D2.1

EeB technologies for MEP systems of healthcare buildings

Deliverable Report: D2.1 -

Streamer - Optimised design methodologies for energy-efficient buildings integrated in the neighbourhood energy systems.
The Streamer project is co-financed by the European Commission under the seventh research framework programme FP7.EeB.NMP.2013-5 ; GA No. 608739)

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EeB technologies for MEP systems of healthcare buildings: State-of-the-art review of MEP systems for energy-efficient healthcare buildings.

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Version:	Final
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Colophon

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Abstract

This deliverable is a State of The Art overview in which building systems basic components are described. Mechanical, electrical and plumbing technologies that find their usage in Health Care Buildings are selected and analysed for use in hospitals. Building technologies are grouped into four categories corresponding to their type: Plumbing; Electrical; Heating, Ventilation, Air Conditioning (HVAC) and Other Supporting Technologies. Each category is divided into subcategories according to their system role in the building. Described technologies are assigned to building layers as defined in *Deliverable 1.1. (Hotel, Office, Hot Floor, Industry).*

The first part of the document consists of the State of the Art analysis of realizing building systems with energy saving priority. Research is done for technologies that refer to the room and building level. Considerations about energy integrated neighbourhood systems will be further discussed in *Deliverable 2.7* and *Deliverable 2.8*.

A study on technologies application in the hospital indoor environment is done regarding each system separately. Building management systems (BMS) are also discussed. Currently used, best practice solutions, which contribute to improve total energy efficiency of the healthcare facility, are presented. Some guidelines of how energy efficiency can be achieved are given. Second part of the deliverable brings to the reader the State of the Art knowledge about selected optimization methodologies at room and building levels.

In Appendix 1 devices responsible for energy conversion, distribution, delivery and storage are described and some basic parameters are given as well as their characterization of usage. Parameters that can be optimized are presented within this part of the document.

In Appendix 2 basic formulas are given to present how parameters mentioned in the text can be calculated.

The report is organized as follows:

1. SoTA and best practice solutions of MEP technologies considerations (chapter 1);
2. Chosen methodologies for MEP system optimization (chapter 2);
3. Parameters and description of selected technologies (appendix 1);
4. Formulas (appendix 2).

The first part classifies the building systems and gives an overview on areas where savings can be done and how it can be achieved.

The second part provides the description of chosen optimization methodologies with underlining the optimization criterion.

Appendix 1 brings the parameters describing each family of technologies with detailed description of selected solutions. Appendix 2 brings formulas being a substantive supplement to the document.

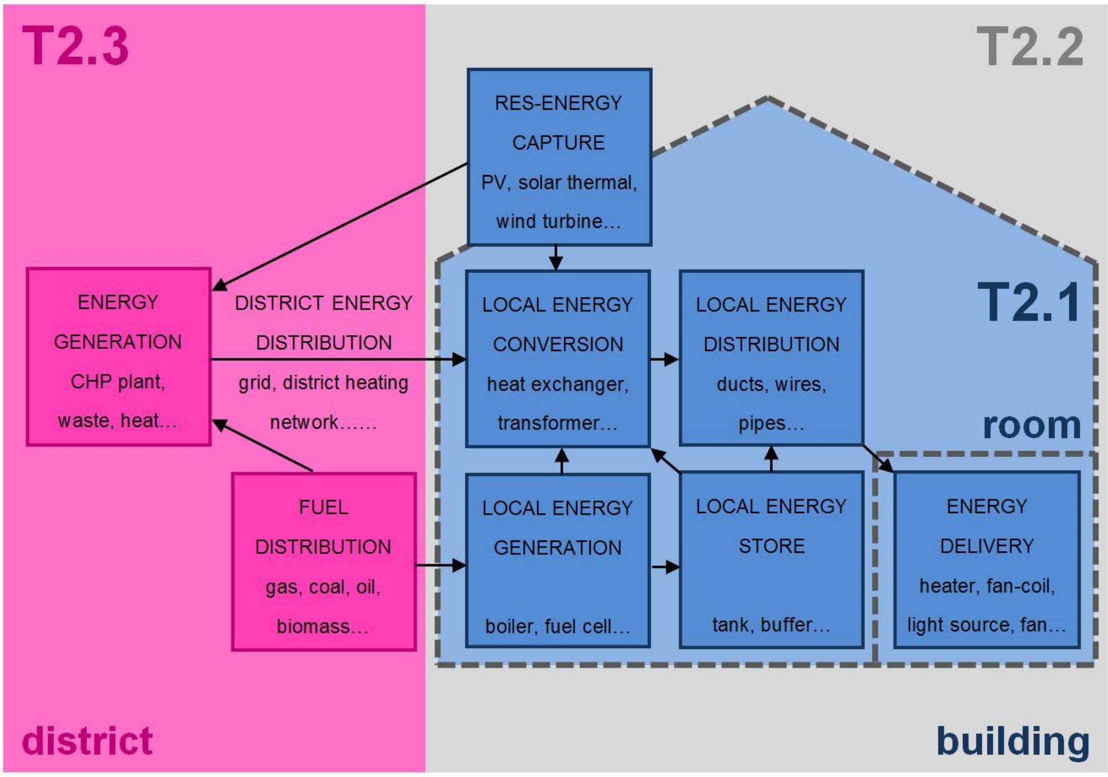
Publishable executive summary

Main aim of this deliverable is to present solutions which will be later adapted for implementation in new and retrofitted buildings in order to achieve energy savings. The range of energy saving solutions available on the market and technologies is wide. This is because nowadays, in order to achieve EU's 3x20 goals, the market is forced to introduce more efficient and energy friendly technologies. However, it is a problem to properly design the installation size and loads so that the system can work with high efficiency. The human factor is another important issue, which influences the total energy usage in the building. People, especially staff members, should be aware of reasonable and wise energy management.

This deliverable is a State of The Art in which building systems basic components are described. Mechanical, electrical and plumbing technologies, which find their usage in Health Care Buildings, are selected and analysed for use in hospital. Building technologies have been grouped into four categories corresponding to their type: Plumbing, Electrical, HVAC and Others (Supporting Technologies). Each category has been divided into subcategories according to their system role in the building. Devices responsible for energy conversion, distribution, delivery and storage are described and some parameters are given together with characterization of usage as optimization of devices operation is curtail case in the project. Research is done for technologies, which refer to the room and building level, considerations about energy integrated neighbourhood systems will be discussed in *Deliverable 2.7* and *Deliverable 2.8*. Study on which technical solution can be applied in the hospital environment and how it can improve total energy efficiency of the healthcare facility is also elaborated. As a result guidelines of how energy efficiency can be achieved are presented.

Second aim of this deliverable is to select and describe the optimization methods, which could later support other STREAMER Project Work Packages. Both Economical and Ecological aspects are taken into account within these considerations.

The report is related with other deliverables from WP2 and it is an input for further considerations regarding retrofitting and new design solutions of integrated EeB solutions for MEP and energy systems which will be done within deliverables *D2.2 Retrofitting solutions of integrated EeB solutions for MEP and energy systems* and *D2.3 New designed solutions of integrated EeB solutions for MEP and energy systems*. The correlation between other WP2 tasks is shown in the picture below.



Deliverable D2.1 is influenced by parallel STREAMER reports, which are: *D1.1Taxonomy of healthcare districts focusing on EeB morphology and features* and *D3.1 Building-oriented EeB KPIs of newly designed and retrofited buildings*. It also relates to *Deliverable 2.4 EeB technologies for building envelope and space for healthcare buildings,* which is dedicated to building envelope EeB solutions as this section of the designs process influences MEP technologies.
This report brings SoTA knowledge for other WP`s. Information about most important energy saving technologies which find application in Hospital facilities is presented.

Mechanical, electrical and plumbing (MEP`s) devices are responsible for keeping indoor conditions on the required level to provide comfort of usage and building proper maintenance. To achieve that all MEPs have to generate, distribute, deliver and storage energy so that indoor conditions in the building with particular reference to air temperature and humidity as well as safety (e.g. concentrations of gases such as carbon dioxide, powders, CO, voltaic organic compounds, below the accepted safety standard thresholds) are kept as requested. It is important that MEP units cooperate, creating one integrated network and support building with energy, which should be adequate to current needs. Flexibility of the system and proper management provides energy savings and creates better environment for the users.
When it comes to optimizing the energy usage in Hospitals standard solutions, which is common practice while office or public building auditing may not find application. The main problem is that most of hospital departments work 24h/7days, that is why i.e. introducing night overcooling in the whole building cannot be applied as some spaces required mechanical ventilation operating all day long and fresh air has to be delivered constantly. Lighting in most of the hospital areas have to be switched on even during the day.

Nevertheless there are some practical and technical solutions, which may help to achieve reduction of energy use. The brief review of actions presented in the document is given below.

Plumbing systems

Energy reduction in this field of operation can be achieved by improving the sanitary system at the first step. This is possible by reducing the consumption of water by upgrading toilets (one leaking toilet alone can waste more than 190 liters of water every day; one dripping faucet or showerhead can waste up to 3785 liters per week[1]), equip showers and taps with low- flow faucets and use of more efficient washing machines. Besides that **optimization actions**, covering following issues, should be done:

- achievement of maximal efficiency of water production and distribution,
- piping insulation thickness,
- circulation system effectiveness,
- pumping system effectiveness,
- storage possibilities with introduction of buffer tank loading schedule
- reuse of gray water
- use of rain water for flushing the toilets.

Table 1 is an outcome of study on energy efficient plumping technologies.

Technology	Usage in Hospital Care facilities: HOTEL	HOT FLOOR	OFFICE	INDUSTRY
Hands free faucets	Recommended solution	Recommended solution	Recommended solution	No need / not recommended
Pipes insulation: Supply/return/circulation pipe	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory
Insulated Buffer tank	Recommended solution	No need / not recommended	No need / not recommended	Should be/ obligatory
Night hot water production	No need / not recommended	No need / not recommended	No need / not recommended	Recommended solution
Solar collectors for DHW production	Recommended solution	No need / not recommended	Recommended solution	Recommended solution
Heat Pumps for DHW production	No need / not recommended	No need / not recommended	No need / not recommended	Recommended solution
Solar cells for DHW production	Recommended solution	Recommended solution	Recommended solution	Recommended solution
Pumps with VDS	Recommended solution	Recommended solution	Recommended solution	Recommended solution
Hot water temperature control (fixed value control)	No need / not recommended	No need / not recommended	No need / not recommended	Should be/ obligatory
Legionella prevention system	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory
Heat recovery from waste water	No need / not recommended	No need / not recommended	Recommended solution	Recommended solution

Table 1 Water system technologies application in Hospital Spaces

Should be/ obligatory (red) Recommended solution (green) No need / not recommended (blue)

Technologies marked as obligatory are these, which are driven by law regulations or are commonly used. Recommended solutions are these which application can bring energy savings but are new technologies or not so well known. No need or not recommended appears while technology is not necessary to be applied i.e. Hands free faucets are not required by law regulations but are

[1] Hospitals Save Costs With Water Efficiency , U.S Department of Energy http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/hea_water_efficiency_fs.pdf

recommended for Hotel, Hot Floor and Office area as they contribute to water savings. On the other hand, there is no need to install these taps in Industry area.

Electrical

This sector was divided on Lighting technologies and Elevator/Escalator technologies. Patient, staff and visitors' satisfaction and wellbeing depends on created environment. That is why **lighting** is one of the main factors to be considered describing Quality of the Environment. In Hot Floor and Industry area lighting is needed for the process so that it has to be fitted to the requirements. The clue to achieve low electrical energy use for lighting is to design the building with maximum use of natural daylight. Lighting, in Hotel and Office part, should be a complementary system, which provides space with required quantities of light density.

Reduction of Hospital operation and maintenance costs can be realized by:

- Installing light-emitting diodes (LEDs) in exit signs (*which use 44 kWh of energy per year*)
- Eliminating incandescent lamps
- Replacing older T12 or T8 technologies with Super T8 lamps and high-efficiency electronic ballasts.[2]

Elevators are responsible for flexible and convenient communication and have to be maintained in good conditions. Hospital buildings even if not high need to be equipped in elevators and escalators.

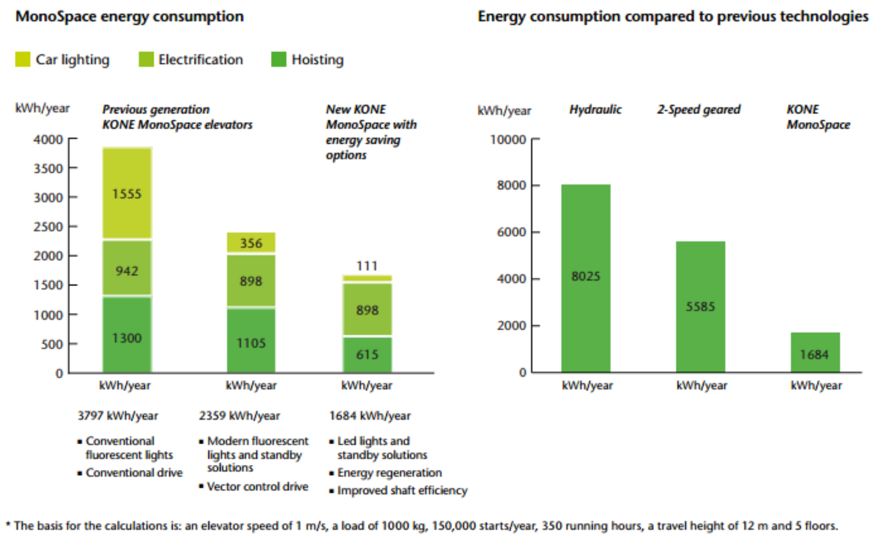


Figure 1 Energy consumption by elevator type

Source: http://cdn.kone.com/www.kone.tw/Images/brochure-kone-elevator-medical-solutions.pdf?v=2

[2] Building technologies program, U.S. Energy Department, Energy Efficiency &Renewable Energy : The http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/hea_lighting_fs.pdf

The solutions which are used to achieve energy saving are shown in the Figure1, comparing the energy consumptions for each of them. It is visible that installation of LEDs in elevators and other technologies can significantly reduce the use of energy.
Table 2 is an outcome of study on energy efficient electrical technologies.

Technology	Usage in Hospital Care facilities			
	HOTEL	HOT FLOOR	OFFICE	INDUSTRY
Installing low energy consuming lighting	Green	Green	Green	Green
Passive Infra Red sensors in bathrooms and staircases	Green	Blue	Green	Blue
Energy saving technologies in elevators (LEDs, energy regeneration)	Green	Green	Green	Green
Emergency Power system	Red	Red	Red	Red
PV cells for electrical energy production	Green	Blue	Green	Green
DC grid	Green	Green	Green	Green
Smart grid	Green	Green	Green	Green

Table 2 Electric system technologies application in Hospital Spaces

Red: Should be/ obligatory; Green: Recommended solution; Blue: No need / not recommended

HVAC Systems

Healthcare facilities are aiming of healing patients. Indoor environment quality has to meet all requirements and criteria stated for the hospitals. HVAC system has to be reliable and have to create favorable ambient for patents, providing contamination and germ free environment all day long. Combining design of reliable system, which will meet all the healthcare requirements, with idea of decreasing the energy use is the main issues discussed within following report.

This sector consists of consideration about heating systems, ventilation systems and air conditioning (cooling) systems, covering study on conversion, distribution and storage technologies. Table 3 is an outcome of study on energy efficient HVAC solutions.

Technology	Usage in Hospital Care facilities			
	HOTEL	HOT FLOOR	OFFICE	INDUSTRY
Air heat local recovery	Green	Blue	Green	Green
Air recirculation	Blue	Blue	Red	Green
VAV system	Red	Red	Red	Blue
Fans and pumps dumpers with VSD	Red	Red	Red	Red
Hybrid ventilation	Green	Blue	Green	Green
Multi split air conditioning systems	Green	Green	Green	Blue
VRF system	Red	Red	Red	Blue

Cooling ceiling panels	Green	Green	Green	Blue
Chilled beams	Green	Green	Green	Blue
Free cooling system	Green	Blue	Green	Blue
Floor heating (low temperature heating)	Green	Green	Green	Blue
Pipes insulation	Red	Red	Red	Red
Cold water storage tank	Blue	Blue	Blue	Green
Local reversal heating pumps	Green	Green	Green	Blue
Night chilled water production	Blue	Blue	Blue	Red
Absorption chillers	Blue	Blue	Blue	Green
Condensing gas boilers	Blue	Blue	Blue	Green
District heating (if possible connection)	Green	Green	Green	Green
CHP units	Blue	Blue	Blue	Green
Automatic control - central	Red	Red	Red	Red
Automatic control – individual	Green	Red	Green	Blue
Weather regulation	Red	Red	Red	Red
Control system (BMS)	Green	Green	Green	Green

Table 3 HVAC system technologies application in Hospital Spaces

Red: Should be/ obligatory — Green: Recommended solution — Blue: No need / not recommended

Technologies signed as obligatory are these which influence highly on energy efficiency and comfort but as far as research shows are not required by law regulations, recommended solutions is group of technologies which contribute to energy savings but stay additional, and are optional choice. No need appears when technology is not proper for selected area of hospital space.

Supporting technologies

Within this sector, technologies, which support building management and realization of process dedicated to chosen space, are described.

A Building Management System (BMS) is a computer-based control system installed in the building that controls and monitors the building's mechanical and electrical equipment such as heating, ventilation, lighting and fire systems. The improvement of BMS controls provides benefits to building occupants, building owner and the maintenance provider, are as follows:

- Good control of internal comfort conditions
- Provision of individual room control
- Increased staff productivity
- Effective monitoring and targeting of energy consumption
- Improved plant reliability and life
- Effective response to HVAC related complaints
- Save time and money during maintenance
- Flexibility on change of building use
- Effective use of maintenance staff
- Early detection of problems
- Satisfied occupants and happier workforce

Table 4 is an outcome of study on BMS subsystems, which leads to save energy.

Subsystem	Usage in Hospital Care facilities: HOTEL	HOT FLOOR	OFFICE	INDUSTRY
Elevator	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory
Lighting management	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory
Shading control	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory	No need / not recommended
Emergency Power System	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory
HVAC system management	Recommended solution	Should be/ obligatory	Recommended solution	No need / not recommended
Water system management	Recommended solution	Recommended solution	Recommended solution	No need / not recommended
Renewable Sources management	No need / not recommended	No need / not recommended	No need / not recommended	Should be/ obligatory
Medical Gas management	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory
Monitoring system to combat Legionella	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory
MRI monitoring	No need / not recommended	Should be/ obligatory	No need / not recommended	No need / not recommended
Monitoring the quality and use of electricity	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory
Monitoring of the electrical installation	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory	Should be/ obligatory

Table 4 BMS subsystem application in Hospital Spaces

Should be/ obligatory — Recommended solution — No need / not recommended

Selected methods of MEP system optimization

The best way to optimize environment at the room level is to control HVAC system according to changing indoor conditions and human occupancy. To realize this advantageous ventilation system, one driver should control heating/cooling system, though this sometimes is hard to realize due to technical issues. For realization of ventilation, heating and cooling VAV system is recommended. To optimize system work optimal start and stop should be set. Fans should work with variable speed. Moreover use of communicating controllers on the VAV terminals, enables to optimize static pressure control function to minimize duct pressure so that saves fan energy. This kind of optimization can be done at room level.

Economic evaluation procedure for energy systems in buildings is tool, which gives a possibility to compare different solutions according to their annuity costs and global costs at building level. Within EN 15459 Standard a procedure of evaluation of the energy system is introduced. Steps given enable to estimate economic aspects of the building system. Standard gives knowledge and explain in detail how to provide calculations. The analytic model consists of 6 steps approach. The Standard standardizes required inputs, calculation methods and required outputs for economic calculations of energy systems related to the energy performance of the building. This methodology can be use to evaluate if chosen action is economically confirmed.

List of acronyms and abbreviations[3]

- AC: Air Conditioning
- AHU: Air handling Unit
- ATES: Aquifer Thermal Energy Storage
- BEMS: Building Energy Monitoring System
- BMS: Building Management Systems
- BTES: Borehole Thermal Energy Storage
- COP: Coefficient Of Performance
- DC: Direct Current
- DHW: Domestic Hot Water System
- EPS: Emergency Power System
- GHG: Green House Gases
- IAQ: Indoor Air Quality
- MEP: Mechanical, Electrical ,Plumbing technologies
- SEER: Seasonal Energy Efficiency Ratio
- SPF: Seasonal Performance Factor
- VAV: Variable Air Volume System
- VRF: Variable Refrigerant Flow System
- WP: Work Package
- WSHP: Water Source Heat Pump

Definitions

Primary energy- energy contained in the raw fuels, which has not been conversed or transformed.

Unit average efficiency – is referred by primary energy delivered to the unit dived by energy gained after the conversion. Can be given in % or in fraction. Efficiency for some devices can be higher than one.

Average energy usage – average primary energy used by the device for operation, refers in *kWh*.

Serviced area – reference unit used to describe size of the area which can be served be one unit, refers in m^2.

Lifespan- expected lifetime for component (or system) normally specified in years. *Definition according to EN 15459 Energy Efficiency for Buildings — Standard economic evaluation procedure for energy systems in buildings*

[3] Formulas needed for calculation of values are given in Appendix 2

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CONTENTS **44**

1. State of the art of MEP technologies for Healthcare facilities

"Energy consumption and cost savings opportunities result from the simultaneous interaction of behavioral, organizational and technological changes.[4]" (Natural Department of Canada)

Figure 1 A model for change

Source: http://www.nrcan.gc.ca/energy/efficiency/buildings/embp/4005

1.1 Introduction

Mechanical, electrical and plumbing (MEP`s) devices are responsible for keeping indoor condition on required level to provide comfort of usage and building proper maintenance. To achieve that all MEPs have to generate, distribute, deliver and storage energy so that indoor conditions in the building with particular reference to air temperature and humidity, as well as safety (e.g. concentrations of gases such as carbon dioxide, powders, CO, voltaic organic compounds, below the accepted safety standard thresholds) were kept as requested. It is very important that MEP units cooperate, creating one integrated network and support building with energy adequate to current needs. Flexibility of the system and proper management provide energy savings and create better environment for the users.

When it comes to optimizing the energy usage in Hospitals standard solutions, which are common practice while office or public building auditing, may not find application. The main problem is that most of hospital departments work 24h/7days, that is why i.e. introducing night overcooling in the whole building cannot be applied. Some spaces require mechanical ventilation operating all day long, as fresh air has to be delivered constantly. Lighting in most of the hospital areas has to be switched on even during the day. Nevertheless there are some practical solutions, which may help to achieve reduction of energy use. Within this report, State of the Art solutions, which can contribute to achieve energy savings, are described.

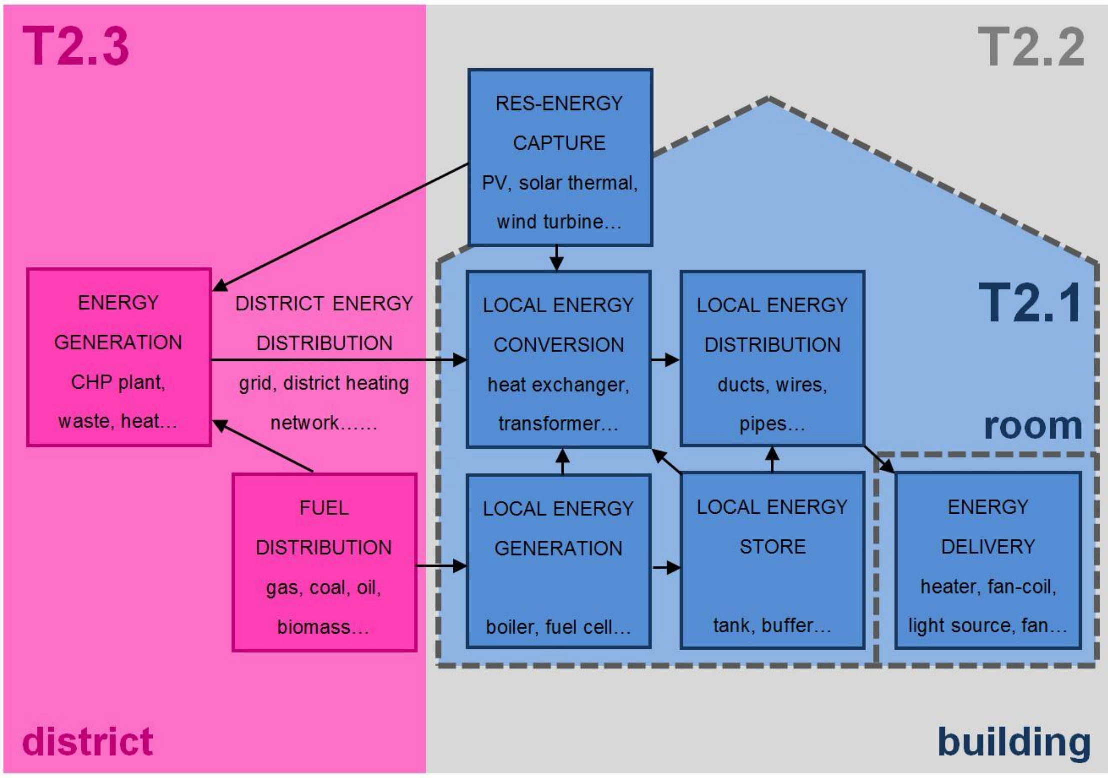
The question is where to find the energy and costs savings having on mind that priority in the Hospital is healing patients. Within this deliverable it will be shown that some savings can be found in improving

[4] http://www.nrcan.gc.ca/energy/efficiency/buildings/embp/4005

MEP system and applying more efficient technologies together with wise management. It has to be remembered that equipment installed in public buildings, regarding Healthcare facilities has to be monitored and certificated according to national certification standards. All working unit has to fulfil the technical requirements and be maintained in good technical conditions. As systems in hospitals are usually complex and wide the answer may be found not in increasing the efficiencies of working units, which has to be high anyway, but by optimizing their work within the system and adapt to serviced area needs. This can be realized in few ways, concerning economical aspects (investment and maintenance costs during the whole operation life of the system), ecological aspects (primary energy consumption, CO_2 emission), reliability (possibility of failure), and human factor (patients and staff satisfaction).

Climate conditions and architect preferences in envelope design influences the amount of energy needed to be delivered by MEP equipment. It has to be pointed out that the biggest influence of final outcome of every MEP system has building shape and envelope as space function can be changed during the facility life. It has been known that site effects such as day lighting, amount of solar gains or heat capacity of partitions can significantly influence the energy performance of the building. First thing to do while finding the optimal energy system for new buildings is to design optimal building structure, which will fit climate conditions. For retrofitting, improvement of existing structures should be done to eliminate unwanted energy flows. Considerations about building envelope are provided in D2.4. Further deliverables D2.2 and D2.3 will cover retrofitting and new design solutions of integrated EeB solutions for MEP and energy systems.

The report is related to other deliverables from WP2 and it is an input for further considerations regarding retrofitting and new design solutions of integrated EeB solutions for MEP and energy systems which will be done within deliverables *D2.2 Retrofitting solutions of integrated EeB solutions for MEP and energy systems* and *D2.3 New designed solutions of integrated EeB solutions for MEP and energy systems*. The correlation between other WP2 tasks is shown in the picture below.



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The best way to optimize the technical installations is to ensure devices to work with high efficiencies on nominal parameters and support control system which will manage to adapt operation parameters of the device to current demands. Later chapters will provide best practice solutions to achieve that goal. First thing which should be done is defining where in Hospital facility energy is wasted and where savings can be done without influencing human comfort and safety. For this purpose Energy usage distribution in Hospital Care Facilities have to be done. As an example, in the pie chart below (Figure 2) electrical energy usage for units operation in Health Care Facilities in Sweden is presented.

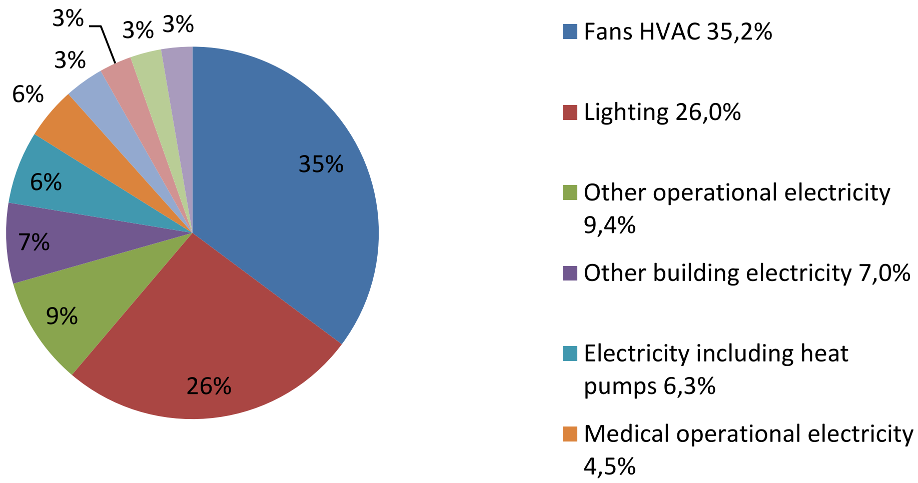

Figure 2 The chart is electricity use in health care facilities in general in Sweden. [1]

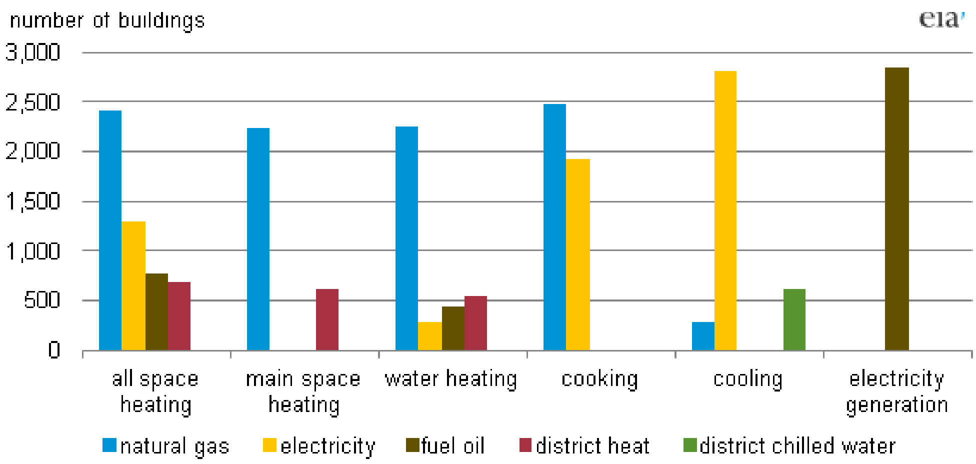

Figure 3 Primary energy sources used in healthcare buildings

As it can be seen at the diagram (Figure 3) that for large hospitals (according to EIA research) main space heating and water heating is provided by natural gas sources which characterize high efficiencies and low emissions.

