neZEH
NEARLY ZERO ENERGY HOTELS

Assessment of the state of the art of existing technologies to support nZEB renovations

WP2 Experience and viability of nZE refurbishment projects, D2.4c

Issued by REHVA, Created 15-Sep-13, Last update 10-Dec-13

www.nezeh.eu

Co-funded by the Intelligent Energy Europe
Programme of the European Union

Contract N°: IEE/12/829/SI2.644758

THE EU INITIATIVE NEARLY ZERO ENERGY HOTELS (neZEH)

neZEH's scope is to accelerate the rate of refurbishment of existing hotels into Nearly Zero Energy Buildings (nZEB), providing neZEH's scope is to accelerate the rate of refurbishment of existing hotels into Nearly Zero Energy Buildings (nZEB), providing technical advice to hoteliers for nZEB renovations, demonstrating the sustainability of such projects, challenging further large scale renovations through capacity building activities, showcasing best practices and promoting the front runners. The project covers seven (7) EU countries: Greece, Spain, Italy, Sweden, Romania, Croatia, France and has a wide EU level impact.

The expected results are:

- An integrated set of decision support tools to assist hoteliers in identifying appropriate solutions and designing feasible and sustainable nZEB projects;
- A dynamic communication channel between the building sector and the hotels industry, which will enable the exchanging between demand and supply side and the endorsement of the nZEB concept;
- Demonstration pilot projects in 7 countries to act as "living" examples; aiming to increase the rate of nZE renovation projects in the participating countries
- Practical training, informational materials and capacity building activities to support nationally the implementation and uptake of nZEB projects;
- Integrated communication campaigns to increase awareness for the nZEB benefits, to promote front runners and to foster replication; challenging much more SMEs to invest in refurbishment projects in order to achieve nZE levels.

In the long term, the project will assist the European hospitality sector to reduce operational costs, to improve their image and products and thus to enhance their competiveness; contributing in parallel to the EU efforts for the reduction of GHGs.

neZEH started at May 2013 and will end at April 2016 and is co-financed by the Intelligent Energy - Europe (IEE) programme.

PROJECT PARTNERS

Technical University of Crete, Renewable and Sustainable Energy Systems Lab (ENV/TUC) *Project Coordinator*	Greece
United Nations World Tourism Organization (UNWTO)	EU/Int.
Network of European Regions for a Sustainable and Competitive Tourism (NECSTouR)	EU
Federation of European Heating, Ventilation and Air-conditioning Associations (REHVA)	EU
Agency of Braşov for Energy Management and Environment Protection (ABMEE)	Romania
Creara Consultores S.L. (CREARA)	Spain
ENERGIES 2050 (ENERGIES 2050)	France
Energy Institute Hrvoje Požar (EIHP)	Croatia
Istituto Superiore sui Sistemi Territoriali per l'Innovazione (SITI)	Italy
Sustainable Innovation (SUST)	Sweden

PROJECT COORDINATOR

Associate Professor Theocharis Tsoutsos, Renewable and Sustainable Energy Systems Lab.
School of Environmental Engineering, TECHNICAL UNIVERSITY OF CRETE (ENV/TUC)

WP2 LEADER

Federation of European Heating, Ventilation and Air-conditioning Associations (REHVA)

DELIVERABLE EDITOR

Federation of European Heating, Ventilation and Air-conditioning Associations (REHVA)
Work Team: Zoltan Magyar (REHVA) Anita Derjanecz (REHVA), Andrei Lițiu (REHVA)

www.nezeh.eu

LEGAL NOTICE

CONTENTS

Introduction 5

1. Existing nZEB technologies 7

1.1 Windows changing 7

1.2 Inflector windows insulation 8

1.3 Building insulation 8

1.4 Building envelope air tightness 9

1.5 Prevention of high unnecessary air change rate 9

1.6 Installation of sun shading devices 9

1.7 Exterior works to improve summer comfort 10

1.8 Energy saving light bulbs (CFL, LED) 11

1.9 Energy efficiency rating of electrical appliances 12

1.10 Energy efficient motors in HVAC applications 12

1.11 High efficiency boilers 13

1.12 Efficient solutions for active space cooling 13

1.13 Micro CHP 15

1.14 Efficient ventilation systems, min. 70% efficiency heat recovery 16

1.15 Key card systems to switch off electricity in guest rooms 18

1.16 Lighting controls 18

1.17 Thermal insulation of boilers, DHW tanks and water pipes 18

1.18 Balancing of heating, cooling and air conditioning systems 19

1.19 Regulation of space heating and cooling 19

1.20 Free cooling 20

1.21 Utilization of the waste heat of chillers 20

1.22 Hybrid ventilation system 21
1.23 Low temperature heating (including acceptable heating energy generation) 22
1.24 High temperature cooling 22
1.25 Geothermal energy (heat pump) 23
1.26 Aerothermal energy (heat pump) 24
1.27 Hidrothermal energy (heat pump) 25
1.28 Solar powered absorption chiller 25
1.29 Micro hydropower 26
1.30 Wind energy (small scale wind turbines) 26
1.31 Biomass boiler 27
1.32 Solar thermal 28
1.33 Solar thermal for swimming pool 29
1.34 Photovoltaic panel 30
References: 32

Introduction

The aim of the recent report on the state of the art nZEB technologies was to define and assess the state of the art existing nZEB technologies and elaborate an overview for hotel owners with recommendations on advantages and disadvantages of the technologies and provide some advice on how to choose the most appropriate technologies. Of course these suggestions are general advices only, for a proper decision about energy refurbishment of a building it is necessary to consult with a specialised engineer who can provide adequate, tailor made help.

According to the EPBD recast[1] nZEB means a building that has a very high energy performance and the required energy should be covered from renewable energy. We can define as "nZEB technology" or packages of technologies all technical equipment (e.g. HVAC solutions, RES technologies) and interventions (e.g. thermal insulation of the building envelope) in a building, which improve the energy performance in order to fulfil the national nZEB requirements. Main nZEB technologies are the following: changing or improving the windows, install sun shading, insulation and increasing the air-tightness of the building envelop, using energy saving light bulbs, installation of PV panels, application of energy efficient motors, electrical appliances, efficient heating (boiler, micro CHP, heat pump, geothermal), cooling, ventilating and air conditioning solutions.

