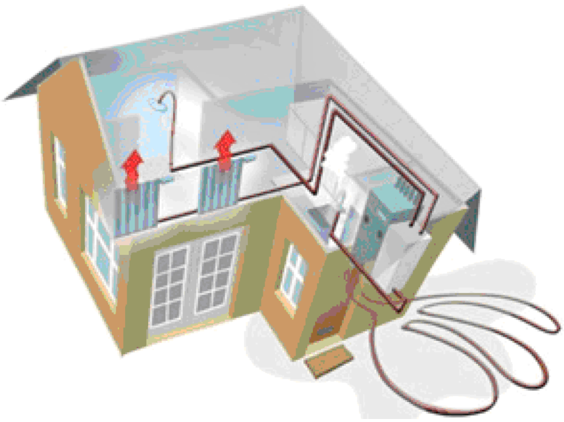


Figure: Illustration of a ground source closed loop brine/water heat pump (*Reference: Dansk energi, 2011, Den lille bla om varmepumper. www.danskenergi.dk)*

The average efficiency of such system ranges from 280 and 500%, while for heating in Northern European climates the efficiency ranges from 290% and 340% [33]. (see below Table: Technology and cost characteristics of heat pumps for heating and cooling in single family dwellings in 2007). The average cost of a heat pump system ranges from 10.000€ to 16.000€ for 8 kW (for the prices in 2012) [34].

Performance of heat pumps

When comparing the different heat pumps in cold climates, a heat pump with a ground heat source (closed loop) has a better energy performance than the ambient-air-based heat pumps. This is due to the cold ambient air during winter (and therefore low efficiency), which requires periodical defrosting of the evaporator. The ground source heat pump in general has larger investment costs than the ambient air based heat pump. For cold climates, heat pumps often require a backup system (which might be electrical or fuel).

A number of parameters influence the performance of the heat pumps, such as the design of the heat pump (the type of heat pump and choice of components); the design temperatures and the control settings of the heat emitter system; and the climatic conditions. Therefore, there will be large variations in generalized performance data for heat pumps, which can be seen below in Table "Technology and cost characteristics of heat pumps for heating and cooling in single family dwellings in 2007".

Table: Technology and cost characteristics of heat pumps for heating and cooling in single family dwellings in 2007 (Reference OECD/IEA, 2011, Technology Roadmap, energy Efficient Buildings: Heating and cooling)

[33] Dansk energi, 2011, Den lille bla om varmepumper. www.danskenergi.dk

[34] JRC study on "Best available technologies for the heat and cooling market in the European Union" (2012) http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26689/1/eur%2025407%20en%20-%20heat%20and%20cooling%20final%20report-%20online.pdf

	North America	China and India	OECD Pacific	OECD Europe
Typical size (kW_{th})	2-19	1.5-4	2.2-10	2-15
Economic life (years)	15-20	15-20	8-30	7-30
Costs				
Installed cost: air-to-air (USD/kW_{th})	360-625	180-225	400-536	558-1 430
Efficiency (%)	250-450	220-350	250-650	250-350
Installed cost: ASHP (USD/kW_{th})	475-650	300-400	560-1 333	607-3 187
Efficiency (%)	250-440	250-440	250-500	250-440
Installed cost: GSHP (USD/kW_{th})	500-850	439-600	1 000-4 000	1 170-2 267
Efficiency (%)	280-500	280-500	280-500	280-500

Where: air-to-air represents an air heat pump with heat source of an ambient air, ASHP denotes water heat pump with heat source of an ambient air, and GSHP derbies water heat pump with ground source closed brine.

Table: Comparison of 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[35]	COP[36]	Primary Energy factor[37]	Primary Energy (kWh)	Primary energy saved (%)[38]
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%**

Additional resources:

1. Further information on heat pumps is available on at www.egec.org and www.groundreach.eu
2. Natural Resources Canada's Office of Energy Efficiency www.oee.nrcan-rncan.gc.ca /
3. Publications on case studies on heat pumps. www.groundmed.eu
4. Heating and Cooling With a Heat Pump by Natural Resources Canada's Office of Energy Efficiency http://oee.nrcan.gc.ca/sites/oee.nrcan.gc.ca/files/pdf/publications/infosource/pub/home/heating-heat-pump/booklet.pdf
5. Information about a European-wide educational programme (GEOTRAINET project) for the training and certification programs of geothermal installations: www.geotrainet.eu

Annex III shows the estimated projections for the cost and performance for some heating and cooling technologies, including heat pumps, in 2030 and 2050. It indicates the significant difference between different design options and sizes.

[35] Based on the Lower Heating Value (LHV)
[36] This ratio is a function of the outdoor or temperature or the ground temperature
[37] 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%.
[38] Seasonal effects are not considered in this calculation. (-) is saving and (+) is wasting in comparison with the first case of the table

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.

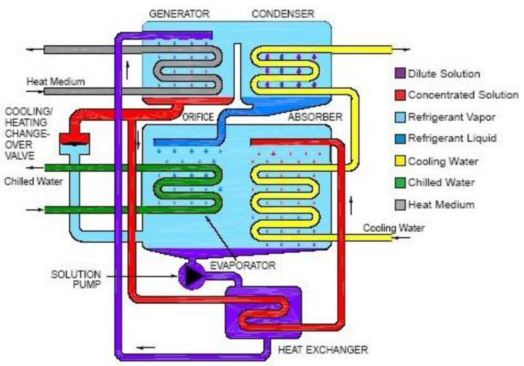


Figure 1: Refrigeration absorption cycle

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 80ºC energy source and an energy sink under 30-35ºC. Therefore the energy can be provided by solar thermal collectors[39] 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 160ºC 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[40], 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).

3.7. HVAC SYSTEM INDICATORS[41]

HVAC systems maintain a building's comfortable indoor climate through Heating, Ventilation and Air Conditioning (Cooling). These systems profoundly influence energy consumption in buildings. Efficiency improvements in HVAC systems can lead to substantial savings, but these savings will also depend on the efficiency of the building in general. Efficiency improvements in HVAC systems should consider not only general performance characteristics (such as energy efficiency ratio) but also consider performance over the period of operation, which is defined by seasonal performance factor.

The performance of HVAC systems is characterized by two parameters, such energy efficiency ration and seasonal performance factor. The energy efficiency ratio (EER) measures the amount of electricity required by an air conditioning 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)

---

[39] www.iea-shc.org/task38/index.html

[40] POSHIP The Potential of Solar Heat in Industrial Processes www.aiguasol.com/poship.htm

[41] 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.

$E_{cooling}$: 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 air conditioning 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.

3.8. 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.

4. CHP - COMBINED HEAT AND POWER GENERATION

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

Cogeneration units can run on a variety of fuels, all of which offer unique environmental benefits compared to the conventional technology alternatives (**Figure**: The cogeneration principle). The following type of fuels can be used:

- Fossil fuel.
  - *Natural gas.* Natural gas benefits from several factors, such as its high heating value, an attractive fuel cost and being available in many locations. In addition, it is a cleaner fuel with low carbon content. It produces 40 to 50% less CO2, than coal fired CHP[42]. These characteristics make natural gas fuel of choice in Cogeneration systems. In Europe, natural gas is the widely used fuel in CHPs with a share of 39.4%.
  - *Heating oil.* Heating oil has high energy content per volume and is very easy to transport and store.
- Renewable fuels. In Europe, 11% of electricity produced by CHPs comes from renewable fuels[43]. Cogeneration fuelled by renewable energy combines the advantages of environmental sustainability and maximum energy efficiency.
  - *Biomass*. Solid biomass (wood derived) is combusted CHP for heat production. Several systems can be considered, depending on the size. Small-scale heating systems for households typically use firewood or pellets. Medium-scale users typically burn wood chips in grate boilers while large-scale boilers are able to burn a larger variety of fuels, including wood waste and refuse-derived fuel. Heat can also be produced on a medium or large scale through cogeneration which provides heat for industrial processes in the form of steam and can supply district heat networks.
  - *Biogas.* Biogas is used via conversion of bioenergy or capture and upgrade or "waste". Many small-medium sized CHP are operating on biogas. Biogas produces no net carbon emissions.
  - *Biodiesel.* The biodiesel fuel is made from biomass such as vegetable oils or rapeseed oil. According to *COGEN Europe,* biodiesel price can be competitive in the future.
  - *Geothermal.* A growing area of interest is focusing on the use of heat from geothermal source to be coupled to a CHP unit.

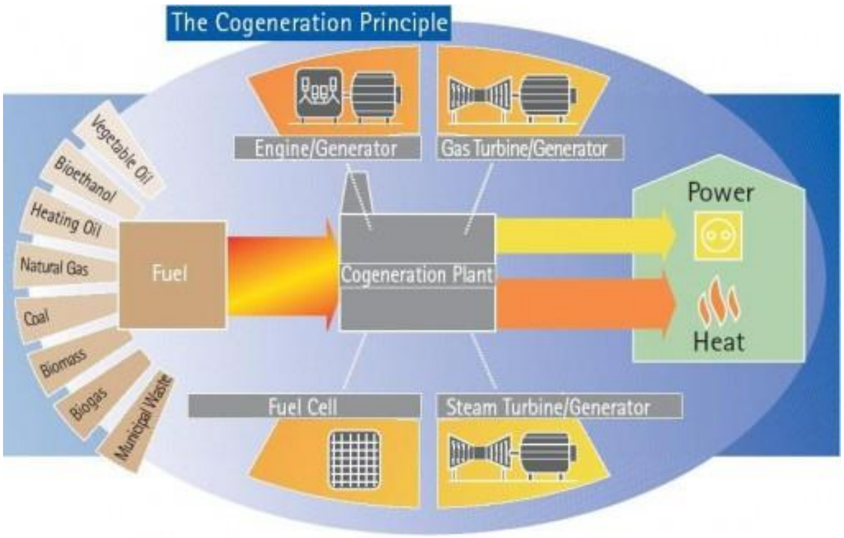


Figure: The cogeneration principle

Source: COGEN Europe[44], The European Association for the Promotion of Cogeneration

[42] www.cogen-challenge.org

[43] IEA Publication, Co-generation and renewables: Solutions for a low-carbon energy future (2011) http://www.iea.org/publications/freepublications/publication/name,3980,en.html

[44] The European Association for the Promotion of Cogeneration, http://www.cogeneurope.eu/

CHP leads to a reduction of fuel consumption by approximately 10 - 25% compared with conventional electricity and separate heat production (**Figure:** The cogeneration Plant and Separate Heat and Power Production). The reduction of atmospheric pollution follows the same proportion. 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. 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.

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%

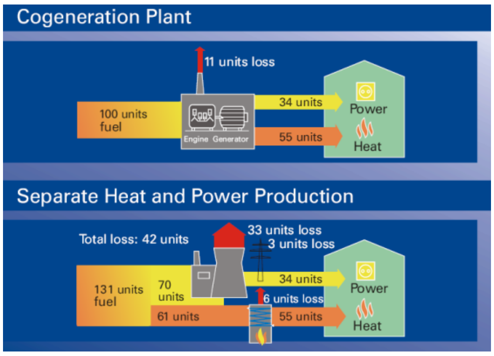


Figure: The cogeneration Plant and Separate Heat and Power Production

Source: COGEN[45] Challenge Project – Supported by Intelligent Energy Europe

4.1. Industrial CHP

Industrial CHP are ranging in scale from a few MW_e to the size of a conventional power station, where the typical system size is 1 – 500 MW_e. These plants provide high value heat – at the temperatures and pressures required by industry – along with electricity. In some cases surplus heat can also be used to meet heat requirements of the surrounding local community. Likewise, electricity that is surplus to the needs of the site can be fed into the local network.