1.1 Plumbing systems

In Hospitals both hot and cold water demand is high. It is mainly because water is needed for medical and hygienically purpose as well as in the kitchens and laundries. Hospital centers have their own water management systems. As an example value taken for calculations of water system in Poland according to National Standards average water usage in multi-ward Hospital is 650l/bed/day[5].

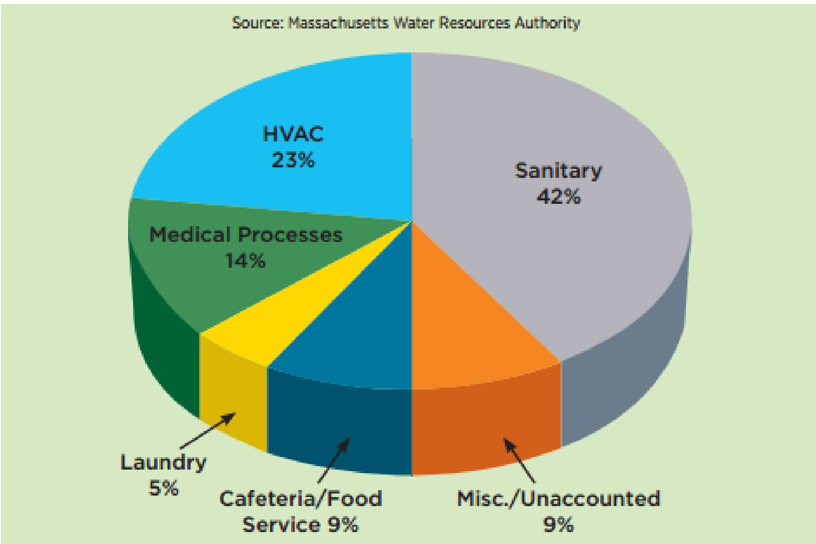

Figure 3 Hospital Water Usage- Example study

Source:http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/hea_water_efficiency_fs.pdf

[5] Source: Polish national standard giving the average water usage

The pie chart (Figure 4) shows average water distribution in hospitals for each process. It was prepared within U.S. Department of energy efficiency report, in which seven Massachusetts hospitals took part. The final outcome of the report showed that there is a 20% potential of reduction of the water usage in the facilities. This can be achieved by **improving the sanitary system at the first step** by reducing the consumption of water by **upgrading toilets** (one leaking toilet alone can waste more than 190 liters of water every day; one dripping faucet or showerhead can waste up to 3785 liters per week[6]), **equip showers and taps with low- flow faucets** (appendix 1, chapter 2.3.1) and **use of more efficient washing machines**. Besides that actions optimization, covering following issues, should be done:

- achievement of maximal efficiency of water production and distribution,
- piping insulation thickness,
- circulation system effectiveness,
- pumping system effectiveness,
- storage possibilities with introduction of buffer tank loading schedule
- reuse of gray water
- use of rain water for flushing the toilets.

Human factor is also very important; it is good to make staff aware that they have big influence on water savings. This can be done by organizing workshops or by placing sings in toilets, kitchens etc. that will be reminding about the reasonable water management.

Sewage production is significant and hospital wastewater has to be treated with special care to minimize the risk of contamination. **Heat from warm water can be reused** (Appendix 1, chapter 2.2.2), however it is not recommended to use this practice in Hot Floor area and Hotel where contamination risk is high.

1.1.1 Water supply systems

Water supply system in large hospital facilities is expanded. Amount of water hot and cold is forced by single space requirements. Though building final form influences energy needed for water supply in the facility as well. Pumps are characterized by pumping height, which depends on pipelines length and building height. The higher the building is the more energy is needed for pumping.

The optimization at the room level is slightly inconvenient; having in mind that water is needed for the patient service, hygienic reasons and cleaning. Nevertheless water usage can be reduced by **using handless faucets controllers** (Appendix1, chapter 2.3.1). From technical point of view there is no contraindication in **collecting rainwater and using it for toilet flushing purpose in Office or Hotel area**.

When it comes to the hot water, heat losses should be reduced, it can be realized by insulating hot water and circulation pipelines. Hot water can be prepared in renewable sources with cooperation with conventional fuel fired devices or in each of them separately (different sources were described in Appendix1, chapter 2.1).

To recognize the most optimal system criteria analysis of available renewable and conventional fuels should be done due to chose the suitable DHW production system and suitable application of renewable sources such as Solar Panels or Heat Pumps. Storage possibilities and pipes insulation thickness should

[6] Hospitals Save Costs With Water Efficiency , U.S Department of Energy
http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/hea_water_efficiency_fs.pdf

be also taken into account. For auxiliary equipment an analysis on how much electrical energy is needed for operation should be done. This can be performed according to European certification standards methodology and European Standards. While calculating energy demand circulation and heat losses through piping should be considered.

Nowadays, for achieving energy efficient water supply system using the renewable sources following technologies may be used:

- **Heat pumps** *(described in Appendix 1 chapter 2.1.13)*

  Water requires 55-60^{o}C, what is more it is important for DHW system to keep required hygienically parameters to prevent *Legionella* growth. That is why from time to time, if stored in buffer tank, water has to be overheated to 60^{o}C-70^{o}C. This requirement influences reduction of the COP due to larger temperature lift compared to the use of heat pumps for space heating source with lower distribution temperature. To reach higher temperature additional electrical heater is required or second method, less energy requiring, water chlorination can be designed (method described in appendix 1 chapter 2.5.1). Nevertheless while using a heat pumps energy savings of 40-60 % are possible compared to electric heaters.[7]

  Positive influence on increasing COP level has extraction of heat from warm waste water but in case of healthcare centers possibility of water contamination is higher (some leaks may appear in heat exchanger). This solution is recommended for office part of the building where risk of contamination is lower or those rooms in hotel area where the water pollution risk is low. Worth to mention is that Heat Pumps working with CO_2 lead themselves particularly well to DHW due to achieving higher COP. (D.Harvey)

- **Solar panels** *(described in appendix 1 chapter 2.1.14)*

  This solution relies on weather conditions and if several cloudy days occur the required energy needed for heating up the water cannot be delivered. That is why, especial in hospitals placed in less sunny zones, should be somehow combined with other energy sources working as an integrated bivalent system. Solar systems should be equipped in storage tanks and be prevented from freezing while working in close loop. It has been a common practice to use solar panels in hospitals and public building as this nonrenewable source installation were covered by national grants.

1.1.2 Measurements of water supply system performance

To describe the water supply system performance it is important to:

- Set the minimal and maximal energy performance requirements for DHW system, what is :
  - **Maximal amount of primary energy needed to prepare hot water** relative to served area (hotel, hot floor, industry, office, etc.) in kWh/m^2 or in GJ/m^2
  - **Maximal CO_2 emission** during the hot water production
  - **Maximal electrical energy consumption for pumping** related in kWh/year
  - **Minimal efficiency of hot water system** expressed as ratio of consumed energy to produced energy

[7] L.D. Danny Harvey “A handbook on Low-Energy Buildings and District Energy Systems”; London Sterling, VA

- **Minimal share of renewable sources in energy production** the amount of hot water produced in renewable sources to total amount of produced hot water

- Set minimal lifespan of system components
- Set maximal maintenance costs

These values should be set separately within the countries as prices may be different.

The calculation methodologies are described in national technical standards being the implementation of EPBD or some additional information can be found in EN Standards.

1.1.3 Water system technologies in correlation to Hospital spaces and KPI`s

As a conclusion of water system considerations after analysis of the SoTA, the authors propose to achieve STREAMER goals as presented in Table 1. Technologies marked as obligatory are driven by law regulations or are commonly used. Recommended solutions are those which application can bring energy savings but are new technologies or not so well known. No need or not recommended appears while technology is not necessary to be applied i.e. Hands free faucets are not required by law regulations but are recommended for Hotel, Hot Floor and Office as they contribute to water savings. On the other hand, there is no need to install these taps in Industry.

Possible measurements to estimate KPI`s are shown in Table 2

Technology	Usage in Hospital Care facilities			
	HOTEL	HOT FLOOR	OFFICE	INDUSTRY
Hands free faucets	[green]	[green]	[green]	[blue]
Pipes insulation: supply/return/circulation pipe	[red]	[red]	[red]	[red]
Insulated Buffer tank	[green]	[blue]	[blue]	[red]
Local hot water preparation	[blue]	[blue]	[green]	[blue]
Night hot water production	[blue]	[blue]	[blue]	[green]
Solar collectors for DHW production	[green]	[blue]	[green]	[green]
Heat Pumps for DHW production	[blue]	[blue]	[blue]	[green]
Solar cells for DHW production	[green]	[green]	[green]	[green]
Pumps with VDS	[green]	[green]	[green]	[green]
Hot water temperature control (fixed value control)	[blue]	[blue]	[blue]	[red]

Legionella prevention system				
Heat recovery from waste water				

Table 2 Water system technologies application in Hospital Spaces

Should be/ obligatory: Recommended solution No need / not recommended

Possible measurements to estimate KPI`s related to electrical systems are presented in Table 2

KPI	Measurements	Tool
Energy Performance and Efficiency	Primary energy consumption	Measurements on site ; National Certification Standards
	CO_2 and GHG emission	Measurements on site
Financial base for comparison	Investment costs	Cost estimation model
	Maintenance costs	Practical knowledge; EN15459 - Economic evaluation procedure for energy systems in buildings
	Lifespan	Practical knowledge; EN15459 - Economic evaluation procedure for energy systems in buildings
Quality of the Environment & Operational Efficiency	Water pollution prevention	Contamination tests
	Water filtration	Water quality tests

Table 3 Proposed tools for KPI`s measurements

1.2 Electrical

1.2.1 Lighting technologies considerations

The clue to achieve low electrical energy use for lighting is to design the building with maximum use of natural day light. Lighting, in Hotel and Office part, should be the complementary system which provides space with required quantities. Patient, staff and visitors' satisfaction and wellbeing depends on created environment. That is why lighting is one of the main factors to be considered describing Quality of the Environment. In Hot Floor and Industry area lighting is needed for the process so that it has to be fitted to the requirement.

According to U.S. Department of Energy savings on lighting can be significant without affecting the deterioration of comfort. There is a wide range of commercially available technologies which are cost-effective.

Reduction of Hospital operation and maintenance costs can be realized by:

- Installing light-emitting diodes (LEDs) in exit signs (*which use 44 kWh of energy per year*)
- Eliminating incandescent lamps

- Replacing older T12 or T8 technologies with Super T8 lamps and high-efficiency electronic ballasts.[8]

(Lighting technologies were wider described in appendix 1 chapter 2.2.3).

Another important factor is lighting control, big influence here have staff awareness of being responsible for energy savings and turning off lights while rooms are not in use. The solutions, which are recommended nowadays as a best practice given in Building Technologies Program are:

- Incorporating day lighting controls in patient rooms and public spaces with large window areas.
- Integrating controls that enable continuous dimming (100 to 5 percent lamp power).
- Installing occupancy sensors in spaces that are frequently unoccupied, such as restrooms, stairwells, service areas, and mechanical plants.
- Using sensors that include dimming and stepping options for spaces that utilize day lighting.
- Incorporating exterior motion sensors, which save energy and can enhance security[5].

1.2.2 Elevators/Escalators considerations

Elevators are responsible for flexible and convenient communication and have to be maintained in good conditions. Hospital buildings even if not high need to be equipped in elevators and escalators because some patients are not able to use stairs.

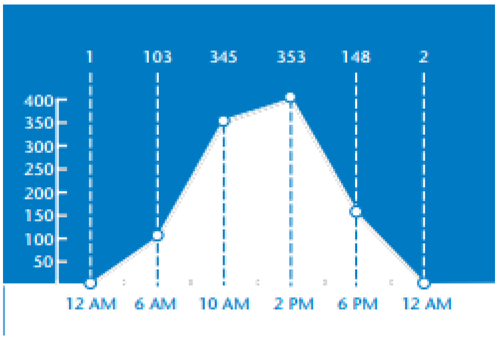

Figure 4 Intensity of elevators starts/hours in a 15-floor hospital building

The figure above shows that intensity of elevator use is the highest from 10AM to 2 PM, this is followed by human behavior which as it is wider described in Deliverable 1.1 influences the energy use profile in the building. It is hard to influence this factor, however this does not mean that energy saving cannot be done within this sector of MEP. There is a new trend in building, which **introduces energy saving elevators** on the market. There are few manufacturers which are producing energy savings lifts as an example the new Universite de Montreal Hospital Center can be recalled as an example. Producer of elevators introduces new technology: "*A traction drive mechanism of a counterbalance system provides a smooth ride and eliminates machine room installation and use of hydraulic oil. The result is a motor-operated elevator that offers efficiency and convenience while conserving space inside your home's interior. Green technology extends beyond this elevator's operation*." (Nationwide Lifts)

According to one of pioneer manufacturer in developing energy saving elevators technologies, the annual energy consumption of a typical mid-size elevator is reduced from over 20,000 kWh to one third, in use of the latest energy saving options reduction of the energy consumption reaches 5000 kWh/year.

[8] Building technologies program, U.S. Energy Department, Energy Efficiency &Renewable Energy : The http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/hea_lighting_fs.pdf

The solutions which are use to achieve energy saving are shown at the diagram below (Figure7), comparing the energy consumptions for each of them. It is visible that installation of LEDs in elevators and other technologies can significantly reduce the use of energy.

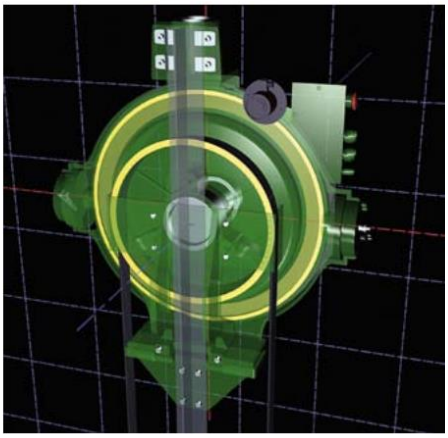

Figure 5 Efficient hoisting and energy regeneration

As an example of energy saving solution so called EcoDisc® is given (Figure 6) being designed by one of following elevator producer KONE. According to technical data, "*The very high mechanical and electrical efficiency of EcoDisc® saves a considerable amount of energy compared with other solutions: it consumes 50% less energy than a geared two-speed traction elevator and 70% less than a hydraulic elevator. It also recovers braking energy, which can be converted into electricity for use elsewhere in the hospital. This regenerative feature alone can save 20-30% of the elevator's annual energy consumption*". (KONE)

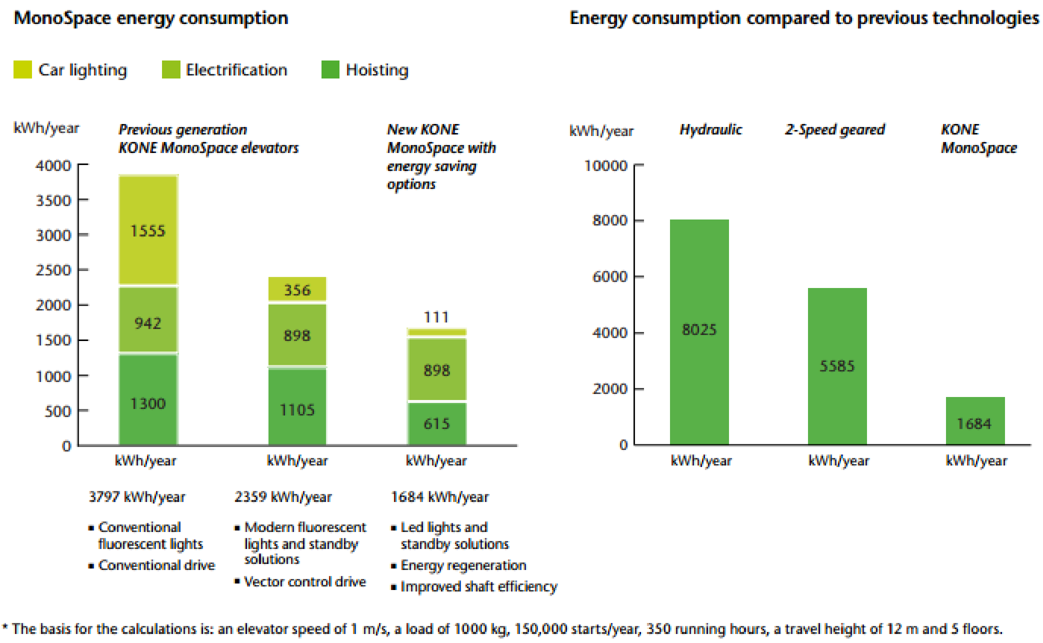

Figure 6 Energy consumption by elevator type

Source: http://cdn.kone.com/www.kone.tw/Images/brochure-kone-elevator-medical-solutions.pdf?v=2

Lifts designed for hospitals need to ensure smooth and quiet operation, there are few kinds of elevators, which have to be in Hospital building and their number depends on space function. Types of lifts are:

- Patient - trauma elevators
- Patient -service elevators
- Freight elevators
- Visitor-passenger elevators[9]

Elevators should be considered while describing KPIs` connected with human satisfaction and safety as they are used for evacuation purpose and Energy Performance and Efficiency.

Measured value in case of elevators: electrical energy consumption for operation in *kWh/year*

1.2.3 Measurements of electrical system performance

Characterization of electrical system performance should cover specification of electrical energy use for working devices of the same type and destination servicing space of one function. The maximal energy usage should be given for specific device while in operation, this value should be assign for particular space in the Hospital regarding its function, according to space typologies given in Deliverable 1.1. Working schedules should be based on activities connected to Medical Care and human behavior.

1.2.4 Electrical systems technologies in correlation to Hospital spaces and KPI`s

As a SoTA solution which in authors' opinion can bring savings are as presented in Table 3.

Technology[10]	Usage in Hospital Care facilities			
	HOTEL	HOT FLOOR	OFFICE	INDUSTRY
Installing low energy consuming lighting	green	green	green	green
Passive Infra Red sensors in bathrooms and staircases	green	blue	green	blue
Energy saving technologies in elevators (LEDs, energy regeneration)	green	green	green	green
Emergency Power system	red	red	red	red
PV cells for electrical energy production	green	blue	green	green
DC grid	green	green	green	green
Smart grid	green	green	green	green

Table 4 Electric system technologies application in Hospital Spaces

red: Should be/ obligatory; green: Recommended solution; blue: No need / not recommended

[9] Kone Solutions for Medical facilities "Managing the flow of people and Materials in Medical facilities" http://cdn.kone.com/www.kone.us/images/kone-solutions-for-medical-facilities.pdf?v=2

[10] Technologies are described in Appendix 1

Possible measurements to estimate KPI`s related to electrical systems are presented in Table 4

KPI	Measurements	Tool
Energy Performance and Efficiency	Primary energy consumption	Measurements on site; National Certification Standards
	CO_2 and GHG emission	Measurements on site
Financial base for comparison	Investment costs	Cost estimation model
	Maintenance costs	Practical knowledge; EN15459 - Economic evaluation procedure for energy systems in buildings
	Lifespan	Practical knowledge; EN15459 - Economic evaluation procedure for energy systems in buildings
Quality of the Environment & Operational Efficiency	Noise	Measurements on site
	Light intensity, colour, etc.	Measurements on site, EN12464 Light and lighting. Lighting of work places. Indoor work places

Table 5 Proposed tools for KPI`s measurements

1.3 HVAC Systems

Healthcare facilities are aiming of healing patients. Indoor environment quality has to meet all requirements and criteria stated for hospitals. **HVAC system has to be reliable and have to create favorable ambient for patents, providing contamination and germ free environment all day long.** Combining design of reliable system, which will meet all the healthcare requirements, with idea of decreasing the energy use is the main challenging task for HVAC engineers.

HVAC criteria for hospitals are different from country to country as they are stated by national law and technical requirements and in many cases are individual requirements given by hospital to support performed treatments.

Within this chapter and analyses of SoTA solutions improving energy efficiency of HVAC elements, which may possibly find their application in Medical Centers, was done.

1.3.1 Ventilation systems considerations

Main function of ventilation systems is to remove contaminants from air through filtration, dilution, and maintain air pressure difference between the rooms if necessary. Criteria for air purity, number of air exchanges and temperatures according to room functions are given in specific guidelines for medical care HVAC designing such as ASHARE standards and can be used in all climates zones as they are subjected to function of the room. As IAQ refers to room destination, different more restricted requirements have to be met in the surgery room in comparison with rooms destined for longer term patients' hospitalization (Hotel) or Offices.

Rooms for patients with decreased immunology and surgery wards have to be kept in upper pressure to surrounding rooms so that germs could not infected the air. Operation Theater has to be kept in more restricted conditions and has to have its own IAQ handling system (usually laminar ceilings). In this case air recirculation cannot be applied. Patients with infectious diseases have to be treated in under pressure conditions to prevent other patients' infections. Air has to be well filtrated.

The amount of air needed for dilution usually exceeds significantly air needed for keeping required temperature and humidity in the rooms. According to ASHARE design guide[11], where study for HVAC energy efficient design in medical care buildings in USA, constant volume reheat system was used the most often in Hospital Care Facilities. It is because this solution is simple and easy in exploitation and enables to control both temperature and humidity, providing sufficient amount of air needed for dilution purpose. Unfortunately this system is not leading to energy savings.

In case study, done in ASHRE guide, in the base line model critical care areas are served by multiple-zone, CAV AHUs with local reheat coils. All other areas were served by multiple-zone, VAV AHUs. Cooling was provided by air cooled direct-expansion equipment and heating was provided by gas-fried, water boilers or electric heatres. Though guide is dedicated to small health care facilities (smaller than 8400m^2) it is worth considering because proposed there solutions help to achieve even 30% decrease of energy usage. Study showed that reheat energy is 20% of total energy use in the building. This study can be expanded for big Healthcare districts.

[11] ASHARE guide book "Advance energy design guide for health care facilities."

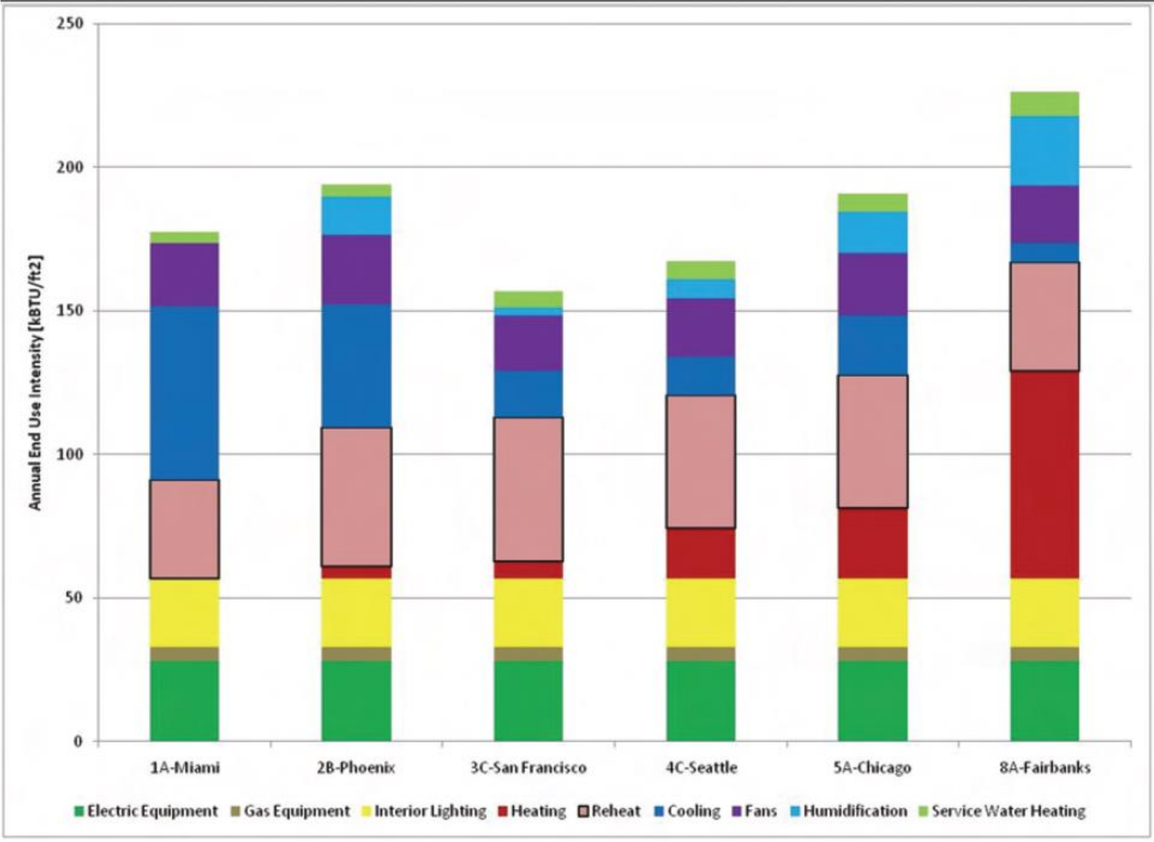

Figure 8 Reheat energy in comparison to other energy used in healthcare facilities [12]

Solutions for improving HVAC system given in ASHERE Guide are:

- Multiple zone, VAV systems with direct expansion cooling or water chiller and either a hot water coil, indirect gas boiler, or electric heater in the air handler and either a hot water coil or electric heater in the VAV terminal,
- Water source heat pumps (WSHPs) with either a water boiler or electric heater and a dedicated outdoor air system for ventilation,
- Fan-coil with a water chiller and either a water boiler or electric heater and a DOAS for ventilation.

However, according to the mentioned Guide, WSHPs and fan-coils are not recomended for Critical Care areas because they have limited filtration capability and can produce noise. There is also a maintenace aspect, WSHPs and Fan-coils are difficult to keep in cleanliness. If not well operated the moisture can apperar on the surface. (All listed above technologies were described in Appendix 1)

First described sollution is recomneded for Critical Care Areas:

- Surgery rooms,
- Recovery rooms,
- Deliver rooms,
- Intensive care,
- Substerile service areas,

[12] ASHARE guide book “Advance energy design guide for health care facilities.”

- Triage.

All recalled solutions are applicable aiming to achieve lower energy usage for Noncritical Care Areas, which are:

- Patient rooms,
- Examination rooms,
- Treatment room,
- Offices.

It seems that State of the Art solution improving energy efficiency of Ventilation is replacing CAV system with VAV system guaranteeing better environment adjustment to current demands (VAV system operation was described in Appendix 1, chapter 2.2.10).

Fan used in ventilation ducts as well as in fan-coils should be equipped in variable speed motors VDS (Appendix 1 chapter 2.2.9). Another worth considering possibility for ventilation for fresh air purpose and dilution in Health Care Facilities seems to be **Hybrid Ventilation** which connects features of natural and mechanically driven air flow. This kind of supporting rooms with air can be realized especially in areas where IAQ is not required on the high purity level and natural ventilation does not work in a proper way. Fans uses great percentage of total energy demand, use of hybrid fans could significantly decrease the electrical energy needed for ventilation purpose (solution was described in Appendix 1 chapter 2.2.6).

Anaylisis of delivery units showed that for hospital purpose promising solution for delivering the fresh air to the room are active **chilled beams** (described in Appendix 1 chapter 2.3.14). Energy usage can be reduced from 20% to 50% depending on the building and climate. Energy savings are caused by eliminating energy usage by fans and enabling the system to work with water of higher parameters what influences rising of chilling system effectiveness.

Another solution which helps to achive energy efficiency goal is **installation of recovery units in the room**. It is an energy efficient alternative to extract ventilation and an effective remedy for damp problems (Appendix 1 chapter 2.3.9). **Heat recovery can be realizaed on the room level or at the building level, in the exchanger being a part of central AHU**. Recuperators or plate heat exchangers consist in a sandwich of metal plates with interlaced air paths, transferring thermal energy between air streams from one side of the plate to the other. They allow **to increase the efficiency of the systems up to 70%**, eventhough can signigicantly decrease amount of energy needed for ventilartion purpose. AHU operation and its elements were described wider in Appendix 1 chapter 2.1.10.

Air recirculation is not recomneded in Hotel area and hardly ever used in Hotfloor area, though it can be applied in Office.

1.3.2 Heating system considerations

Heating systems are responsible for mantaining indoor temperture at required level. Expecially in central and East Europe where heating season lasts half a year. In those regions it has been a common practice that ventylation system does not cover heat losses in the building. The main aim of achieving the low energy usage for heating is without a doubt **a thermomodernisation** of the facility which leads to decreasing heat losses thougth the external partitions. It effects that heating system can be smaller if energy will be well disposed. In Hospital main advatage is that temperature in the rooms for patients has to be 20^{o}C to 25^{o}C constantly as pateints are not exposed to risk of overcooling. However there are rooms in hospital which do not require so stable conditions and indoor temperature can be lower. It refers mainly to technical rooms, where temeperature or humidity is not required to be monitored, or kitchens, where heat gains are high. Another important factor which influensces reduction of heat losses in new build faciliteis is wise use of solar gains during the day and prevention from extended heat losses though the fenestration placed on north facades.

Nowadays, **heat sources available on the market characterized with high efficiencies, influence the energy performance of the system; however to achieve that they have to run at nominal loads, what has to be taken into acount while designing the whole system**. Choice of the local heat source is mostly conditioned by designed system parameters such as water temperature. For incerase enery efficieny **low temperature systems are recommended**, this solution give possibility to use solar, geothermal or other natural energy to produce heat. **Low temperature distribution systems such as floor heating and wall heating makes indoor environment more comfortable for the user**. Another possibility, if available, is connection to the **district heating**. This option can cover heat supply for DHW, heating and technological heat (i.e. for AHU water heater) within one substation. Heat transfer in this case is very efficent. (Appendix 1, chapter 2.1.6). If heat is produced outside the building (neighbourhood) it seems to be the most wise solution.
Proper regulation brings significant savings. Presented below solution is one possible option for floor heating reguation available on the market, presented here as an example.