Beside the above technologies, there are several "soft" measures available, which can help to significantly reduce the energy consumption of a hotel with law or no investment costs. Theas measures (e.g. continuous monitoring, energy audit, staff training, and guest information) can't be considered as nZEB technologies, but because of their importance in terms of relative law-cost measures with high potential energy saving, we give a short overview about them below before providing an overview about the nZEB technologies in the next chapter.

The **continuous energy consumption monitoring** is a very effective way to reduce the energy consumption. Typical energy saving with this solution is 8-10% (HES report), but it can be much more, depend on how many energy consumer systems are monitored, what is the time-interval of the measuring, and what are the possibilities for regulating the energy consumption. The energy saving can be even 30% (e.g. iSERV project[2], Mckenzie House). Typically the size of the investment is low, because the sub meters usually are not expensive, the potential energy saving classified also low, but according to the above mentioned, it can be even high as well. Energy consumption monitoring is recommended to implement in whatever climate zone and hotel standard, because practically it is independent from them. In the high standard hotels the energy monitoring is classified as highly recommended, due to these hotels' larger energy demands.

---

[1] The **Energy Performance of Buildings Directive** 2010/31/EU (EPBD) is the main legislative instrument to reduce the energy consumption of buildings. Under this Directive, Member States must establish and apply minimum energy performance requirements for new and existing buildings, ensure the certification of building energy performance and require the regular inspection of boilers and air conditioning systems in buildings. Moreover, the Directive requires Member States to ensure that by 2021 all new buildings are so-called 'nearly zero-energy buildings' . Source: DG Energy, http://ec.europa.eu/energy/efficiency/buildings/buildings_en.htm

[2] http://www.iservcmb.info/, case study about the Mckenzie House: http://www.iservcmb.info/McKenzie

The **energy audit**, made by an energy expert, identifies the energy production,- and consumer systems, and gives quantitative information about the energy consumption of heating, cooling, ventilation and domestic hot water supply system. Moreover, the energy audit identifies short and long-term energy saving solutions taking into consideration the initial situation of the building, the financial investment, the local factors such as energy price, and climate, therefore it is highly recommended to perform the energy audit in whatever climate zone and hotel standard.

The financial investment necessary for an energy audit can be classified as medium, because usually it is only a few percent of the annual energy cost, but the potential energy saving even in a relatively modern hotel can be high. Bringing the **EU Ecolabel**[3] to accommodations strongly contributes to preserving the resources tourism itself benefits from such as clean water and the environment. It helps tourist accommodations and camp sites to optimize the processes like energy, water and waste management, resulting in lower costs and higher quality. The Eco-label concerns not only the energy systems, but other areas.

neZEH project focuses on the nearly zero energy consumption of hotels. A detailed energy audit, made by an expert, contains deeper information on the energy saving solutions than EU ECO label energy analysis, although EU Eco-label for Tourist accommodation services can be a good way to support the hotels in reducing energy consumption, and becoming environmentally friendly. The EU Eco-label is classified as 'recommended' in every climate zones. In the hotel standards ranking, the EU Eco-label is considered as 'recommended' in the low and medium quality hotels, and "highly recommended' in the high standard hotels (more energy consumers more potential, prestige of the Eco-label, etc.)

Providing **information and training to the staff** to ensure application of environmental measures and encourage environmentally friendly behaviour is a mandatory criterion of the EU eco-label. Involving staff in the energy action plan is necessary for the energy efficiency to be successful, because a lot of actions they should take to support the efforts for achieve the nearly zero energy consumption of the hotel. The financial need is classified 'low', because the training is cheap, the potential energy saving classified also 'low', but it can be higher as well. Staff training is highly recommended to implement in whatever climate zone and hotel standard to achieve the nZEB level.

Providing **information to guests** on the hotel's environmental policy, on the actions taken and on the way the guests can support the environmental objectives is a mandatory criterion of the EU Eco-label. Involving the guests is essential for the energy efficiency to be successful, because with simple actions they can help a lot to reduce the energy waste. The financial need is classified 'low', because providing information is cheap, the potential energy saving classified also 'low', because it is difficult to quantitatively evaluate the energy reduction that one will get from guest involvement. Nonetheless, information provided to guests is highly recommended to implement in whatever climate zone and hotel standard to achieve the nZEB level.

[3] Further information: http://www.traintoecolabel.org/r/en/accomodation

1. Existing nZEB technologies

1.1 Windows changing

Windows have very high impact on the heating and the cooling demand of the hotel buildings, therefore the energy saving potential of windows changing or modernizing is significant. The prices vary from one country to another, but it is sure that the financial investment size of the windows changing is high, so it has to be part of a long-term energy efficiency measurement. However, the potential energy saving is high, when the building has old windows with high heat transfer coefficient values (>2.5 W/m^{2}K).

Windows changing is highly recommended in any type of the hotels, or climate zones, except Zone I, where the windows insulation is classified as 'feasible'. The reason is in Zone I, the heating degree day is much lower, therefore the heating demand and the heating energy consumption are also lower.

The effect of windows changing mainly depends on the glazing. The climatic conditions of the hotel's location, and the orientation of the facades affect the choice of the glazing from energy point of view.

The lower heat transfer coefficient ensures the significant reducing of the heating energy consumption. Concerning the state of the art solutions, the heat transfer coefficient of a three-layer glaze can be even U_g = 0,4 W/m^{2}K, with g=62% (Internorm).

The potential energy saving depends on the heat transfer coefficients of the existing and the new windows, and the rate of the windows on the building envelope. The thermal energy saving can be even 40%.

Benefits (Advantages):

- Reduces heating loads;
- Reduces cooling loads, if glass has a special coating, with a high solar heat gain coefficient;
- Increases acoustic comfort;
- Increases thermal comfort.

Limitations (Disadvantages):

- High investment cost.

1.2 Inflector windows insulation

In'Flector Window Insulator is a see through radiant heat barrier window insulator, which can be applied in the manufacturing of vertical blind, horizontal blinds and skylight panels. The product is a patented process of an aluminium coated polyethylene sheet, which is laminated to a sheet of carbon graphite, that is then perforated and laminated to a sheet of clear polyester.