CHP facilities can be found in all manufacturing industries except apparel manufacturing and leather and tanning. However existing industrial CHP capacity is concentrated in a few industries [41]: Paper and Allied Products (20%), Chemicals and Allied Products (40%), and Petroleum Refining and related Products combined (15%) represent more than two thirds of the total electric and steam capacities at existing industrial CHP installations. These industries have been traditional hosts for CHP facilities. The plants generally have high process related thermal requirements not subject to daily and seasonal weather-related fluctuations, so energy is an important part of their business, and operation and maintenance personnel are available and competent to manage CHP systems.

In some industries, low-cost fuel sources (i.e. waste streams) are available for use in CHP systems. While industrial systems over 1 MW_e make up the bulk of global CHP capacity, many smaller-scale industrial sites have smaller systems, utilising technologies similar to those used in commercial buildings. Typical prime movers for industrial CHP are steam turbines, gas turbines, reciprocating engines (i.e., compression ignition) and combined cycles for larger systems.

[45] www.cogen-challenge.org project supported by Intelligent Energy Europe

4.2. Micro CHP

Small-scale CHP installation refers to the production of heat and power for commercial and public buildings, apartments and individual houses. These units meet the demand for both space heating and hot water whilst providing electricity to supplement or replace the grid supply. As compact systems, they are extremely simple to install. The system might be based on engines or gas micro-turbines.

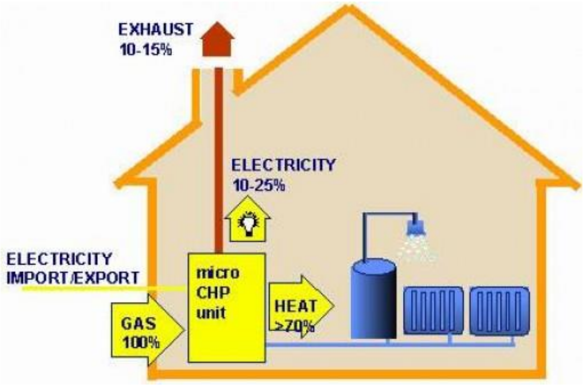


Figure: Small-scale CHP for buildings

Source: COGEN Europe[46], The European Association for the Promotion of Cogeneration

Micro CHP provides the following key benefits:

- Micro-CHP allows the supply of both heat and electricity from a single energy source.
- Carbon emissions are reduced by generating electricity at the point of use – avoiding the system losses associated with central power production.
- Economic savings are generated for the user, by reducing imported electricity and selling surplus electricity back to the grid. This means lower energy bills for energy customers.
- Security of supply is greatly enhanced by reducing reliance on centralised power production
- Micro-CHP also allows gas to be used more efficiently.

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[47]. CO_2 emissions of micro cogeneration systems are in the range 300-400 g/kWh_e.

Additional resources:

1. Article of The European Association for the Promotion of Cogeneration, Micro CHP – edging towards the mass market, Cogeneration and On-Site Power Production. 2009. Can be assessed from the Website of The European Association for the Promotion of Cogeneration: http://www.cogeneurope.eu/medialibrary/2011/06/14/c68cb18d/COSPP-article-Micro-CHP-edging-towards-the-mass-market.pdf
2. Article of The European Association for the Promotion of Cogeneration, Micro CHP – edging towards the mass market, COGEN Europe briefing paper on micro CHP, Micro CHP: Empowering people today for a smarter future tomorrow, 2010. Can be accessed from the Website of The European Association for the Promotion of Cogeneration: http://www.cogeneurope.eu/medialibrary/2011/06/14/2a43be57/171210-COGEN-Europe-briefing-paper-on-micro-CHP.pdf
3. Report "Cogeneration at Small Scale, Simultaneous Production of Electricity and Heat" from the 6th Framework Programme of the European Union:

[46] The European Association for the Promotion of Cogeneration, http://www.cogeneurope.eu/

[47] Micro cogeneration: towards decentralized energy systems. Martin Pehnt, Martin Cames, Corinna Fischer, Barbara Praetorius, Lambert Schneider, Katja Schumacher, Jan-Peter Voss – Ed. Springer

http://www.erec.org/fileadmin/erec_docs/Projcet_Documents/RESTMAC/Brochure4_Cogeneration_low_res.pdf

4.3. Micro Commercial CHP[48]

The use of CHP in commercial buildings and multi-residential complexes has increased steadily. This is due largely to technical improvements and cost-reductions in smaller-scale, often pre-packaged, systems that match thermal and electrical requirements. Colleges and university, Government buildings, hospitals, offices, airports and health/sports centres represent almost 90% of installed CHP in the commercial sector utilizing gas turbines in the 1-10 MW range. Typical prime movers for this kind of CHP are reciprocating engines (i.e., spark ignition), stirling engines, fuel cells and microturbines. These examples of commercial and institutional CHP users tend to have significant energy costs as a percentage of total operating costs, as well as balanced and constant electric and thermal loads (the temporal coincidence of heating / cooling demand with electricity demand can be particularly important for these applications*).* Residential "micro" CHP technologies are also beginning to be developed and sold at the individual household level, and thus represent a potential mass market CHP product, provided fully competitive and reliable products can be brought to market.

4.4. Fuel Cells and Trigeneration

Fuel Cells: A new development is the use of fuel cells for cogeneration. Fuel cells convert the chemical energy of hydrogen and oxygen directly into electricity without combustion and mechanical work such as in turbines or engines. A fuel cell consists of two electrodes separated by a membrane. Hydrogen passes over one electrode and oxygen over the other. The electrode surface has a catalyst that splits the hydrogen gas into protons and electrons. The protons only can pass through the membrane and react with the oxygen and electrons on the other side to make water. The electrons cannot pass through the membrane and, in the process of bypassing the membrane, produce electricity for use in the home. Fuel cells are much less polluting and about twice as efficient as typical steam-turbine electricity production. Once the hydrogen is obtained, the fuel cells' only by-products are heat and water. The hydrogen is usually produced from natural gas by a process known as reforming.

The total efficiencies of cogeneration systems reach 85% to 90%, while the heat to power ratio is in the range 5:4. Fuel cells with a capacity of 1 kW_e provide heat and power to single family houses, whereas bigger applications of around 300 kW_e can be used in hospitals for example. Fuel cells are an emerging technology and their high cost precludes their use in most on-site generation applications: fuel cells are finding a small niche market in smaller applications with high power costs, severe environmental constraints, and high power quality requirements.

Trigeneration: With total system efficiencies 30% to 50% greater than "cogeneration" is the simultaneous production of power/electricity, hot water and/or steam, and chilled water from one fuel[49]. A trigeneration power plant is a cogeneration power plant that has added absorption chillers for producing chilled water from the heat that would have been wasted from a cogeneration power plant. 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.

Trigeneration plants can reach system efficiencies that exceed 90%. In addition to the economic benefits and advantages, trigeneration plants reduce use of primary energy resources and help environment by dramatically reducing greenhouse gas emissions such as carbon dioxide - when compared to typical power plants.

[48] The European Association for the Promotion of Cogeneration, http://www.cogeneurope.eu/
[49] www.polysmart.org are financed by the 6th Framework Programme of the European Union

4.5. District Heating/Cooling and Cogeneration

District Heating and Cooling (DHC) networks provide a major opportunity for CHP development. The fundamental idea behind modern district heating is to recycle this surplus heat which otherwise would be wasted- from electricity production, from fuel and biofuel-refining, and from different industrial processes (**Figure:** The diversity of resources used by district heating and cooling systems). DHC with CHP can provide the double benefit of reducing costs and impacts of both electricity generation and heat supply. District cooling offers the same opportunity for decarbonizing cooling supply. These benefits stem from the fact that these applications are inherently energy efficient and produce energy where it is needed. Their benefits include:

- Dramatically increased flue efficiency (see Figure: The cogeneration Plant and Separate Heat and Power Production);
- Reduced emissions of CO2 and other pollutants;
- Cost savings for the energy consumer;
- Reduced need for transmission and distribution networks
- Beneficial used of local energy resources (particularly through the used of waste, biomass mad geothermal resources in DHC systems), providing a transition to a low-carbon future

Due to enhanced energy supply efficiency and utilisation of waste heat and low-carbon renewable energy resources, CHP, particularly together with district heating and cooling (DHC), is an important part of national and regional GHG emissions reductions strategies

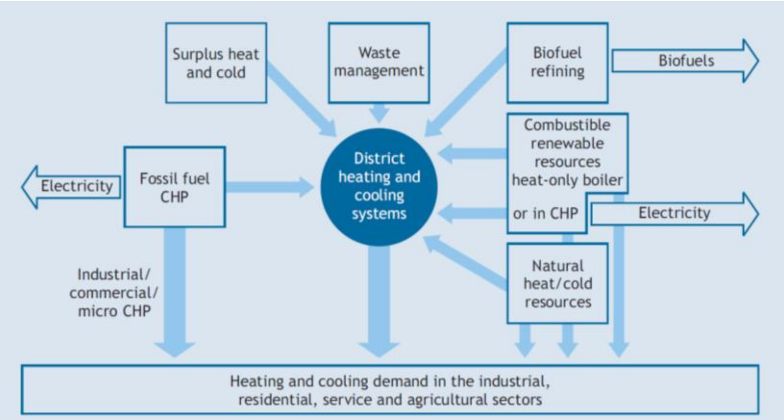


Figure: The diversity of resources used by district heating and cooling systems[50]

Table presents the majority of CHP applications for industrial, commercial/institutional, and DHC. Advancements in technology development have led to the availability of smaller CHP systems, with reduced costs, reduced emissions and greater customisation. As a result, CHP systems are increasingly used for smaller applications in the commercial and institutional sectors, and are being incorporated more often into DHC systems.

Table: The summary of CHP applications for industrial, commercial/institutional, and DHC

Feature	CHP – industrial	CHP – commercial / institutional	District heating and cooling
Typical customers	Chemical, pulp and paper, metallurgy, heavy processing (food, textile, timber, minerals), brewing, coke ovens, glass furnaces, oil refining	Light manufacturing, hotels, hospitals, large urban office buildings, agricultural operations	All buildings within reach of heat network, including office buildings, individual houses, campuses, airports, industry
Ease of integration with renewables and waste energy	Moderate – high (particularly industrial energy waste streams)	Low – moderate	High

[50] Euroheat and Power

Temperature level	High	Low to medium	Low to medium
Typical system size	1 – 500 Mwe	1 kWe – 10 MWe	Any
Typical prime mover	Steam turbine, gas turbine, reciprocating engine (compression ignition), combined cycle (larger systems)	Reciprocating engine (spark ignition) , stirling engines, fuel cells, microturbines	Steam turbine, gas turbine, waste incineration, CCGT
Energy/fuel source	Any liquid, gaseous or solid fuels; industrial process waste gases (e.g. blast furnace gases, coke oven waste gases)	Liquid or gaseous fuels	Any fuel
Main players	Industry (power utilities)	End users and utilities	Include local community ESCOs, local and national utilities and industry
Ownership	Joint ventures/ third party	Joint ventures/ third party	From full private to full public and part public/private, including utilities, industry and municipalities
Heat/electricity load patterns	User- and process-specific	User-specific	Daily and seasonal fluctuations mitigated by load management and heat storage

In most cases, the decision to install a CHP plant as part of a DHC system will hinge on the same factors as for an industrial installation, including: the timing and nature of the thermal load, fuel availability, and opportunities for the economic use of the electricity. However, population density is also a key consideration, because DHC systems rely on a concentrated demand for space heating/conditioning. This is important because of the need to minimise the distances that heat can be transported, and due to the high costs of installing heat distribution systems. Countries with the largest number of heating degree days tend to have the greatest penetration of district heating. Moreover, due to the highly capital-intensive nature of these systems, DHC supports a greater level of local government involvement in providing services. As a result, DHC systems may be communally owned, but funded by public and/or municipal authorities. District cooling is being increasingly pursued as an alternative to conventional electricity- or gas-driven air conditioning systems. Due to the use of resources that would otherwise be wasted or difficult to use, district cooling systems reach efficiencies that are between 5 and 10 times higher than with traditional electricity driven equipment[51]. They can contribute to avoid electricity peak loads during cooling season, offering cost savings and reliability benefits.