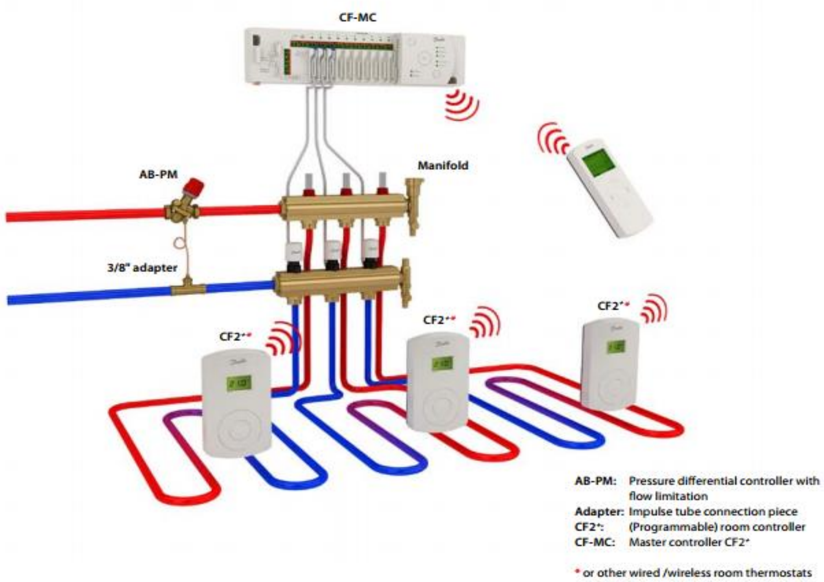

Figure 9 Floor heating pressure and temperature regulation system
Source: http://heating.danfoss.com/PCMPDF/VBHRA202_AB-PM_brochure_A4_UK_low-res.pdf

"With a room thermostat in each room, the indoor temperature is controlled via the zone valve on each loop. This turns the system from a static into a dynamic, variable-flow system, which requiresautomatic balancing. Placing an AB-PM valve in front of the manifold delivers automatic balancing for each department, independently of other apartments in the same building[13]." (DANFOSS) This system can be easily powered

[13] Danfoss " Consistent hydronic control Continuous energy savings "

by low temperature heat source such as condensing boler or heat pump. This example is one of many market offerts with similar mode of action.

At the space level there are three different methods of controlling the heating system. Automatic Regulation, Central Regulation and Local Regulation. At present a typical ward has just one sensor positioned at the furthest part of the ward and this controls a simple zone valve. There is a conflict between the rooms at the supply end of the ward and those at the far end of the system, as the rooms at the far end (where the temperature sensor is located) will be set at a comfortable level, whereas the rooms at the start of the heating circuit will experience overheating, as a result of maintaining comfort levels at the location of the sensor.

By installing a temperature sensor and local valve and actuator in each room / bay, the desired temperature can be maintained thereby improving the patient / staff environment and assisting clinical effectiveness (regulation technologies were described wider in Appendix 1, chapter 2.2.5).

1.3.3 Cooling systems considerations

Reducing the cooling load depends on building shape and orientation; the choice of building materials; on window size and other issues which are decided in early designing phase. Cooling load can be calculated according to methodology given in EN ISO 13790 *Energy performance of buildings — Calculation of energy use for space heating and cooling*. The size of system results mostly from building geometry and used materials, the most significant savings can be done while making decision at this level of design. Nevertheless savings can be done by wise cooling system design, operation and control. The most important factor which determines the system is space with assigned humane activity and function.

Knowing all that, currently the system flexibility seem to be the most accurate feature. If there is a need for cooling few rooms which have the same destination Variable Refrigirant Flow (VRF) system is recommended (Appendix 1, chapter 2.2.13). Another question is what kind of delivery unit should be instaled (fancoil, ceiling panels, chilling beams, etc.). **Connecting cooling system with Ventylation system is also good solution**. Amount of fresh air will be delivered to the room and conditioned in a way which will be adequate to current humidity and temperature in the room (this is a miain advatagous of VAV ventylation system).

The main thing is **not to overestimate the system**, according to Danny Harvey(2006) typical design values gives overestimated numbers, he claims that lighting load is about 20 W/m^2, while measuerments showed that in reacent systems this value has average of about 14 W/m^2 and will probably be lower while improving lighting technology. Design guidelines overestimate the cooling loads by occupants and by office equipment this results in ovesizeing the cooling equipment and force it to work at smaller fraction of its peak capacity. Vapour compressor chillers efficiency , according to the author, is 50-60% of full load, even if equiped in Variable Speed Drives (VSD). **Proper system sizing is very important** while there is a goal of energy savings. This should be tested as a priotity while optimizing the cooling system.

However, there are a lot more possible technologies which are more or less efficeint. In energy saving point of view **free cooling (cooling towers)** seems to be a good solution to find significant energy saving in all European Countries. Figure 9 presents basic scheme of the system, which d*uring the* *summer operates as a conventional cooling tower/chiller system. During the winter, the chiller is bypassed, and the cold water produced by the cooling tower cools the chilled water serving the load through a heat exchanger. Systems of this type have been operated successfully in colder climates and are economical in warmer climates as well.*[14] To measure the performance of the unit COP is used. Cooling towers can also influence the energy savings as they permit more effective chilling. In case of cooling tower dimensioning oversizing can reduce the energy use.

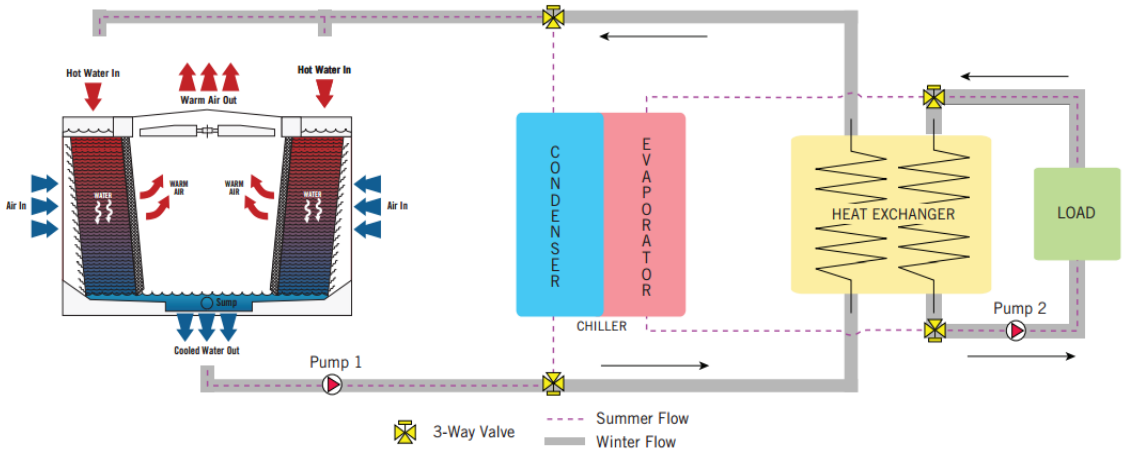

Figure 7 Cooling Tower and Heat Exchanger Free Cooling System

Source: http://baltimoreaircoil.com/english/resource-library/file/1473?dl=1

Cooling efficiency increases with cooling capacity. It should be pointed that window air conditioners and wall conditioner are the least efficeint and **commercial centrifugal chillers are the most efficient**. **It is more energy efficient to supply chiller water from cental chillers, with appropriate individual control and metering**. Another posiibility is to connect building to **the district cooling system** if available. Third solution is to **install heat pumps in individual space units** that would be connected to water circulation loop in heat exchanger. Anyway this solusion is less efficient than centralized chilling. (D. Harvey 2006)

For chilled water production absorption chillers may be used, but this technolgy is not popular on the market.

To save primary energy **night production should be considered**. Chilled water produced during the night can be later storage i.e. in PCM materials with melting point in the 8°-12°C. Moreover PCM materials can be also placed in the rooms so that cooling loads would be smaller. But it has to be rememberd that if such an improvement would be done, **chillers sholud be addapt to new cooling demands so that they could work on high efficieny** (D.Harvey 2006).

Cooling storage technologes were wider discribed in Appendix1, chapter 2.4.4.

1.3.4 Integrated heating, hot water production and air conditioning

[14] BAC technical resources “Minimizing Energy Costs with Free Cooling” Product and application Handbook 2012

System integration is possible while using the Heat Pump. This gives an opportunity to combine hot water, heating, cooling and ventilation requirements of the building in a way that can lead to energy savings[15]. Technical information how this can be achieved can be found in "A handbook on Low-Energy Buildings and District Energy Systems" by L.D. Danny Harvey

1.3.5 Measurements of HVAC system performance and possible technologies application in each Hospital space

Energy savings can be done at room level and building level. To achieve that **heat loads** regarding the climate zone (solar gains) **should be given according to space function** to set the maximal values.
Performance of motors should be measured regulary and serviced according to technical requiremnts.
To set the system efficiency **distribution losses should be eliminated** and all the **ducts and pipse should be insulated propely**. **Ducts should be cleaned and maintain in good conditions** to prevent air contamination and secure good air quality (Appendix1, chapter 2.2.8). **Devices operation should be constantly monitored** and controlled so their working point is always highly placed on the efficiency curve**. Motor driven units should be equiped in VDS** (Appendix 2.3.3).

Action which should be taken to find siutable system:

- Calculation of heat losses through partitions and for ventilation according to national standard.
- Detailed simulation of room activities and internal loads to estimated heat gains within the space.
- Definition what type of system is needed for the process and their requirements (to see what kind of system can cover most of the controlled in the room parameters)
- Choose the most energy efficient and reliable system of heat distribution.
- Choose the source which can cover the demands and work effectively while operating on designed earlier parameters.

1.3.6 HVAC systems technologies in correlation to Hospital spaces and KPI`s

Application of described solutions regarding Hospital funcion spaces are given in Table 5.

Technology[16]	Usage in Hospital Care facilities			
	HOTEL	HOT FLOOR	OFFICE	INDUSTRY
Air heat local recovery				
Air recirculation				
VAV system				

15 L.D. Danny Harvey "A handbook on Low-Energy Buildings and District Energy Systems"; London Sterling, VA
16 Technologies are described in Appendix 1

Fans and pumps dumpers with VSD	Red	Red	Red	Red
Hybrid ventilation	Green	Blue	Green	Green
Multi split air conditioning systems	Green	Green	Green	Blue
VRF system	Red	Red	Red	Blue
Cooling ceiling panels	Green	Green	Green	Blue
Chilled beams	Green	Green	Green	Blue
Free cooling system	Green	Blue	Green	Blue
Floor heating (low temperature heating)	Green	Green	Green	Blue
Pipes insulation	Red	Red	Red	Red
Cold water storage tank	Blue	Blue	Blue	Green
Local reversal heating pumps	Green	Green	Green	Blue
Night chilled water production	Blue	Blue	Blue	Red
Absorption chillers	Blue	Blue	Blue	Green
Condensing gas boilers	Blue	Blue	Blue	Green
District heating (if possible connection)	Green	Green	Green	Green
CHP units	Blue	Blue	Blue	Green
Automatic control - central	Red	Red	Red	Red
Automatic control – individual	Green	Red	Green	Blue
Weather regulation	Red	Red	Red	Red
Control system (BMS)	Green	Green	Green	Green

Table 6 HVAC system technologies application in Hospital Spaces

Red: Should be/ obligatory — Green: Recommended solution — Blue: No need / not recommended

Possible measurments to indicate KPI`s are given in Table 6.

KPI	**Measurements**	**Tool**
Energy Performance and Efficiency	Primary energy consumption	Measurements on site ; National Certification Standards
	CO_2 and GHG emission	Measurements on site
Financial base for comparison	Investment costs	Cost estimation model
	Maintenance costs	Practical knowledge; EN15459 - Economic evaluation procedure for energy systems in buildings
	Lifespan	Practical knowledge; EN15459 - Economic evaluation procedure for energy systems in buildings
Quality of the Environment &	Noise	Measurements on site

Operational Efficiency	IAQ	Tests on site, Filters with proper purity class
	Thermal comfort	Subjective evaluation, Comfort indicators

Table 7 Proposed tools for KPI`s measurements

1.4 Supporting technologies

Systems which are also important and should be optimzed are contorl system and medical gases delivery system. Within this chapter information about available energy saving solution will be wider described.

1.4.1 Building control system considerations

A Building Management System (BMS) is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as heating, ventilation, lighting and fire systems. A BMS consists of software and hardware; the software program, usually configured in a hierarchical manner, can be proprietary, using such protocols as C-bus, BACnet (ISO 16484-5), LonWorks (ISO/IEC 14908.1), KNX (CEN EN 13321-1, EN 13321-2, EN 50090) and so on. The BMS monitors and controls the heating, ventilation and air conditioning ensuring that they operate at maximum levels of efficiency and economy. At present this is achieved by similar means to those outlined in Individual Regulation of Heating Systems whereby a whole ward or department may be controlled by just one temperature sensor, usually at the far end of the heating circuit. The improvement of BMS controls provides benefits to building occupants, building owner and the maintenance provider, as follows:

- Good control of internal comfort conditions
- Provision of individual room control
- Increased staff productivity
- Effective monitoring and targeting of energy consumption
- Improved plant reliability and life
- Effective response to HVAC related complaints
- Save time and money during maintenance
- Flexibility on change of building use
- Effective use of maintenance staff
- Early detection of problems
- Satisfied occupants and happier workforce

(Appendix1, chapter 2.2.4).

Table 7 presents subsystems, which find usage in Healthcare facilities; moreover subsystems were assigned to the certain zone, according to division made in Deliverable 1.1. Only those subsystems were selected which may have an impact on energy efficiency.

Subsystem	Usage in Hospital Care facilities: HOTEL	HOT FLOOR	OFFICE	INDUSTRY
Elevator	Red	Red	Red	Red
Lighting management	Red	Red	Red	Red
Shading control	Red	Red	Red	Blue
Emergency Power System	Red	Red	Red	Red
HVAC system management	Green	Red	Green	Blue
Water system management	Green	Green	Green	Blue
Renewable Sources management	Blue	Blue	Blue	Red
Medical Gas management	Red	Red	Red	Red
Monitoring system to combat Legionella	Red	Red	Red	Red
MRI monitoring	Blue	Red	Blue	Blue
Monitoring the quality and use of electricity	Red	Red	Red	Red
Monitoring of the electrical installation	Red	Red	Red	Red

Table 8 BMS subsystem application in Hospital Spaces

Red: Should be/ obligatory — Green: Recommended solution — Blue: No need / not recommended

KPI	Measurements	Tool
Energy Performance and Efficiency	Reduction of the overall electricity use	Measurements on site
	Reduction of the overall hot water use	Measurements on site
	Reduction of the energy for heating use	Measurements on site
Financial base for comparison	Investment costs	Cost estimation model. The cost should be less than 1% of the value of the building
	Maintenance costs	The savings achieved by management installations(by BMS) should be sufficient to cover the cost of maintenance and modernization
	Lifespan	N/A

Quality of the Environment & Operational Efficiency	Comfort level	Measurements on site, Comfort indicators
	Patient satisfaction	N/A, subjective opinion, (questionnaires)
	Staff satisfaction	N/A, subjective opinion (questionnaires)

Table 9 Proposed tools for KPI`s measurements

1.4.2 Medical gas

Medical gas installations are obligatory in special areas in Hospital like Intensive care wards, Operation Theater and other rooms.

Type of systems:

a.) Medical Air: Comprising - air compressors, air receiver, pharmacopeia dryer bank, pressure reducing valves and distribution pipework. Emergency back-up via cylinder manifold.

b.) Medical Vacuum: Comprising – vacuum pumps, reservoirs, bacterial filters and distribution pipework. Back-up via portable units at local level.

c.) Oxygen: Comprising – liquid oxygen vessel, emergency back-up via second liquid oxygen vessel, pressure reducing valves and distribution pipework.

d.) Nitrous Oxide and Gas Mixture (O^2/N_2O)– Comprising - cylinder manifold, distribution pipework pressure reducing valves and distribution pipework. Emergency back-up via cylinder manifold.

e.) Locations supplied with medical gases; Accident & Emergency, Theatres, Wards, ITU, HDU, S.C.B.U., Endoscopy, Dermatology, Delivery, Dental, Out-Patient Clinics, etc.

Parameters:

a) Temperature - Ambient at point of use.

b) Humidity - Dew Point -40^{o}C

c) Pressure - Medical Air: 7 & 4 bar, Oxygen, Nitrous Oxide, Gas Mixture (O2/N2O): 4 bar and Medical Vacuum: between 67and 87 kPa below atmospheric pressure.

Technologies are more connected to the process than to the building function itself, though some elements such as compresors, regarded as a MEP equipment, consume significant amounts of energy needed for the process not for the building maintenance and opreation itself. System has to be monitored, pressure has to be kept in given range, there are certain European Standards which give the knowledge and parametres for designing and maintenance of such installations. Designing and

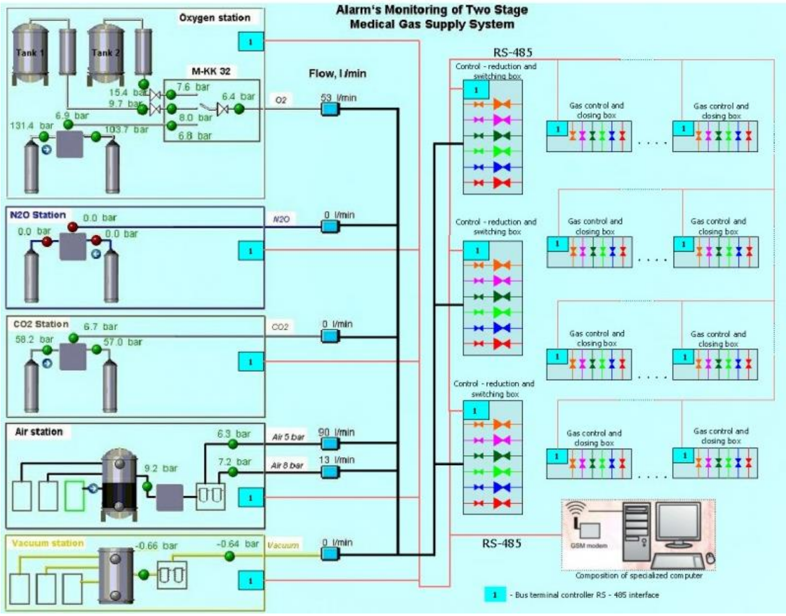

Figure 8 Medical gas control panel
Source:
http://www.medtech.lt/products/medical_gas_monitoring_systems

maintenance of the system should be provided by qualified, experienced engineers as those systems are directly related for human life. Performer of the installation in order to get CE certificate for the installation has to follow European Standards from group EN 737. According European Driective 93/42/EEC all medical gas equipment has to be certyficated with CE.
The most common system failures are Low and High pressure and are monitored by pressure switches in the distribution pipe lines with alarm sounder/indicator at both local level and to 24 hour manned location, e.g. Switchboard.

1.4.3 Steam production

In hospitals, steam can be used for applications such as sterilisation, humidification, heating and hot water production and cooking. However if there is a low temperature heating system steam is not used for this purpose. Steam can be produced in boliers or in steam generators, distribution is easy and does not reqire regulation. It is importat to provide good pipe and all fittings insulation otherwise heat losses will be significant and steam condensation in the pipelines can be bigger than designed, return condensation pipes should also be insulated. According to Electrical Engineering Portal *The hotter the condensate is returned to the boiler, the lower the energy consumption. Each 6°C increase in temperature of the condensate yields an energy saving of 1%*.[17] Figure 11 shows how big are steam boilers can be when used for Hospital needs.

[17] http://electrical-engineering-portal.com/energy-efficency-in-hospitals-steam-part-4

Figure 9 Hospital Boiler room for Steam production

Source: http://www.tuttnauer.com/blog/saturated-steam-sterilization-methods

2. Considerations for design and optimization of MEP systems

2.1 Optimization at room level

Criterion: Temperature, humidity, pressure

Tool: Optimization of system operation in the room, and as proposition ASHRAE standards 62.1 and 90.1.

The best way to optimize environment at the room level is to control HVAC system according to changing indoor conditions and human occupancy. To realize this advantageous ventilation system, heating/cooling system should be controlled by one driver, though this sometimes is hard to realize due to technical issues.

For realization of ventilation, heating and cooling VAV system is recommended solution. To optimize system work optimal start and stop should be set. Optimal start is determined by time needed to bring each room from current conditions to required and is determined by Building Automation System (BAS).

This strategy prevents from keeping unnecessarily unoccupied rooms in set conditions and helps to save energy. Optimal stop is also determined by BAS system and set unoccupied set point before scheduled end of occupancy. Only heating and cooling system are off while occupancy, fans continue to deliver fresh air and dumpers are still open.

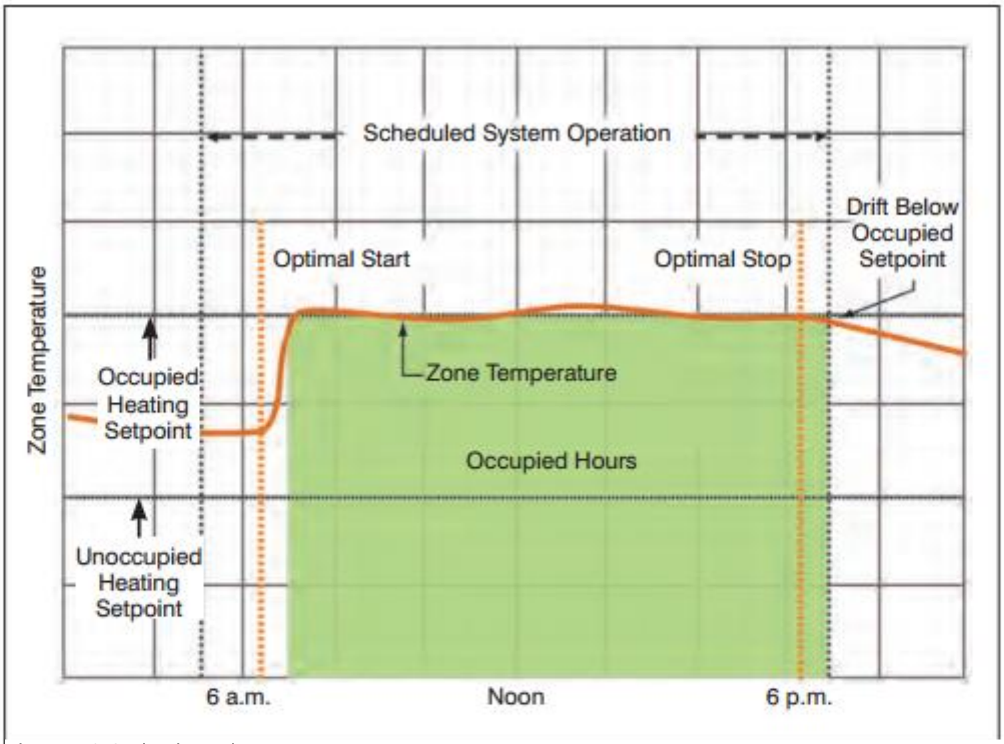

Figure 10 Optimal start/stop

Source: John Murphy “High performance VAV systems” ASHRAE Journal, October 2011

Fan pressure optimization is realized by method given by J.Murphy *"The VAV air-handling (or rooftop) unit varies the speed of the supply fan to maintain the static pressure in this location at a constant set point. With this approach, however, the system usually generates more static pressure than necessary. When communicating controllers are used on the VAV terminals, it is possible to optimize this static pressure control function to minimize duct pressure and save fan energy. Each VAV controller knows the current position of its airflow-modulation damper. The building automation system BAS continually polls these individual controllers, looking for the VAV terminal with the furthest-open damper. The setpoint for the supply fan is then reset to provide just enough pressure so that at least one damper is nearly wide open. This results in the supply fan generating only enough static pressure to push the required quantity of air through this "critical" (furthest-open) VAV terminal.*
At part-load conditions, the supply fan is able to operate at a lower static pressure, consuming less energy and generating less noise."

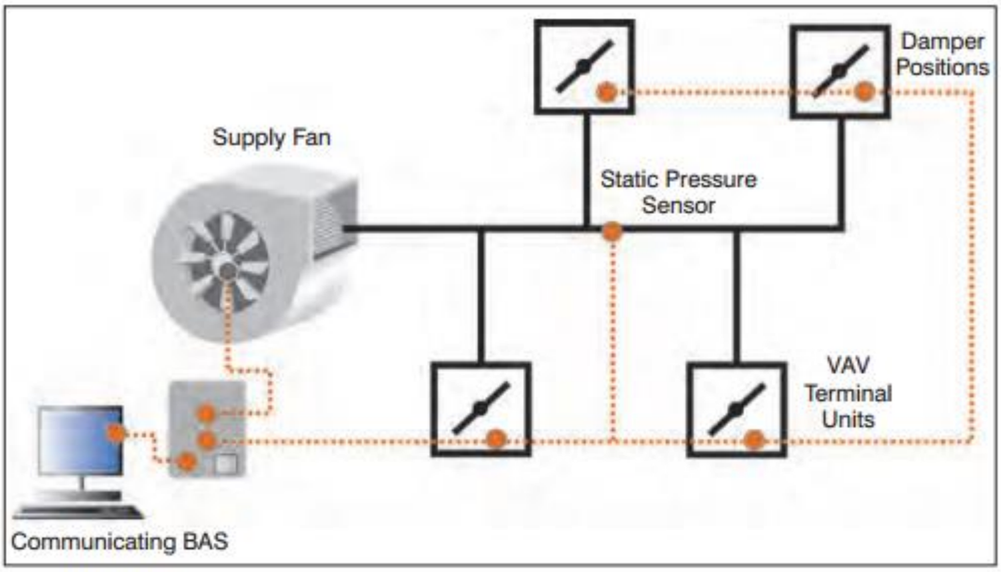

Figure 11 Fan – pressure optimization
Source: John Murphy "High performance VAV systems" ASHRAE Journal, October 2011

Presented solutions are an example of possibilities, which can be applied while designing of VAV system control structure. More regulation options are available, according to regulated parameters and accuracy of regulation as well as possibility of using reheat energy.

2.2 Optimization at building level

2.2.1 Economic aspects

Criterion: Costs

Tool: EN 15459: Economic evaluation procedure for energy systems in buildings

This tool gives a possibility to compare different solutions according to their annuity costs and global costs. Within this Standard a procedure of evaluation of the energy system is introduced. Steps given in the EN 15459 enable to estimate economic aspects of the building system. Standard gives knowledge and explain in detail how to provide calculations. The analytic model consists of 6 steps approach.

The Standard standardizes required inputs, calculation methods and required outputs for economic calculations of energy systems related to the energy performance of the building.

Methodology:

STEP1 – Financial Data *(needed information)*

- Design payback period of the building */in years/*
- Duration of the calculation */in years/*
- Inflation rate /%/
- Market interest rate /%/
- Rate of development of human operation costs /%/
- Rate of development of energy prices /%/

STEP 2- General information about project

Within this step basic information about building envelope, elements number their costs and lifespan are collected.

STEP 3 – System characteristics

- Investment costs for building construction and system related to energy
- Periodic costs of replacement
- Running costs except energy costs *(needed information)*
  - Maintenance costs */% of investment/*

STEP4 – Energy costs

- Energy consumption
- Energy costs- information needed at this stage concern energy (Gas, electric, etc.) for main and auxiliary equipment, power and unit price.

STEP 5 – Global costs

- Calculation of replacement costs and final value
- Global cost replacement

STEP 6 – Annuity calculation costs

2.2.2 Ecological aspects

Criterion: CO_2 emission, GHG emission

Tool: Methods and algorithms how CO_2 emission and GHG emission can be calculated are given by National Regulations. In general for calculation following values are required: heat of combustion *MJ/kg,* used fuel *kg*, CO_2 emission factor, oxidation factor. Some installations according to national law require constant or periodic measurements of CO_2 emission on site.

3. Conclusion

This document presents solutions which will be later adapted for implementation in new and retrofitted buildings in order to achieve energy savings. The range of energy saving solutions available on the market and technologies is wide. This is because nowadays, in order to achieve EU's 3x20 goals, the market is forced to introduce more efficient and energy friendly technologies. However, it is a problem to properly design the installation size and loads so that the system can work with high efficiency. The human factor is another important issue, which influences the total energy usage in the building. People, especially staff members, should be aware of reasonable and wise energy management.

As a general conclusion, there is a potential for energy savings regarding building MEP technologies. There are areas which can be better controlled and regulated. Future action should be based on gathered knowledge and approaching toward implementation of system operation optimization methods so that STREAMER main goal is achieved.

This deliverable is SoTA knowledge for further deliverables which will be provided within following work packages: WP1, WP2, WP3, and WP7.