The unique benefit of the inflector products is that each side of the inflector material provides different benefits for different climate conditions. In the summer the In'Flector Window Insulator are positioned so that the silver side (aluminium) faces out and reflects 72% of radiant heat back out through the window (reducing the greenhouse effect in buildings). It also reflects 65% of solar gain back out through the window (reducing overheating in buildings); and reflects 92 % of damaging UV rays back out through the windows (reducing fading & sun damage); controls glare (especially for computers & televisions); provides daytime privacy (one way vision); provide cool day lighting with a view. In colder climates in the winter the In'Flector Window Insulators are reversed, so that the silver side is facing inward, reflecting the thermal heat back into the building reducing heat loss through the windows. The energy saving can be up to 40%. Inflector windows insulation is recommended in any type of hotels.

Benefits (Advantages):

- Reduces heating loads;
- Reduces cooling loads;
- Increases acoustic comfort;
- Increases thermal comfort.

Limitations (Disadvantages):

- In winter time it has to be reversed for reflecting the thermal heat back into the building.

1.3 Building insulation

The heat transfer coefficients of the building structures (external walls, roof, ground or cellar floor slab, etc.) is essential factor of the heating and cooling demand of the hotel building. The thermal insulation of the building structures is one of the most expensive measurements, but probably it has the biggest impact on heating energy saving.

Insulation is best placed on the exterior of the wall, as it enables the building to benefit from the thermal mass of the walls and eliminates the thermal bridges.

The most common types of insulation for hotel applications are expanded polystyrene (EPS), extruded polystyrene (XPS), fiberglass and mineral wool for external insulation. There are several things to consider before making an insulation decision like thermal performance of the building structures, lifetime performance, fire safety, moisture and condensation, air infiltration and environmental benefits.

Thermal insulation of building structures is highly recommended in any type of hotels, or climate zones, except Zone I, where the thermal insulation is classified as ‘feasible’. The reason is the same as it was written in the windows insulation section.

Benefits (Advantages):

- Significantly reduce heating loads;
- Increases thermal comfort.

Limitations (Disadvantages):

- Relatively high investment cost.

1.4 Building envelope air tightness

Air filtration through the windows and doors is an uncontrolled flow of air into the hotel. Badly fitting windows and doors increase the heating and cooling energy consumption. The sealants can easily install with low cost for reducing the air filtration. The potential energy saving depends very much on the features of the given building, therefore it is considered ‘low’, but it can be even 20% in some cases. Increasing building envelope air tightness is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to their more strict thermal comfort demands.

Benefits (Advantages):

- Reduced air filtration.

1.5 Prevention of high unnecessary air change rate

In a hotel, typically, the guest rooms are not occupied at all times. For adequate flexibility, the ventilation units should be able to shut off, when no one is in the room, and should be turned down, when the air quality is acceptable. The air quality should be measured with IAQ sensors, and the air volume should be controlled by VAV system. The shutting down of the ventilation system of guest rooms can be achieved by occupancy sensors. The effect of the reduction of the air change rate is less heating and cooling demand of the supply air. The prevention of high unnecessary air change rate is recommended in every climate zone and hotel standard. Prevention of high unnecessarry air change rate is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to their higher energy need of these hotels.

Benefits (Advantages):

- Less heating and cooling demand of the fresh air.

1.6 Installation of sun shading devices

Installation of external sun-shading devices is highly recommended in hotels that are exposed to the summer sun. Well-designed sun shading devices will help keep the building cool and comfortable and limit the air-conditioning needs of the hotel.

A sun shading device acts as a barrier to solar radiation. This most efficient solution, when the sun shading device is placed outside the window, because in this case much of the solar radiation is reflected back to the outside before reaching the window. When the protection is placed inside, only a small part of the incoming solar radiation is reflected back to the outside.

Outside sun shading devices are recommended because they are more efficient than inside sun shading devices in terms of heat protection. The solar heat gain of the windows can be reduced even 80-90% with outdoor sun shading devices.

Sun shading devices can be fixed or movable. For rooms exposed to the East or the West, it is better to install movable sun shading devices, because they can be removed in winter to let the sun come in and heat the air. For rooms exposed to the South, either movable or fixed shading devices can be installed, because even with fixed shading devices sufficient winter sun will be allowed into the room. Sun shading devices are recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to their more strict thermal comfort demands.

Some solar shading systems can be used to produce electricity, when they contain photovoltaic modules.

Benefits (Advantages):

- Less cooling load;
- Better thermal comfort;
- Better visual comfort.

1.7 Exterior works to improve summer comfort

The landscape around the hotel is able to reduce summer heat gain and cooling demand. The possible solutions can be the followings:

- Planting a deciduous shade tree on the southwest or southeast side of the hotel reduce the cooling needs and help maintain a comfortable indoor air temperature. Also Green surfaces help to reduce urban “heat island” effects and improve air quality.

- Installing open water surfaces for evaporative cooling. For cooling to occur, it is best if the fountain or pool is active, with water and air mixing to encourage evaporation, and it is on the North side of the building.

- Choosing the right ground cover for the surrounding area also plays an important role in summer comfort: the ground cover of the surrounding area of the hotel influences heat radiation and reflection onto windows and walls. It is better to choose ground cover that minimises ground reflection and keeps the ground surface cooler, thereby preventing re-radiation. On the south side of the hotel it is recommended to use only permeable pavement or permeable light-coloured concrete. You may also use bushes and plants to shade pavements, or cover pavements with wood.

- Green walls act as an exterior thermal insulation material for summer and for winter. Green walls conserve energy by insulating the hotel building envelope, reducing the need for heating in the winter and cooling in the summer (a green wall can reduce the temperature of walls by as much as 10°C in summer thus lowering cooling needs inside the building.

- Green roofs act as an exterior thermal insulation material for summer and for winter, and have a greater cooling power than green walls in summer.

Improving summer comfort with exterior works is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to their more strict thermal comfort demands.

Benefits (Advantages):

- Reduces heating and cooling loads;
- Reduces urban heat island effect;
- Increases thermal comfort.

Limitations (Disadvantages):

- Take care of green walls and roofs.