Additional resources:

4. The European Association for the Promotion of Cogeneration, http://www.cogeneurope.eu
5. The CODE project (www.code-project.eu) has published Cogeneration – Case Studies Handbook, 2011, which can be downloaded from http://www.code-project.eu/home/latest-news/new-cogeneration-case-studies-handbook/
6. IEA Publication, Co-generation and renewables: Solutions for a low-carbon energy future, 2011. http://www.iea.org/publications/freepublications/publication/name,3980,en.html
7. IEA Publication, Cogeneration and District Energy, 2009. http://www.iea.org/publications/freepublications/publication/name,3805,en.html

[51] Euroheat and Power

8. IEA Publication, Combined Heat and Power, 2008 http://www.iea.org/publications/freepublications/publication/name,3769,en.html

9. Report form the project supported by Intelligent Energy Europe, Meet cooling needs in SUMMER by applying HEAT from cogeneration (SUMMERHEAT) http://eaci-projects.eu/iee/page/Page.jsp?op=project_detail&prid=1746&side=downloadablefiles

5. FUEL CELLS

This chapter describes flues cells technology for generating electricity, which has traditionally been a rather polluting process. In addition to electricity, fuel cells produce water, heat and, depending on the fuel source, very small amounts of nitrogen dioxide and other emissions.

5.1. Fuel Cells Technology

Unlike internal combustion engines or coal/gas powered turbines, fuel cells do not burn fuel. They convert the chemical energy of the fuel into electricity through a chemical reaction. Thus, fuel cells don't produce large quantities of greenhouse gases associated with fuel combustion, such as carbon dioxide (CO2), methane (CH4) and nitrogen oxide (NOx). Fuel cell emissions amount to water in the form of steam and low levels of carbon dioxide - or no CO2 at all, if the cell uses pure hydrogen as a fuel. In additional, fuel cells technology operates silently, because they do not involve noisy high-pressure rotors or loud exhaust noise and vibration.

A fuel cell converts the chemical energy from a fuel into electricity through a chemical reaction with oxygen or another oxidizing agent. Fuel cells consist of an anode (negative side), a cathode (positive side) and an electrolyte that allows charges to move between the two sides of the fuel cell (Figure: Principle scheme for Fuel Cells). Electrons are drawn from the anode to the cathode through an external circuit, producing direct current electricity. As the main difference among fuel cell types is the electrolyte, fuel cells are classified by the type of electrolyte they use, i.e., high and low temperature fuel cells (PEMFC, DMFC). Hydrogen is the most common fuel, but hydrocarbons such as natural gas and alcohols (i.e., methanol) are sometimes used. More information on natural gas fuel cells can be found in the section 5.3 of this Guidebook. Fuel cells are different from batteries in that they require a constant source of fuel and oxygen/air to sustain the chemical reaction, and they produce electricity as long as these inputs are supplied.

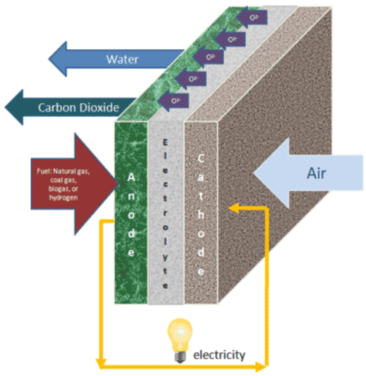


Figure: Principle scheme for Fuel Cells[52]

Fuel cells have the following advantages compared to conventional power sources, such as internal combustion engines or batteries[53]:

- Fuel cells have a higher efficiency than diesel or gas engines.
- Most fuel cells operate silently, compared to internal combustion engines. They are therefore suited for buildings with specific requirements, for example hospitals.
- Fuel cells can eliminate pollution caused by burning fossil fuels; hydrogen fuelled fuel cells produce only water as by-product.
- If the hydrogen comes from the electrolysis of water driven by renewable energy, then using fuel cells eliminates greenhouse gases over the entire cycle.
- Fuel cells do not need conventional fuels such as oil or gas and can therefore reduce economic dependence on oil producing countries, creating greater energy security.

[52] http://energy.gov/fe/why-sofc-technology
[53] http://www.fuelcelltoday.com/about-fuel-cells/applications/stationary

- Fuel cells are not grid-dependent, because hydrogen can be produced anywhere where there is water and a source of power, and generation of fuel can be distributed.
- The use of stationary fuel cells to generate power at the point of use allows for a decentralised power grid that is potentially more stable.
- Low temperature fuel cells (PEMFC, DMFC) have low heat transmission which makes them ideal for many applications.
- Higher temperature fuel cells produce high-grade process heat along with electricity and are well suited to cogeneration applications (such as, combined heat and power for residential use).
- Operating times are much longer than for batteries, since increasing operating time requires only increased amount of fuel, but it does not require enhancing capacity of the unit.
- Unlike batteries, fuel cells have no "memory effect" when they are getting refuelled.
- The maintenance of fuel cells is simple, since there have no major moving parts.

5.2. Main applications

Fuel cells can be applied for low-quality gas from landfills or waste-water treatment plants to generate power and lower methane emissions. Fuel cell are also used to power fuel cell vehicles, including automobiles, buses, forklifts, airplanes, boats, and motorcycles.

Power generation: Fuel cells are used for primary and backup power for commercial, industrial and residential buildings, and in remote or inaccessible areas. A fuel cell system running on hydrogen can be compact and lightweight, and have no major moving parts. This together with absence of combustion ensures that high reliability fuel cells can be achieved. Furthermore, fuel cell electrolyser systems do not store fuel, but rather rely on external storage units, thus they can be applied in large-scale energy storage.

The energy efficiency of a fuel cell is between 40–60% depending on the type of fuel cells[54]. This can increase up to 85% if a by-product of fuel cells - waste heat - is captured for use, for example for heating buildings. Thus their efficiency is higher than efficiency of traditional coal power plants, and in cogeneration systems, fuel cells could save 20–40% of energy costs[55].

Additional recourses:

1. The report of The Business Case for Fuel Cells (by Breakthrough Technologies Institute in Washington, D.C., and the U.S. Department of Energy's Fuel Cell Technologies Program) gives an overview of practical application of fuel cells technology. http://www.fuelcells.org/uploads/BusinessCaseforFuelCells.pdf
2. The project of Stuart Island Energy Initiative has involved application of fuel cell to provide full electric back-up to the off-the-grid residence. http://www.siei.org/fuelcell.html

Cogeneration: A residential-scaled energy system of flue cells is one of the available technologies for micro combined heat and power (microCHP) or microgeneration. Residential and small-scale commercial fuel cells are available to fulfil both electricity and heat demand from one system. Fuel cell technology in a compact system converts natural gas, propane, and eventually biofuels—into both electricity and heat, producing carbon dioxide (and small amounts of NOx) as exhaust.

The system generates constant electric power and sells excess of generated power back to the grid. Simultaneously, the system produces hot air and water from the waste heat. The waste heat from fuel cells can be diverted during the summer directly into the ground providing further cooling while the waste heat during winter can be pumped directly into the building. Micro CHP is usually less than 5 kW_e for a residential applications and small enterprises[56].

A residential-scaled fuel cell is an alternative energy technology that increases efficiency by simultaneously generating power and heat from one unit, on-site within a home. This allows a

[54] http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/fc_types.html
[55] http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/48219.pdf
[56] http://www.cogen.org/ Cogen Europa

residence to reduce overall fossil fuel consumption, reduce carbon emissions and reduce overall utility costs, while being able to operate 24 hours a day.

Additional resource:

1. The practical examples of applying fuel cell technologies can be retried from the following link: http://www1.eere.energy.gov/hydrogenandfuelcells/applications.html. The examples involve specialty vehicles, emergency backup power, and prime power for critical loads.

5.3. Natural Gas Fuel Cells

For fuel cells, the most usually fuel is hydrogen, because it produces no emission of harmful pollutants. However, other fuel can be employed and natural gas-powered fuel cells are considered to be efficient alternative when natural gas is available at competitive rates. In fuel cells, a stream of fuel and oxidants passes over electrodes that are separated by an electrolyte. This produces a chemical reaction that generates electricity without requiring the combustion of fuel, or the addition of heat as is common in the traditional generation of electricity. When natural pure hydrogen is used as fuel, and pure oxygen is used as the oxidant, the reaction that takes place within a fuel cell produces only water, heat, and electricity. With other fuel, fuel cells result in very low emission of harmful pollutants, and the generation of high-quality, reliable electricity[57].

The benefits of natural gas-powered fuel cells are the following:

- *Environmental benefits* - Fuel cells provide the clean method of producing electricity from fossil fuels. While a pure hydrogen and oxygen fuel cell produces only water, electricity, and heat, other types of fuel cells emit trace amounts of sulfur compounds and very low levels of carbon dioxide. However, the carbon dioxide produced by fuel cell use is concentrated and can be readily recaptured, as opposed to being emitted into the atmosphere.
- *Efficiency* - Fuel cells convert the energy stored within fossil fuels into electricity much more efficiently than traditional generation of electricity using combustion. This means that less fuel is required to produce the same amount of electricity. The National Energy Technology Laboratory[58] estimates that fuel cell generation facilities (in combination with natural gas turbines) can be produced that will operate in range from 1 to 20 MW_e with 70% efficiency. This efficiency is much higher than the efficiencies that can be reached by traditional generation methods within given output range.
- *Distributed Generation* - Fuel cells can come in extremely compact sizes, allowing for their placement wherever electricity is needed. This includes residential, commercial, industrial, and even transportation settings.
- *Reliability* - Fuel cells are completely enclosed units, with no moving parts or complicated machinery. This results into a reliable source of electricity, capable of operating for many hours. In addition, they are very quiet and safe sources of electricity. Fuel cells also do not have electricity surges, meaning they can be used where a constant, reliable source of electricity is needed.

Additional resources:

1. Informational resource on the natural gas technologies, including fuel cells can be found on website site that has been developed and is maintained by the Natural Gas Supply Association: http://www.naturalgas.org

[57] http://www.naturalgas.org Website site has been developed and is maintained by the Natural Gas Supply Association to serve as an informational resource on the many aspects of natural gas

[58] http://www.naturalgas.org Website site has been developed and is maintained by the Natural Gas Supply Association to serve as an informational resource on the many aspects of natural gas

6. ENERGY MANAGEMENT SYSTEMS IN BUILDINGS (BEMS)

This chapter related to the technical measures of energy management systems in buildings , which is technical specification for increasing effectiveness of energy management in organizations that are managing building stock (described in Part I of this Guidebook, Chapter 7.2.6: Integration of an Energy Management System based on ISO 50001:2011).

A significant part of building energy management systems is dedicated to automation of control of physical processes related to creation of indoor climate such as heating, ventilation, and air-conditioning (HVAC). It usually uses software to control energy-consuming units and equipment, and can monitor and report on their performance. BEMS facilitates the integration and interoperation of equipment, appliances, and devices via a network of sensors and controls. Such a BEMS enables two-way data flow between the end user and the end devices in near-real time. It offers remote management of energy- and resource-intensive building subsystems, such as HVAC and lighting, from a central platform, web-based portal, or cloud-based software application. The performance of the BEMS is directly related to the number of comfort parameters, technologies presented, type and source of energy consumed in the buildings. BEMS are generally composed by:

- Sensors and controls:Controllers, sensors (temperature, humidity, luminance, presence…) and actuators (valves, switches…) for different types of parameters Sensor and control technologies for a BEMS provide the intelligent backbone that connects equipment, building subsystems, and analytical tools in near-real time to foster a proactive, reactive, and sometimes autodidact, efficient building technology ecosystem. While sensors and controls are the critical enabling aspect of a BEMS, often they are the most overlooked piece of the system.
- Equipment: HVAC central system with local controllers for separate areas or rooms (when zoning of complex buildings that have multiple functions) and central computer assisted control;
- Software systems: Central control management software for separate areas or rooms (when zoning occurs);
- Services: Monitoring through energy consumption measurement devices. Energy monitoring and targeting is the collection, interpretation and reporting of energy use. Its role within energy management is to measure and maintain performance and to locate opportunities for reducing energy consumption and cost.