Appendix 1

Contents

MEP`s system categories designation

1.Plumbing	2. Electrical	3. HVAC	4. Others
1.1 Water	2.1 Lighting	3.1 Heating	4.1 Medical gases
1.2 Sewage	2.2 Elevators/Escalators	3.2 Ventilation	4.2 BMS
		3.3 Air-conditioning	

List of described technologies:

Category	Technology name
Energy Conversion Technologies	
Non renewable	
1.1/3.1	Coal boiler
1.1/3.1	Liquid gas boiler
1.1/3.1/3.2	Gas boiler
1.1/3.1/3.2	Condensing gas boiler
1.1/3.1/3.2	Electric boiler
1.1/3.1/3.2	District heating (substation)
1.1/2.1/2.2/2.3/3.1/3.2	CHP
2.1/2.2	Fuel cell
2.1/2.2	Thermoelectric power generator
3.2/3.3	AHU
3.2/3.3	Absorption Chiller
3.2/3.3	Compressor Chiller
Renewable	
1.1/3.1	Heat pump
1.1/3.1/3.3	Solar panels
2.1/2.2	Photovoltaic
Energy Distribution Technologies	
1.1/3.1/3.2/3.3	Circulation pump
1.2	Sewage heat recovery
2.1	Light Management System
3.1	Regulation
3.2	Hybrid ventilation

3.2	Dampers
3.2	Air ducts
3.2	Fans with variable speed
3.2	VAV system
3.2	Air recirculation system
3.3	Free cooling system
3.3	VRF cooling system
Energy Delivery Technologies	
1.1	Water Tap
2.1	Lighting
2.2/3.1/3.2	Motors (elevators, escalators)
3.1	Electric heating: IR panels
3.1	Electric floor heating
3.1	ClimaRed ® system
3.1	Air heating (air heaters)
3.1	Water heating systems
3.2	Ultrasonic humidifier
3.2	Local Heat Recovery
3.3	Split air conditioner (Single and Multi) / AC – heat pump
3.3	Multi-Split air conditioner
3.3	Wall mounted local air-conditioning unit
3.3	Cooling ceiling panels
3.3	Fan coil
3.2/3.3	Chilled beam
Energy Storage Technologies	
1.1	Local buffer tank for DHW
2.1	Batteries
3.1	Small ATES/BTES
3.3	Cold storage with ice/local storage
Supporting Technologies	
1.1	Chemical disinfection of domestic hot water
4.2	BMS
4	EPS (Emergency Power System)

4	DC grid
4	Smart grid

1.1 Parameters

No	Name	Definition	Format	Dim.	Units	Value range	Sym	Comments
	Proposed parameter name	*Short definition to describe the parameter*	*What type of input it would be*	*Proposed dimension for the parameter [SI units or Others]*	*International System of Units [SI] or Other Systems [O]*	*Expected values range*	*Proposed symbol*	*To show what parameter refers*
A	**Unit**							
01	**Unit nominal power**	A rated or named value stating the power that a component, circuit, device, piece of equipment, or system can produce, consume, dissipate, or otherwise safely handle, when used in a given manner. Source: technical data sheet, documentation	Number	W	[SI]	Unit specific	P	To select the appropriate device to cover designed loads, to determine other factors from technical data sheet
02	**Annual Electric energy consumption**	Electrical power consumption by the unit within one year Source: site measurements, technical specification of equipment	Numbers	kWh/year	-	Unit specific	Q_{el}	To indicate how much electricity is used for unit operation during the whole year. Can be use to estimate KPI and building performance.
03	**Annual primary energy consumption**	Primary energy consumption by the unit within one year Source: site measurements, technical specification of equipment	Numbers	kWh/year	-	Unit specific	Q_{pr}	To indicate how much primary energy is used for unit operation during the whole year. Can be use to estimate KPI and building performance.
04	**Electric energy demand**	Demand for electric energy necessary for operation of the device referred to 1 square meter of surface supported Source: national certification standard, site measurements, technical specification of equipment	Numbers	W/m^2	[Si]	Site specific	q_{el}	To indicate how much energy is used for unit operation during the whole year. Can be use to estimate KPI and building performance.

No	Name	Definition	Format	Dim.	Units	Value range	Sym	Comments
	Proposed parameter name	*Short definition to describe the parameter*	*What type of input it would be*	*Proposed dimension for the parameter [SI units or Others]*	*International System of Units [SI] or Other Systems [O]*	*Expected values range*	*Proposed symbol*	*To show what parameter refers*
05	**Hours of operation**	Hours when device is in operation during the whole year. Source: National Building Certification Standards, building time schedules	Numbers	h/year	-	Unit specific	t_{op}	Value depends on building operation schedule. Refers to conversion, delivery and distribution devices.
06	**Seasonal unit effectiveness**	Describe the unit performance while working with variable loads. Referred as average value for periodically measured ratio of energy produced to energy consumed. Source: measurements on site	Numbers	Percents	1-100%	Unit specific	η_{ses}	To verify unit performance during the whole working season. Parameter can help to point out oversized units.
07	**European Seasonal Energy Efficiency Ratio**	Used for estimation seasonal performance of chillers and air conditioners Calculated basing on EER values. (explained in Appendix 2) Source: manufacturers data	Numbers	-	-	Unit specific	ESEER	To calculate seasonal efficiency of cooling system. According to device type and system destiny (comfort or precision Air Conditioning), carrier type
08	**Coefficient Of Performance**	Describe by ration of heat energy produced in the condenser to energy (electrical power) delivered to the compressor.	Numbers	Percents	1-100%	Unit specific	COP	Value used for temporary rating of heat pump performance for given operation temperature.
09	**Seasonal Performance Factor**	It gives an information about how much heat was delivered to the heating system/ DHW during the calculation period (year, month, heating season) and how much electrical energy was use for the whole processes (heat pump compressor, pumps, electrical heater, etc.).	Numbers	Percents	1-100%	Unit specific	SPF	Gives an overview on the whole heat pump system efficiency during the operational season in real conditions.
10	**Storage capacity**	Capacity of energy which can be stored within the device and used later for the	Numbers	*W*	[SI]	Unit specific	Q_{st}	To describe ability of energy storage of single device (heat tanks, chilled water

No	Name	Definition	Format	Dim.	Units	Value range	Sym	Comments
	Proposed parameter name	*Short definition to describe the parameter*	*What type of input it would be*	*Proposed dimension for the parameter [SI units or Others]*	*International System of Units [SI] or Other Systems [O]*	*Expected values range*	*Proposed symbol*	*To show what parameter refers*
		process.						tanks, accumulators, batteries, etc)
B	**System**							
01	**System productivity**	Energy (Power) delivered by the system to one square meter of serviced area. Source: National Building Certification Standards, manufacturers data	Numbers	W/m^2	[O]	System specific, National standard specific requirements (lighting)	E_s	Designing optimal lighting power and surface heating and cooling system.
02	**Annual preventive maintenance**	Total annual costs which are spend for system/unit service and conservation	Numbers	Euro/year	[O]	Site specific	M	Refers to all system/units in the considered property
03	**Thickness of pipe/ducts Insulation layer**	Thickness of insulation layer	Numbers	cm/m	[O]	National standard specific	d	To optimize energy losses during distribution.
04	**Flow**	Amount of carrier which runs through the cross section of the pipe/duct in a set period of time	Numbers	m^3/h	[O]	System specific, Design Standards	V	To dimension the system
05	**Dimension**	Characteristic value describing pipe/duct size (cross section are, diameter, wall thickness etc.)	Numbers	mm	[O]	Pipelines series	-	To dimension, design and perform the system.

2.1 Energy conversion technologies

2.1.1 Coal Boiler

Cat. 1.1/3.1

Description:

A coal-fired boiler is an industrial or utility boiler that generates thermal energy (hot water or steam) by burning coal within the boiler firebox or combustion chamber. Its primary purpose is the building's main source of heating and hot water generation and is connected to a pipe work distribution system. This delivers the heated fluid via circulating pumps to the buildings point of use such as radiators and clarifiers, and then returning the cooled fluid back to the boiler.

Figure 12 Coal boiler with automatic fuel supplier

A typical installation will comprise of a coal boiler, coal storage bunker, transfer feed system, transfer hopper, and coal feed line, ash disposal system and flue system often with a fan. There are a variety of coal boiler types available, but the main ones include cast iron sectional and shell and fire tube types.

Stokers are classified according to the method of feeding the coal into the boilers combustion chamber. A number of different stoking arrangements exist to continually feed the boiler including underfeed, sprinkler and moving bed systems. They are usually arranged for either semi or fully automatic control.

Coal boilers normally contain a large volume of water to provide the reserve of energy needed to enable them to generate heat quickly in response to changes in building load. Combustion takes place at temperatures from 1300-1700°C, depending largely on coal grade with efficiencies approximately 80%. The boilers will have in integral control system that will be connected to the main building management control system (BMS).

The burning of coal is a complex operation involving the storage, handling and combustion of solid material, and the handling and disposal of gaseous and solid waste. Coal is the generic term given to solid fuels with high carbon content. There are several types of coal each relating to the stages of coal formation and the amount of carbon content, but bituminous and anthracite types are the main types used in coal boilers.

Ash is produced when the coal is burned and requires to be removed from the boiler, usually involving manual intervention and disposal. During this process it is normal that a reduction in boiler capacity occurs whilst de-ashing takes place. The ash produced by the coal is light, and a proportion is carried over into the exhaust gases and expelled to the atmosphere.

Coal fired boilers are subject to increasingly stringent environmental regulations, air quality limits and codes of practice. Coal contains an average of 1.5% sulphur by weight, and may be as high as 3% depending upon where the coal was sourced. During the combustion process the sulphur will combine with oxygen from the air to form SO_2 or SO_3 and hydrogen from the fuel will combine with oxygen from the air to form water. After the combustion process is completed, the SO_3 combines with the water to produce sulphuric acid, which can condense in the boiler flue often causing corrosion if the correct flue temperatures are not maintained. Often it is carried over into the atmosphere with the flue gases.

Substantial maintenance procedures are required to coal boilers, including each item related to the coal burning operation (flue system / storage / handling/ combustion / waste disposal/ electrical). Typically the frequency of maintenance would be carried out every 12 months along with a full inspection, but some components require 1, 3 and 6 monthly inspections.

Parameters:

Nominal thermal power [kW]: from 14 kW
Electrical energy usage [kW]: only for automatic control
Thermal efficiency [%] from 50-80 %, typically 75-80%
Emissions (mg/MJ): according to designed / installed device

Characterization of Usage:

Hours of operation [h/year]: according to system working schedule; very site specific, depending on the final end uses and from the climate of the site
Lifespan [years]: 20-30
Annual preventive maintenance [euro/year]: *every 1, 3, 6 and 12 months*; 20% of investment costs
Control: response times according to system load changes

2.1.2. Liquid gas boiler

Cat. 1.1/3.1

Description:

A liquid gas boiler is an industrial or utility boiler that generates thermal energy using liquid gas as it primary fuel system. The boilers primary purpose is the building's main source of heating and hot water generation and is connected to a pipe work distribution system. This delivers the heated fluid via circulating pumps to the buildings point of use such as radiators and clarifiers, returning the cooled fluid back to the boiler.

Figure 13a Liquid gas storage tank

Liquid gas is often referred to as liquid petroleum gas (LPG). It exists in two forms as either butane or propane, or can be a mixture of the two. A powerful odorant is added so that it can be easily detected. Liquid gas is used as a fuel in a range of applications including in heating, cooking appliances, industrial applications, in vehicles and as a propellant and refrigerant. However propane with its lower boiling point is suited to outdoor storage and is primarily used for liquid gas boilers. Liquid gas is considered to be a relatively clean fuel, producing lower air pollutants and carbon dioxide when compared to other fossil fuels.

A typical liquid gas boiler installation will comprise of a boiler, burner, flue system and pressurized liquid gas storage tank.

For heating applications, liquid gas can be stored in bulk storage vessels, either above or below the ground. The gas is stored in pressurized tanks to keep it liquefied. The location of the liquid storage tank requires careful consideration to allow safe handling. For instance, there are guidelines and codes of practice that dictate the minimum safe distance from the closest buildings, depending on the tank capacity. Also liquid gas tanker delivery access is important and should also be considered along with security and restricted access to the tanks.

Liquid gas is flammable and heavier than air so that it will settle and may accumulate in low level locations such drainage systems and basements, where it could present a fire or explosion or suffocation hazard. When the risks are properly identified and managed, liquid gas can be safely used as a boilers fuel source.

There are a variety of liquid gas boiler types available, but the main ones include cast iron sectional, cast aluminum, steel sectional and steel shell. Typical liquid gas boiler efficiencies are approximately 90%. The boilers will have in integral control system that can be connected to the main building management control system (BMS).

Liquid gas burner types include atmospheric, forced draught and pre mix, with its primary function of discharging the liquid gas at low velocity. Atmospheric burners are quiet in operation and generally can be used on boilers rated up to 1MW. Forced draught burners include an integral fan, which is used for providing all of the air required for combustion. As a result, very often this type of burner can be noisy.

It is important that regular maintenance is carried out on the boiler, flue system and liquid gas burner. Typically this would be carried out every 12 months along with a full inspection. Also the pressurized storage vessel should be regularly inspected and also the liquid gas pipe work whether it is above or below ground. It is essential that adequate ventilation of the boiler house is provided to allow for combustion air requirement.

Parameters:

Capacity (kW): according to designed / installed device

Efficiency (%): typically 90%

Emissions (mg/MJ): according to designed / installed device

Characterization of Usage:

Hours of Operation (h/year): according to system working schedule

Lifespan (years): 25-30

Annual preventive maintenance (euro/year): 10% of initial investment cost

Boiler inspection period: every 12 months

Storage tank inspection period: every 6 months

2.1.3 Gas boiler

Cat. 1.1/3.1/3.2

Description:

Conventional gas boiler burns natural gas to heat cold water; the outputs of the process are hot water, for the heating system or for sanitary water, and steam (water vapor and carbon dioxide).

In standard plants (*i.e.* not condensing boiler) this steam is expelled directly in the atmosphere with a countable amount of its potential heating energy wasted.

Boilers can be classified as follows:

- fire-tube boiler: the water fills the boiling barrel and an external furnace leads the hot gas in the barrel through a metal pipes system, it's possible to improve the system by increasing the heating surface making the gases reverse direction through a second parallel tube or just having a multiple pipes system. This kind of boiler has a high steam storage capacity but its steam production is not very effective.
- Water-tube boiler: in this type the cold water runs inside the furnace through the pipes and leads the steam out from a valve. Water tube boilers can be designed to exploit any heat source and are generally preferred in high pressure since the high pressure steam is contained in small diameter pipes, allowing to have more of them in the barrel, this kind of boiler has a high steam production but a low steam storage capacity

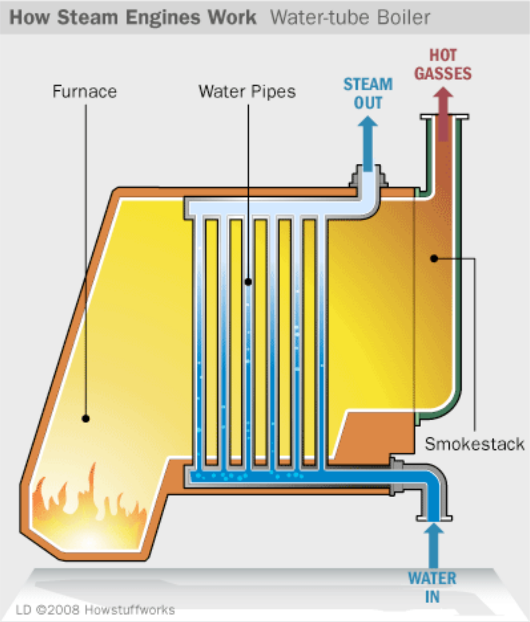

Figure 14 Fire- tube gas boiler

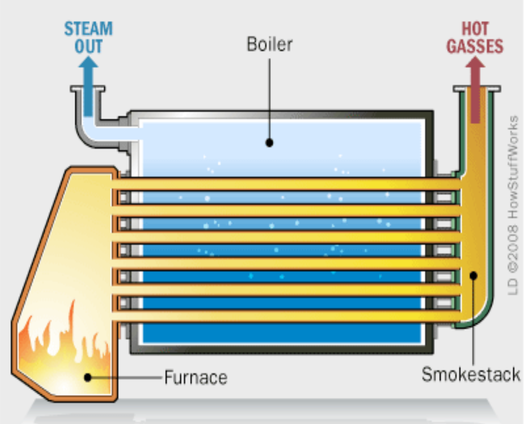

Figure 15 Water-tube gas boiler

Parameters:

Nominal thermal power [kW] *according to designed/ installed device*

Electrical energy usage [kW]: *according to designed/ installed device*

Thermal efficiency [%] given as the ratio between the thermal energy output and the primary energy of the fuel

Boiler efficiency vs. heating boiler load factor curve

Characterization of Usage:

Hours of operation [h/year]: very s*ite specific, depending on the final end uses and from the climate of the site*

Lifespan [years]: *10*

Annual preventive maintenance [euro/year]: *normally included in the plant management O&M contract*

2.1.4 Condensing gas boiler

Cat. 1.1/3.1/3.2

Description:

The term ‘condensing boiler’ refers to the fact that the boiler produces condense from time to time.

Condensing boilers recover heat from exhaust gases produced during the combustion of gas that would normally be released into the atmosphere through the flue.

This exploits the highest potential from the primary energy of the fuels allowing the switch from its lower calorific value up to higher calorific one.

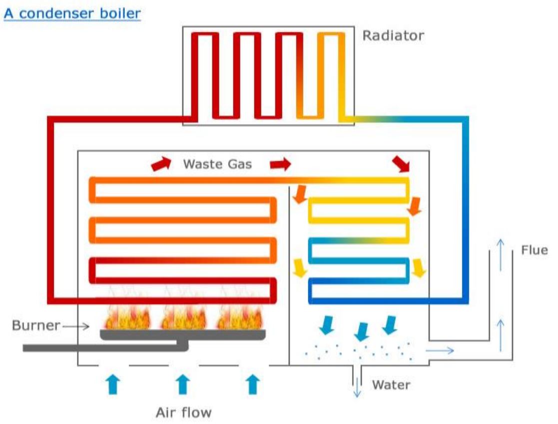

Figure 16 Condensing gas boiler

To use this latent heat, the water vapor from the exhaust gas is turned into liquid condensate. In order to make the most of the latent heat within the condensate, condensing boilers use a larger heat exchanger, or sometimes a secondary heat exchanger.

Due to this process, a condensing boiler is able to extract more heat from the fuel it uses than a standard efficiency boiler. It also means that less heat is lost through the flue gases.

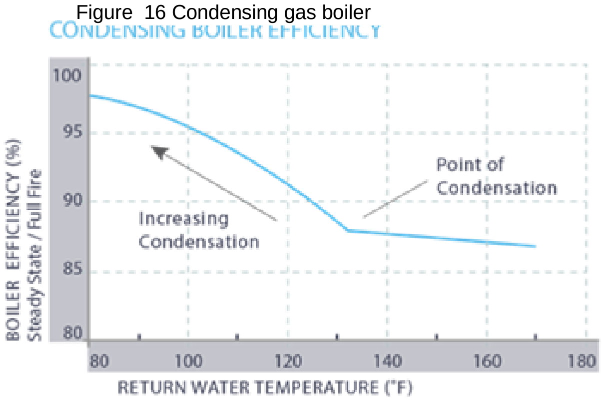

Figure 17 Condensing boiler efficiency

A high efficiency condensing boiler captures much more of that steam’s energy to heat the water more efficiently. The efficiency of a condensing boiler depends on the temperature of water going into the boiler, also called the return or entering water temperature; the lower the return water temperature, the greater the boiler’s ability to condense.

This can explain why condensing boilers show their highest efficiency when coupled with low temperature heating terminals (e.g. radiant floors) and/or during temperate season, when days are not very cold.

Condensing boilers are in every condition more efficient than the conventional boiler, but the efficiency really starts below the temperature of 130°F - 54°C, so that they can actually condense some of the diluted steam that otherwise goes out throughout the chimney

Parameters:

Nominal thermal power [kW]: from 6 up to 20 000kW *according to designed/ installed device*

Electrical energy usage [kW]: *only for automatic control*

Thermal efficiency [%] *if condensation appears higher than 100%*

Boiler efficiency vs. heating boiler load factor curve

Characterization of Usage:

Hours of operation [h/year]: very s*ite specific, depending on the final end uses and from the climate of the site*

Lifespan [years]: *20*

Annual preventive maintenance [euro/year]*: normally included in the plant management O&M contract*

2.1.5 Electric boiler

Cat. 1.1/3.1/3.2

Description:

An electric water boiler is used for maintaining water at a constant temperature. It is typically used to provide an immediate source of hot water, for instance in household and commercial use or at the room level of a hospital.

An electrical boiler consists of a cylindrical vessel or container that keeps water continuously hot and ready to use. Some models offer multiple temperature settings. The water reservoir is made of stainless steel or copper.

Electric boilers operate completely independently. They are not connected to a central heating system. Installation is quick and easy because no gas or air supply and flue require is necessary.

Figure 18 Electrical boiler

In temperate zone countries, where ambient temperature are seasonally colder, tiny point-of-use (POU) electric storage water heaters with capacities ranging from 8 to 32 liters are made for installation in kitchen and bath cabinets or on the wall above a sink. They typically use low power heating elements, about 1 kW to 1.5 kW.

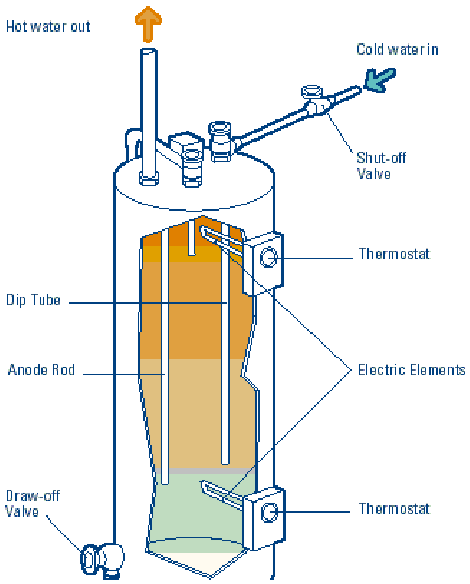

Figure 19 Electrical boiler – cross section

Parameters:

Voltage: 220-240 V

Volume ± 3-20 litres

Nominal Power: ± 500-2200 W

Warm-up time up to 65º C: ± 10-23 minutes

Maximum pressure: ± 8 bar

Maximum temperature: ± 60-85º C

Characterization of usage:

Low maintenance

Efficiency: ± 95%

Advantage: using electricity at a relatively slow rate and storing the heat for later use.

Disadvantage: over time, the water inside the tank will cool down causing the heating system to activate to heat the water back up. Additionally, once the tank's supply of hot water has been exhausted, there is a significant delay before hot water is available again. Larger tanks tend to provide hot water with less temperature fluctuation at moderate flow rates.

2.1.6 District heating

Cat. 1.1/3.1 /3.2

Description

A district heating substation is a component in a district heating system that connects the main network to a building's own heating system. The heating of a property heated by district heat is based on a water-circulated system. Heat energy is transmitted from the district heating network to the radiator pipe and tap water systems of the property through the heat distribution centre. Usually, the heat substation includes heat exchangers for heating and hot tap water. District heating substations for HTS systems normally operate with a differential pressure in the range 0,1 to 0,8 MPa; the most common range is 0,1 to 0,6 MPa. The quality of the circulation water that carries the heat can affect performance. Therefore, water treatment and control and monitoring of contributory water for the system are important.

Figure 20 Substation

The system should be closed from air and cold water uptake to prevent corrosion. Therefore suitable pressure maintenance is necessary. Another aspect is that magnetite - as a corrosion product - builds a homogeneous oxygen surface layer with high corrosion resistance on metallic surfaces. But this protection layer is only built at temperatures higher than 100°C. So this effect cannot be used in domestic warm water systems. Compliance with the standard values for chemical water treatment unalloyed ironwork materials, rustproof steels and coppers, separately or in combination, can be applied. Aluminum or aluminum alloys should not be used in direct contact with the circulation water, otherwise alkali-induced corrosion is possible. Iron and copper can lead to deposits and failures in zones with low flows. Experience shows that concentrations of iron N 0,10 mg /l and copper N 0,01 mg/l are in the normal range.

Substation can be divider to:

- Central source – substation section

  Heat generated in the central source is delivered thought pre insulated pipes to the substations. Proper pressure is provided by pumps. Heat losses are usually negligible. Pipe is usually run underground so that insulation is improved. There are usually revision stations on the pipe track with dehydration valve on the lowest points and vent valve at the highest points. There are few possible solutions for realization of pipelines: pre-insulated pipes or flexible pre-insulated pipes. Both are recommended, as thermal properties are similar. Pipeline has to be equipped in compensators or be designed in a way, which enables to overtake thermal prolongation of pipes. District water flows and pressure are given by the heat supplier. This section should be further discussed in Deliverables regarding neighborhood districts.

- Substation – end user section

  This part of grid is placed in the technical room in the building. Required space and performance guidelines are given by relevant regulation. Substation room has to be localized in the basement or at the ground level. Pipe passage through the partition should be tight. On the district part there should be installed: shut-off valves, filter, distiller, heat meter, dehydration valve, vent valve, pressure stabilization valve, heat exchangers, thermometer, manometer, etc.

On the building site there should be control sensors, shut-off valves, regulation valves, filters, expansion vessel, safety valve, pumps, etc.

Pipes and fittings should be insulated.

The following standards and EU directives are relevant for a district heating substation:

Pressure Equipment Directive (97/23/EC)

Measuring Instruments Directive (2004/22/EC)

Energy Performance of Buildings Directive (2002/91/EC)

Machinery Directive (2006/42/EC)

Energy Services Directive (2006/32/EC)

Eco-design Directive (2005/32/EC)

EN/CEN standards: EN 1434, CEN 311, etc.

Parameters:

High-temperature system (HTS)

Operating data: 100^{o}C; 1,6 MPa, differential pressure 0,1-0,8 MPa

Low-temperature systems (LTS)

Operating data: 85^{o}C; 0,6 MPa, differential pressure 0,3-0,35 MPa

Standard values for district heating water quality:

- Electrical conductivity (μS/cm) 100-1500
- pH: 9,5-10
- Oxygen (Mg/L): <0,02
- Alkaline (mmol/L) <0,02

Source: Guidelines for District Heating Substations, Euroheat & Power Guidelines for District Heating Substations

2.1.7 CHP Unit

Cat. 1.1/2.1/2.2/2.3/3.1/3.2

Description:

Cogeneration, also known as combined heat and power (CHP), is a system of technologies working together for the combined production of both electricity and heat; these plants are proved to be more performing than the traditional separate heat and power (SHP) in fact its efficiency is about 80% compared to the 45% of common SHP.

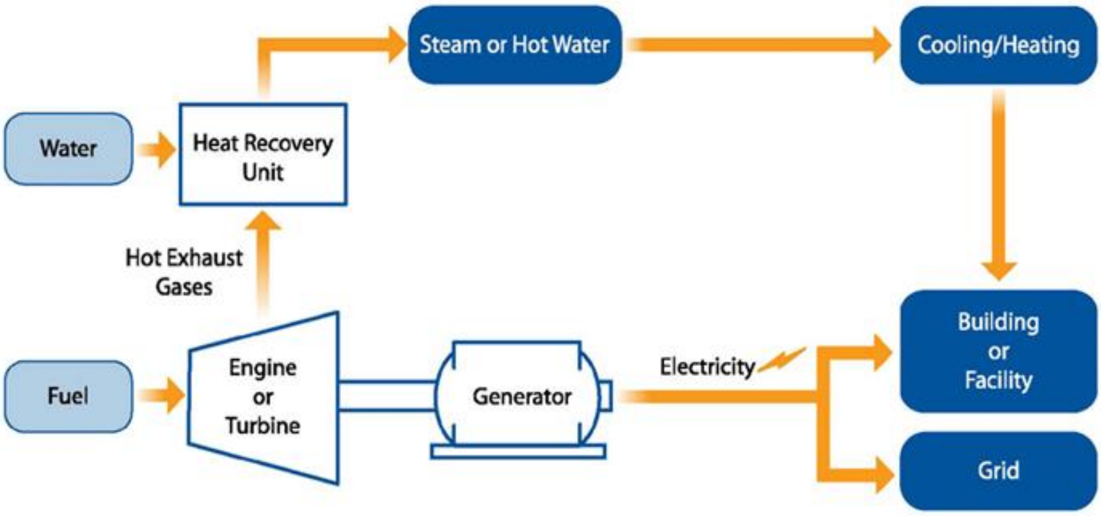

Figure 21 Engine with heat recovery unit.

In the last years this technology developed extremely fast, so nowadays it's possible to have microCHP in private houses and small buildings, spreading (thanks also to lower prices) the principles of energy saving: use of otherwise wasted energy, less pollutions, point of use near the point of production (on-site generation), no big power plants. Hospitals were among the first facilities that adopted these plants in order to reduce the considerable energy requirements, through an optimization of the energy transformation processes.

The two most common CHP system configurations are:

- <u>Gas turbine or engine with heat recovery unit</u>

  The fuel (from renewable or non-renewable source) is burned to generate electricity for the building's facilities or the general grid. The steam from the combustion process is led to the heat recovery unit where it heats cold water converting this exhaust gas in thermal energy. This power is then used to cool or heat the building it's connected to.

- <u>Steam boiler with steam turbine</u>

  Mainly used in industrial process; in this system the steam turbine produces steam as main output and electrical energy led to the generator. The steam is used for the heating or cooling and the electricity feeds the grid or the facilities

Benefits of a CHP system:

- At constant amount of output energy, CHP needs less fuel to work; so its efficiency is higher than other technologies.
- Being a combination of technologies, it can be designed to perfectly fit the need of the building, increasing or reducing the heat or the electricity plant, avoiding useless productions.
- Reduced pollution and greenhouse gases production.
- A lower need of fuel means lower bills, so the economical aspect is also involved.

Parameters:

Electric Efficiency [%]: *according to designed/ installed device*

Thermal Efficiency [%]: *according to designed/ installed device*

Total Efficiency [%]: *according to designed/ installed device*

Thermal Power [kW]: *according to designed/ installed device*

Electric Power [kW]: *according to designed/ installed device*

Characterization of Usage:

Average working time [h/year]: s*ite specific, depending on the final end uses and from the feeding CHP/ heat source characteristic*

Lifespan [years]: *10*

Annual preventive maintenance [euro/year]: *normally included in the plant management O&M contract*

2.1.8 Fuel Cell

Cat. 2.1

Description:

A Fuel Cell is a device that converts chemical energy into electricity without any need of heat and/or power cycle.

Electrical power is produced by the oxidation of a fuel, mainly hydrogen or methanol. It is the reverse process of electrolysis. Choosing hydrogen as input product of the system will cause a completely recyclable waste product, water vapor. Fuel cell has a basic advantage over traditional CHP system: its energy need is very low compared to the electricity produced, so this system is perfect for those buildings that have a green-and-low-energy demand goal; and since a fuel cell create electricity with a chemical process rather than by combustion. It's not unusual, anyway, to have a fuel cell combined with a micro CHP for the heating of a building; like in many other technologies the system is based on the combination of different plants so its efficiency can be increased optimizing their interaction and their use. This is due to the fact that hydrogen is not available at its simple free state molecule, so that it has to be produced breaking bigger and more complex molecules such as methane (through thermal reforming) or water (through the same electrolysis, every time there is an excess of production from renewables). Three basic elements are involved: an anode, a cathode and an electrolyte sandwich between them. When the input hydrogen get in contact with the anode it splits into H^+ ions and electrons e^- (1); then the H^+ ions pass through the electrolyte (2) and in the meanwhile the electrons are directed to the circuit (3) where the electricity is produced; the protons got to the other side finally bond with the oxygen (4) and we have the waste product of the system: heat and water (5).