1.8 Energy saving light bulbs (CFL, LED)

In a typical hotel the lighting takes 12% of the energy demand, therefore installing energy saving light bulbs in the hotel is generally one of the easiest ways to reduce electricity consumption. In many countries the final electricity consumption needs much primary energy, due to the bad efficient of the electricity production, thus the electricity reducing can be very important. Using of energy saving light bulbs is recommended in any type of hotels.

Several types of energy efficiency lighting technology exist, such as:

Compact Fluorescent Lamps (CFL): While CFLs do not start at full intensity like incandescent bulbs, nearly all CFLs nowadays turn on instantly and reach full illumination very quickly. Some CFLs are marketed as ‘instant on’ and have no noticeable warm-up period. A typical CFL uses around 75% less electricity and lasts between eight and fifteen times longer than an incandescent light.

Benefits (Advantages):

- CFL uses around 75% less electricity, than an incandescent light globe;
- CFL lasts between eight and fifteen times longer, than an incandescent light globe;

- CFLs are now available with a glass cover, which gives them similar appearance to incandescent light globes.

Limitations (Disadvantages):

- The CFL size does not always exist, what can exactly substitute for an existing incandescent bulb.

Light-emitting diodes (LED) in order to replace old incandescent lamps. They have extremely long life spans, are energy efficient, and come in a variety of colours. As research continues, LEDs continue to improve and be used in new applications. An increasingly popular hotel use is decorative light. The savings depend on the initial lighting system. One manufacturer claimed a 16-watt LED bulb was as bright as a 150 W halogen lamp, so the energy saving can be even 90%.

Benefits (Advantages):

- The life of LEDs is 7 to 10 times more compared to other lights;
- Saving on replacement and maintenance;
- LEDs generate much less heat compared to other lighting systems.

Limitations (Disadvantages):

- LED lights' costs are more than incandescent and fluorescent lights.

1.9 Energy efficiency rating of electrical appliances

The use of energy efficient equipment such as refrigerators, ovens, dishwashers, washing machines, dryers/tumblers and office equipment is an optional criterion of the EU Eco-label. It is easy to implement when a hotel replaces an electric appliance. It is recommended, when a hotel chooses a new product, it has to have high energy efficiency rating according to European energy labelling (introduced by the Council Directive 92/75/EEC). The labelling is available for most household electrical appliances, in particular for catering equipment (refrigerators and freezers, mini-bars, dishwashers), and laundry equipment (washing machines, dryers, etc.). Energy efficiency is expressed in terms of energy class. Class 'A', 'A+' or 'A++' is recommended for catering and laundry equipment, due to their energy need can be 15% of electricity. Energy efficiency rating is recommended in any type of hotels.

1.10 Energy efficient motors in HVAC applications

In the heating, cooling and air conditioning systems, most of the time, the flow rate is adjusted conventionally by modifying the volume flow, using valves or air shutters. The problem with this type of regulation is that motors keep running at full load, while HVAC systems rarely require maximum flow rate, thus resulting in a waste of electricity. The electricity consumption is proportional to the motor's speed cubed, hence adjustment of the speed of motors of pumps and fans, with an electronic device may save up to 70% on electricity compared to on-off systems. When the heating, cooling and air conditioning system flow rates are regulated, the motor should be operated on variable frequency. Utilizing energy efficient motors in HVAC systems is recommended in low standard hotels, and highly recommended in medium and high standard hotels, due to their higher electricity demands.

Benefits (Advantages):

- Saves up to 70% on electricity compared to on-off systems.

1.11 High efficiency boilers

The space heating takes more than 1/3 part of the total energy need of a typical hotel, therefore it is recommended to use high efficiency boilers, such as condensing boiler. Condensing boilers are high efficiency boilers, recapturing water vapour heat that would otherwise be lost. These boilers extract more heat from the hot flue gases because they have a larger heat exchanger, hence the condensing boilers are more efficient than non-condensing boilers. Condensing boiler manufacturers claim that up to 98% thermal efficiency can be achieved, compared to 70%-80% with conventional designs. Typical models offer efficiencies around 90%, which brings most brands of condensing gas boiler in to the highest available categories for energy efficiency. The efficiency can be the highest, when the heating system operates at low temperature, for instance, with floor, ceiling or wall heating system. Utilizing high efficiency boilers is highly recommended in any types of hotels.

If a hotel is planning to improve the thermal insulation of the building, it makes more sense economically and technically to choose and replace the boiler after the thermal insulation work is done. Indeed, the insulation work will reduce the energy needs for space heating, hence a lower power boiler is needed.

Benefits (Advantages):

- 98% thermal efficiency can be achieved compared to 70%-80% with conventional designs.
- When the thermal energy need is becoming lower, the energy efficiency of the boiler is increasing.

1.12 Efficient solutions for active space cooling

The space cooling takes 15% of the total energy need of a typical hotel, therefore it is recommended to use high efficient solutions for active space cooling. Due to the several numbers of guest rooms and public areas, which have to be cooled, it makes more sense to use a central cooling system, instead of local ones. However, in some places only the local cooling system can be installed, in this case it is recommended to use split AC with inverter.

Utilizing efficient solutions for active space cooling is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to the more strict expectations of thermal comfort, and higher energy demand of cooling.

Central system that use a water network for cooling are well suited to zoned heating/cooling and they generally provide good comfort. In addition, they offer good flexibility as regards ventilation and heating/cooling and may be not too difficult to install in an existing building. Energy efficient solutions for central water cooling:

Chilled ceilings: Chilled ceilings are devices mounted at high level within a space, which provide a combination of radiant and convective cooling to the space below. Each unit typically comprises a small chilled water pipe (water temperature 14–18°C for cooling or 30–40°C for heating) arranged in a serpentine pattern and attached to the upper surface of a thin metallic ceiling panel. Alternatively, the pipe may be embedded within the panel, or integrated as a suspended ceiling solution. To improve the acoustic performance of space, models with integrated sound absorption material are recommended. Typical cooling output is around 50–70 W/m². With chilled beams relatively high chilled water temperatures can be used, which increases the chiller efficiency and give a potential for free cooling.

Benefits (Advantages):

- Can be accommodated in a very shallow ceiling void of around 60–70 mm;
- Provides a quiet, draught-free operation;
- Relatively high chilled water temperatures are used (potential for free cooling);
- Minimal maintenance requirements.