The benefits of energy monitoring & targeting include:[59]

- Achieving energy consumption and cost savings, typically 7%-12%
- Reducing the environmental impact of energy usage
- Providing energy information for assessing energy projects and new plant acquisitions
- Improving preventative maintenance
- Avoiding waste and improving product quality through increased control

Additional resources:

The examples of energy management systems in buildings can be found from the Sustainable Energy Authority of Ireland:

http://www.seai.ie/Your_Business/Technology/Buildings/Building_Energy_Management_Systems_BEMS_.html

[59] Sustainable Energy Authority of Ireland: http://www.seai.ie/Your_Business/Technology/Buildings/Building_Energy_Management_Systems_BEMS_.html

7. DISTRICT HEATING AND COOLING TECHNOLOGIES (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[60]. 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[61].

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.

7.1. Geothermal District Heating with/without absorption heat pump

Geothermal district heating employs heat from underground water reservoirs, which is transferred to a heating system by a heat exchanger. In many cases, heat pumps can also be applied and extract heat from reservoirs located close the ground surface that have lower temperatures than reservoirs located at deeper levels. The compressors can be either a compressor type driven by electricity or an absorption type driven by heat source. An efficient solution is to use heat from a geothermal source and then to increase the temperature of heated medium by applying an absorption driven heat pump. Steam from the boilers in a district heating plant is used to drive the absorption heat pump. The boilers can use biomass or waste materials as energy source. In this case, the temperature of the re-injected water can be around 8°C and the supply temperature of the district heating system is 80°C during winter. The typical system for district heating is a system with a production well, heat exchangers and/or heat pumps, transferring the heat to the district heating network and a reinjection well transferring the cooled water to the reservoir (See Figure: District heating base on geothermal sources). The specific investment cost for this system can be estimated around at 1.6 M€/MW [62].

---

[60] 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

[61] Some data about CO2 emissions from district heating are available on the EUROHEAT project webpage.

[62] JRC study on "Best available technologies for the heat and cooling market in the European Union" (2012) http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26689/1/eur%2025407%20en%20-%20heat%20and%20cooling%20final%20report-%20online.pdf

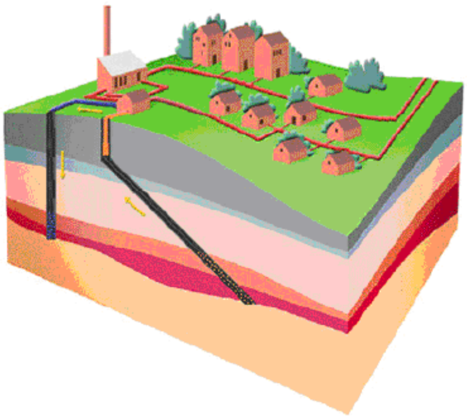


Figure: District heating base on geothermal sources
(Source: Danish Energy Agency and Energinet, DK 2010, Technology Data for Energy Plants)

Figure below gives an example of a system with an absorption heat pump. More information on absorption heat pumps can be found in a section 7.3 The numbers in the figure indicate the energy flows relative to the extracted amount of geothermal heat, 100 energy units. Heat from the warm brine (saline water) from the reservoir is first transferred to the circulating water in the district heating system by the heat exchanger. Then, heat is extracted from the brine by the absorption heat pump and the brine is re-injected to the reservoir. The steam driven absorption heat pump increases the temperature and transfers the heat to the circulating water in the district heating system.

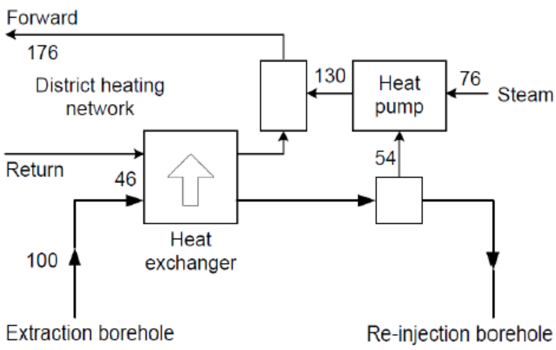


Figure: Illustration of a system with an absorption heat pump
(Source: Danish Energy Agency and Energinet, DK 2010, Technology Data for Energy Plants)

Such systems have good performance, but involve high investment costs. Other difficulties include pollutants in the geothermal water, clogging of the wells and limited availability of the energy source. The technique is only applicable at certain geographic locations. Some locations have available geothermal points with high temperatures while in locations low temperatures heat pumps can be applied, sometimes in combination with heat storage in the ground.

7.2. Solar district heating

For district heating systems, large solar installations are typically applied consisting of solar collectors and a liquid handling unit to transfer and store heat. This system requires additional heat generation capacity to ensure that consumers' demands are satisfied for the periods with insufficient sunshine or wintertime. The technology without a seasonal storage needs a backup energy source, which can be based on biofuels, waste, or fossil fuels as natural gas, oil or coal. Other possibility is the cogeneration with heat and power (CHP).

The described system relates to a system without a thermal storage, while the other system has a diurnal storage in the range of 0.1 – 0.3 m^3 per m^2 solar collector and covers 10 – 25% of the annual heat demand.

The main components of this system are (see Figures: Example of a solar collector field with pit storage and Example of a solar district heating system):

- Solar collectors;
- District heating system;
- Back up heating system;
- Possibly of heat storage.

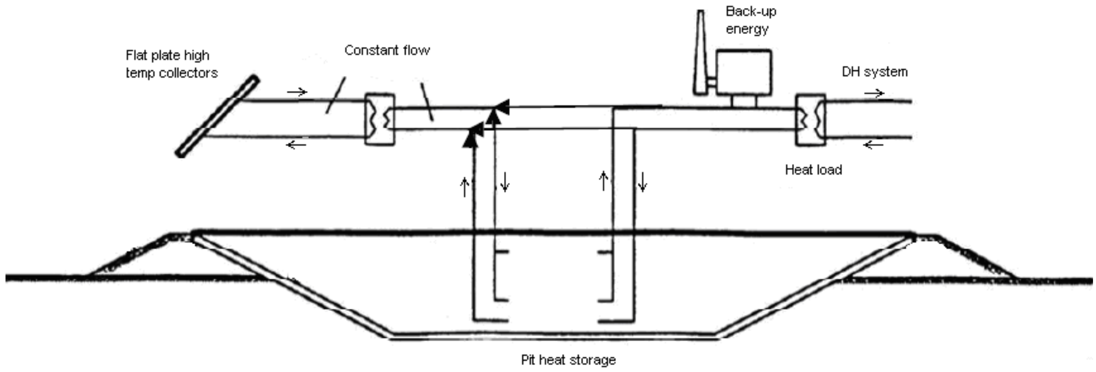


Figure: Example of a solar collector field with pit storage
(Source: Energinet.dk, 2006, Solar heat storages in district heating networks, Project no. 2006-2-6750, IEE PREHEAT).

Figure: Example of a solar district heating system

For district heating applications, highly efficient collectors (e.g. flat plate collectors) are usually employed. There are more efficient solar collector systems such as the concentrating systems, which use different types of mirrors. These systems can generate higher temperatures and are typically used for power generation or high-temperature applications in areas with a high level of direct solar irradiance.

Reference [63] states that a typical annual solar collector output is 500kWh/m2 for Denmark for climatic conditions. The cost for the total system with or without a heat storage is 480€/m2 (i.e., diurnal storage) and 440€/m2, respectively. The cost of the collector and pipes constitutes to nearly half of the total system costs, i.e., 200€/m2. The efficiency of such system is higher for the low temperature level in the district heating system. Due to the climatic variations during the year, more cost effective to have part load coverage 100% coverage of the heating demand instead of 100% coverage. For example in Denmark, this system can cover between 10% and 25% of the annual heating demand.

7.3. Absorption heat pump

[63] Danish Energy Agency and Energinet, DK 2010, Technology Data for Energy Plants.

Absorption heat pumps draw heat from the ambient and convert the heat to a higher temperature through a closed process by using heat, for example steam, hot water, flue or natural gas. Gas-fired heat pumps offer an economic alternative to gas boilers. Traditional heating methods that involve the combustion of fossil fuels do not fully extract the chemical energy of the fuels because they rely solely on the transfer of thermal energy via cooling of hot gases. By contrast, a heat-pump cycle capitalizes on the availability of the combustion process by producing work via an engine to move heat from a cold reservoir to a warm reservoir. The amount of heat that can be moved is many times the heat contained in the fuel powering the machine, providing a two- to threefold benefit.

Absorption heat pumps use thermal energy instead of electrical energy for operating the entire cycle (**Figure:** Process diagram of absorption heat pump compression cycle). The heat pumps using the absorption cycle are thermally driven instead of mechanically driven.

For obtaining thermal energy, the following sources can be used:

- solid fuels: hard coal and derivatives, oil, renewable biofuels;
- other renewable energies, such as solar or geothermal;
- wastes (charcoal, MSW and industrial wastes),
- natural gas or derived gases, such as flue gas.

For the low-temperature heat source, one of the most obvious possibilities is to use residual heat from other processes.

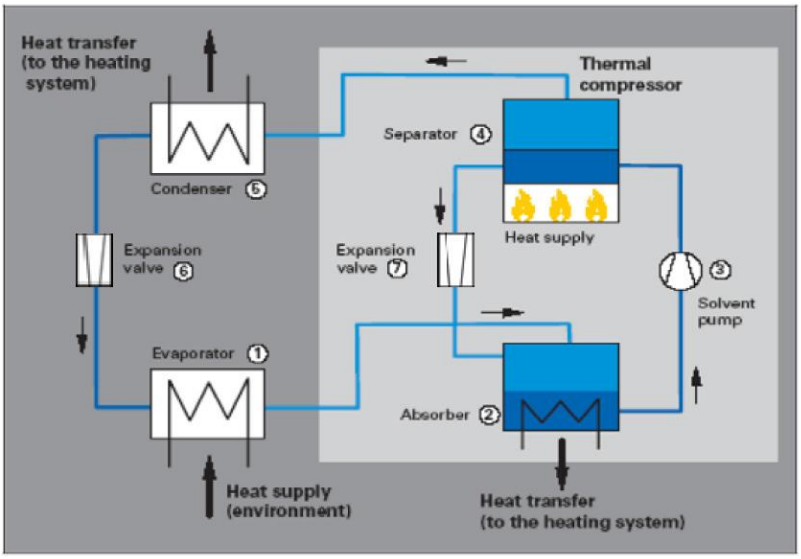


Figure: Process diagram of absorption heat pump compression cycle[64]

The heat pump technology can help to reduce CO2 emissions when the energy is supplied from renewable sources.

Often the absorption heat pumps for space heating are driven by gas while industrial applications are driven by high-pressure-steam or waste heat. Absorption systems use the ability of liquids or salt to absorb vapour. The most common pairs for working fluid and absorbent are respectively:

- Water and lithium bromide
- Ammonia and water

The compression of the working fluid is achieved in a solution circuit, which consists of an absorber, a solvent pump, a thermal compressor and an expansion valve. Vapour at low pressure from the evaporator is absorbed in the absorber, which produces heat in the absorber. The solution is pumped to high pressure and transported to the thermal compressor, where the working fluid evaporates (transformed to vapour) with the assistance of a high-temperature heat supply. The vapour is

[64] 7 EC – DG ENER, 2007, Ecodesign preparatory study of Boilers (Lot 1), Task 4 - Technical Analysis (incl. System Model). In: http://ecoboiler.org

condensed in the condenser while the absorbent is returned to the absorber via the expansion valve. Heat is extracted from the heat source in the evaporator. Heat at medium temperature is released from the condenser and absorber. High-temperature heat is provided in the thermal compressor (generator) to run the processes. A pump is also needed to operate the solvent pump but the electricity consumption is relatively small for that purpose (< 1 % of drive energy). The input to the absorption cycle heat pumps is a heat source (e.g. ambient air, water or ground, or waste-heat from an industrial process) and energy to drive the process. The delivery temperature is depending on the heat source temperature and on the driving source for the energy.