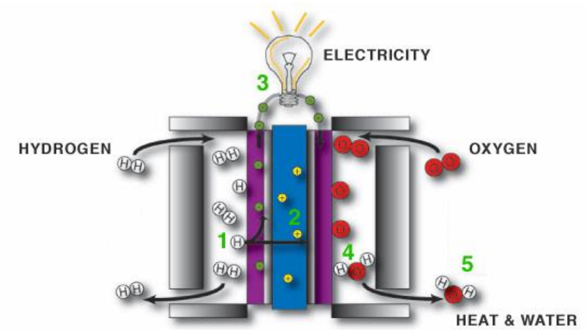

Figure 22 Chemical process in a FC .

These are the chemical reaction involved:

$H_2 \rightarrow 2H^+ + 2e^-$

$O_2 + 4e^- + 4H^+ \rightarrow 2H_2O$ + heat

Parameters:

Working temperature [°C]: *according to designed/ installed device*

Typology of electrolyte

Nominal Power [kW]: *according to designed/ installed device*

Efficiency [%]: *according to designed/ installed device*

Characterization of Usage:

Hours of operation [18] [h/year]: up *to 8000 hours/year, depending on the final end uses characteristic demand.*

Lifespan [years]: *5*

Annual preventive maintenance [euro/year]: *normally included in the plant management O&M contract*

2.1.10 Air handling unit

Category: 3.2/3.3

Description:

The setting of ideal temperature and humidity in indoor spaces can be guaranteed by the operation of mechanical systems, called Air Handler, or, more often, Air Handling Unit (AHU). These systems through specific thermodynamic transformations allow setting precisely the temperature and moisture levels of indoor air to desired levels and, after having conditioned it they circulate air trough supply ducts as far as each air vent of the air circuit.

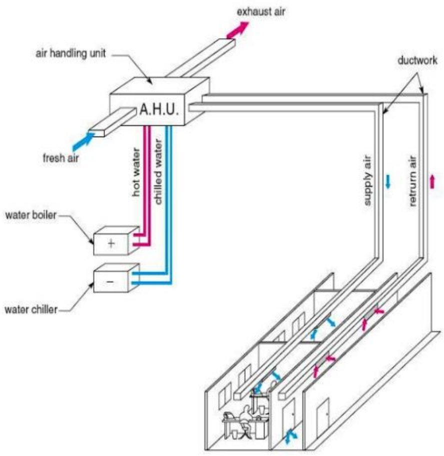

Figure 23 AHU Unit

This systems, belonging to the category of heating, ventilating, and air-conditioning (HVAC) are usually made by putting together, within a large metal box, a blower, one or more heating elements (operating both in the cold and the hot season), one cooling element (operating only in the hot season), filter racks or chambers, sound attenuators, and dampers.

The most of the times, these systems considers a two-way ductwork circuit, the first one to distribute the conditioned air through the building rooms, the second to return the air in excess to the AHU, in order to partially recirculated it or to recover thermal energy thanks to a pre-heating of the new fresh air, taken from outside, before discharging the fraction in excess to the outdoor. This help in maintaining e controlled level of pressure of indoor air as well.

The core of these systems are the heating/cooling elements, these parts of the systems are the places where heating and/or cooling, provided from elsewhere in the building (i.e. from central plants, normally from boilers and compression chillers, respectively), is yielded to the air stream flowing into the exchangers conditioning it to the targeted values of temperature and humidity achieving hence the desired heating/cooling effect.

Several combination of the installed equipments are possible in relation to the climates, cold, hot, humid, dry where the plants are operating.

The main energy transformations that take place within the air handling units are respectively:

- heat exchanges at constant specific humidity, they take places in the heat exchanger coils transferring thermal energy from the liquid heated/cooled in central plant, to the air flowing in the unit
- adiabatic humidification, during the cold season to increase the air specific humidity of the conditioned air up to the desired value, requiring hence a second post-heating battery to increase its temperature up to comfort requirements. The advantage of adiabatic humidification versus isothermal one is that the first one does not involve the contribution of thermal energy from an external source but find it directly from the flowing air causing a momentary decrease of its temperature (hence the necessity of the post heating section). Spray mist is the most

common technology: water is diffused either by a nozzle or other mechanical means into fine droplets and carried by the air.

- cooling & dehumidification, necessary in humid climates during the hot season: The process in which the air is cooled sensibly and at the same time the moisture is removed from it is called as cooling and dehumidification process. Cooling and dehumidification process is obtained when the air at the given dry bulb and dew point (DP) temperature is cooled below the dew point temperature. Again, at the end of this process there is the necessity to post-heat the conditioned air, now with the perfect degree of specific humidity, to set the temperature at the comfort level as well.

All these energy transformations can be effectively described and studied using both the psychometric and the Mollier chart.

Air handling units are normally very energy intensive and they often are installed in combination with other plants, such as radiators, fan coils, etc, when one wants to add a strict control of indoor humidity to the standard heating and cooling of indoor spaces.

There are some basic issues that are normally followed by designer in order to lower the primary energy demand associated to the thermal energy delivered to the air stream though the exchangers.

A precise management of the recalculating air fraction help in reducing at the minimum the requirements but sometimes are not allowed due to hygienically necessity (e.g. in the operating theatres and in other hot floors departments). The savings are obtained simply because the use of exhausted air recovered from the indoor space is at a temperature that is considerably higher than outdoor air in winter and lower in summer, reduces the amount of volumes respectively to be heated/cooled.

Recuperators or plate heat exchangers consist in a sandwich of metal plates with interlaced air paths, transferring thermal energy between air streams from one side of the plate to the other. They allow increasing the efficiency of the systems up to 70%.

Many other techniques are frequently used to optimize air handling units efficiency, such as controller of the air flow rate in relation to the necessity coming from the local end uses (e.g. in the operating theatres one can regulate the amount of volume per hour provided by the unit in accordance of the typology of surgery that is in progress.

According to Commission Regulation (EC) No 641/2009 of 22 July 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products energy efficiency requirements are as follow:

1. From 1 January 2013, glandless standalone circulators, with the exception of those specifically designed for primary circuits of thermal solar systems and of heat pumps, shall have an energy efficiency index (EEI) of not more than 0,27.

2. From 1 August 2015, glandless standalone circulators and glandless circulators integrated in products shall have an energy efficiency index (EEI) of not more than 0,23.

The calculation methodology of described in the Annex II, point 2 of above mention Commission Regulation.

International Standards:

Europe:

- Mechanical characteristics - European Standard EN1886:2007 : Ventilation for buildings - Air Handling Units - Mechanical performance
- Rating performances - European Standard EN13053:2006+A1:2011: Ventilation for buildings - Air Handling Units - Ratings and performance for units, components and sections.
- Eurovent Air Handling Units Energy Efficiency Class Fourth Edition – 2013

World:

- 2012 ASHRAE Handbook--HVAC Systems and Equipment

Parameters:

Air Flow Rate [m3/hour]: according to designed/ installed device

Heating nominal Power [kW]: according to designed/ installed device

Cooling nominal Power [kW]: according to designed/ installed device

Electrical energy usage [kW]: according to designed/installed device

Recirculation fraction [m3/hour]: according to designed/ installed device

Recuperator efficiency [%]: according to designed/ installed device

Characterization of Usage:

Hours of operation [h/year]: very site specific, depending on the final end uses

Lifespan [years]: 10

Annual preventive maintenance [euro/year]: normally included in the plant management O&M contract

2.1.11 Absorption Chiller

Cat.: 3.2/3.3

Description:

The standard vapor compression refrigeration system is composed by condenser, evaporator, expansion valve and a compressor. The refrigerant gets condensed in the condenser and it gets evaporated in the evaporator. The refrigerant produces cooling effect in the evaporator and releases the heat to the atmosphere via the condenser.

In the absorption cooling cycle the compressor is replaced by a generator and an absorber. The steps of this cooling system are:

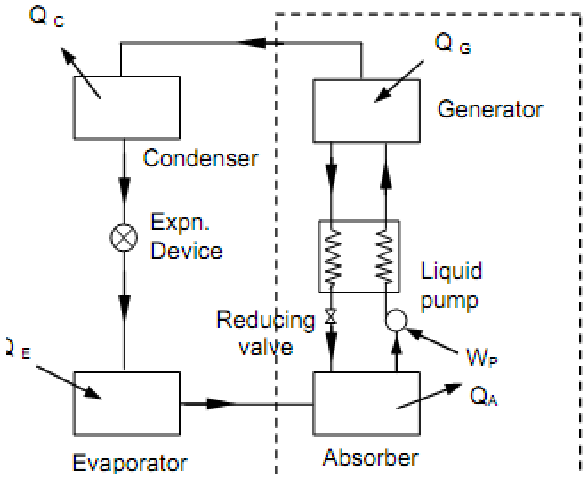

Figure 24 Absorption Chiller refrigerant cycle

- condenser: as in the traditional condenser, the refrigerant (such as ammonia or lithium bromide) enters the condenser at a high temperature and pressure; here it’s condensed by cold water;
- expansion valve: it causes the refrigerant to get colder and its pressure is suddenly reduced;
- evaporator: the refrigerant enters the evaporator in the form of a cool, low-pressure mixture of liquid and vapor, then it flows to the absorber
- absorber: when the absorbent absorbs the refrigerant entering in the absorber, its volume decreases and the compression of the refrigerant occurs. Thus absorber acts as the suction part of the compressor. The heat of absorption is also released in the absorber, which is removed by the external coolant;
- pump: the output of the absorption process is as mixture of refrigerant-absorbent, which is then pumped to the generator, increasing its pressure;
- generator: the refrigerant-absorbent solution is heated by an external source (it can be hot water or steam). Due to heating the temperature of the solution increases. The refrigerant in the solution gets vaporized and it leaves the solution at high pressure. The high pressure and the high temperature refrigerant then enter the condenser and the cycle starts again.

Benefits of a vapor absorption cycle

When the environmental conditions allow its operation [e.g. availability of wasted heat to be recovered), this type of cooling system is more efficient than the basic vapor compression cycle and this efficiency can be reassumed as follows:

- Absorption cooling is ideal when it is combined with CHPs in order to recover low enthalpy heat coming from the energy cascade, otherwise wasted; This thermal waste management is particularly energy and cost effective, both in the hot and cold season, increasing the general efficiency of the process from primary energy source to end users;
- The liquid pump is used instead of the compressor: pumping a liquid is easier and cheaper than compressing a gas, and it needs less input energy;

- The kind of refrigerants used is less dangerous for the environment or for the global warming; an example of refrigerant can be distilled water, less impacting than the halocarbons used in the vapor compression refrigeration system;
- It causes less noise and vibration and needs little maintenance;
- Compared to mechanical chillers, absorption system is less performing, but its low COP is balanced by reduced operating costs and by the fact that it's not sensitive to load variation.

Parameters:

COP [%]: *according to designed/ installed device*

Heating nominal power [kW]: *according to designed/ installed device*

Cooling nominal power [kW]: *according to designed/ installed device*

Recirculation fraction [m^3*/hour]: according to designed/ installed device*

Kind of refrigerant (lithium bromide, ammonia, distilled water)

Characterization of Usage:

Hours of operation [h/year]: very s*ite specific, depending on the final end uses and from the feeding CHP/ heat source characteristic*

Lifespan [years]: *10*

Annual preventive maintenance [euro/year]: *normally included in the plant management O&M contract*

2.1.12 Compressor Chiller

Cat.: 3.2/3.3

Description:

Chiller is a heart of the air conditioning system; machine produces chilled water for cooling purpose and uses about 60% of the total HVAC power demand. Thermodynamic cycle is realized in the unit raising and lowering the heat potential of the refrigerant. In simple words refrigerant runs in a closed cycle, which runs as follows: liquid faze of refrigerant evaporates in the evaporator and chills the water. Later, gas faze is compressed in the compressor (temperature rises with pressure). Hot vapor is next condensed in the heat exchanger (condenser) where heat is transferred to the air, refrigerant runs through expansion valve where pressure is dropped. Cycle repeats.

Figure 25 Chiller

Mechanical chillers are usually electrical powered. There are four types of electrical chillers available on the market: Reciprocating compressors, Scroll compressors, Screw compressors, Centrifugal compressor. Effectiveness of the chillers depends of its type and size: for chillers up to 100tons it is recommended to use as a first choice reciprocating compressors, next scroll and screw ones, from 100-300 tons best compressor is screw next scroll and centrifugal, for size bigger than 300tons the best solution in centrifugal compressor and screw compressor as a second choice.

One chiller can serve multiple numbers of cooling units or only one unit. First solution seems to be better because there are only one or two working units installed in the technical room instead of many single units installed locally.

It has to be remembered that for chiller it is better to work close to its full load than when it’s only partially loaded.

Chillers are usually situated on the building roofs and special foundation should be predicted as they cause additional bearing loads and vibrations on the roof slab. System should consist of at least two working units connected to EPS.

Parameters

Cooling capacity: according to design loads

Design efficiency [kW/ton]: according to design loads

ESEER [-]: c.a. 4.50

Characterization of usage:

Maximum operating power input [kW]: given in device electrical data according to chosen unit

Maintenance costs [euro/year]: according to electrical energy prices and service

2.1.13 Heat pumps

Cat.:1.1/3.1

Description:

Heat pump is a heating device, which uses low temperature energy source and raise energy potential from lower to higher state by constant thermal conversion of refrigerant running in a closed cycle. Heat is taken from cold source and driven to the hot one. The vapor faze of refrigerant is compressed and condensed in the evaporator, expand in the expansion valve and evaporated in the evaporator. This enables to gather heat with low energy potentials in raise it to the high level in the compressor.

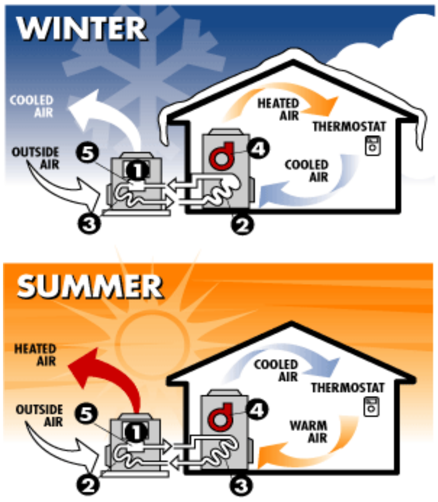

Figure 26 Heat pump working mode

Heat pumps are commonly used as a low temperature heat source, compatible with special heating systems such as floor/wall heating, they can be used to produce domestic hot water in combination with non-renewable source such as gas boiler or electrical heater.

Heat pumps can be divided according to down energy Source (cold source).

- Ground (GSHP) – low temperature heat is taken from the earth, there are two possibilities of collecting energy: in horizontal or vertical collectors. In both cases ground exchanger is a pipeline horizontal/vertical oriented fulfilled with carrier medium (usually glycol). Vertical exchangers are cheaper to build but bigger collecting area is required comparing to horizontal exchangers which are long drills. Main problems are high costs and risk of soil hypothermia and legal permissions needed from horizontal drills.
- Air (ASHP) - heat is extracted from ambient air in outdoor exchanger. ASHP can support indoor room with heat during the winter and chill the space in the summer, work of this device is reversal. Main problems are risk of freezing of the external exchanger when temperature falls down the 0^oC.
- Exhaust Air (ESHP)- heat is extracted from air from warm room areas such as kitchens, bathrooms, etc. and transferred within a ESHP to tap hot water or low temperature heating system (e.g. under floor heating).
- Hybrid (HHP) – it is a twin source system using air and ground when air temperature is to low as a cold source.

Parameters:

$\eta_{H,g}$- the ration between total gross production of electricity and the primary energy consumption for electricity production, shall be calculated as an EU average based on Eurostat data.

SPF- estimated seasonal performance factor, gives information about seasonal performance of the unit and is close to real value as it takes into account difference in source temperature among the year [-]

SPF= 1/ $\eta_{H,g}$·1,15

Heat pump type	SPF (new/retrofitted buildings)
Air/water	3,5/3,0
Brine/water	4,0/3,5
Water/water	4,5/4
Direct evaporation	4,2/3,7

According to EHPA 2008

Heat pump type	$\eta_{H,g}$ (new/retrofitted buildings)
Water/water	3,8/3,5
Glycol/water	3,5/3,3
Air/ water	2,7/2,5

COP – coefficient of performance is a ratio of heating or cooling provided to electrical energy consumed by the compressor (can be calculated according to data collected from BMS). Gives information about temporary efficiency of the unit.

Power [kW]: adequate for energy demand for the building

Characterization of usage:

Electrical energy usage [kWh]: form building energy usage monitoring system

Lifespan: approximately 14 years /according to the Air Conditioning, Heating & Refrigeration Institute (AHRI)/19

[19] http://www.ceedirectory.org/Content/centralairconditionerandheatpumpefficiency_2.aspx

2.1.14 Solar panels

Cat.: 1.1/3.1/3.3

Description:

Solar thermal collectors convert solar radiation into useful heat. A number of technologies, including unglazed, flat-plate, evacuated tube and concentrating collectors, are available on the market to provide the temperatures and efficiency needed by different applications. The three distinct temperature ranges in which solar thermal collectors operate and their corresponding applications and technologies are defined in the table.

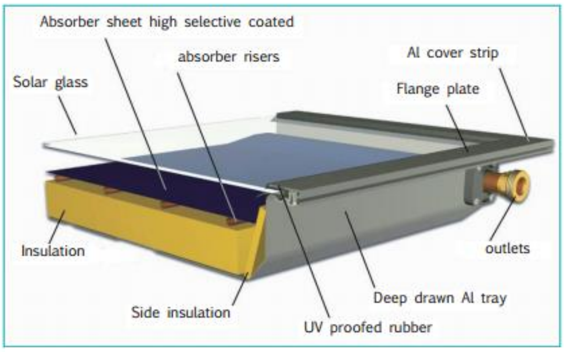

Figure 27 Solar Panel cross section

Temperature needed by the application	Type of application	Collector technologies used
Low temperature 20ºC-95ºC	Swimming pools, domestic hot water heating, space heating, district heating, solar cooling and low temperature process heat.	Unglazed flat plate, evacuated tube and CPC concentrators
medium temperature 95ºC-250ºC	Process heat, desalination, water treatment, high efficiency solar cooling, district heating and cooling	High efficient vacuum insulated flat plate, evacuated tube, CPC and other low concentrating linear Fresnel and parabolic trough collectors.
High temperature >250ºC	High temperature process heat and electric power via thermal power cycles.	Parabolic troughs and linear Fresnel collectors, solar dishes and solar towers

In addition, solar thermal heat can be used to drive a thermal cooling machine and can, therefore, be used as energy source for cooling.

In Central and Northern Europe forced circulation system are used, in which the heat transfer fluid is driven through the system by a pump. In Southern Europe, simple thermo siphon systems are very popular, since they are low cost using natural convection to carry hot water from the collector to the water store placed above.

Certification:

The Solar Keymark is the main quality label for solar thermal products and is widely spread across the European market and beyond. The Solar Keymark is a CEN/CENELEC European mark scheme, solely dedicated to:

- Solar thermal collectors (based on European standard series EN 12975)
- Factory made solar thermal systems (based on European standard series EN12976)

Parameters:

The efficiency of a solar collector depends on the ability to absorb heat and the reluctance to "lose it" once.

It depends on the following parameters

η_0: Maximum efficiency if there is no heat loss* [-]

a_1 1st order heat loss coefficient [W/ (K·m2)]

a_2: 2nd order heat loss coefficient [W/ (K2·m2)] G: Total (global) irradiance on the collector surface [W/m2]

T_m: Mean collector fluid temperature [°C]

T_a: Temperature of the ambient air. [°C]

<u>Other parameters:</u>

Aperture area (Aa) - m2

Gross area m2

Characterization of Usage:

Lifespan [years]: FPC up to: 25, ETC up to 30

2.1.15 Photovoltaic

Cat.: 2.1/2.2

Description:

Solar photovoltaic is today the second largest renewable energy technology after hydro power. PV plant converts solar radiation into direct current electricity (photovoltaic effect) thanks to the special photosensitive material included in the base-module of the system: the solar cell. The cells are assembled together into panels and then into arrays according to the energy requirement.

Each element is composed as it's shown

- glass (usually 4 mm): this specific glass must have a low concentration of iron in order to guarantee the maximum transparency;

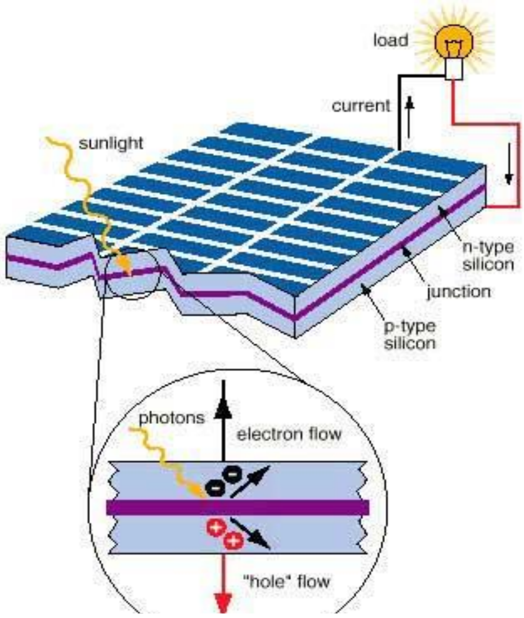

Figure 28 Photovoltaic slab cross section

- laminating: composed of Ethylene Vinyl Acetate (EVA), before and after the cells so the inner PV module is completely isolated and protected after the polymerization of the EVA;
- cells: mainly made of monocrystalline silicon ,polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulphide; this is the core of the system, the place where the photovoltaic effect takes place;
- plastic sheet (or another glass plate);
- aluminium frame and junction box: to connect all the element together and to the electrical system; the frame also guarantees the vacuum in the cell.

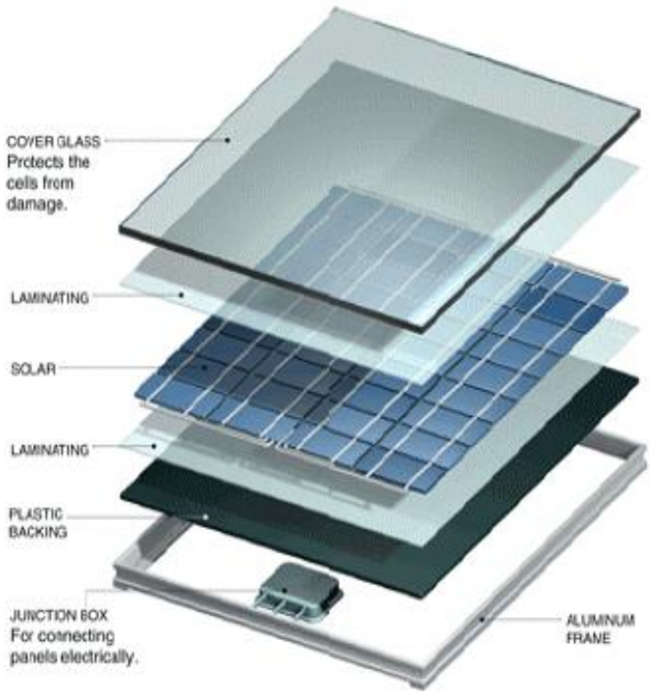

Figure 29 Photovoltaic cell build

<u>The process:</u>

The silicon in the cell is doped and a p-n junction is obtained: the p-layer (+) has a very high hole concentration while the n-layer (-) has more electrons concentration. The different charges naturally move in order to have the balance, and when it is reached every other movement of the charges is contrasted.

The sun light adds photons to the system, giving to electrons the energy to pass to the other layer; if the electron moves a hole is created, as well as a differential of potential, and then the charges move again and current is produced.

The most common type of photovoltaic cells are made of mono/polycrystalline silicon, this technology cover about the 90% of the total PV manufacturing; another 8-10% is covered by the silicon thin-film cells; the remaining production is for particular technologies, researches and prototype

Parameters:

Wattage [W] *according to designed/ installed device*

Power tolerance [kW]: *according to designed/ installed device*

Weight [kg]

Module Electric Efficiency [%]: *electric efficiency of the module at Standard Test Condition*

BOS Efficiency [%]: *efficiency of the Balance Of System (BOS), cables, inverters, swithches, etc, all the devices that allow the availability of the power produced by the photovoltaic at the requested frequency (normally 50 Hz) and voltage required by the end users*

Characterization of Usage:

Average working time [h/year]: very s*ite specific, depending on location, averaging in Europe from 900/950 (United Kingdom, Denmark, Finland) to 1400 h/year (south of Italy and Spain, Greece, Cyprus, Malta)*

Lifespan [years]: 5*0*

Annual preventive maintenance [euro/year]: *normally included in the plant management O&M contract*

2.2 Energy distribution technologies

2.2.1 Water circulation pump with variable speed

Cat.: 1.1/3.1/3.2/3.3

Description:

Figure 30 Wilo Stratos circulation pump

www.buildinggreen.com/auth/article.cfm/2010/8/30/High-Efficiency-Variable-Speed-Pumps-from-Wilo-and-Grundfos/

Circulation pumps can be use in every closed system such as: domestic hot water preparation systems, in heating system, cooling systems, etc. Impeller sets the flowing medium in motion so that medium with requested parameters can reach every receiving point. Circulation pumps does not upraise the medium pressure they are only responsible for keeping fluid in a constant flow that is why they only need to overcome the friction of a piping system. Circulation pumps can be optimized by introducing an operating time schedule adequate to anticipated demand periods in the building instead of running constantly for 24 hours. This can be achieved by using variable-frequency drives (VFDs), which are integrated to modulate the pump speed or flow rate. This enables to set optimum pump speed according to current demand. The VFD is directly integrated into the pump and that it's available for smaller pumps. Pumps have permanently charged electronically commutated motors (ECMs) that reduce energy use by about 50%. Electricity savings of 70%–90% can be realized, characterizing some systems already available in the market

According to Commission Regulation (EC) No 641/2009 of 22 July 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products energy efficiency requirements are as follow:

1. From 1 January 2013, glandless standalone circulators, with the exception of those specifically designed for primary circuits of thermal solar systems and of heat pumps, shall have an energy efficiency index (EEI) of not more than 0,27.

2. From 1 August 2015, glandless standalone circulators and glandless circulators integrated in products shall have an energy efficiency index (EEI) of not more than 0,23.

The calculation methodology of described in the Annex II, point 2 of above mention Commission Regulation.

Parameters:

Power [kW]: according to designed/ installed device

Electrical energy usage [kW]: according to designed/installed device

Characterization of Usage:

Hours of operation[20]: 5840 h/year

Lifespan: 10-20 years

Annual preventive maintenance[21] : 2% of initial investment costs

[20] Polish Regulation of the Minister of infrastructure which is an executive act of EU Directive 2002/91/WE

2.2.2 Sewage heat recovery

Cat.: 1.2

Wastewater is an available but underestimated source of energy can be recovered both from raw and cleansed sewage. Used water is generally hotter than 10°C what makes it possible to recover heat from it. There are few possible methods of obtaining heat from sewage. From raw sewage heat can be recovered directly in the building in so called in-house recovery system, from the sewer or from the wastewater treatment plant.

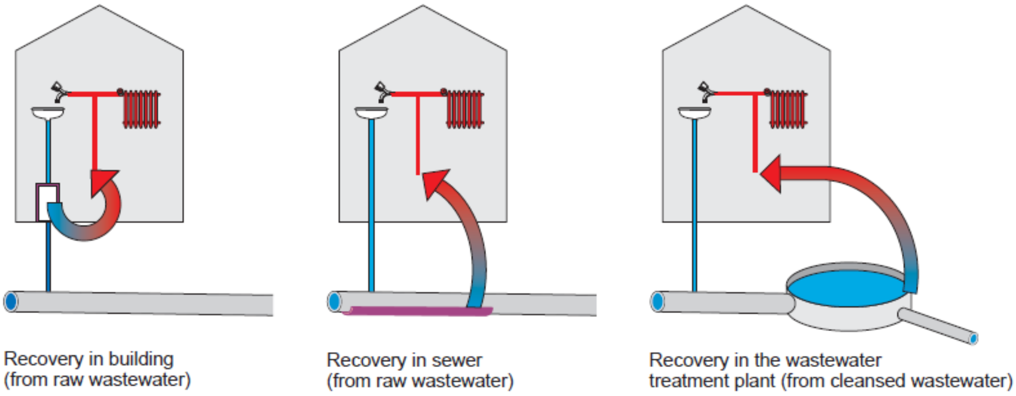

Figure 31 Possibilities for energy recovery from wastewater (SwissEnergy 2005)

In in-house installation gained heat is usually used for heating-up water. In installations where quantity of wastewater is more or less on constant level tube-bundle heat exchangers, operated according to the through-flow principle are used. When wastewater flow is not constant spiral-tube heat exchangers are installed in integration with storage and filters. These systems are mostly used in family houses. The main problem of heating –up water with sewage is risk of contamination what is conditioned by quality of sewage water that is why this type of heat recovery installations are not recommended for health care facilities.

For heat recovery from the sewer two methods can be distinguished: first possibility is usage of gutter-shaped heat exchanger elements made of stainless steel mounted in the sewer bed. Usually heat is transferred from the exchanger by the energy carrier medium and connected with the heat pump loop. Preconditions[22] are as follow:

- a sewer diameter of >800 mm,
- a quantity of water during dry weather of >30 l/s
- Water-covered surface in the sewer bed of at least 0.8 m^2 per meter sewer length during dry weather.