Limitations (Disadvantages):

- Water temperature must be controlled relative to room conditions, to avoid condensation;
- Heating and cooling output is limited and may not be suited to spaces with high heat losses/loads;
- Condensation risks in a hot and humid climate require special attention;
- Slow reaction to space internal and external load changes;
- A separate ventilation system is required;
- Hard ceiling surface may result in poor acoustic performance.

Active chilled beam: The active chilled beam system is primarily used for cooling and ventilating spaces, and can also be used for heating in some applications. Active chilled beams are connected to both the ventilation supply air ductwork, and the chilled water system. The main air handling unit supplies primary air into the various rooms through the chilled beam. Primary air supply induces room air to be recirculated through the heat exchanger of the chilled beam. In order to cool or heat the room either cold (14–20°C) or warm (30–40°C) water is cycled through the heat exchanger. The recirculated room air and the primary air are mixed prior to diffusion in the space. Room temperature is controlled by the water flow rate through the heat exchanger. Typical cooling output is 50 W/m²–120 W/m².

Benefits (Advantages)

- Can provide a quiet, draught-free operation;
- Relatively small ceiling void depth, around 300 mm;
- Relatively high chilled water and low heating water temperatures are used (potential for free cooling and heating);
- Minimal maintenance requirements;
- Provides a prefabricated option to integrate lighting or other building services within the units.

Limitations (Disadvantages)

- The ventilation fan should run in heating mode (also during night time when ventilation is not needed);
- Condensation risks in a hot and humid climate require special attention;
- Water temperature must be controlled relative to indoor conditions to avoid condensation.

1.13 Micro CHP

Combined heat and power (CHP), also known as co-generation, is the simultaneous generation of both usable heat and electrical power from the same source. CHP systems can be used in applications where there is a significant year-round demand for heating in addition to the electricity generated. CHP is accomplished through a variety of different technologies powered by all fuel types (i.e. solid, oil and gas, including biomass). Micro-CHP has an electric output of 1 kW and provides heated water for space heating and domestic hot water applications. Utilizing micro CHP is recommended in any types of hotels.

Benefits (Advantages):

- Can be powered using biofuels;
- Provides a continuous supply of electricity;
- Generated heat can be used to power absorption chillers;
- Possibility of exporting the excess electricity to the national grid (depending on local policy).

Limitations (Disadvantages):

- Requires predictable and relatively constant loads for optimum performance;
- Requires full use of generated heat for optimum efficiency;
- Typically, to be cost-effective, CHP systems will require to be operated for a minimum of four to five thousand hours per annum (around 60%). (BSRIA)

1.14 Efficient ventilation systems, min. 70% efficiency heat recovery

Energy recovery is a mean of taking energy (heat/cold) from exhaust air and transferring it either to the supply air or domestic hot water. The most common types are:

- Plate heat-exchangers (recuperative heat exchanger);
- Thermal wheel (regenerative heat exchanger);
- Run-around coil system.

Plate heat-exchangers are relatively simple devices with no moving parts. They consist of a framework supporting a number of thin plates with air passages in between. The plates are normally of metal but can be made from other materials and the plates may have flat, corrugated or finned surfaces. A thermal wheel (also known as a rotary regenerator) consists of a matrix in the shape of a wheel rotating slowly between adjacent fresh air and exhaust air ducts. The wheel rotates at between 8 to 15 rev min. As it does so the matrix material in the airstream absorbs heat from the warmer air stream, and releases the heat into the cooler air stream, which flows through the wheel in the opposite direction. The rotary heat exchanger has the highest efficient, therefore it is needed to ensure min. 70% efficiency of heat recovery.

A run-around coil system consists of one or more coils located in the exhaust air duct connected to one or more coils in the fresh air intake. It can work in both heating and cooling modes.

The sensible heat recovered from exhaust air reduces the quantity of energy required for heating or humidifying the outdoor air in air conditioning systems. Also, the total heat extracted from outdoor air by the heat exchanger reduces the quantity of energy required for cooling or dehumidifying the outdoor air.

Utilizing the highest energy efficienty ventilation system is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to the higher thermal energy demand.

Benefits (Advantages):

- Saves energy (e.g. electricity with cold recovery);
- Reduction in the primary heating and refrigeration plant size;
- Reduced size of the heating and cooling coils from the air handling unit;

Limitations (Disadvantages):

- Heat exchanger cost;
- Additional fan power needed to drive air through the heat exchanger.

1.15 Key card systems to switch off electricity in guest rooms

In many case, the hotel lighting usage patterns do not reflect a significant dip in energy consumption, during 11 am to 5 pm, when guest rooms are typically unoccupied. Rather, that guest room lights are on 20-25% of the time, during this time period. The key card system is helping for this, because before the guests away from their rooms, they will only be able to close the door with the key card. If the key card socket is empty, the system is automatically switches off the selected equipment (e.g. TV, lighting). Hotels that have installed key card systems report that they have reduced the electricity consumption in guest rooms by 20 to 30%.

Utilizing key card system is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to more convinient service of guests, and higher energy demands.

Benefits (Advantages):

- Reduces electricity consumption.

1.16 Lighting controls

Using lighting controls, such as occupancy sensors and time switch programs result that the lighting energy costs will be significantly reduced. The principle of lighting control is to light only those areas that are occupied or truly need light in the hotel. This can be achieved with technical measures, such as automatic devices. Lighting controls allow the hotel to vary the level of artificial light output, but they can be also used to alter the mood or ambiance of the lighting to suit different times of the day. Lighting control is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to their higher energy demand, but it has to be taken into account, that lighting control can't be applied in every room of 5 stars hotels, because guests should not enter a dark space.

Benefits (Advantages):

- Reduces electricity consumption.

Limitations (Disadvantages):

- Can't be applied in every room of 5 stars hotels, because guests should not enter a dark space.