Absorption pumps can be used for following applications:

- Heat pumps for district heating systems with heat generation capacity from 1 to 10 MW. It uses ambient temperature as a heat source and supplies temperature of 80 °C, by applying mechanical compression type compressor with a CO2 refrigerant. The COP2 can vary from 2.8 to 3.5. The investment cost is estimated to be 0.5 – 0.8 M€ per MW heat output[65].
- Heat pumps for district heating systems with heat generation capacity from 1 to 10 MW. For the heat source, industrial waste heat can be used and temperature of 35°C is required. A mechanical compression type compressor with a NH3-refrigerant is applied and temperature supplied by such pumps is 80 °C. The COP varies from 3.6 to 4.5, while the investment cost is estimated to be 0.45 – 0.85 M€ per MW heat output[66].
- Absorption heat pumps that used flue gas condensation in connection with MSW and biomass plants which are non-fossil based energy sources. However natural gas can also be used (steam driven). Such pumps raise the district heating temperature from 40 °C – 60 °C to about 80 °C, by applying an absorption type compressor with BrLi-H2O refrigerant. The typical capacity is 2 to 15 MW of heat generation with the COP equal to 1.7. The investment cost for the heat pump is from 0.15 – 0.2 M€ per MW heat output[67].

7.4. Seasonal storage

The most cost-effective heat storage for large volumes of district heating systems is a long-term (seasonal) storage in a water pit. (Figure: Construction of seasonal storages and Figure: Investment costs show the different possibilities for the construction of seasonal storages).

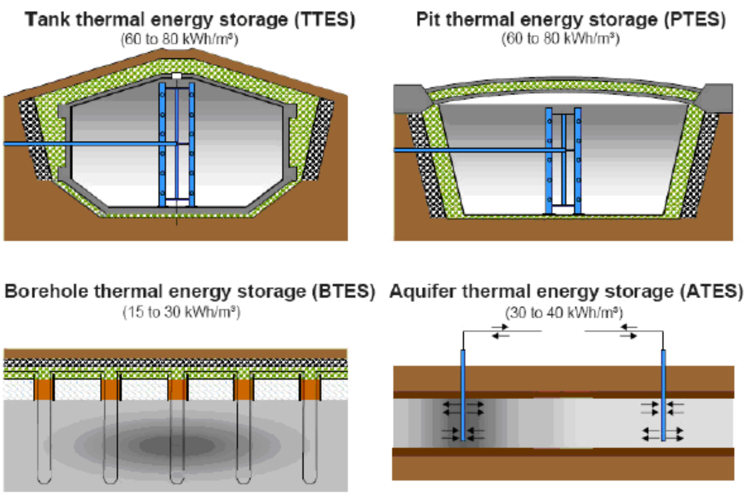


Figure: Construction of seasonal storages

---

65 JRC study on "Best available technologies for the heat and cooling market in the European Union" (2012) http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26689/1/eur%2025407%20en%20-%20heat%20and%20cooling%20final%20report-%20online.pdf

66 JRC study on "Best available technologies for the heat and cooling market in the European Union" (2012) http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26689/1/eur%2025407%20en%20-%20heat%20and%20cooling%20final%20report-%20online.pdf

67 JRC study on "Best available technologies for the heat and cooling market in the European Union" (2012) http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26689/1/eur%2025407%20en%20-%20heat%20and%20cooling%20final%20report-%20online.pdf

(Source: Danish Energy Agency and Energinet, DK 2010, Technology Data for Energy Plants)

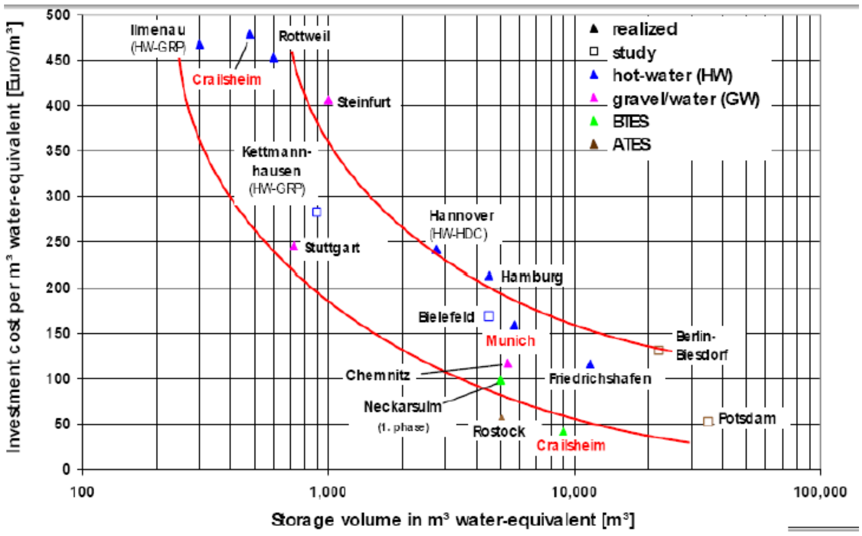


Figure: Investment costs of seasonal heat stores in Germany GRP: Glass-fiber reinforced plastic. HDC: High-density concrete

(Source: Danish Energy Agency and Energinet, DK 2010, Technology Data for Energy Plants)

Hot water tanks (TTES) have been used in Germany for sizes of up to 12.000m^3. These tanks are normally constructed from concrete or steel, and are relatively expensive compared to constructions in which the ground is used as a structural or thermal component. Their advantage is that their properties are easier to control and the tightness is better because they are not influenced by the local soil conditions. A water pit (PTES) is essentially an opening in the ground lined by a waterproof membrane, filled with water and covered by a floating and insulating lid. The excavated earth that surrounds the opening can be used as a dam, thus increasing the water depth. The storage capacity is 60 – 80kWh/($m^3 \cdot a$) [68]. This type of storage has been realized in the large Marstal Solar District Heating system (Denmark). One of the challenges of this type of storage is maintaining the membrane 100% watertight over many years of thermal cycling. The ground water flow can cause heat loss, since this type of storage sometimes is not (well) insulated at the bottom. The omission of bottom/side insulation is possible due to the high volume/surface ratio in very large systems. For storage of solar heat only, a solar collector of approximately 4 m^3 per m^2 is required. The temperature interval of 85-90°C covers a large storage. The efficiency of 80% (56kWh/(m3·a)) is achieved without a heat pump and increases to 95% (67kWh/(m3·a)) when a heat pump is used to discharge the storage[69]. Another possible technology is the application of tubes in boreholes (BTES). They are typically used with heat pumps and they operate at low temperatures (0 to 30°C). The storage can reach efficiencies in the range of 90% to 100% when the storage operates around the annual average temperatures of the ground and there is no strong natural ground water flow. This type of thermal storage is sometimes also applied as a heat sink in comfort cooling systems. Underground aquifers (ATES) are constructed by using direct heat exchange in vertical wells. Typically, there is one central well which is surrounded by a number of peripheral wells. The aquifers are typically used for low-temperature applications in combination with heat pumps for cooling during summer and heating during winter. A potential problem is the chemical composition of the water in the aquifer, which might affect the performance.

7.5. District Cooling

In a district cooling system, chilled water (or brine) is produced at a central plant and distributed through the underground network of pipes to the buildings or consumers connected to the system. The chilled water is used primarily for air-conditioning systems. After returning from such systems, the temperature of the water is increased and the water is returned to the central plant where

---

[68] JRC study on "Best available technologies for the heat and cooling market in the European Union" (2012) http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26689/1/eur%2025407%20en%20-%20heat%20and%20cooling%20final%20report-%20online.pdf

[69] JRC study on "Best available technologies for the heat and cooling market in the European Union" (2012) http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26689/1/eur%2025407%20en%20-%20heat%20and%20cooling%20final%20report-%20online.pdf

the water is cooled and re-circulated through the closed loop system (see Figure: Illustration of a district cooling system).

Figure: Illustration of a district cooling system

(Source: ETSAP, 2010, Cement production, Energy Technology System Analysis Programme. In: www.etsap.org)

A heat pump takes up energy at a lower temperature level and rejects this energy at a higher temperature level. The energy uptake in the heat pump may be very cold and can be used for cooling. In district cooling, the centrally produced cold can therefore be produced by the different types of heat pumps (chillers) described in the previous sections describing the district heating technologies. The energy source for operating the chillers can be electricity or heat in the case of absorption heat pumps. Another possibility is to apply free cooling from a heat sink such as seawater or a river. These systems can also be combined with a cold storage which most commonly is based on freezing of ice, but can also be based on other phase-changing materials. It is also possible to use a system in connection with a district heating system where hot water is produced centrally and then distributed to a number of locally placed heat operated chillers (the same principle as absorption heat pumps). It is possible to operate absorption chillers at temperatures as low as 85°C. The idea is to use surplus heat produced for the district heating system, which during periods uses energy, for example from waste materials or municipal solid waste. This technique can also be used with geothermal heat for geothermal district cooling even if it in general is poorly developed in Europe[70]. The principle is used in some cases with the geothermal heat from the region of Paris Basin (France). The combination of district cooling based on absorption chillers and district heating is especially advantageous during the summer when the needs for heating is limited to mainly domestic hot water. This type of system is expected to be competitive with other solutions as centrally based district cooling systems or locally placed electrical driven chillers.

The advantage of a district cooling system is that it is possible to use less energy and emit less CO_2 compared to other alternative systems such as traditional individual systems operated by electrically driven chillers. By aggregating the need for cooling, it is possible to employ more efficient cooling technologies and optimize dimensioning than it will be possible to implement in individual buildings. The disadvantage is the investment cost, the running costs and losses in the piping system. If absorption chillers are used in combination with district heating or if free cooling systems are used instead of electrically driven chillers it is possible not to use electricity for cooling and instead of this use a technology with limited CO_2 emissions.

Additional resources:

1) JRC study on "Best available technologies for the heat and cooling market in the European Union" (2012) http://ec.europa.eu/dgs/jrc/index.cfm?id=1410&dt_code=NWS&obj_id=15750&ori=RSS. The report describes technologies based on renewable energy sources combined with high-efficiency energy technologies Sectors covered are district heating (including combined heat and power generation), industrial technologies, service and residential technologies and finally agriculture

[70] EGEC. European Geothermal Energy Council, 2007, Geothermal Innovative Applications for a Sustainable Development. In: www.egec.org

and fishery technologies. The descriptions of the technologies include the advantages and disadvantages. The full version of the report is available from: http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26689/1/eur%2025407%20en%20-%20heat%20and%20cooling%20final%20report-%20online.pdf

2) Report of International Energy Agency "*Cogeneration and District Energy*" (published in 2009) provides "best practice" policy approaches used by different countries to expand CHP and district energy use: http://www.iea.org/publications/freepublications/publication/CHPbrochure09.pdf
In the annex of this report policy-type case studies are presented, including utility supply obligations and building regulations case studies.
http://www.iea.org/media/freepublications/archives/CHPbrochure09annex.pdf

3) Report of International Energy Agency *"COMING IN FROM THE COLD: Improving District Heating Policy in Transition Economies",* published in 2004. This report aims to help governments design policy approaches that can effectively address the key challenges facing the district heating sector: more efficient, environmentally friendly district heating. It provides a recommendations on supply and demand policy sequencing, highlights steps to be taken for better regulation or for introducing the competition: http://www.iea.org/textbase/nppdf/free/archives/cold.pdf

4) International association of district heating and cooling provides information on DH technology and presents examples of advanced projects: http://www.euroheat.org/ It publishes a technical guidelines (for example, "Guidelines for District Heating Substations"), reports and studies (for example, "Good Practice in Metering and Billing") and documents on certification of DH components. Most items are freely available to download.