The bigger problem with heat recovery from wastewater is that sewage cannot be cooled down too much. The sewage treatment plant technology requires specific temperature conditions and the

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[21] *EN 15459 Energy Efficiency for Buildings — Standard economic evaluation procedure for energy systems in buildings*

[22] Felix Schmid, " **SEWAGE WATER: INTERESTING HEAT SOURCE FOR HEAT PUMPS AND CHILLERS"** SwissEnergy Agency for Infrastructure Plants Gessnerallee 38a, CH-8001 Zürich, Switzerland

efficiency of biological sewage treatment (nitrification) dependents on sewage temperature. That is why minimum sewage damping temperature should be consulted with sewage plant operator.

Parameters:

Minimum dumping temperature [^{o}C]: according to sewage operator requirements

Heat exchanger power [kW]: according to design system

Characterization of usage:

Sewage average heat flow [m^3/h]: according to design system

Sewage average temperature [^{o}C]: according to design system

2.2.3 Light management system

Cat.: 2.1

Description:

Effective automatic lighting controls can detect presence and daylight to reduce lighting requirements and minimize running costs.

- Zoned lighting
- Presence detector
- Daylight sensor

Figure 32 Infra-red sensor

Zoned lighting: for corridors and larger administration areas where lighting levels can be adjusted according to daylight availability by either switching to 'off' or continuous up/down dimming (Figure 1).

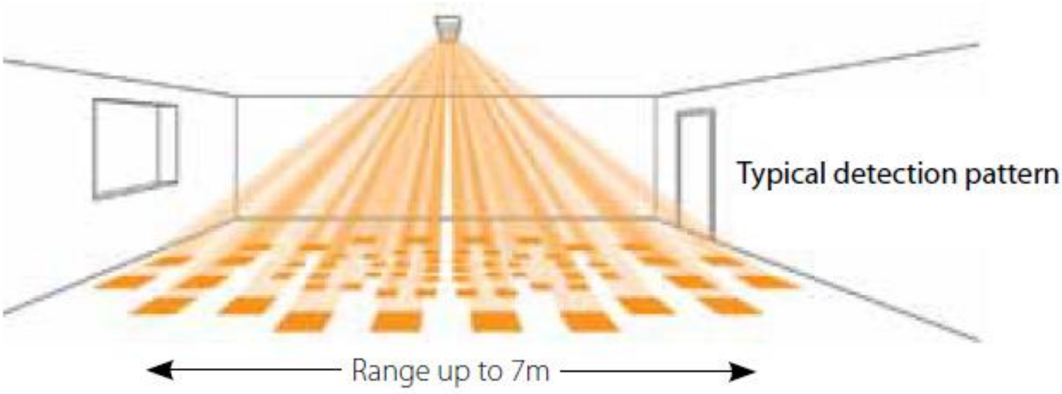

Figure 33 Infra-red presence detection for 'zoned' areas can also provide daylight sensing and manual override control

Presence detectors: for small areas such as toilets, equipment stores, medical record stores, wherever variable occupancy occurs. Available as infra-red (Figure 2) for cellular areas or ultrasonic detectors, with ranges between 5m and 60m depending on the application.

Daylight sensors: to turn lights on and off and also dim lights when sufficient daylight is available in circulation areas and administration areas. They can be integrated with a presence detector. They should be used for external floodlighting.

Lighting to bed spaces should be on individual switches and should be switched off if the bed is unoccupied.

Central lighting control systems should be of the digital type. DALI (Digital Addressable Lighting Interface) is one of the appropriate options.

Controls should be set to ensure that fluorescent lamps are not switched on and off at too short an interval. Fluorescent tubes which have 'soft start' i.e. electronic starters or electronic high frequency ballast types, provide a less detrimental impact on the life cycle of lamps

Parameters:

According to designed/ installed device

Electrical energy usage [kW]: *according to designed/installed device*

Energy saving

- Zoned lighting: 5 to 20% reduction of used electricity for lighting, reducing hours of operating by 30%

- Presence detector 5 to 20% reduction of used electricity for lighting, reducing hours of operating by 30%
- Daylight sensor 5 to 20% reduction of used electricity for lighting, reducing hours of operating by 60% in daylight zone

Characterization of Usage:

Hours of operation [h/year]: according to building lighting schedule

Hot floor: 2.900

Hotel: 5.000

Office: 2.600

Industry: 2.400

Lifespan [years]: *10*

Annual preventive maintenance [euro/year]: *1% of initial investment costs*

2.2.4 BMS system and BEMS system

Cat.: 2.3

Description:

A Building Management System (BMS) is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as heating, ventilation, lighting and fire systems. A BMS consists of software and hardware; the software program, usually configured in a hierarchical manner, can be proprietary, using such protocols as C-bus, BACnet and so on.

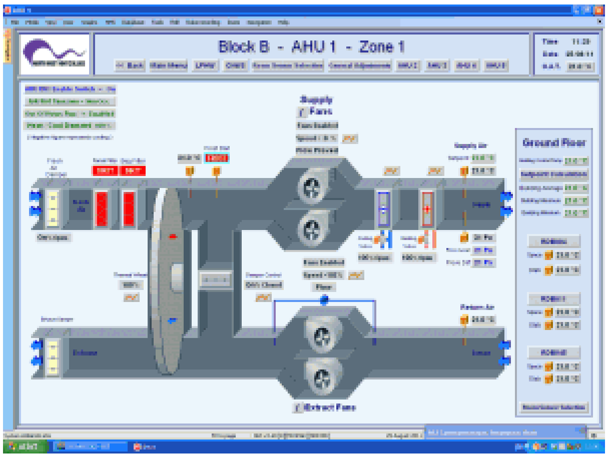

Figure 34 BMS system interface

Building Management Systems are most commonly implemented in large projects with extensive mechanical, electrical, and plumbing systems. Systems linked to a BMS typically represent 40% of a building's energy usage; if lighting is included, this number approaches 70%. BMS systems are a critical component to managing energy demand.

In addition to controlling the building's internal environment, BMS systems are sometimes linked to access control (doors controlling who is allowed access and egress to a certain part of the building).

The BMS monitors and controls the heating, ventilation and air conditioning ensuring that they operate at maximum levels of efficiency and economy. At present this is achieved by similar means to those outlined in Category 3.1 (Individual Regulation of Heating Systems) whereby a whole ward or department may be controlled by just one temperature sensor, usually at the far end of the heating circuit.

Extensive and improved heating controls are required to monitor and adjust space temperature and heating valve positions in individual rooms or bays. This will provide greater control resulting in an improved environment for patients and staff and a saving in energy. The aspiration of energy efficiency does not end with the installation of the BMS; it starts with the ongoing improvement and design. It is crucial that as much control hardware is provided as possible in order to maintain optimum building energy efficiency. Software must also reflect the physical presence of temperature sensors, valves, actuators, pumps, air handling units, boilers etc. via a graphics page on the BMS. The more local controls, the greater the opportunity to achieve energy savings. The information then needs to be monitored, analyzed and acted upon in order to be effective.

Time scheduling should be implemented wherever possible to achieve optimization. There is no point heating an empty room and there are means to ensure that heating start up times are utilized to the maximum. Occupancy sensors and time scheduling are reliable methods of achieving optimization.

The improvement of BMS controls provides benefits to building occupants, building owner and the maintenance provider, as follows:

- Good control of internal comfort conditions
- Provision of individual room control

- Increased staff productivity
- Effective monitoring and targeting of energy consumption
- Improved plant reliability and life
- Effective response to HVAC related complaints
- Save time and money during maintenance
- Flexibility on change of building use
- Effective use of maintenance staff
- Early detection of problems
- Satisfied occupants and happier workforce

BEMS

Description:

Building Control System (BMS) is responsible for control and management building mechanical and electrical equipment. Building Energy Monitoring System (BEMS) is an advanced BMS to give the opportunity for Performance management (energy, comfort, installation and process). BMS is a static control system, but BEMS is the dynamic control system, with real-time calculation and comparing of the installation performance related to the design parameter. Including suggestions for energy optimization.

Figure 35 Dashboard KPI.

2.2.5 Regulation

Cat.: 3.1/3.2/3.3

Description:

An Actuator is a piece of equipment used to operate a valve on or off. The proposal is to install local heating valves and actuators on every bay and cubicle on each ward. By controlling temperature on an individual basis, not only is the patient more comfortable, but there is a significant cost to be saved on heating.

There are different types of valve and control. The Basic type is a 24V operation that is either in an open or closed state dependent upon requirement, and intermediate positions are not held. This is of little use in our case so a modulating type would be chosen.

This works by virtue of a 0-10V control signal that will open or close the valve dependent upon the signal sent to it via the temperature sensor and outstation.

Figure 36 Actuator

The most distinctive feature of this application is that changing conditions require frequent adjustment of the actuator, e.g. to set a certain flow rate. Sensitive closed loop applications require adjustments within intervals of a few seconds. The demands on the actuator are higher than in an open–close duty so both mechanics and motor have to be designed so as to be able to withstand the high number of starts without any deterioration in control accuracy. The running time is limited by the relative on-time; for modulating actuators this is usually 25%.

All these controls, set points and space temperatures would then be brought back to the BEMS and depicted on a graphics page to show the state of the valve, the heating set point and the current space temperature.

At present a typical ward has just one sensor positioned at the furthest part of the ward and this controls a simple zone valve. There is a conflict between the rooms at the supply end of the ward and those at the far end of the system, as the rooms at the far end (where the temperature sensor is located) will be set at a comfortable level, whereas the rooms at the start of the heating circuit will experience overheating, as a result of maintaining comfort levels at the location of the sensor.

By installing a temperature sensor and local valve and actuator in each room / bay, the desired temperature can be maintained thereby improving the patient / staff environment and assisting clinical effectiveness.

A further option would be to consider a wireless installation, which would provide a saving on installation costs.

There are three different methods of controlling the heating system. Automatic Regulation, Central Regulation and Local Regulation.

Automatic Regulation

Automatic Regulation would involve changes to the environment being carried out automatically to adapt to current conditions. An example would be the control of a main heating valve based upon the outside air temperature. This valve would then provide the heating for a ward / department and the environment in that area would be governed by the outside weather conditions. This method is deployed in certain areas of the hospital.

Central Regulation

Central Regulation of the heating system would involve the set points and heating controls for the whole building being set at one central point. This option would not be deployed at the hospital as there are so many different needs and requirements within many areas. For example a maternity unit, where new born infants are cared for or a Special Care Baby Unit, where tiny babies require extensive and extreme care, would need to be warmer than a physiotherapy unit, where adults would undergo exercise and manipulative treatment.

This type of control would therefore not be the preferred option.

Local Regulation

Local Regulation involves the installation of heating zone valves. The valves would then be controlled via a local temperature sensor and provide the correct temperature required to maintain the environment to the desired conditions. Local Regulation would be the preferred option in order to maintain consistent local environment and it would also result in energy savings.

At present a typical ward has just one sensor positioned at the furthest part of the ward and this controls a simple zone valve. There is a conflict between the rooms at the supply end of the ward and those at the far end of the system, as the rooms at the far end (where the temperature sensor is located) will be set at a comfortable level, whereas the rooms at the start of the heating circuit will experience overheating, as a result of maintaining comfort levels at the location of the sensor.

By installing a temperature sensor and local valve and actuator in each room / bay, the desired temperature can be maintained thereby improving the patient / staff environment and assisting clinical effectiveness.

A further option would be to consider a wireless installation, which would provide a saving on installation costs.

2.2.6 Hybrid ventilation

Cat.: 3.2

Description:

Hybrid ventilation is a building ventilation system that integrates natural (i.e. passive) and mechanical (i.e. active) ventilation components to create a high efficiency and healthy ventilation system for a building. This has made it possible to satisfy relatively strict indoor air quality requirements for most of the time, using different features of both natural ventilation and mechanical systems at different times of the day or season of the year.

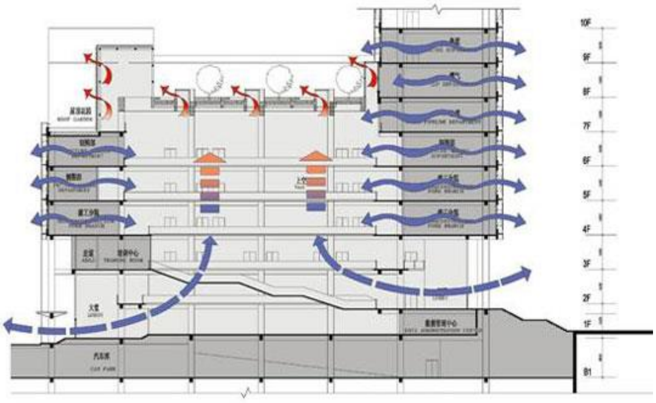

Figure 37 Air flow in the building

We expect the assistance of mechanical system(s) would only be needed during very limited period of the year, possibly just during the most severe weather situations.

Figure 38 Low pressure VBP base.

A hybrid ventilation system is important to a building's sustainability because it demonstrates an appropriate use of technology, includes renewable, high-efficiency, low-carbon components (e.g. earth air tubes); it has also been shown to result in healthier indoor environments when used properly. In any case the use of hybrid ventilation lowers significantly the operation of the mechanical plants and the related primary energy demand.

Clearly in the months of extreme weather, natural ventilation would make no contribution.

The demand control is based on Indoor Air Quality, where the most influencing parameter is CO_2. Various parameters may be measured depending on the objectives of the control strategy.

Presented low pressure VBP base, being a part of a hybrid ventilation system, operation parameters are the same as in case of natural ventilation. Basing working mode is mechanical operation with natural air flow support. This combination enables to achieve lower electrical energy usage by fans.

According to manufacturer data some of available on the market fans use 9,7 W while working on upper gear delivering 180 m3/h of air. Simple calculations showed that even if working constantly on upper gear early costs of unit operation would be c.a. 8,5 euro[23].

[23] Calculation was made by recalculating Polish currency and current electrical energy costs.

Parameters:

Predicted Mean Vote according to designed/ installed device

CO_2 concentration [ppm]: according to designed/ installed device

Natural flow rate [m3/h or volume/h]: flow rate of outdoor air expected from the building envelope

Characterization of Usage:

Hours of operation [h/year]: very site specific, depending on the site climate. Always seasonal

Lifespan [years]: not determined

Annual preventive maintenance [euro/year]: no maintenance is required

2.2.7 Dampers

Cat.: 3.2

Description:

To control the air flow in central ventilation systems, all the secondary AHUs have dampers that opens and closes depending on the operating hours for different activities in the building. The dampers at the AHUs when these are of type 2 can leak a lot of ventilation flow in the closed position when the central system is still running at a very high pressure.

In a best practice retrofitting project at Karolinska University Hospital at Huddinge, the dampers from the beginning was of type 2. Below it is shown that at 500 Pa it leaks about 600 m^3 / h.

By Multiplication this leakage to the 800 aggregate that were in the K U H at Huddinge, can we understand that the leakage was very huge all the year. So the energy loss was thermal and cooling energy. By changing the dampers from type 2 to type 4, the energy saving was almost 350 000 kWh / year heat energy and 20 000kwh/ year for the electricity. That because the dampers type 4 leaks less than 20 m3 / h at 500pa. It may be noted that this type was already available at the market when the system was configured.

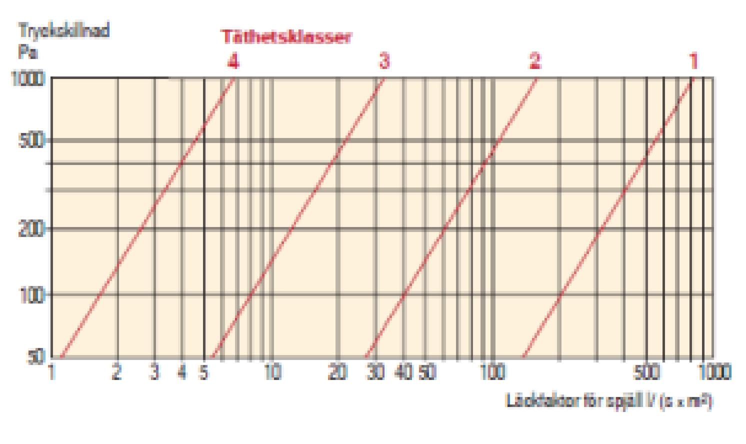

Figure 39 Maximum allowable leakage factor closed damper (HVAC AMA 98). Note that the figure does not report higher pressure difference than 1000 Pa. Tightness Requirements in higher pressure difference must therefore specified before order

Selection of damper

With increasing demands for energy, reliable and long-term cost efficiency requirement choice of dampers become increasingly important. To ensure intended function of the dampers is supplied with increasing frequency with factory installed actuators. Mounting and function test dampers with actuators is performed when the appropriate Facilities staff with a good knowledge of both gate-like control.

The main selection criteria for the damper is:

- Tightness of the closed gate, Operating Temperature, Compressive strength, Corrosion resistance, sound generation and Heat leakage through the gate.

Characterization of Usage:

Tightness Classes: Involuntary ventilation through the damper is leaking because of improper installation or wrong Damper class, gives annually large energy losses. The losses can limit by the use of dampers with higher tightness.

2.2.8 Air ducts

Cat.: 3.2

Description:

Duct systems account for a large fraction of the energy use in a building. This is further increased with a leaky duct system. The supply air flow has to cover the sum of total nominal air flow and the leaking flow. With leaky ductwork this will lead to a considerable and costly increase of the needed fan power. Many studies have identified defective ventilation systems and insufficient airflows as a main reason for occurrence of sick buildings - the supply air needed to assure a good air quality should thus reach the areas where it is needed and not disappear along its transport through the building.

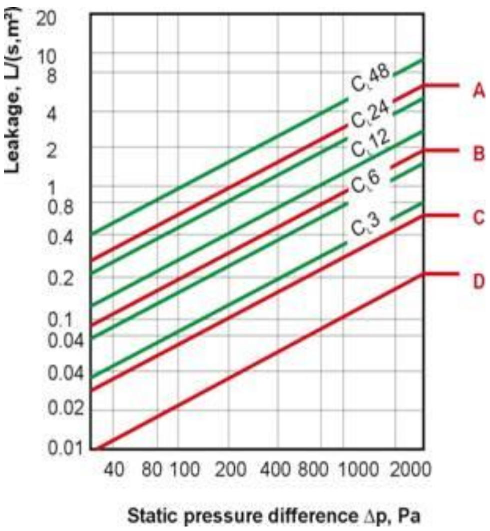

Figure 40 Leakage in Static Pressure difference function

Characterization of Usage:

Air tightness standards - Duct air tightness classes A to D are defined in European Standard EN 12237 for circular ducts and EN 1507 for rectangular ducts respectively. Another standard for testing and classification of air tightness of ductwork components (EN 15727) was approved in 2010. Class “A” is counters intuitively the worst class, but this established class scale cannot now be changed. The leakage test method for system commissioning is described in EN 12599. Air tightness classes for air handling units are defined in EN 1886 (classes L1 to L3, where L1 is the best, equivalent to duct class C). System standards like EN 13779 give further recommendations for air tightness class selection for different purposes.

2.2.9 Efficient, energy-saving fans with variable speed

Cat.: 3.2

Description:

Fans are a mechanical machine which produces fluid (usually air) motion. Working unit consists of a rotating blades and hub together called an impeller, a rotor, or a runner. Fans are in general equipped in electrical driven motors but there is also a possibility to use hydraulic motors and internal combustion engines. It can be used in ventilation system and air condition systems, cooling system as well as in personal thermal comfort systems. Fans are also used to create under pressure or overpressure depending on room requirements and function. Main role of fan as a part of mechanical ventilation system is to create required pressure need to overcome supply fresh air for hygienic reasons as well as outtake exhaust air from the rooms. Fans can be installed in the Air Handling Unit both supply and extract side. Another possibility is to install fan within the ducts or in the delivery unit.

Figure 41 Duct fan

The speed of motor can be controlled by an adjustable speed drive (ASD) also called variable-speed drive (VSD) and variable-frequency drive (VFD). The first option in which drive is integrated to modulate the fan speed or air flow rate. This enables to set optimum speed according to current demand. The VFD is a system for controlling the rotational speed of an alternating current (AC) electric motor by controlling the frequency of the electrical power supplied to the motor. When adjustable speed drives are used, the fans operate continuously at a speed that is adequate to actual needs. This kind of regulation of motor speed prevents from mechanical and hydraulic stresses and provides smoother operation.

Adjustable speed drive motors use less energy than fixed speed motors. When fan motor is driven by the fixed speed motors air flow does not change according to actually needs and in most cases is much higher than required, though air flow can be regulated by a dumper but still it is not energy efficient solution.

Parameters:

Fan Total Pressure [Pa]: according to designed/ installed device

Motor power [kW]: according to designed/ installed device

Electrical energy usage [kW]: according to designed/installed device

Characterization of Usage:

Hours of operation [h/year]: according to design system and environmental conditions

Lifespan[24] [years]: 15

Annual preventive maintenance[9] :6% of initial investment costs

[24] *EN 15459 Energy Efficiency for Buildings — Standard economic evaluation procedure for energy systems in buildings*

2.2.10 VAV Ventilation system

Cat.: 3.2

Description:

Variable Air Volume system is one of possible HVAC system solution for heating, ventilating, cooling and air conditioning purpose.

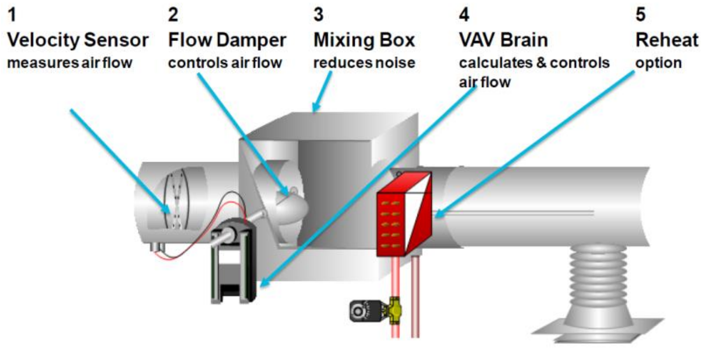

Figure 42 Variable air volume (VAV) Terminal Unit

In simplest VAV system air temperature is constant and only air flow rate varies to meet the actual heat gains and losses within the served room/zone. Air flow is regulated by flow dumper installed in so called VAV box, dumper is calibrated and equipped with actuator. Such systems use special air diffusers, fans with variable speeds and automatic cooperating with temperature sensors, presence detectors and carbon dioxide detectors The VAV unit is connected to control system and can be easily operated.

Variable air flow systems are found cost-effective when used in the objects with variable demand for fresh air. Air volume reduction influences reduction of electrical energy needed for the fan. How much energy will be saved depends on chosen method used to modulate the air volume. Another savings are done within the cooling system, refrigeration energy is lower comparing to work on full load.

Advantageous of VAV system is the possibility to meet dissimilar requirements in different rooms/zones using only one AHU unit. Indoor conditions can be hold on required level if every independently controlled room will be equipped with terminal unit and thermostat. This system enables to cool rooms, which have bigger heat gains and at the same times does not allow other rooms to be overcool.

VAV systems are very energy efficient and often recommended.

2.2.11 Air recirculation systems

Cat.: 3.2

Description:

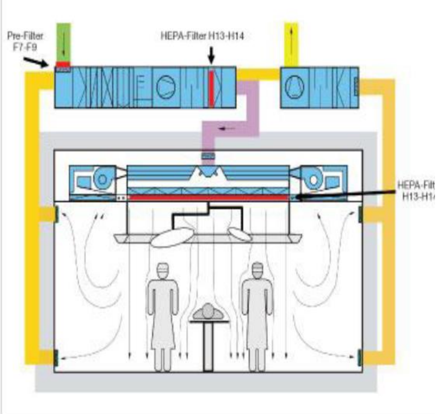

Figure 43 Air circulation in Operating Theatre

Air recirculation systems allows to deliver the minimum amount of fresh air into the given area, mixed with recirculated air to make the ventilation system energy-efficient. Part of exhaust air is driven into closed circle and mixed with fresh air. This solution allows decreasing amount of fresh air what influences on AHU and ducts size. However recirculated air in many cases has to be previously filtered before mixing with fresh air, this is important when indoor conditions has to be kept on required level of purity. Depending on recirculated exhaust air volume and its conditions sometimes preheat of intake air is not needed what decreases installation costs. In AHU mixing chamber exhaust air and fresh air is mixed in preset proportions. This operation influence on decreasing the energy demand needed for later air preparation (heating/cooling) to obtain required parameters.

Regarding specific air conditions, which are required in medical rooms' recirculation systems, are rather not used in Hospitals and require sanitary inspector permission. Main reason of not designing air recirculation system in Health centers is risk of air contamination and germs propagation as well as legal restrictions.

Parameters:

Mixed air ratio: 10% to 90%

Characterization of Usage:

Required amount of fresh air have to be delivered.

2.2.12 Free cooling

Category: 3.2/3.3

Description:

Free cooling is a production of chilled water without a chillier. Water is cooled by external air. In objects where cooling demand occurs during the whole year it is possible to retrieve and use cold from the outside air. For this purpose, the refrigeration system should be equipped with an extra loop in which a special module with heat exchangers and fans provides free cooling. When the damper is open cooling air is taken directly from the exterior, excluding compressor operation. If the internal temperature is higher than the external temperature, the damper will remain open and the evaporator fan will start to take external air. If the external temperature is higher than the internal temperature, the damper stays closed and air is recycled.[25]

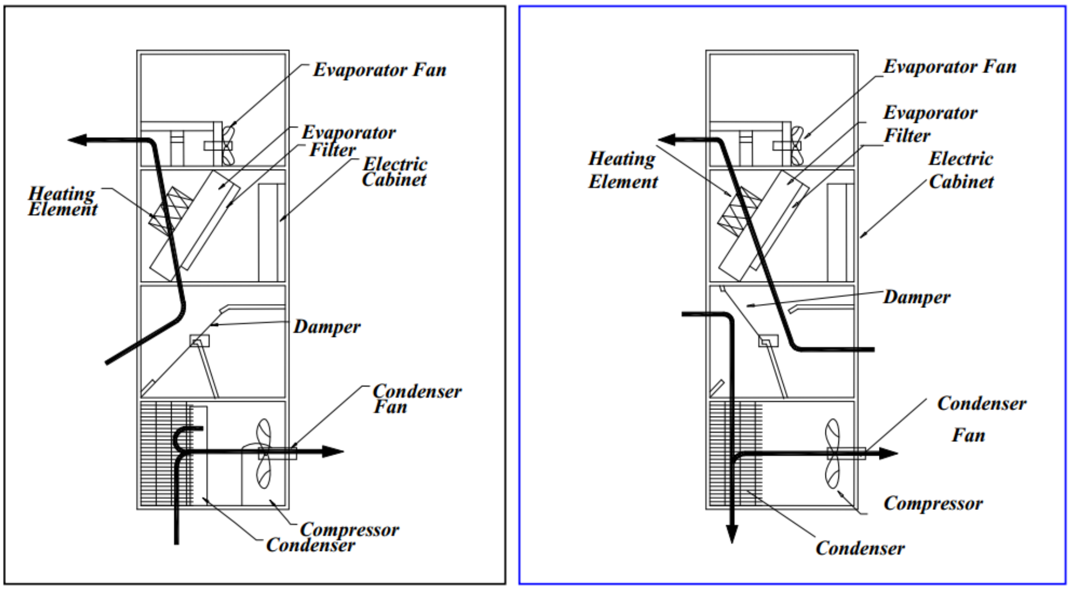

Figure 44 The motorized damper for free cooling purposes in air refrigeration unit which conducts the flows of internal and external air.

[25] Efficiency of Free Cooling Technique in Air Refrigeration Systems ; A. Al-Salaymeh ,M.R. Abdelkader

2.2.13 VRF cooling system

Cat.: 3.3

Description:

Variable refrigerant system is a HVAC technology for air conditioning.VRF system enables to connect large number of indoor units (evaporators) to one outdoor unit (condenser). Indoor units are connected to the same pipe network what gives a possibility to decrease the number of outdoor units and in many cases influences of final architectural outcome of the façade.

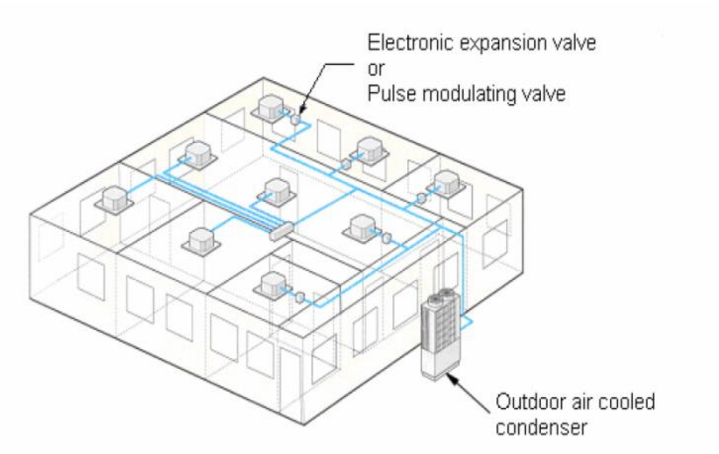

Figure 45 VRF system with Multiple Indoor Evaporator Units

Moreover systems enable better control and regulation. All VRF systems can work in heat pump mode. System can provide thermal comfort in areas with highly diverse heat/cool demand. Additionally the system allows transferring heat or cooling from one area to another in case the zones demand is opposite.

Inverter-driven scroll compressor can be used in VRF technology what permits as many as 48 or more indoor units to operate from one outdoor unit (depending from manufacturer to manufacturer). The inverter scroll compressors are capable of changing the speed to follow the variations in the total cooling/heating load as determined by the suction gas pressure measured on the condensing unit.