1.17 Thermal insulation of boilers, DHW tanks and water pipes

Insulation of boilers, hot water storage tanks and water distribution systems is a very efficient way to keep the water hotter for longer, especially if the equipment is exposed to cold conditions in winter. By reducing heat loss, insulation allows for a lower water temperature setting and thus provides energy and money savings for the hotel. In addition, insulation of water distribution systems results in a shorter time for the guests to get hot water, when they turn on a faucet or showerhead, which helps conserve water. Adding insulation to the DHW storage tank can reduce stand-by heat losses by 25-45% and save around 4-9% on water heating costs. Thermal insulation of boilers, hot water storage tanks and water distribution systems is feasible in any type of hotels.

Benefits (Advantages):

- Reduces heat losses of equipment.

1.18 Balancing of heating, cooling and air conditioning systems

The goal of the hydronic balancing is to provide such pressure differences, which ensure the designed volume flow on every balancing valve (heating/cooling) and air shutter (ventilation). During the balancing process – on behalves of economic operation – one has to try to achieve the smallest pressure differences on the valves, securing the optimal pumps' and fans' operation. The balancing has to be begun with opened valves, after staring pumps/fans in the designed circulation direction and on proper pressure. During the balancing of the system, the designed volume flows have to be adjusted. Without balancing the HVAC systems, there can be over-heated/cooled and under-heated/cooled spaces. Balancing of the HVAC systems is highly recommended in any type of hotels.

Benefits (Advantages):

- Hydronic balancing reduces energy consumption;
- Better thermal comfort.

1.19 Regulation of space heating and cooling

Concerning the typical total energy consumption by end-use in hotels (Leonardo Energy: Energy Efficiency in Hotels, 2008), the space heating (31%) and cooling (15%) take together almost the half of the energy consumption. Therefore the regulation of space heating and cooling has a big role in an energy efficient operation. Regulation of space heating and cooling is highly recommended in any type of hotels to ensure the following functions:

- In hotel rooms the indoor temperature can be adjusted by the user to (e.g. ± 3 ° C from set point)
- Automatic devices can be used to turn off heating and air conditioning when windows are open.
- In case of heating with radiator, using thermostatic valves, or for more accurate control, groups of radiators on the same circuit can be controlled by one motorised valve, which is linked to an electronic air thermostat.

- Using reduced heating in temporary used areas (e.g. conference room), and in the unoccupied rooms

Benefits (Advantages):

- Reduces energy consumption of heating and cooling;
- More accurate control.

1.20 Free cooling

The free cooling operation can be used for compact and separated chiller system as well. In case of using a compact chiller it has to be examined, whether the existing chiller can be complemented with free cooling module. During spring and autumn, significant electricity saving can be achieved by free cooling, without using the compressor of the chiller. Utilizing free cooling is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to their higher energy demands.

Separated chillers cool down water and they are linked to a heat rejection unit by pipework, enabling the chiller to be located in a plant room. The dry cooler can be installed parallel with a chiller in order to provide free cooling in cold and temperate climates, or even in warmer climates during spring and autumn. The dry cooler is heat rejection equipment, in which fans induce the air flow over finned tubing through, which an aqueous glycol solution or water is passed instead of refrigerant. It may cool water sufficiently in winter to avoid operating the refrigeration plant. Adiabatic sprays can be added to improve their performance.

Benefits (Advantages):

- Saves electricity (no need to run chillers all the time).

Limitations (Disadvantages):

- Chiller is also required to ensure year around cooling;
- Brings benefits only during cold weather conditions;
- Can be noisy and may require special precautions depending on the application.

1.21 Utilization of the waste heat of chillers

The waste heat can be used for compact and separated chiller system as well. In case of using a compact chiller it has to be examined, whether the existing chiller can be complemented with waste heat utilization module. The chillers' waste heat can satisfy one part of the DHW demand. The temperature of the waste heat is lower, hence it can be used only for pre-heating the DHW storage tank. The connecting for the existing system is possible with preheating storage tank. Utilizing waste heat of chiller depends on the cooling demands of the building. Regarding the cooling demands are expected higher in higher standard hotels, therefore utilizing waste heat of chiller is feasible in low standard hotels, recommended in medium standard hotels, and highly recommended in high standard hotels.

Benefits (Advantages):

- Utilizes waste heat of chiller saves thermal energy;

Limitations (Disadvantages):

- The temperature of waste heat is lower, it can be used only for pre-heating the DHW.

1.22 Hybrid ventilation system

Hybrid ventilation is a combination of natural and mechanical ventilation and exploits both systems as required. This entails either interchangeable periods of natural ventilation and mechanical ventilation, or a balancing of the two principles such that mechanical ventilation takes over when the external conditions so require. The result is an effective and energy-efficient ventilation solution that maintains healthy indoor climate and comfort. In order to use a hybrid ventilation solution conditions for the use of natural ventilation must be in place. Hybrid ventilation system is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to their higher energy demand.

There are three basic forms of hybrid ventilation:

- Natural Ventilation + a VAV/CAV system
- Natural Ventilation + a decentralised system
- Natural Ventilation + extraction

Benefits (Advantages):

- Saves electricity;
- Better controllability of indoor air temperature than in natural ventilation alone.

Limitations (Disadvantages):

- Higher HVAC heating/cooling loads in naturally designs which are also unsuitable for very severe climate zones;
- Commissioning is complicated;
- Outdoor air contaminants and particulates can enter building;
- Heat recovery is difficult;
- Sophisticated control algorithms are necessary to effectively combine advantages of natural and mechanical ventilation.

1.23 Low temperature heating (including acceptable heating energy generation)

The possibility of using low temperature heating depends on the heating equipment of the heating system. The surface-heating systems (floor, ceiling, wall heating) are suitable for the operation by low temperature heating medium. The typical heating supply temperature is 30-40 °C. The low temperature heating ensures the higher efficiency of the applicable heating energy producers, as condensing gas boilers or heat pumps. Low temperature heating system is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to their higher energy demand.

Benefits (Advantages):

- Leaves the floor space virtually free from heating/cooling services;
- Improved Heat Source Performance;
- No radiation asymmetry.

Limitations (Disadvantages):

- Slow response to change in temperature setting.

1.24 High temperature cooling

The possibility of using high temperature cooling depends on the heating equipment of the cooling system. The surface-cooling systems are suitable for the operation by high temperature cooling medium. The typical cooling supply temperature is 14-18 °C. The high temperature cooling ensures the higher efficiency of the applicable cooling energy producers, as chillers or heat pumps. High temperature cooling system is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to their higher energy demand.