5) Renewable in District Heating Systems, namely solar district heating:

   i) General information about solar district heating systems http://www.solar-district-heating.eu with a list of large scale solar heating plants located in Europe and with a nominal capacity higher than 700 kWth: http://www.solar-district-heating.eu/SDH/LargeScaleSolarHeatingPlants.aspx

   ii) Examples of solar energy application to district heating systems in many countries provided in a database (developed under SOLARGE project). http://www.solarge.org/index.php?id=2 Examples of application of solar energy in decentralized heating systems are also presented.

   iii) Information on renewable heating and cooling on Renewable Heating & Cooling webpage, developed by the European Technology Platform: www.rhc-platform.org

8. WATERGY: IMPROVEMENT OF OVERALL WATER SYSTEM EFFICIENCY

Energy and water are the essential ingredients for sustaining daily activities and ecosystems. These two resources are also highly linked, where energy is employed to provide water services, while water is used in energy systems. The energy for activities such as pumping, treating and heating water and generating steam consumes a significant part of municipalities' fuel and electricity reserves. Therefore a combined approach to water and energy efficiency can yield to greater energy and water savings, employing technologies for optimizing energy use in municipal water systems and/by implementing cost-effective efficiency actions.

Municipalities are powerful actors to pursue the potential of water efficiency as:

- More than half of the developing world's population is expected to live in the cities by 2020[71].
- The total electricity consumption for water sector is expected to grow globally by 33 percent by 2020[72].
- In 2025 one-third of the global population is expected to live in chronic water shortage areas. [73]
- In developing countries municipal water utilities are loosing between 30 to 60 percent of water; municipalities of developed countries loose water between 15 and 25 percent.[74]
- Maintenance and operational practices improvements, elimination of waste of usable water (leaks, malfunctioning equipments) in large cities of developing countries could double the water availability[75] and reduce energy use.

Municipality can actively reduce the fossil fuels-based energy consumed in water supply systems[76] 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.

Water – Energy Efficiency Management Approach

A combined approach to water and energy efficiency can bring bigger savings than focusing separately on water or energy efficiency. By using combined technical and managerial improvements, the Alliance to Save Energy Watergy programme's[77] propose to:

- include performance targets,
- strengthening capacity,
- implementing low-cost efficiency improvements
- and to add medium-cost capital investments
- minimizing operating costs
- and generating own revenues through renewable energy sources onsite (ex: through the installation of bio-gasification technologies).

Improvements often pay for themselves in a span of a few months to several years.

---

[71] Mukami Kariuki, “WSS Services for the Urban Poor,” <www.wsscc.org/vision21/docs/doc16.html> (accessed December 2001).

[72] Based on an analysis done by Laura Lind of the Alliance to Save Energy, using Model Energy Code Links (MECS), 1991. See also Arora and LeChevallier 1998.

[73] WRI, “Freshwater Systems, Water Quantity,” <www.wri.org/trends/water.html> (accessed December 2011).

[74] United States Department of Energy, “Tomorrow’s Energy Today for Cities and Counties,” <www.eren.doe.gov/cities_counties/watersy.html> (accessed December 2011).

[75] Water Supply and Sanitation Collaborative Council, “Water Demand Management and Conservation,” <www.wsscc.org/activities/vision21/docs/doc26.html> and <www.who.int/water_sanitation_health/wss/sustoptim.html> (accessed December 2011).

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

[77] Alliance to Save Energy, "Watergy: taking Advantage of Untapped energy and Water Efficiency Opportunities in Municipal Water Systems" (first Handbook 2002; updated in 2007); English (version 2007): http://www.watergy.org/resources/publications/watergy.pdf Russian (version 2002): http://watergy.org/resources/publications/watergy_russian.pdf

The Figure below summarises steps used for successful implementation of the Alliance to Save Energy Watergy projects[78].

Management Commitment
• Leadership from top management is essential to engage middle management and frontline staff to implement projects

↓

Technical management and Analysis:
• Inventory and map the applications that use water & energy • Conduct an energy audit of the system(s) • Establish goals and benchmarks • Develop baselines and metrics • Strengthen capacity of technical staff

↓

Implementing Efficiency Measures:
Repair/Replace Pumps Leak detection and repair Pressure management (lower pressure following leak reduction) Install/Replace Automation Metering and monitoring Low-friction pipes System design and Layout

↓

Achieving Energy, Water and Money Savings

Opportunities for supply and demand side improvements

Water utilities can gain energy efficiency through the improvements of supply-side as well as demand side[79].

Supply-side improvement opportunities

Common Problems	Possible solutions
• Leaks in: - Water distribution mains and pipelines; - Piping and equipment connections; - Valves; - Meters; - Corroded or damaged system areas. • High level of friction in internal pipe surface (c-value for pipes) • Improper system layout; • System overdesign; • Incorrect equipment selection; • Old, outdated equipment; • Poor maintenance; • Waste of usable water.	• System redesign and retrofitting of equipment by answering key questions: 1. Is the pump correctly designed and efficient? - Energy-efficient motors; - Adjustable speed drives; - Impellers, valves, capacitors; - Lower friction pipes and coatings. 2. Are the heads matched? (pump heads with system heads) 3. Is a variable speed drive installed to match varying capacities? 4. Are controls efficient?[80] • Pump impeller reduction; • Leak and loss reductions; • Equipment upgrades; • Low-friction pipe; • Adjustable speed drive motors; • Capacitors, transformers; • Maintenance and operation practices improvements; • Water reclamation and re-use.

Demand-side improvement opportunities

[78] Alliance to Save Energy, "Achieving Energy Efficiency in Water Supply & Wastewater Treatment Utilities through Watergy Strategies" by Robert B. Lung, Laura Van Wie-McGrory, Brian C. Castelli (http://ase.org/sites/default/files/iwa_paper_alliance.pdf

[79] Alliance to Save Energy, "Watergy: taking Advantage of Untapped energy and Water Efficiency Opportunities in Municipal Water Systems" (first Handbook 2002; updated in 2007); English (version 2007): http://www.watergy.org/resources/publications/watergy.pdf Russian (version 2002): http://watergy.org/resources/publications/watergy_russian.pdf

[80] CII 1998, pp.55–58.

By improving the demand-side the water utilities can create"win-win" situations for themselves and for their customers.

Benefits for utility companies	Benefits for consumers
• Reducing water demand can increase system capacity; • It can help to avoid new investments in new facilities; • Less water floating in the systems is reducing costs of pumping and frictional energy losses; • Investments in demand-side programmes bring short and long-term cost benefits.	• Demand reduction reflects on reduced cost of service delivery; • Less water shortages.

The key of success is to provide customers the same or even bigger benefits by using less water. Municipal utilities can carry out promotional and educational programmes aiming to reduce the demand-side consumption from residents and industry, such as education and outreach; residential and Commercial water audits, providing suggestions for improvements, water efficiency kits, information brochures and booklets for citizens and industry; rebate/installation programs; awards and prizes for the best initiatives by private and public, commercial organisations.

Coordinating demand-side measures with the supply system actions can bring greater benefits for both sides. For example, by coordinating a major demand-side program with the purchase of new energy-efficient pumps, the water utility can save money by reducing water moving through the system, and can buy smaller, less expensive pumps to meet the reduced pumping demand. Very often, the demand reduction leads to system upgrades and adjustments to new water demand levels.

Very often the end-user can not see any direct value by using water inefficiently. The most common water saving technologies are following:

- Ultralow flush toilets;
- Toilet dams or other water displacement devices;
- Low-flow showerheads;
- Efficient faucet aerators;
- Efficient clothes and dish washers;
- Xeriscaping (planting plants that are able to adjust to climate conditions and save large amounts of irrigation water);
- Drip irrigation;
- Energy-efficient water heaters;
- Hot water on-demand systems.

The most common efficiency measured used by businesses and industry[81] are:

- Recycle process water;
- Improve equipment, adjust equipment and part replacement practices;
- Use domestic water efficiency techniques, such as low-flush toilets and urinals, faucet aerators, low-flow showerheads, etd.
- Change operational practices;
- Adjust cooling tower blow down;
- Reduce landscaping irrigation time schedules;
- Repair leaks;
- Install spray nozzles; install automatic shut-off nozzles.

Additional resources:

1. Report "Watergy: taking Advantage of Untapped energy and Water Efficiency Opportunities in Municipal Water Systems" (2007) published by Alliance to Save Energy by the Office of Energy, Environment and Technical in the Economic Growth Agriculture, and Trade Bureau of USAID (by J. James, S.L Campbell, E.G. Godlove). Report describes technologies for optimizing energy use in municipal water systems by implementing cost-effective efficiency actions. The full version of the report is available in http://www.watergy.org/resources/publications/watergy.pdf Russian (version 2002): http://watergy.org/resources/publications/watergy_russian.pdf

[81] North Carolina Department of Environment and Natural Resources 1998, 120 pp.

2. Report "Achieving Energy Efficiency in Water Supply & Wastewater Treatment Utilities through Watergy Strategies" published by Alliance to Save Energy (by Robert B. Lung, Laura Van Wie-McGrory, Brian C. Castelli) The report highlights a combined approach to water and energy efficiency that can yield to greater energy and water savings: http://ase.org/sites/default/files/iwa_paper_alliance.pdf

9. OFFICE APPLIANCES[82]

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[83], available for energy-efficient office equipment, covers a wide range of products from simple scanners to complete desktop home computer systems. The requirements and

[82] 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/

[83] Further information available at www.eu-energystar.org

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%.

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.

10. BIOGAS[84]

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[85].

10.1. LANDFILL BIOGAS RECOVERY[86]

Waste disposal in landfills[87] can generate environmental problems, such as water pollution, unpleasant odours, explosion and combustion, asphyxiation, vegetation damage, and greenhouse gas emissions.

Landfill[88] 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". The national directives or standards can also be applied for landfill gas in countries of Eastern Partnership and Central Asian Countries.

10.2. 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%[89]. The biodigester can also be

[84] Some examples of biogas projects may be found in the webpage http://ec.europa.eu/energy/renewables/bioenergy/bioenergy_anaerobic_en.htm

[85] See chapters 2 and 3 of the part II of this guidebook.

[86] 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

[87] The information given may not be relevant for countries where landfills are no longer allowed.

[88] 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

[89] 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

fed by vegetable or animal wastes. Therefore, it can be used in the food industry such as in big municipal sewage facilities.

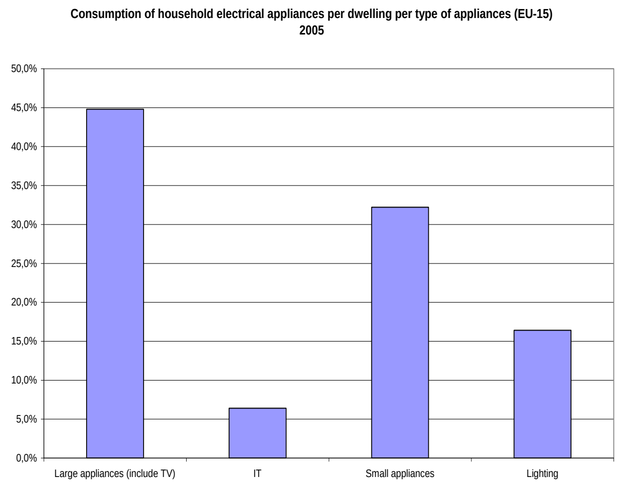
Modern plants can be designed to reduce odours to a minimum extent. Biogas plants may be designed to fulfil the prerequisites for approval by the food industry to use the bio-fertilizer in agriculture.