In comparison with multi-split systems, VRF systems contribute to minimize the refrigerant path and less copper tubing is needed. Minimizing the refrigerant path allows for maximizing the efficiency of refrigerant work.[26]

VRV/VRF systems find usage for cooling only, heat pumping or heat recovery. On heat pump models there are two basic types of VRF system: heat pump systems and energy-recovery.[1]

[26] http://www.seedengr.com/Variable%20Refrigerant%20Flow%20Systems.pdf

2.3 Energy delivery technologies

2.3.1 Water tap

Cat.: 1.1

Description:

Water flow through the tap:

- Without aerator 10-15 dm^3/h
- With aerator 5-8 dm^3/h

Figure 46 Tap with faucet aerator

Figure 47 One-handle mixer tap

Figure 48 Infra red tap

Water savings according to installed faucet type are[27]:

- 25% : one-handle mixer tap
- 50% : thermostatic tap
- 60% : infra red tap

Water can be saved by

- Hydraulic regulation of circulation : 5%
- Night pump operation time limits : 5%
- DHW pipes insulation : 5%

27 http://www.ign.org.pl/files/cieplawoda.pdf

2.3.2 Lighting type

Cat.: 2.1

Description:

Lighting in hospitals must be suitable for medical staff to do their work and meet the needs of patients and their visitors. Good lighting can help provide a comfortable recovery environment. The main criteria for energy efficient and effective lighting in hospitals are:

References2829

High efficiency lighting can be classified into three main groups:

- **HF TL8**, T8 (26mmØ) Triphosphor Fluorescent Tubes Use T8 with Electronic High Frequency (EHF) control gear
- **T5**: T5 (16mmØ) Triphosphor Fluorescent Tubes These tubes are available in High Efficiency (HE) and High Output (HO) versions
- **LED**: Light-emitting diode

Figure 49 Example LED light source

Existing Lamp Type	Replacement Lamp Type	Benefits
Incandescent GLS 40W 60W 75W 100W 150W 	CFLi (integral ballast) 9W-11W 11W-14W 15W-19W 20W-25W 26W-29W 	75% energy saving Up to 12 times the lamp life of an incandescent lamp Use 'warm white' (2,700 K) CFLi lamps
Mains Voltage Halogen Dichroic Reflector 35W 50W 	CFLi (GU10 fitting) 7W 11W 	80% energy saving Seven times the lamp life As the light distribution differs between these two lamp types lower light levels may be expected
T12 (38mm) or T8 (26mm) switch start luminaires. 	T5 (16mm) high efficiency fluorescent tube. 	Between 30% and 50% energy saving A conversion kit is required which includes the new electronic control gear (kits can also be used for T12 to T8 conversions) Further energy savings can be made by using fewer fluorescent tubes when 'clip-on' tube reflectors are used within luminaires with no internal reflectors
T8 (26mm) Halophosphor fluorescent tube 	T8 (26mm) Triphosphor fluorescent tube 	10% energy saving Twice the lamp life achieved when used with electronic ballasts Fluorescent triphospor tubes are available with up to 60,000 hours lamp life

Figure 50 Maintenance and lamp replacement

[28] http://www.seai.ie/Publications/Your_Business_Publications/Technology_Guides/Hospitals.pdf
[29] http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/hea_lighting_fs.pdf

Characterization of Usage:

Depending on the typology and function of the area

Type	***Consuming power***	***Hours of operation***	**Annual preventive maintenance**
	[W/m²]	*[hours]*	*% of initial investment costs*
HF-TL8	*12*	*17.000*	*3%*
HF-T5	*9*	*19.000*	*2%*
LED	*7*	*50.000*	*1%*

Lifespan [years]: *15*

Electricity uses by lighting different level

Type	***Consuming power***	***Consuming electricity***
	[W/m²]	*[kWh/m²/year]*
Hot floor	*10-30*	*40-60*
Hotel	*5-10*	*35*
Office	*7-15*	*20-30*
Industry	*15*	*40*

2.3.3 Motors

Cat.: 2.2/ 3.1/3.2

Description:

Electrical motors are responsible for a large part of the energy consumption in a hospital. Motors drive air-handling units, refrigeration systems, escalators, elevators, fans and so on. As motors are indirectly responsible for a large part (generally 20-40%) of the electrical energy consumption it is important to have high efficiency motors and motor systems. The problem with motors is that they out of sight, but running all year round, consuming energy.

Motors are part of a drive chain. It starts with the electricity supply and ends with the device that is driven by the motor, such as a fan or an elevator. In the figure below and example is given from the losses that occur. In a typical pump system the useful energy is around 40% of the electrical energy supplied. In a fan the losses will be lower, but are still considerable.

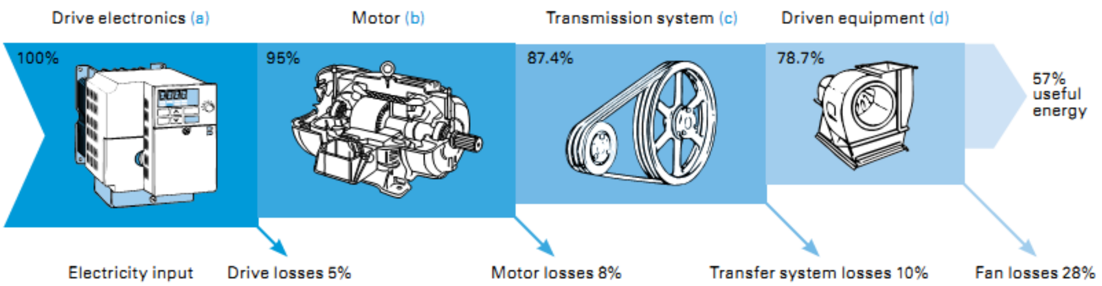

Figure 51 Losses in fan-system.

Considerable energy savings can be achieved by good system design to minimize the motor load. A small increase in duct or pipe size can significantly reduce system losses and thus greatly reduce the fan or pump power required.

Applying direct current motors in for example fans, elevators and so on will reduce the energy consumption significant. Savings up to 50% are achievable.

Figure 52 VSD

Using variable speed drive is another method to lower the energy consumption of electrical motors. In applications where the motor is required to serve a variety of load conditions or has a continuously variable demand, an effective solution for reducing energy consumption is to adjust the speed of the motor to the process demands by equipping it with a VSD.

Savings up to 50% are achievable.

High efficiency motors

Motor efficiencies continue to improve. In 2008 the International Electrotechnical Commission (IEC) Motor efficiency classification standard (IEC60034-30) was introduced. This classifies motor efficiency according to the labels IE1, IE2 and IE3 where IE3 is the most efficient, see the graph below. Especially for the smaller motor sizes the improvement of an IE3 motor as compared to an IE1 motor (or an older one with an even lower efficiency) is very significant. In partial load the difference in efficiency is even higher.

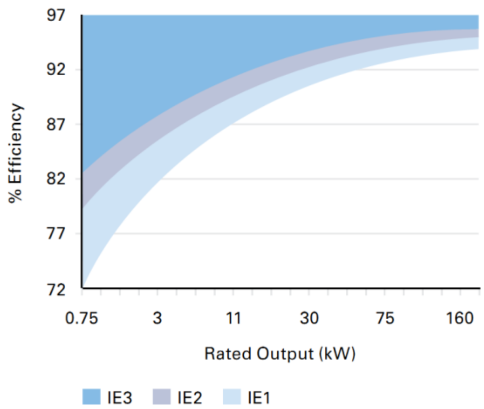

Figure 54 IE1-IE3 motor efficiencies

Stage 1 From 16 June 2011	Motors must meet the IE2 efficiency level.
Stage 2 From 1 January 2015	Motors with a rated output of 7.5kW – 375kW must meet EITHER the IE3 efficiency level OR the IE2 level and be equipped with a variable speed drive.
Stage 3 From 1 January 2017	Motors with a rated output of 0.75kW – 375kW must meet EITHER the IE3 efficiency level OR the IE2 level and be equipped with a variable speed drive.

Figure 53 Minimum efficiency requirements

From a life cycle cost point of view it is important to realize that the running cost of a motor in its entire lifetime is 20-50 times its initial investment. So saving 5% extra energy at the cost of a higher initial investment is very worthwhile.

2.3.4 Electric heating; IR panels

Cat.: 3.1

Description:

InfraRed (IR) heating panels use far infrared technology. They warm objects directly by radiation without heating the surrounding air. IR heaters produce heat instantly so there is no need to preheat a room. Instead of wasting energy on heating the whole room IR heaters can be directed exactly at specific areas and objects that need to be heated. The panels have the quickest response time of any heating technology and - because the panels can be individually controlled for each room or location within that room - the quick response feature can result in cost and energy savings compared with other systems when rooms are infrequently occupied and used a short period of time.

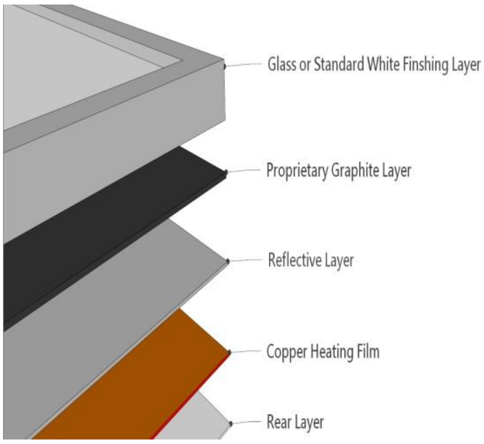

Figure 55 Electric heating panel cross section

The panel warms a room by heating up a carbon graphite and nickel layer to an approximate temperature of ± 100 degrees Celsius. As the element heats up, the panel emits infrared heat energy to objects within its field of view.

IR heating panels can be installed either on walls or (suspended) ceilings, depending on the model of the heating panel. Floor stands are also available for flexible placement of the panels.

They can be used in a diversity of rooms e.g. living rooms, bathrooms and other domestic dwellings. The panels can also be used in commercial buildings -like offices, hotels, yoga studios, barns, salons, spas and hospitals as well. Installation is not only in new buildings but also retro-fitted.

Infrared heating is a realistic alternative to standard heating systems. If it is used correctly, advantages in terms of energy consumption can be seen, as well as in the areas of costs and the CO_2 balance.

They output 86% of their input energy, which is a much higher efficiency than conventional heating methods.

The requirement for each room will be different depending on certain variables such as room size, ceiling height, insulation, windows, etc.

Some panel systems can be implemented with smart systems in residential and commercial premises through actuators and temperature sensors, for instance wireless thermostats.

Parameters:

Power: 290 W (panel size 593x593x30 mm/room size 0-4 m²);

1.300 W (panel size 606x1506x 30mm/room size 20-25 m²)

Characterization of usage:

Life expectancy: ± 100.000 hours

Maintenance free

2.3.5 Electric floor heating

Cat.: 3.1

Description:

Electrical floor heating provides a heating system by convection and radiation. Electric floor heating is interesting only and only if small surfaced should additionally be heated and it is not cost efficient to use water based heating systems. It offers an energy saving alternative to keeping the forced air heating system running throughout the entire building and can help reduce a building overall energy consumption.

The system can be controlled using a programmable or non-programmable thermostat and is a viable alternative to water radiators. It is also an easy heating replacement during renovations.

Figure 56 Floor heating mat

Electric floor heating can be installed as the primary, whole-building heating system or as localized floor heating for thermal comfort (bathrooms). Other applications for which the systems are suited include snow/ice melting for walks, driveways and landing pads, turf conditioning of football and soccer fields and frost prevention in freezers and skating rinks.

Because of the relatively high cost of electricity and primary energy use, and the low energy efficiency of the technology, electric radiant floors are usually only cost-effective if they include a significant thermal mass such as a thick concrete floor and the electric utility company offers time-of-use rates. If green (reusable) electricity is purchased electric floor heating can be a cost efficient (total cost of ownership / life cycle costing) way to use sustainable energy. Time-of-use rates allow to "charge" the concrete floor with heat during off-peak hours. If the floor's thermal mass is large enough, the heat stored in it will keep the building comfortable for eight to ten hours without any further electrical input, particularly when daytime temperatures are significantly warmer than night time temperatures. This saves a considerable number of energy money compared to heating at peak electric rates during the day.

If rooms comply with modern insulation requirements the system can act as an effective and efficient heat source. This means less dependence on additional heat sources, as well as reduced energy costs associated with heating. However, for rooms with lower insulation levels (in older buildings), additional heat sources may still be required, especially if upgrading insulation values proves difficult.

Electric heating elements, mats or cables, can be cast in a concrete floor slab ("poured floor system" or "wet system"). They can also be placed under the floor covering ("dry system") or attached directly to a wood sub floor ("sub floor system" or "dry system"). Ceramic tile is the most common and effective floor covering for radiant floor heating, because it conducts heat well and adds thermal storage. Common floor coverings like vinyl and linoleum sheet goods, carpeting, or wood can also be used, but any covering that insulates the floor from the room will decrease the efficiency of the system.

Characterization of Usage:

Consumption ±100-150 Watt/m² per hour

Mats available in different sizes

Formats in 120 and 240 Volt

Service- and maintenance-free

Hygienic and healthier because air circulation is limited

More freedom in interior choice

Average warm-up time: 15 to 30 minutes tile-backer board, 30 minutes to 1 hour timber floors, 2 to 3 hours insulated concrete and 2 to 5 hours un-insulated concrete.

2.3.6 ClimaRed® system

Cat.: 3.1

Description:

ClimaRad is a Decentralised Heat Recovery and Heating system. It is patented and developed for domestic dwellings and can be installed in a diversity of rooms e.g. living rooms, bedrooms, studies and other domestic dwellings. But this system can also be used in public institutions -like schools and hospitals- or in commercial buildings -like hotels and offices. It fits in centralized building management systems of larger offices or public buildings.

Figure 57 Clima Red system

In contrast to central ventilation systems it is easy to install in existing buildings, because the system only requires a small air intake and exhaust opening through the façade behind the ClimaRad ®. It is also suited for use in renovations.

The required ventilation air is first preheated by the recovery heat exchanger contained in the ventilation unit and subsequently passes over the warm radiator before entering the room.

The radiator-ventilation combination is suitable for use in combination with low temperature systems (LTS). The radiators must be properly dimensioned for this purpose.

By making use of DC fans combined with a highly efficient power supply, electricity consumption is low.

The system optimizes the energy saving potential. It features a counter-current air-to-air heat recovery system extracting heat from polluted air before it leaves the room. This heat is used to preheat fresh, colder air from outside in the same heat exchanger. This system saves a considerable amount of energy, but also enhances the heating comfort avoiding cold draughts.

The system has six functions within a single system: heating, ventilation, controlling indoor air quality, filtering of outside air, local waste heat recovery (WHR) and night cooling.

ClimaRad ® has sensors for CO_2 concentrations and humidity that automatically keeps the desired level by operating the ventilation system. A passive night cooling option ensures that there is a sufficient difference between inside and outside temperatures. With the easy-to understand control panel personal preferences can be set.

Parameters

Electrical energy/power [kW]:

Power fans: ± 10 Watt in case of 40 m3 air intake/ 40 m^3 air exhaust;
± 25 Watt in case of 80 m3 air intake/ 80 m^3 air exhaust;

Standby power: ± 1,5 Watt (fans off).

Characterization of Usage

Functions

Heat recovery (ventilation air)

Ventilation can be CO_2 controlled

Heating (based on a water fed distribution system, also low temperature heating is possible)

Application

Room level

Refurbishment

New buildings

Ventilation unit

Fans : 2 x 28V DC;

Exhaust: continuously variable up to max. 125 m^3/h;

Noise level: 28 dBA at 40 m^3/h;

Electrical connection: 230 VAC/50 Hz;

Electrical connection: 45 W max.;

Heat exchanger: PP heat exchanger; efficiency > 85%

Air filters: 2 x HAF filter (3MTM) Class 6-7

Filter lifespan: The air intake filters in homes on average need to be replaced 1 x every 18 months. The air exhaust filters on average require replacement 1 x every 3 years. The exact lifespan of the air intake filters is highly dependent on the environment in which they are used, for example in the countryside as opposed to along a highway.

Adjustable air quality range: 800, 1000, 1200, 1400 and 1600 ppm CO_2 (Other values can be programmed if desired)

Type of CO_2 sensor: Non Dispersive Infrared (self-calibrating)

CO_2 sensor measurement range: 0 - 2000 ppm

Radiator

Heat output at 75/65/20: 1021 to 4712 Watt with a temperature regime of 75/65/20 according to the EN 442 standard.

2.3.7 Water heating systems

Cat.: 3.1

Description:

Water heating systems are the most popular solutions since water in an excellent energy carrier because of its physical properties. High thermal capacity, good pumping properties and availability makes these systems suitable almost in every case. There are many possibilities to realize water heating system. The most popular and also recognized in the Health Care Facilities are: wall radiators (heat transfer by convection) and floor heating, less popular because of its worse heat gradient but still common is ceiling heating and wall heating. In all surface heating systems (floor, ceiling, wall) heat is transferred by radiation.

Radiators:

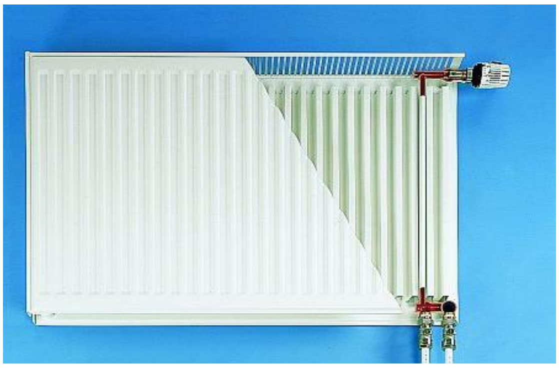

Figure 58 Radiator

Heat exchangers usually made from material, which is a good heat conductor. Radiators are installed on the walls, usually underneath the window to extend heat exchange by convection. Size of the radiator is adequate to the designed power demand of the room and energy carrier parameters (usually high). Power delivered by the singe radiator can be controlled, either by thermostatic valve mounted at the supply pipe (individual/ quantity regulation) or by the water temperature change (central/quality regulation). Price depends on manufacturer and size of the unit. Main disadvantageous is dust sintering caused by high temperature of radiator walls and difficulty with keeping radiators clean because of its ribbed build, however to meet this problem some of manufacturers have Hygiene version of plate radiator available in their offer. Another problematic issue is that patient placed near to the radiator can feel uncomfortable because of air dryness and extended air movement.

Parameters:

Water parameters: High (90/70^{o}C; 70/50^{o}C)

Low (50/35 ^{o}C)

Radiator power [kW]:

Floor heating

Figure 59 Floor heating

Is one of the most types of surface heating. Pipes are placed under the floor. Built of layers is very important and usually consist of: floor construction layer, insulation layer, damp-proof layer, screed (50-75 mm), and finishing layers. Pipes are placed between the damp-proof layer and screed. It is important to adjust the finishing layer so that it can be used with floor heating without any problems. Size of radiator is conditioned by free floor room (by free floor it is understood an area where no furniture is placed).

Floor heating has low thermal gradient what makes people feel satisfy, it is proved that floor heating is considered as the most comfortable heating system. Main disadvantageous are connected with maintenance of installation, once pipe under the floor is leaking bigger works are needed to fix the breakdown. It is important to remember that the maximum floor temperature cannot be higher than 29^oC (26^oC is optimal) in the rooms and 34^oC in the bathrooms.

Parameters:

Water parameters: Low (50/40^oC; 45/35 ^oC)

Radiator power from square meter [kW/m^2]:

2.3.8 Ultrasonic humidifier

Cat.: 3.2

Description:

An Ultrasonic humidifier is a component in the air handling unit to humidify air in an energy efficient way. The humidifier consists of a water tank with demi-water and contains a membrane or vibrating plate. By ultrasonic vibration at a frequency of 1.7 MHz, the dematerialized water is very finely atomized (1µm size) and added to the air.

Figure 60 Ultrasonic humidifier

Parameters:

Humidifier efficiency max 85%

An Ultrasonic Humidifier needs only 7% of the power required by an electrode steam humidifier

Every 8.000 hours the vibrate plate need to be replaced.

Characterization of Usage:

Hours of operation [h/year]: *5000*

Lifespan [years]: *10-20*

Annual preventive maintenance [euro/year]: *10% of initial investment costs*

2.3.9 Local heat recovery

Cat.: 3.2

Description:

An SRHR (Single Room Heat Recovery) unit is an energy efficient controlled and balanced ventilation system. It extracts continually the moist air from the room and replaces it with clean filtered, fresh, pre heated outside air. The fresh outside air passes through a heat exchanger that recovers (exchange) heat with the exhaust air flow before the air is discharged outside. This reduces the heat or cooling demand of the room.

The local unit is suitable for domestic (bathrooms, toilets, kitchens, utility rooms, bedrooms and living rooms) and commercial applications (hotels, offices and meeting rooms). In existing buildings, single room heat recovery ventilators can be quicker and less disruptive to fit than ducted whole house heat recovery systems.

It is an energy efficient alternative to extract ventilation and an effective remedy for damp problems.

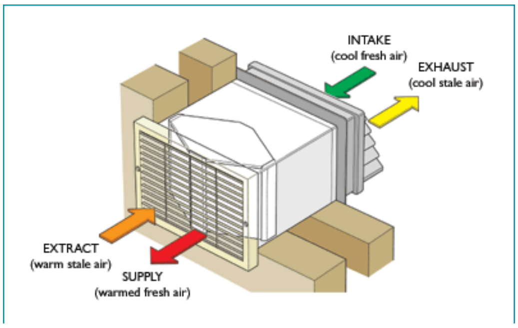

Figure 61 Local heat recovery Unit

Figure 62 Local heat recovery Unit

Figure 63 Unit

Parameters

Performance (m³/h)

Boost	± 35-80
Base load	± 5-45

Power consumption (W)

Boost	± 20-40
Base load	± 2-12

Sound (dB)

Boost	± 30-50
Base load	± 15-30

Direct current motor power: ± 25 W

A unit is capable to provide efficient ventilation of up to 60 m² area

Voltage/frequency: 110-230 V/50-60 Hz

Characterization of usage

Up to 90% heat recovery

Controls condensation and eliminates mould

Particularly good for the refurbishment sector

Maintenance: every 6 months-1 year

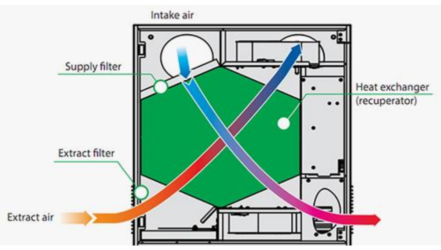

Figure 64 Local heat recovery Unit cross section

2.3.10 Split air conditioner (Single and Multi) / AC – heat pump

Cat.: 3.3

Description:

The mean function of a split air conditioning/heat pump is cooling and sometimes heating of rooms by circulating air over a cooling/heating coil. Often dehumidifying is also an important function of the systems. Split systems can be divided into two types. The difference between the types is the number of indoor units attached. The number of units inside can vary in so-called single-split and multi-split systems.

*Single-split system (*one unit outside/one unit inside)

Single split systems (not portable), usually called ductless air conditioners, consist of two components, which are separated partly outside and partly inside. There are also types available that are integrated and can be placed directly in a window: the so called window unit. These systems are commonly found in residential and small commercial installations. The most common type of indoor unit is the wall mounted type though other types like ceiling mounted and floor mounted are also used.

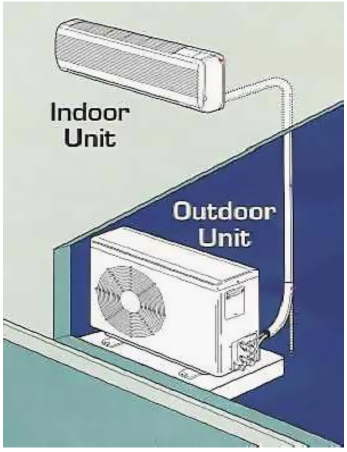

Figure 65 Single split air unit

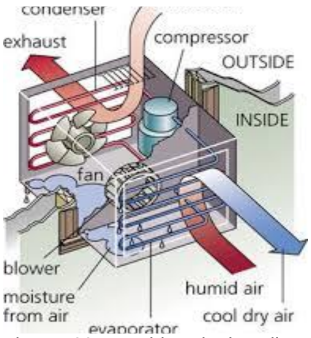

Figure 66 Monobloc single split air unit

The “hot” side, or the condensing unit -including the condensing coil, the compressor and the fan- is situated outside a room on the ground or on the roof. The “cold” side is located inside a room and consists of an expansion valve and a cold coil. The inside and outside unit are connected by a power cable, refrigerant tubing, and a condensate drain.

*Multi-split systems (*one unit outside/up to eight units inside)

The inside units can be placed in different rooms or at two different locations inside a large room. The number of inside units depends on how much heating or cooling is required for the building. The maximum number of inside units is approximately 8.


Figure 67 Outside unit/ condenser

For both the single as well as the multi split units a heat pump function can be included in the system. This makes it possible to heat the connected room(s). These so called *Air-Source Heat Pump* (ASHP) models consists of one or more factory-made assemblies which normally include an indoor conditioning coil(s), compressor(s), and outdoor coil(s), including means to provide a heating function. ASHP models provide the function of air heating with controlled temperature, and may include the functions of air-cooling, air-circulation, air-cleaning or (de)humidifying.

Figure 68 Multi split / connection to outside unit

The system can be easily switched seasonally to supply heat instead of cold.

Parameters:

Cooling capacity: ±0,15-14,0 kW

Heating capacity: ±0,15-16,5 kW

Noise: ±20-70 dB(A)

Airflow: ±250-6000m3/h

Power source: 230 V/1 phase/50 Hz

Current: ±2,0-15,0 A

Energy Efficiency Ratio EER*: ±2,5-6,0 (at 230 V)

(Seasonal) Energy Efficiency Ratio (Cooling) SEER: ±5,5-9,0

Coefficient Of Performance COP**: ±2,0-6,0 (at 230 V)

(Seasonal) Coefficient Of Performance (Heating) SCOP: ±3,0-5,5

Annual Energy Consumption (Cooling): ±100-450 kWh (at 230 V by an average of 500 hours per year)
(Heating): ±650- 2800 kWh (at 230 V by an average of 500 hours per year)

Characterization of usage

Benefits:

high energy efficiency;

no ducts only refrigerant lines, so they avoid the energy losses associated with the ductwork of central forced air systems;

in comparison to other add-on systems, they offer more interior design flexibility because of the small size;

the ductless systems are easier to install than some other types of space conditioning systems. For example, the connection between the outdoor and indoor units generally requires only a three-inch hole through a wall for the conduit. Most manufacturers provide a variety of lengths of connecting conduits, and, if necessary, the outdoor unit can locate up to 50 feet from the indoor evaporator. This makes it possible to cool rooms on the front side of a house, but locate the compressor in a more advantageous or inconspicuous place on the outside of the building.

Disadvantage: there must be a place to drain condensate water near the outdoor unit.

2.3.11 Wall mounted local air conditioning unit

Cat.: 3.3

Description:

Unitary systems, the common one room air conditioners, sit in a window or wall opening, with interior controls. Interior air is cooled as a fan blows it over the evaporator. On the exterior the air is heated as a second fan blows it over the condenser. In this process, heat is drawn from the room and discharged to the environment. A large house or building may have several such units, permitting each room to be cooled separately.

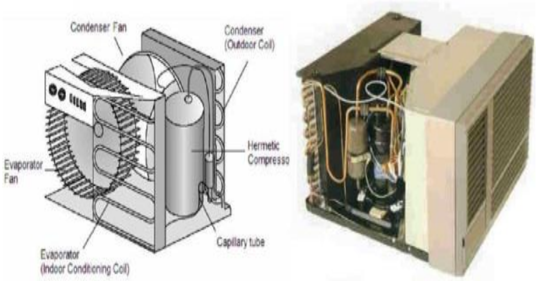

Figure 69 Wall mounted air conditioning unit cross section

Disadvantage: large hole cut into wall.

PTAC systems are single, self-contained units installed through a wall and often found in hotels. The compressor system both cools and heats. To cool, the units compressor pumps refrigerant to cool the coils which attracts heat and humidity, which is then exhausted to the outside. To heat, this functionality is reversed. The refrigerant is used to heat the coils, and when air passes over it the unit pushes the heated air into the room. PTACs are larger than a typical through-the-wall air conditioner. PTACs are often seen in the hospitality industry and are approved for commercial use, but they are also suitable for residential applications.

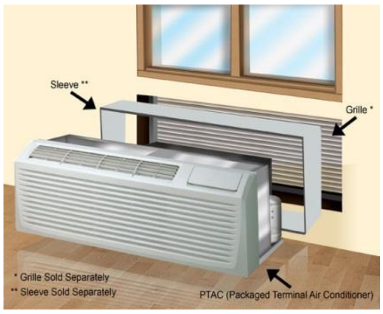

Figure 70 Wall mounted air conditioning unit cross section

Benefits: single unit, efficiently cooling and heating a room.

Disadvantage: large hole cut into wall.

An *all-in-one system* is a self-contained air conditioning solution effectively eliminating the need for pipe work and external condensers.

Benefits: ideal solution in circumstances where it is necessary to maintain a building's external aesthetics, since the grilles are discreet in appearance by comparison to standard fixed air conditioning systems (Unitary and PTAC).

Figure 71 Wall mounted air conditioning unit

In keeping with the décor and design of a given room, the system may be installed at any height. Though at default it is ready for low level mounting, it can be modified for high level mounting simply by reversing the casing in order to accommodate the change in airflow.

Figure 72 Outside surface

Parameters:

Capacities:

Cooling	± 0.6-20 kW
Outdoor Design Temperature ºC DB/WB	35/25
SEER*	up to 27
EER*	up to 15

* (Seasonal) Energy Efficiency Ratio (the higher the SEER rating, the more energy efficient is the air conditioner)

Voltage/Frequency/Phase	115-265/50-60/1
Room Sizing Guide	10-15 m² (20 kW)/175-250 m² (25 kW)
Noise level	Indoor unit ± 20-50 dB(A), Outdoor Unit ± 45-55 dB(A)
Recommended Fuse Size	± 6-30 A
Running Current Clg (Rated/Max)	± 7.7/9.0-17.3

Characterization of usage:

Applications: room additions/renovations, at home (bed and family rooms, wine cellars etc.), commercial (hotels, restaurants, computer rooms, offices etc.).

Efficiency: high for low operating cost, ability to set the temperature to preferred comfort level, ability to turn off units in unoccupied rooms.