The following cooling systems are suitable for high temperature operation:

- Chilled ceilings: See details in section 'Efficient solutions for active space cooling'
- TABS: It is a specific type of chilled ceiling and floor heating/cooling, where either water pipes or air ducts are integrated into a concrete slab or cast into the slab. The slab offers the opportunity to store energy as heat and operate the cooling/heating at differen times with respect to thermal loads. TABS is a base load system; the temperature drift around an equilibrium (self-regulating effect).

Benefits (Advantages):

- The need for cooling/heating is distributed over a longer period, which leads to lower peak loads, thus allowing the use of smaller conditioning plants;
- By avoiding suspended ceilings floor height can be reduced;
- Relatively high chilled water and low heating water temperatures are used (potential for free cooling and heating);
- Low installation and maintenance costs.
- Favourable temperature levels improve heat source performance (heat pump COP).

Limitations (Disadvantages):

- Water temperature must be controlled relative to room conditions, to avoid condensation;
- Heating and cooling output is limited and may not be suited to spaces with high heat losses/loads;
- As sound absorption material cannot be installed into a ceiling it may lead to poor acoustical performance;
- Condensation risks in a hot and humid climate require special attention;
- Difficult to change pipes after installation;
- Slow reaction to space internal and external load changes;
- Separate ventilation system is required.

1.25 Geothermal energy (heat pump)

The ground source heat pump transfers thermal energy stored within the Earth (i.e. in water tables, underground rivers and soil) to air or water. The thermal energy is collected with closed loop coils in either horizontal or vertical format. Horizontal ground collectors (coils or spirals) are buried below freezing depth over a certain surface area, depending on the heating/cooling demand. Vertical ground collectors (pipes or loops) are placed in bored wells that can reach 100 meters or more in depth. Geothermal heat pump system is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to their higher energy demand.

Benefits (Advantages):

- Geothermal energy is renewable and accessible;
- Emission free operation on-site;
- Good life span, estimated at around 20 years for inside components and up to 50 years for the collectors;
- Low noise.

Limitations (Disadvantages):

- High initial cost (equipment + digging);
- In case of horizontal loops the ground surface above them must be left free;
- Not suitable for rocky soil.

1.26 Aerothermal energy (heat pump)

The air to water heat pump is an air source heat pump that draws stored heat from ambient air and transfers it by means of a heat transfer medium to a water heating circulation loop. Electrical energy is used to operate this cycle. Heat is extracted from the ambient air via an externally located unit which houses the evaporator. This heat is carried by the medium and is then transferred to the water (for heating and domestic hot water purposes) in the internally located condenser. This cycle can work in reverse to provide cooling. Air to water heat pumps are often used in buildings for domestic hot water preparation. Aerothermal heat pump system is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to their higher energy demand.

Benefits (Advantages):

- Air as a renewable heat source is accessible and practically unlimited;
- Lower installation cost than geothermal heat pumps;
- Emission free operation on-site;
- Low operation and maintenance costs.

Limitations (Disadvantages):

- Low efficiency (COP) for below 7°C outside temperature;
- Noise caused by external unit fan.

Another type of aerothermal heat pump is the air to air heat pump. The air to air heat pump draws stored heat from the ambient air and transfers this energy to supply air or directly to the indoor air. This cycle uses electrical energy. It can operate in both cooling and heating modes.

Benefits (Advantages):

- Air as a renewable heat source is accessible and practically unlimited;
- Lower installation cost than geothermal heat pumps;
- Easy to install;
- Emission free operation on-site;
- Low operation and maintenance costs.

Limitations (Disadvantages):

- High initial cost;
- Low efficiency (COP) for below 7°C outside temperature;
- Noise caused by external unit fan.

1.27 Hidrothermal energy (heat pump)

The ground water has almost constant temperature through the year, and has a good thermal conductivity; therefore it can be thermal source for a heat pump. Making source and reinjection wells need relatively high investment cost. Due to the system is opened, the environmental impact always has to be analysed. Further special using is when the thermal-source is a lake or a river, in this case, the coil is placed in the lake or river. Hydrothermal heat pump system is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to their higher energy demand.

Benefits (Advantages):

- Renewable heat source;
- Emission free operation on-site;
- Low noise.

Limitations (Disadvantages):

- Environmental impact;
- Appropriate ground-water is needed.

1.28 Solar powered absorption chiller

Absorption chillers differ from mechanical vapour compression chillers in the fact that they utilize a thermal or/and chemical process to produce the refrigeration effect necessary to provide chilled water. There is no mechanical compression of the refrigerant taking place within the machine. In an absorption chiller a heat source (e.g. solar heat) drives the cooling process, thus the compressor is replaced by a chemical absorber, generator and a pump.

The using of solar energy by an absorption chiller depends on the cooling demands of the building. Regarding that the cooling demands are expected higher in higher standard hotels, therefore using of solar energy by an absorption chiller is feasible in low standard hotels, recommended in medium standard hotels, and highly recommended in high standard hotels.

Benefits (Advantages):

- Solar heat can be used to produce cold water;
- Saves electricity;

- The refrigerants used do not damage the atmosphere and have no global warming potential;
- They have few moving parts and have correspondingly lower maintenance requirements compared to conventional chiller;
- Absorption machines are quiet and vibration-free.

Limitations (Disadvantages):

- Less efficient than compressor-driven chillers (typically COP= 1, meaning that as much heat need to be used as cooling is produced), primarily because water is a less efficient refrigerant than fluorocarbon-based refrigerants;
- Larger and heavier components than compressor-driven chiller systems of equal capacity;
- Higher investment and maintenance cost than compressor-driven chillers.

1.29 Micro hydropower

If there is a suitable site, harnessing the energy in a stream or creek can be cost-effective way to make renewable electricity. Compared to the sun and wind's variability, a stream's flow is relatively constant, however hydro resources are the most site specific, since the property must have usable water source. Mycro hydropower system is feasible in any type of hotels.

Benefits (Advantages):

- Relatively constant renewable energy source;
- Saves electricity.

Limitations (Disadvantages):

- Site specific, the property must have usable water source.