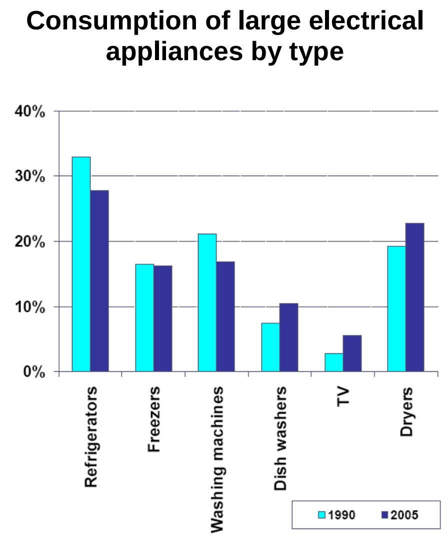
11. ADDITIONAL DEMAND SIDE MANAGEMENT[90] MEASURES GROUNDED ON HUMAN BEHAVIOR (HABITS AND MENTALITY)

The purchase of Green Electricity[91] (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.

The purchase of energy effienct homes and applicences are other source of energy conservation/savings. Directive 1995/13/EC implementing directive 1992/75/EEC, and Directives 1996/60/EC, 1998/11/EC, 2002/40/EC, 2006/32/EC, 2010/30/EU, 2010/31/EC effective for all EU countries and other members of Energy Community Treaty[92] (Ukraine and Moldova as contracting parties and Georgia as candidate country) oblige domestic appliance producers to label their products, offering to the customers the possibility to know the energy efficiency of these devices. The national directives or standards can also be applied for labelling domestic appliances in countries of Eastern Partnership and Central Asian Countries. 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 and even buildings. It is highly recommended to choose A+ or A++ labeled appliances or buildings.

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[93].





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

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[94]. This study made a quantitative analysis with an on-line interactive "energy

[90] Demand Side Management Information available on the International Energy Agency Demand Side Management webpage www.ieadsm.org
The Topten websites provide a selection of best appliances from the energy point of view www.topten.info (project supported by Intelligent Energy Europe)
[91] 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
[92] Title II of the Treaty establishing the Energy Community extends the *acquis communautaire* to the territories of the Contracting Parties. The Energy Community *acquis* comprises the core EU energy legislation in the area of electricity, gas, environment, competition, renewables, energy efficiency, oil and statistics. Fyrther information available at http://www.energy-community.org/portal/page/portal/ENC_HOME/ENERGY_COMMUNITY/Legal/EU_Legislation
[93] Further information available at www.econhome.net projects are supported by Intelligent Energy Europe
[94] 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

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[95] 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/

[95] 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.

12. ENERGY AUDITS[97] AND MEASUREMENTS AS TECHNICAL STUDY OF ENERGY SAVINGS

The purpose of Energy Audits is to perform an analysis of energy flows in every engineering construction (for example, building or district heating network) 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 construction 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. Energy audit typically includes energy use at a given local climate criteria, thermostat settings, roof overhang, and solar orientation. This could show energy use for a given time period and the impact of any suggested improvements per year. Once the energy and performance data are collected and correctly analysed, it is possible to propose corrective measures aimed at improving the energy efficiency of the engineering construction. 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.

As measurement and data acquisition are an important issue in evaluation of energy and cost effects of implemented energy-efficiency projects according to the reccomendations of energy auditors, the way to do it has to be planned in advance. More information on measurement and verification of implementation of different energy saving measurements can be found on the IPMVP webpage www.evo-world.org.

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.

[97] 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

13. SPECIFIC MEASURES FOR INDUSTRY

Additional resources:

Report of International Energy Agency **"Clean Coal Technologies - Russian version**": This short report from the IEA Coal Industry Advisory Board presents industry's considered recommendations on how to accelerate the development and deployment of this important group of new technologies and to grasp their very significant potential to reduce emissions from coal use. The widespread deployment of pollution-control equipment to reduce sulphur dioxide, Nox and dust emissions from industry is just one example which has brought cleaner air to many countries. Since the 1970s, various policy and regulatory measures have created a growing commercial market for these clean coal technologies, with the result that costs have fallen and performance has improved. More recently, the need to tackle rising CO2 emissions to address climate change means that clean coal technologies now extend to include those for CO2 capture and storage.

http://www.iea.org/publications/freepublications/publication/clean_coal_rus-1.pdf

13.1. Electric Motors[98] and Variable Speed Drives (VSD)

Motor driven systems account for approximately 65% of the electricity consumed by industry in European and other countries. 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%[99] in pumps and fans and 15% in air compressors, cooling compressors and conveyors.

13.2. The Energy Management standard ISO 50001

The standard for Energy Management Systems - ISO 50001[100] - is a tool for organizations and companies to review the current energy situation and improve the energy efficiency in a systematic and sustainable way. This standard from the International Organization for Standardization (ISO) provides an internationally recognized framework for organizations to voluntarily implement an energy management system.

The purpose of the Energy Management Standard ISO 50001 is to help companies to organize the process for improving energy efficiency, and it does not prescribe specific performance criteria with respect to energy. It is an approach for industrial and commercial facilities to plan,

---

[98] 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/

[99] 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

[100] Description about ISO 50001:2011 can be retrieved from http://www.iso.org/iso/home/standards/management-standards/iso50001.htm

manage, measure, and continually improve energy performance. ISO 50001 follows the Plan-Do-Check-Act (PDCA) approach and addresses the following steps:

- Energy use and consumption.
- Measurement, documentation, and reporting of energy use and consumption.
- Design and procurement practices for energy-using equipment, systems, and processes.
- Development of an energy management plan and other factors affecting energy performance that can be monitored and influenced by the organization.

The standard is intended to accomplish the following [[101]]::

- Assist organizations in making better use of their existing energy-consuming assets
- Create transparency and facilitate communication on the management of energy resources
- Promote energy management best practices and reinforce good energy management behaviours
- Assist facilities in evaluating and prioritizing the implementation of new energy-efficient technologies
- Provide a framework for promoting energy efficiency throughout the supply chain
- Facilitate energy management improvements for greenhouse gas emission reduction projects
- Allow integration with other organizational management systems such as environmental, and health and safety.

Freely available sections of ISO 50001:2011 can be previewed from:
http://www.iso.org/iso/home/standards/management-standards/iso50001.htm or
http://www.iso.org/iso/home.html

13.3. Best Available Techniques Reference Document (BREF)[102] in Industry

The Best Available Technology (BAT) Reference Document (BREF) aims to exchange information on BAT, monitoring and developments under the article 17(2) 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.

[101] http://www.iso.org/iso/iso_50001_energy.pdf

[102] Energy Efficiency BREF is available on: ftp://ftp.jrc.es/pub/eippcb/doc/ENE_Adopted_02-2009.pdf

14. NATURAL GAS VEHICLES

This chapter describes the use of natural gas as a vehicle fuel, which has an advantage of reduced greenhouse gas emissions and the emissions that affect air quality. The chapter also describes fuelling system along with economics and safety of natural gas technology.

14.1. Natural gas vehicles

Natural gas is widely available all over the world as one of the cleanest fossil fuels. When used as a vehicle fuel, it has fewer greenhouse gas emissions than petrol or diesel, and none of the particulates associated with diesel. Natural gas can be used in all classes of vehicles:

- light transport vehicles (including motorcycles, cars, and vans);
- heavy-duty vehicles (trucks, buses, even ships and ferries).

Natural gas vehicles (NGVs) are available from different manufacturers (an example of the catalogue can be found[103]).

When comparing to traditional diesel or petrol vehicles, natural gas vehicles have the following benefits[104]:

- Reduced greenhouse gas emissions and emissions of nitrogen oxides;
- No particulate emissions associated with diesel;
- Natural gas can be derived from renewable sources, such as biomethane;
- Natural gas vehicles provide noise reductions up to 50%;
- Lower operational costs of NGV;
- Natural gas can be used in all vehicle classes with established technology;
- Widespread availability of natural gas;
- Safer than most liquid fuels.

These benefits are the driving force for the increasing number of NGVs, which has doubled from year 2005 to 2010. International Association for Natural Gas Vehicles (IANGV) is projecting that this will increase to 50 million vehicles by 2020.

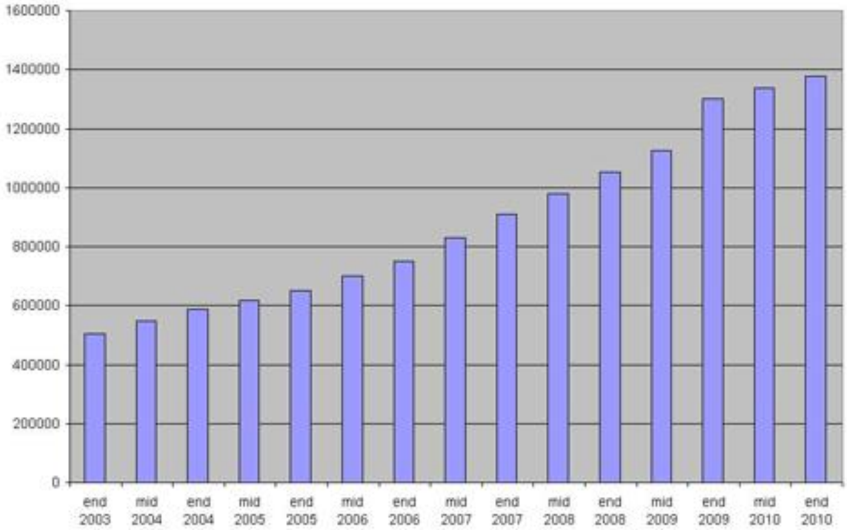


Figure: NGV market grow in Europe from 2005-2010
Source: Association for Natural Gas Vehicles (IANGV)

Among the CoM-East countries, Armenia has the largest share of NGVs (more than 55%) followed by Ukraine and Tajikistan, that have 27% and 11%, respectively. Number of total NGV vehicles (except ships, trains and aircraft), and their shares are presented in Table below (**Table:** Statistical information

[103] http://www.ngvaeurope.eu/cars

[104] http://www.madegascar.eu/Natural-gas-vehicles.269.0.html

on NGVs status in CoM East countries[105]). The data were gathered for year 2011 for all countries, except for Kyrgyzstan, Georgia and Tajikistan, where statistics were available for years 2007, 2008, and 2005, respectively.

Table: Statistical information on NGVs status in CoM East countries[106]

Country	Total NGVs	NGVs shares
Armenia	244.000	55,5%
Belarus	4.600	0,2%
Georgia	3.000	0,6%
Kazakhstan	3.200	0,1%
Kyrgyzstan	6.000	1,9%
Moldova	2.200	0,4%
Tajikistan	10.600	11,9%
Ukraine	388.000	27,1%
Uzbekistan	120.000	7,1%

Natural Gas Systems and Technologies. For natural gas vehicles, there are two following fuel options[107]:

- Mono fuel NGVs that run only on natural gas. Such NGVs can be optimised to run on natural gas by using higher compression ratios, which generally leads to higher engine efficiencies. This is possible because natural gas has a higher octane number than either petrol or diesel, which means the compression ratios can be increased without inducing knocking. Natural gas vehicles have a spark-ignition internal combustion engines and are broadly similar to petrol vehicles but with different fuel storage and delivery mechanisms. Since natural gas does not liquefy under compression, it must either be stored on board vehicles as very high pressure compressed natural gas (CNG), usually at 200bar. CNG fuel tanks have to be strong to withstand in excess of 200bar pressure, and they are usually made out of thick and heavy steel. NGV fuel tanks are therefore either large or heavy, which means natural gas is best suited for larger vehicles such as trucks, buses or vans. Nevertheless, favourable taxation policies can lead to CNG cars being reasonably popular.
- Dual-fuel NGVs that can switch between natural gas and petrol. Many light-duty NGVs (cars and vans) have dual-fuel engines to eliminate the danger of running out of fuel and unable to find a natural gas refuelling station. This is more likely to be a problem with light-duty vehicles since they have more varied and less predictable traveling pattern than trucks or buses. Moreover, light-duty vehicles have difficulties in accommodating large fuel tanks. However, dual-fuel NGVs cannot be optimised to operate on natural gas and therefore do not show full potential for reducing tailpipe emissions.