Annual Power Consumption (kWh): ± 385-1500

2.3.12 Cooling ceiling panels

Cat.: 3.3

Description:

Cooling ceiling panels are considered as a efficient, cost effective solution. According to ASHRAE main advantages of this system are [30] :

- Improved comfort lever in reference to other conditioning systems because of keeping air motion at normal ventilation level,
- Supply air quantities do not exceed required volumes for hygienic reasons,
- Wet surface cooling coils are eliminated what reduces the potential of septic contamination,
- The panel system can use the automatic sprinkler system,
- They are compact so that can be easily used in retrofitted buildings where ceilings are low,
- Quick accommodation of dynamics, time constant for panels is 3 minutes

Figure 73 Radiant ceiling panel s installation

Figure 74 Radiant ceiling panel element

CRCP Heat Transfer Characteristics

Mean panel temperature °F (°C)	Room temperature/AUST °F (°C)	$q_{radiation}$ Btu/h·ft² (W/m²)	$q_{convection}$ Btu/h·ft² (W/m²)	q_{total} Btu/h·ft² (W/m²)	U, overall HT coeff, Btu/h·ft²·°F (W/m²·°C)
50 (10)	72 (22)	19 (60)	18 (57)	37 (117)	1.66 (9.43)
55 (13)	72 (22)	15 (47)	13 (41)	28 (88)	1.61 (9.14)
60 (16)	72 (22)	11 (35)	8 (25)	19 (60)	1.54 (8.75)
65 (18)	72 (22)	6 (19)	4 (13)	10 (32)	1.45 (8.23)
50 (10)	78 (26)	24 (76)	24 (76)	48 (151)	1.73 (9.82)
55 (13)	78 (26)	20 (63)	19 (60)	39 (123)	1.7 (9.65)
60 (16)	78 (26)	16 (51)	14 (44)	30 (95)	1.65 (9.37)
65 (18)	78 (26)	12 (38)	9 (28)	21 (66)	1.59 (9.03)

Parameters:

Chilled water temperature: 7/13°C

[30]Ch.L.Conroy, A.Mumma ; *Ceiling radiant cooling panels as a Viable distributed parallel sensible technology integrated with dedicated outdoor system* ; http://doas-radiant.psu.edu/7-5.pdf

2.3.13 Fan coil

Cat.: 3.3

Description:

Fan coils are used to control air temperature in the room and usually do not deliver fresh air, being a part of the air-conditioning system. These simple devices usually are not connected to the ducts and work only with indoor air. Although some manufacturers offer fan-coils with possibility to supply fresh air by connecting them to the ventilation ducts.

Energy carrier medium is usually chilled or hot water or refrigerant circulated in a closed circle. If fan coil works with cold water it is better to design central system with one bigger chiller. Water parameters are usually 7/12^{o}C.

Fan coil can be exposed in the room what refers to units which are wall mounted, ceiling mounted or freestanding. A concealed fan coil unit is usually installed within a suspended ceiling.

Figure 75 Casette Fan coil

Device can cool the air by driving it thought water/refrigerant -air heat exchanger. Hot air from the room is circulated thought the unit and heat from the indoor air is transfer to the chilled water. If water in the heat exchanger is hotter than indoor air fan coil can work as a heater.

Parameters:

Power input [W]: according to required room loads

Cooling capacity [kW]: according to required room loads

Heating capacity: according to required room loads

Sound level [dBA] : according to requirements stated for the room

Characterization of usage:

Hours of operation [h/day]: according to scheduled occupancy and room function

Costs of maintenance [euro/year]: according to service price

http://www.climatherm.ro/produse/EEDEN08-424_Fancoils_tcm135-98820.pdf

2.3.14 Chilled Beam

Cat.: 3.2/3.3

Description:

Chilled beems are colloing or heating units designed for large buildings being a part of HVAC system. They consists of pipes with water which are passed through a heat exchanger (beam shape) integrated in the suspended celing. Big advantagous of chilled beams is that they do not need mechanical power to circulate the air, that is why the are considered as an energy efficient soultion. Air around the beam when chilled, become denser and falls down towards the floor, warmer air is moving up and replacing it, this causes constant convective flow and air in the room is cooled. Chilled beams find usefull expecial when heat gains are surpassing the amount of hygienical ventilation air what makes them siutable for hospitals and laboratories.

Figure 76 Chilled beam

There are two types of chilling beams :

Passive: uses natural convection coused by air density change, no mechanical fans are used. Units are mounted in the suspended ceiling and are not connected to the fresh air supplying ducts.

Active: are connected to ventilation air. They uses the induction to supply the fresh air to the room by so called induction nozzles which ceate pressure difference across a cooling coil. Fresh air mixes with air recirculated from the room .

Energy usage can be reduced from 20% to 50% depending on the building and climate. Energy savings are caused by eliminating energy usage by fans and enabling the system to work with water of higher parameters what influences rising of chilling system effectiveness.

Parameters

Cooling power: according to required room loads

Heating power: according to required room loads

Fresh air supply: according to requirements stated for the room

Characterization of usage:

Maintenance costs [euro/year]: according to conservation

2.4 Energy storage technologies

2.4.1 Local buffer tank for DHW

Cat.: 1.1

Description:

Buffer tank can be a part of domestic hot water installation, cooling installation and low temperature heating installation. Buffer tanks for DHW are designed in solar insulations, heat pump installation and sometimes in traditional systems. Their main role is adding thermal mass to the system. Buffer tanks enable to cover higher water demand or water demand pick, which can appear during the day. When installed into solar or heat pump system they also equipped with electrical heater in case energy delivered from the source will be not enough to heat up the water to 55^{o}C. It is also important for DHW system to keep required hygienically parameters to prevent Legionella growth that is why from time to time water in the tank has to be overheated to 60^{o}C-70^{o}C. In conventional systems working with non-renewable energy sources or being a part of the district heating substations buffer tanks are loaded in the night and discharged during the day to minimize pumping costs. Buffer tanks have to be well insulated to minimize heat loss through the envelope. They are usually located in the technical room.

Figure 77 Buffer Tank

Buffer tank for DHW has to be attested and designed for water supply. Tanks dedicated for closed cycles such as central heating system should not be used in domestic hot water installation.

Parameters:

Storage capacity: 25 - 2000 dm3

Electrical heater power [kW]: according to designed/ installed device data

Unitary linear heat loss through storage tank envelope [W/m2]: according to designed/ installed device technical data or national standards for building certification

Efficiency [-] : according to producer technical data or year of production (from1970`s – 0,30-0,59 ; from 1977÷1995 - 0,55-0,69; from 1995÷2000 - 0,60-0,74; in low energy standard – 0,83-0,86) /*according to polish national building certification standard, this values are recommended if there is no other information available*/

Characterization of Usage:

Average loading time [h]: according to system working schedule

Number of loading cycles [cycle/day]: according to system working schedule

Lifespan [years]: 20

2.4.2 Batteries

Cat.: 2.1

Description:

A UPS unit is an electronic device to provide short-term power supply to electrical equipment that must ensure a constant power supply, despite black-outs or power losses. Its installation is primary, for example, in hospitals and data centers.

Different types of UPS are available:

- off-line/standby: it's inexpensive and it is recommended for computers and small devices; usually it lasts 10 minutes so it should not be used if the system has several black-outs or power disturbance. In normal condition the AC input power goes directly to the output passing through the filter, where it is standardized. Part of the power is also diverted to the battery charge. When needed, in case of black-out, the battery feeds the inverter and in a few second the system receives the power.
- on-line/double conversion: it's more expensive and a higher energy consumption then the previous one, it is used it those systems that need to be energetically independent from the electrical grid ; In the event of a blackout, there is no transfer time or break in power supply. In this system the charger feed constantly the battery and, different from the off-line UPS, also the inverter, that is always working.
- line interactive: it is a combination of the previous systems; between the filter and the load a regulator is add in order to boost the mains power supply when it falls, so the power can be leveled without the participation of the battery. This device uses the battery only if a total black-out occurs, in other cases the regulator helps in high and low input voltage conditions. Other designs are available, such as hybrid or DC power but the ones described before are the most widespread and used.

For what concern the battery, its lifetime depends on the size and the type of the battery itself, but also on the efficiency of the inverter it's connected to. The capacity of the battery can be anyway be approximate with the Peukert's law; this measure can be useful to estimate the number and dimensions of the batteries.

Parameters:

Maximum power [W]: *according to designed/ installed device*

Characterization of Usage:

Average working time [h/year]: s*ite specific, depending on the reliability of the local power grid*
Lifespan [years]: *variable*
Annual preventive maintenance [euro/year]: *normally included in the plant management O&M contract*

2.4.3 Small Aquifer Thermal Energy Storage and Borehole Thermal Energy Storage ATES/BTES

Cat.: 3.1

Description:

An ATES (aquifer thermal energy storage) stores energy at low temperatures is an aquifer, a water-containing sand layer. An ATES store is composed of a double, totaling two or more wells into a deep aquifer. One half of the doublet is for water extraction and the other half for reinjection, so the aquifer is kept in hydrological balance, with no net extraction.

In the summer season the cold well is used to cool the hospital building and thus providing heat for the warm well. In the winter season heat is provided from the warm well and is upgraded by means of a heat pump and provides cold for the cold well.

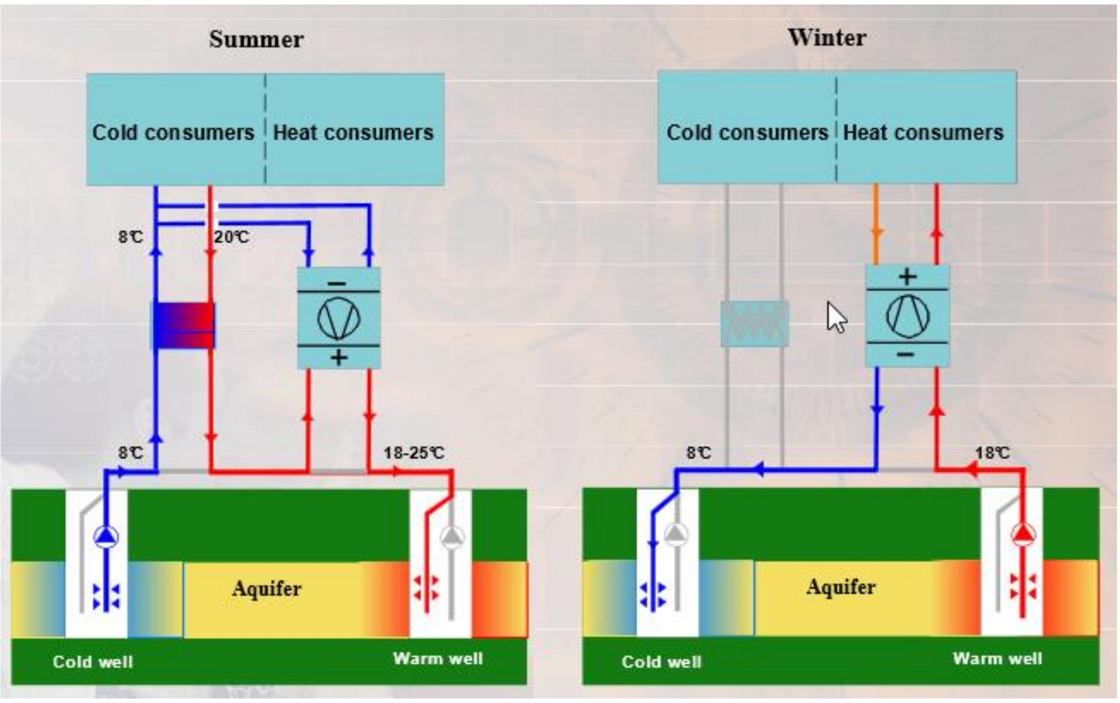

Figure 78 Aquifer thermal energy storage

Typical temperature range: cold well: 5-10°C, warm well: 15-25°C.

ATES is usually applied for large scale systems (mostly large utility buildings and hospitals), due to the relatively high investment cost for the system. It is not suitable for inter-building scale heat storage.

BTES

For small scale heat and cold storage a BTES is more applicable. BTES stand for Borehole thermal energy storage. It is suitable for medium to large applications (over 700 GJ/year) with a temperature range of 0-25 C and low groundwater flow.

In the case of Borehole Thermal Energy Storage (BTES) heat and/or cold are stored in the underground using a borehole heat exchanger (BHE), which consists of a number of plastic U-loops installed in boreholes. The distance between the boreholes is 2 to 3 meters. In the case of heat storage the flow of the heat transport fluid in summer is from the centre to the edge of the storage. In this way the heat is transferred by heat conduction to the surrounding soil. During winter the flow direction is reversed and runs the fluid through the loops from the edge to the centre of the storage. In this way the heat from the surrounding soil is transferred again to the fluid.

Of the main current applications is the storage of solar heat in summer at a relatively high temperature level, up to 80 to 90°C, for direct use of solar heat for space heating during the winter. For this application, a separate heat insulating layer is installed on top of the storage, to reduce heat losses of heat to the atmosphere. Another important application is the combination of storage of both cold and low temperature heat for cooling and heating of buildings. With this application the stored cold is used as much as possible directly, without applying a heat pump.
It is for example applied for heating and cooling of the new hospital in Mollet del Vallès (near Barcelona) uses heat pumps and ground heat exchanger for cold / heat storage in the soil.

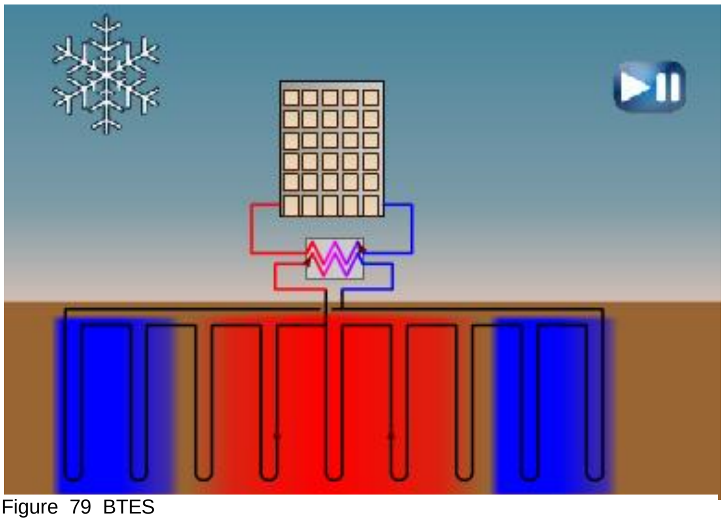

Figure 79 BTES

Parameters:

Power [kW]: *according to designed/ installed device*

COP [-]: *2-5*

Characterization of Usage:

Hours of operation [h/year]: *5000-7000*

Lifespan [years]: 30-*50*

Annual preventive maintenance [euro/year]: *2% of initial investment costs*

2.4.4 Cold storage with ice/local storage

Cat.: 3.3

Description:

Description:

Storage of cold in ice (phase change material) can help to stabilize the load of the chiller systems, as it serves as a buffer to handle peak demands of the cooling system. Besides this it can also help to shift the electricity load from peak hours to off-peak hours. During the night a chiller runs to produce the ice pile. During the day, water circulates through the ice to produce chilled water. On a hot summer day the cooling capacity can be increased just by increasing the flow rate of water through the ice pile.

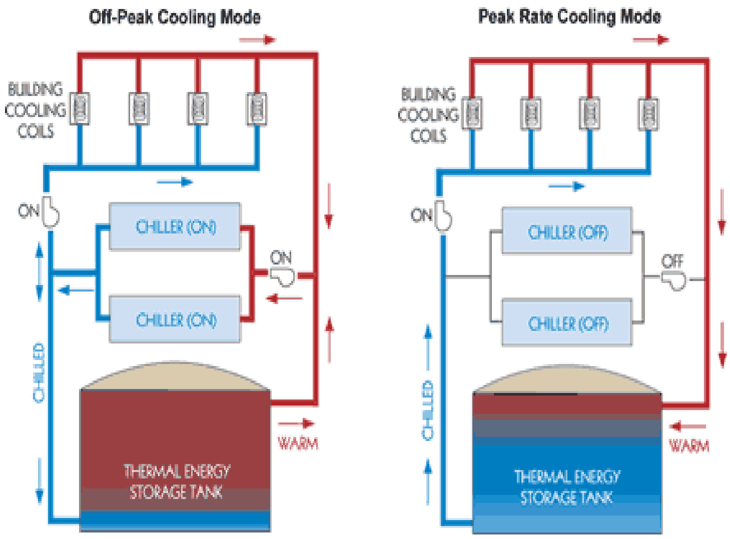

Figure 80 Cold storage for peak shaving

It is also possible to have a partial storage system, in which the chillers run almost continuous; during night time and in the colder hours of the day the chillers produce ice for the buffer. During the very warm hours of the day the chillers can produce extra chilled water for the air conditioning system.

Ice storage systems are applied in hospitals as well. References can be found at for example: www.calmac.com or other suppliers.

Parameters:

Storage capacity [ton cooling load or kWh]: according to the system design

System efficiency [%]: according to designed/installed device

System volume [m³]: according to designed/installed device

Characterization of Usage:

Hours of operation [h/year]: 2000-*5000*[31]

Lifespan [years]: *20-30 years*[32]

[31] Greatly depending on the climate (Nord or south Europe)

[32] www.calmac.com/benefits/general.pdf

2.5 Supporting technologies

2.5.1 Chemical disinfection of domestic hot water

Cat.: 1.1

Description:

One of the significant problems recognized in big water storage installations such as those present in hospitals is water contamination by bacteria called *Legionella.* This bacteria is responsible for pneumonia and other lungs diseases. *Legionnella* colonize in hot water tanks and in the whole hot water distribution system. In hospitals it is necessary to control water purity that is why distribution system should be under constant measurement control. There are few methods which enable to prevent water from the contamination, first is to overheat the water in the storage tank above 60°C because in this temperature *Legionella* colonies are successfully destroyed. Second method, less energy requiring, is water chlorination. Water chlorination is a chemical process used for antibacterial protection and is realized by adding chlorine to the water. Chlorine is an oxidizing agent what makes it a good disinfectant for pathogens elimination. Concentration of 0,4mg/L can inactivate *Legionella* in 15 minutes[33] but regarding the fact chlorine can easily kill the bacteria in the storage tank it can be difficult to disinfect *Legionella* colonized on the surface of the pipelines because they seems to be more resistant. Another problem is that bacteria may become resistant for current chlorine concentration.

Figure 81 Water chlorination plant

This chemical method of water disinfection is widely used and harmless for health but according to Chlorine chemical properties chlorination can be a reason of faster pipe corrosion. Although this can be solved by chemical coating for hot water pipelines with a sodium silicate precipitate, providing anticorrosion protection.

[33] You-Sen E.Lin"Disinfication of Water Distribution Systems for Legionella "http://www.legionella.org/disinfectreview.pdf

2.5.2 Emergency Power System

Cat.: 4

Description:

An uninterruptable power supply is crucial for running a hospital. To guarantee power supply upon failure or outage of the normal supply system an emergency power system (EPS) is required. This EPS should (automatically or with manual switches) provide electric power to critical users in the hospital within a certain specified time. In the design of the electrical system the critical users should be tagged as such, as non-critical users may or will not have electrical power during an outage.

Figure 82 Diesel generator, source:

Some hospitals have two independent connections to the main electricity grid, to reduce the chance of a power outage, but in case of a very large power outage both connections might fail. Therefore, an EPS is required.

For the design of the EPS system it is important to define if a short stop in power supply of half a minute or a minute, a so called ‘short-break’, is acceptable. This is the time required to start generators for the backup power. In case power supply to the critical users in the hospital should be uninterrupted it is called a no-break system. In addition to the EPS a UPS is required to bridge the time between the power outage and the time required to provide electricity with the generators.

States of the Art EPS techniques are:

- Generators (motor or turbine driven)
- CHP
- UPS (battery or flywheel)

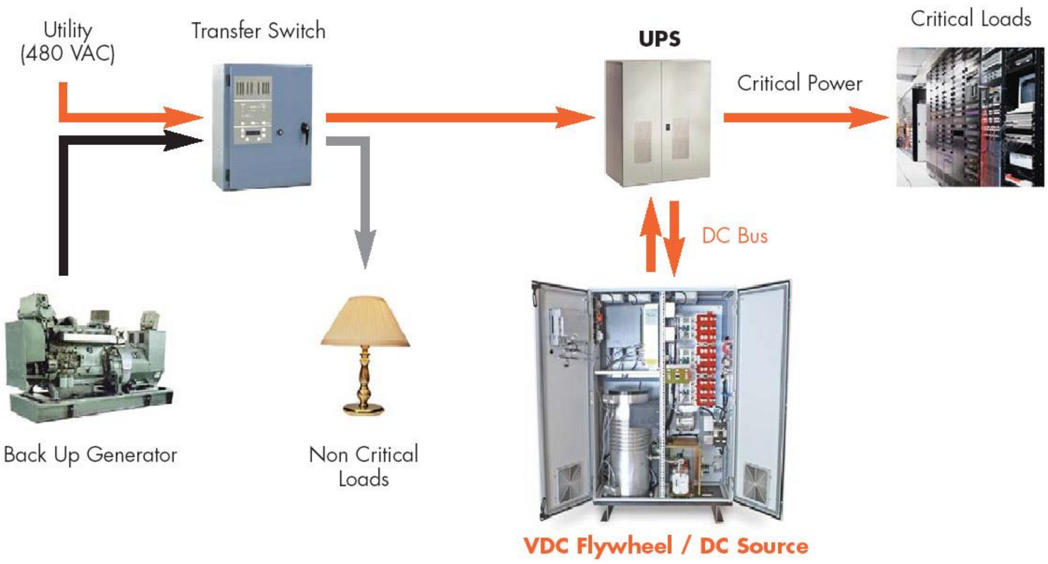

Figure 83 Schematic diagram of EPS

Generators are applied as EPS. Generators can be motor or turbine driven. Motor driven generators are usually applied because of the lower capital cost. Motors can run on diesel, gasoline, natural gas or dual fuel (e.g. diesel and natural gas).

A CHP can be used as EPS-generator as well. In that case the CHP will provide (part of the) heat and power in a normal situation. In case of a power outage of the grid the CHP will be used (without interruption) to supply electricity to the critical users. In that case the CHP should preferably be a dual-fuel system on natural gas and diesel. The natural gas for economic- and environmental reasons, the diesel as pilot fuel and backup in case of a natural gas grid failure.

Figure 84 Dual fuel CHP as EPS

The primary role of any UPS is to provide short-term power when the input power source fails. UPS is not an EPS, as it cannot provide power for a longer period, but an addition to an EPS to bridge the time between power outage and take-over of power generation by the backup generators.

Types of UPS for large scale systems are Flywheel and battery system. A flywheel is a rotating mechanical device that is used to store rotational energy. Flywheels have a high mass and rotate at very high speeds (up to 50.000 rpm) with a very low friction. In case the energy is needed it is converted by applying torque to a mechanical load.

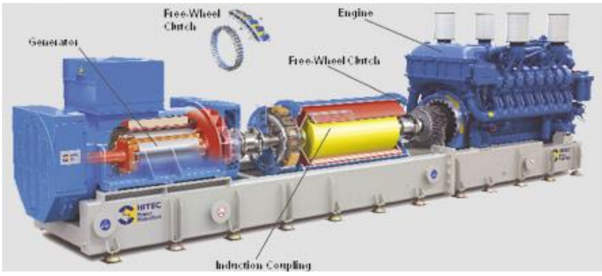

Figure 85 Rotating UPS

Battery-type UPS usually have two function, control the power quality and provide backup. The sizes range from very small units for a single computer to very large sizes for data centers.

Figure 86 Data center UPS battery

2.5.3 DC grid

Cat.: 4

Description:

In the past the AC-grid was chosen as the way to supply electricity. In the current perspective DC offers a number of advantages over AC such as improved safety, more efficient and more reliable power supply.

A DC grid (e.g. 36V)) can potentially offer energy saving for a hospital as the energy losses in cables can be minimized. When electricity is generated by for example PV the conversion of DC-solar energy to an AC-grid with the accompanying energy losses is avoided as well. Besides the lower energy losses also less raw material and thus less primary energy for e.g. converters is required.

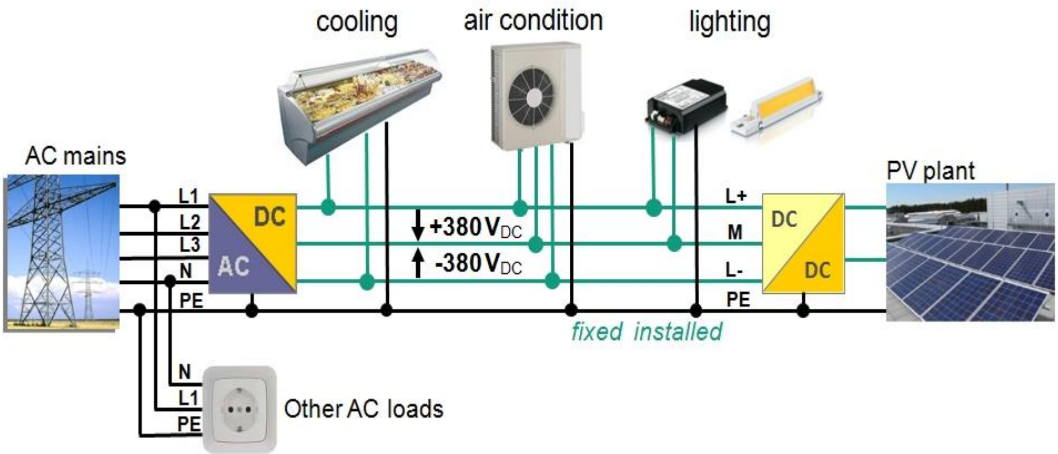

Figure 87 DC grid

Supplying all the electricity for a hospital as DC is at this moment not relevant, as AC power is still required c.q. used. Having a separate DC-grid next to the AC grid or a combined grid makes more sense. In this case the numerous small appliances that indirectly use DC (by converting AC with an integrated converter to DC) will have a higher efficiency by eliminating the conversion losses. Also DC-motors for elevators, HVAC systems and LED lights can directly be connected to the DC-grid. The energy saving that can be realized by avoiding the conversion is practically limited to less than 1 percent. At this moment a DC-grid is thus considered to be State-of-the-Art.

In remote locations, or locations where the normal power supply is unreliable, it makes sense to have a PV- powered DC-grid with DC-battery storage, although the devices using DC are currently more expensive than the devices using AC.

One important remark is that using DC-motors, even connected to an AC-grid, will have much higher energy savings.

2.5.4 Smart grid

Cat.: 4

Description:

A Smart Grid is an evolution of the existing electricity grid with added monitoring, analysis, control and communication capability to maximize the efficiency of the electricity system. The Smart Grid will allow

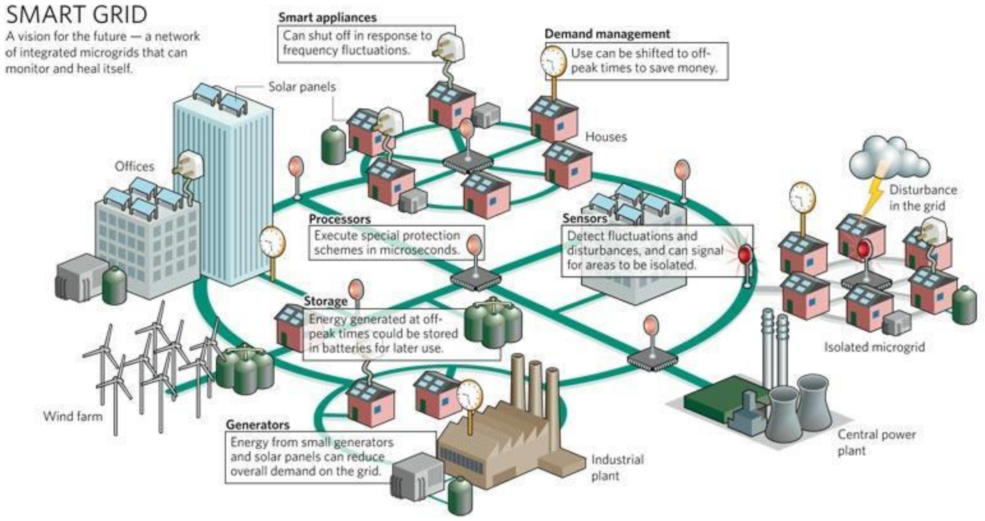

Figure 88 Smart grid

the generation, transmission and distribution of electricity around the system as efficiently as possible. It will also empower the hospital use electricity as economically as possible. The “Smart” bit of the system provides choice and flexibility to manage electrical use while minimizing costs. A Smart Grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies.

A smart grid has a strong link with BMS and advanced BMS/BEMS as all strive to optimize energy while maintaining the required settings. The added value of a smart grid is its possibility to balance supply and demand of energy; when energy supply is limited it can postpone the energy demand of not time-critical activities as dish washing, buffer heating and so on. Contrary, when there is plenty of energy available, for example due to a strong wind, generating more sustainable energy at that moment, those users can use the energy efficient by converting it to heat or other means.

References: http://www.smartgrids.eu & http://www.seai.ie/Renewables/Smart_Grids/What_is_a_Smart_Grid

Content of Figures (Appendix 1)

APPENDIX 2 - Formulas

Formulas describing values mentioned in the text

Coefficient Of Performance, COP – value used for temporary rating of heat pump performance for given operation temperature. Describe by ration of heat energy produced in the condenser to energy (electrical power) delivered to the compressor. This is dimensionless unit.

$$COP = \frac{energy\ generated\ in\ the\ condenser}{energy\ delivered\ to\ the\ compresor}\ [-]$$

Seasonal Performance Factor, SPF – tells about whole heat pump system efficiency during the operational season in real conditions. It gives an information about how much heat was delivered to the heating system/ DHW during the calculation period (year, month, heating season) and how much electrical energy was use for the whole processes (heat pump compressor, pumps, electrical heater, etc.). In Germany and Austria JAZ (germ. Jahresarbeitszahl).

Efficiency, η – within this document efficiency is understood as energy produced by the unit (energy output) to the energy supplied to the unit. This is dimensionless unit or can be referred in percentage.

$$\eta = \frac{enegy\ outputenegy\ input}{} \cdot 100\ [\%]$$

Energy Efficiency Ratio, EER - Rrefers to the air-conditioning cooling performance at a single point. The higher the EER value, the better the air-conditioning efficiency. The units are W/W or kW/h/W.

$$EER = \frac{Cooling\ capacity}{cooling\ power\ consumption}$$

Seasonal Energy Efficiency Ratio, SEER – used for estimation of the seasonal performance of chillers and air conditioners. This is dimensionless unit.

$$ESEER = EER_{100\%} \cdot 0{,}03 + EER_{75\%} \cdot 0{,}33 + EER_{50\%} \cdot 0{,}41 + EER_{25\%} \cdot 0{,}23$$