14.2. Fuelling

Refuelling of NGVs is safer than refuelling of vehicles with petrol or diesel, as no evaporative emissions occur during fuelling[108]. Refuelling procedure takes approximately the same amount of time as for traditional vehicles, and is a simple procedure, where the refuelling nozzle clicks onto the receptacle on the vehicle for filling. When the cylinder is full, the dispenser automatically shuts off, indicating that it is ready to be disconnected from the vehicle. Options for refuelling include public

---

105 *Source: NGVA Europe,* statistical information on the European and Worldwide NGV status: http://www.ngvaeurope.eu/statistical-information-on-the-european-and-worldwide-ngv-status

106 Statistical information is presented for the countries reported in *NGVA Europe.*

107 *Source: International Association for Natural Gas Vehicles*

108 *Source: International Association for Natural Gas Vehicles*

station and home refuelling. The location of public stations located in different countries and a gas supplier that offers home refuelling can be found from "Country specific facts and developments" [109].

14.3. Environmental aspect

Urban Emissions. NGVs are generally very clean in terms of air quality emissions that can affect human health. They involve particulate matter (PM), carbon monoxide (CO), oxides of nitrogen (NOx) and the carcinogenic hydrocarbons (HC). Near-zero PM emissions of NGVs is a particular advantage when natural gas replaces a diesel, which is usually the case for heavy duty vehicles.

In addition, mono-fuel NGVs produce little or no evaporative emissions during both refuelling and combusting fuel in NGVs engines. In petrol vehicles, evaporative and fuelling emissions account for at least 50% of a vehicle's total hydrocarbon emissions.

When comparing to traditional diesel or petrol verticals, the exhaust emissions of natural gas vehicles can be reduced as following[110]:

- Exhaust emissions of carbon monoxide (CO) can be reduced by 70%;
- Exhaust emissions of non-methane organic gas (NMOG) can be reduced by 87%;
- Nitrogen oxides (NOx) can be reduced by 87%;
- Carbon dioxide (CO2) by almost 20% below those of gasoline vehicles.

Greenhouse Gases. Natural gas contains smaller amount of carbon per unit of energy, than any other fossil fuel, and thus produces lower carbon dioxide (CO2) emissions per kilometre of NGVs. While NGVs do emit methane, another principle greenhouse gas, any increase in methane emissions is more than offset by a substantial reduction in CO2 emissions compared to other fuels. Testing of NGVs has indicated that NGVs produce up to 20 % less greenhouse gas emissions than comparable petrol vehicles, and up to 15% less greenhouse gas emissions than comparable diesel vehicles.

14.4. Economics and Safety

Economics. The costs of the NGVs are typically higher than traditional vehicles, but users of NGV have the advantage of cheaper fuel. The same tendency persists for other alternative fuel vehicles. For example, a NGV is approximately 3.000 Euro more expensive when compared to a petrol car, the 800 Euro more expensive when compared to a diesel[111]. However, expenses for the fuel compensate the increased price of a NGV. For example, if 20.000 km is travelled in one year, the NGV amortizes in 4 years.

NGV refuelling stations are expensive and only commercially viable if they refuel a relatively largely number of vehicles. Therefore the market penetration of NGVs suffers from the classic problem, when fuel suppliers are reluctant to construct refuelling stations until there are sufficient numbers of NGVs and operators are unwilling to purchase the vehicles until there are sufficient refuelling stations.

Safety. The fuel storage cylinders used in NGVs are much stronger than petrol fuel tanks. The design of NGV cylinders are subjected to a number of federally required "severe abuse" tests, such as heat and pressure extremes, gunfire, collisions and fires. NGV fuel systems are "sealed," which prevents any spills or evaporative losses. Even if a leak were to occur in an NGV fuel system, the natural gas would dissipate up into the air because it is lighter than air. It also has a narrow range of flammability, that is, in concentrations in air below about 5% and above about 15%, natural gas will not burn. The high ignition temperature and limited flammability range make accidental ignition or combustion of natural gas unlikely. In addition, natural gas is not toxic or corrosive and will not contaminate ground water.

Additional resources:

1. European Natural gas vehicle association http://www.ngvaeurope.eu
2. NGV communications group http://www.ngvgroup.com
3. News and information for the natural gas vehicle industry http://www.ngvglobal.com/

[109] http://www.ngvaeurope.eu/worldwide-ngv-statistics

[110] *Source: International Association for Natural Gas VehicleS*

[111] *Source: International Association for Natural Gas VehicleS*

ANNEX I. Key Elements of the EPBD Recast

- Elimination of the **1000 m^2 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 > 500m² will have to display the certificate (lowered to > 250m² 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 Technologies for Power Generation – High Fuel Price Scenario [a]

Energy source	Power generation technology		Production Cost of Electricity (COE): State-of-the-art 2007	Production Cost of Electricity (COE): Projection for 2020	Production Cost of Electricity (COE): Projection for 2030	Net efficiency 2007	Lifecycle GHG emissions: Direct (stack) emissions	Lifecycle GHG emissions: Indirect emissions	Lifecycle GHG emissions: Lifecycle emissions	Fuel price sensitivity
			€$_{2005}$/MWh	€$_{2005}$/MWh	€$_{2005}$/MWh		kg CO_2/MWh	kg CO_2(eq)/MWh	kg CO_2(eq)/MWh	
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%	350	70	420	Very high
		CCS	n/a	130 ÷ 140	140 ÷ 150	49% [c]	60	85	145	Very high
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	585	Very high
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 Bed 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
Nuclear	Nuclear fission	-	55 ÷ 90	55 ÷ 90	55 ÷ 85	35%	0	15	15	Low
Biomass	Solid biomass	-	80 ÷ 195	90 ÷ 215	95 ÷ 220	24% ÷ 29%	6	15 ÷ 36	21 ÷ 42	Medium
	Biogas	-	55 ÷ 215	50 ÷ 200	50 ÷ 190	31% ÷ 34%	5	1 ÷ 240	6 ÷ 245	Medium
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	
Hydro	Large	-	35 ÷ 145	30 ÷ 140	30 ÷ 130	-	0	6	6	nil
	Small	-	60 ÷ 185	55 ÷ 160	50 ÷ 145	-	0	6	6	
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 efficiencies for carbon capture plants refer to first-of-a-kind demonstration installations that start operating in 2015
[d] Assuming the use of natural gas for backup heat production

Table 2-4: Energy Sources for Heating – High Fuel Price Scenario [a]

Energy source		EU-27 market share by energy source (residential sector) [b]	Fuel retail price (inc. taxes)	Production Cost of Heat (inc. taxes): Running cost	Production Cost of Heat (inc. taxes): Total cost	Lifecycle GHG emissions: Direct (stack) emissions	Lifecycle GHG emissions: Indirect emissions	Lifecycle GHG emissions: Lifecycle emissions
			€$_{2005}$/toe	€$_{2005}$/toe	€$_{2005}$/toe	t CO_2 /toe	t CO_2(eq)/toe	t CO_2(eq)/toe
Fossil fuels	Natural gas	45.4%	1010	1125 ÷ 1400	1425 ÷ 1750	2.5	0.7	3.2
	Heating oil	20.0%	1030	1200 ÷ 1600	1775 ÷ 2525	3.5	0.6	4.1
	Coal	3.1%	590	975 ÷ 1025	1775 ÷ 2100	5.4	0.7	6.1
Biomass, solar and other	Wood chips	11.6%	410	725 ÷ 925	1575 ÷ 2675	0.0	0.3	0.3
	Pellets		610	925 ÷ 1350	1700 ÷ 4175	0.0	0.7	0.7
	Solar		-	275 ÷ 300	1350 ÷ 9125	0.0	0.3	0.3
	Geothermal		-	650 ÷ 1100	1150 ÷ 3775	0.0	0.2 ÷ 5.9	0.2 ÷ 5.9
Electricity		12.3%	1875	1925 ÷ 1975	2025 ÷ 2900	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 Road Transport – Moderate and High Fuel Price Scenario

Energy source for road transport	Cost of Fuels to the EU		Lifecycle GHG emissions [c]
	Moderate Fuel Price Scenario [a] €$_{2005}$/toe	High Fuel Price Scenario [b] €$_{2005}$/toe	t CO_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]	1095 ÷ 1245	1100 ÷ 1300	0.3 ÷ 0.9

[a] *Values are given for 2015, assuming oil price of 57.9$$_{2005}$/barrel as in 'European Energy and Transport: Trends to 2030 - Update 2007'*

[b] *Values are given for 2015, assuming oil price of 83.3$$_{2005}$/barrel 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] *Requires 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*

ANNEX III: Cost and performance goals for heating and cooling technologies, 2030 and 2050
Source: OECD/IEA, 2011, Technology Roadmap, energy Efficient Buildings: Heating and cooling Equipment

	2030		2050	
Active solar thermal				
Installed cost	-50% to -75%		-50% to -75%	
Maintenance cost	0% to -40%		0% to -40%	
Delivered energy cost	-50% to -60%		-50% to -65%	
Thermal energy storage	PCM, thermal-chemical and centralised		PCM, thermal-chemical and centralised	
Installed cost	-50% to -75%		-65% to -85%	
Delivered energy cost	Depends on cycle regime		Depends on cycle regime	
Heat pumps	Space/water heating	Cooling	Space/water heating	Cooling
Installed cost	-20% to -30%	-5% to -15%	-30% to -40%	-5% to -20%
Coefficient of performance	30% to 50% improvement	20% to 40% improvement	40%to 60% improvement	30% to 50% improvement
Delivered energy cost	-20% to -30%	-10% to -20%	-30% to -40%	-15% to -25%
CHP	Fuel cells	Microturbines	Fuel cells	Microturbines
Installed cost	-40% to -55%	-20% to -30%	-60% to -75%	-30% to -50%
Electrical efficiency	35% to 40%	30% to 35%	35% to 45%	35% to 40%
Total efficiency	75% to 80%	70% to 75%	75% to 85%	75% to 85%
Delivered energy cost	-45% to -65%	-10% to +5%	-75% to -85%	-15% to +20%

Note: Improvements in costs or performance are expressed as a percentage relative to the base year (2010) specification. However, the electrical and total efficiencies for CHP are actual percentages, not improvements. For fuel cells, the delivered energy cost is for thermal energy and is based on a long-run cost of CO_2-free hydrogen of between USD 15/GJ and USD 25/GJ in 2050.

Source: OECD/IEA, 2011, Technology Roadmap, energy Efficient Buildings: Heating and cooling Equipment.

European Commission

EUR XXXXX0 EN– Joint Research Centre – Institute for Energy and Transport
Title: Guidebook "How to develop a Sustainable Energy Action Plan (SEAP) in the Eastern Partnership and Central Asian Cities "
Luxembourg: Publications Office of the European Union
2013 –XXX pp. – 21 × 29,7 cm
EUR – Scientific and Technical Research series – ISSN XXXX-XXXX
ISBN XXX-XX-XX-XXXXX-X
DOI XX.XXXX/XXXXX

How to obtain EU publications

Our priced publications are available from EU Bookshop (http://bookshop.europa.eu), where you can place an order with the sales agent of your choice.

The Publications Office has a worldwide network of sales agents. You can obtain their contact details by sending a fax to (352) 29 29-42758.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

LD-xx-xxxxx-EN-C

EUROPEAN COMMISSION

Publications Office