1.30 Wind energy (small scale wind turbines)

Wind turbines convert the kinetic energy in wind into mechanical energy that is then converted to electricity. Turbines are available in a range of sizes and designs and can either be free-standing, mounted on a building or integrated into a building structure. Horizontal-axis wind turbines are the most common type. This type of turbine has a horizontal rotor shaft and generator typically located at the top of a tower. Vertical-axis turbines have a rotor shaft placed vertically. This avoids the need for a tower and the generator is located at ground level. The efficiency of the wind turbines is increased if they are positioned near the edge of the roof. This increase in efficiency is due to the upward moving air streams on the exterior side surface of the building's envelope. Wind energy system is feasible in low and medium standard hotels, although it is not applicable in high standard hotels, due to the higher expectations of the surroundings (noise, shade).

For the installation the following factors shall be considered:

- Annual electricity consumption;
- Landscape potential from wind energy viewpoint;
- The dimension of the place, where the wind turbine can be installed;
- Local regulations refer to the installation and the system power;
- Electricity tariff;
- Acoustic effect;
- Shading effect;
- Economic point of view.

Benefits (Advantages):

- Renewable energy source;
- Electricity generation also during the night and cloudy days.

Limitations (Disadvantages):

- Wind is intermittent, varying from zero to gale force speeds;
- Power output restricted by the wind turbines design.
- Best performance will be obtained in nonurban locations;
- Actual electric power generated may be considerably less than the rotated output of the turbine;
- Building-mounted turbines create structural, vibration and noise implications;
- Access for maintenance or replacement of damaged components may be an issue;
- Costs can be high in relation to the actual amount of electricity generated.

1.31 Biomass boiler

Biomass boilers are supplied with firewood, wood chips or pellets. It has relatively high investment cost, but the biomass heating has lower operating cost than a gas-heating system. Biomass systems typically can be used in those places, where the fuel (wood) is close to the building, so the cost of transportation is low. In case of 'energy-forest' the annual energy yield is 200-350 GJ/ha. Biomass boiler is feasible in low and medium standard hotels, although it is not applicable in high standard hotels, due to the higher expectations of the surroundings (noise).

For the installation of a bio-mass boiler system, the following factors shall be considered:

- Heating demand;
- Modernity and energy efficiency of the existing system;
- How can the biomass boiler be integrated into the existing heating system;
- The location of the boiler house in the facility;
- Suitable location for installing of fuel store and boiler house (architectural viewpoint, place);
- Opportunities and costs of fuel transportation;
- Acoustic effect of fuel storing;
- Emission of pollutant material;
- Staff claim, personal costs;
- Economic and energy efficiency point of view.

Benefits (Advantages):

- Renewable energy source;
- Lower operating cost, than a gas-heating system;
- Can be a good solution far from utilities.

Limitations (Disadvantages):

- Place of fuel storing and puffer tank;
- Relatively high heating water temperature;
- Opportunities and costs of fuel transportation;
- Acoustic effect of fuel storing;
- Emission of pollutant material;
- Staff is needed, personal costs.

1.32 Solar thermal

With active utilising of solar energy, the production of domestic hot water can be made by solar thermal panel. In some climate regions thermal solar panels can be used for heating as well. In summer, there is a possibility for cooling with solar powered absorption machine. Utilising of solar thermal energy is highly recommended in any types of hotels.

Typically the roof is the installation place of the flat-plate collectors or evacuated tube collectors. For the installation of solar thermal systems, the following factors shall be considered:

- Annual DHW demand and its distribution;
- Existing technology for DHW production;
- Orientation and size of the roof surface;
- The location of the existing DHW storage tanks in the facility;
- The installation of DHW storage from architectural viewpoint (available place);
- Economic point of view.

Benefits (Advantages):

- Unlimited renewable energy source;
- Locally available resource;
- Different types of collectors are available, which makes integration flexible for different building types;
- Simple and robust design of collectors.

Limitations (Disadvantages):

- In sunny periods too much heat is generated which can cause water to boil in pipes;
- In case hot water consumption is limited it is important to decide how to use the generated heat.

1.33 Solar thermal for swimming pool

Many hotels have indoor or outdoor swimming pools, which can be heated with solar thermal panels. It is recommended to utilize the energy of thermal panels after they heated the DHW storage tanks. The shift between the swimming pool and the DHW tank heating can be implemented with a motorized valve. Utilising of solar thermal energy is recommended in low and medium standard hotels, and highly recommended in high standard hotels, due to their higher energy need.

Benefits (Advantages):

- Unlimited renewable energy source;
- Locally available resource.

1.34 Photovoltaic panel

The power output of photovoltaic systems is usually described in kilowattpeak units (kWp). The power generated by PV modules varies from a few watts (typically 20 to 60 Wp) up to 300 to 350 Wp depending on module size and the technology used. The yearly sum of global irradiation incident on optimally inclined south-oriented photovoltaic modules in Europe varies from 800-2000 kWh/m^2 and therefore the yearly sum of solar electricity generated by 1 kWp system with performance ratio of 0.75 is 600-1500 kWh/kWp (EU Joint Research Centre). For instance, a PV installation with a 14% efficiency can produce annually nearly 200 kWh/m^2 in Rome, and 130 kWh/m^2 in Copenhagen. Nowadays, the installation cost of PV system is becoming lower, therefore it is getting more and more popular. It can be connected to the grid, or can be local, autonomous power supply. Utilising of PV panels is highly recommended in any types of hotels.

The photovoltaic systems are very environmentally friendly, because their gas emission are absolutely zero, for example there is zero CO_2 emission, which is responsible for the greenhouse effect. The photovoltaic system energy balance is also positive: the required energy for manufacturing a PV panel returns usually in two years.

The following factors shall be considered, for the installation of PV panel in a hotel:

- Annual electricity consumption;
- Local regulations refer to the installation and the system power;
- Electricity tariff;
- Orientation and size of the roof surface;
- Economic point of view;

The annual rate of electricity energy, which produced by PV panel, can be calculated by high reliability. The European Committee has been started the PVGIS project, which has a useful database. On PVGIS website an online calculator tool is available for all: http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php#.

Benefits (Advantages):

- Unlimited renewable energy source;
- Solar energy is a locally available resource (amount depends on location);
- When grid connected, it can displace the highest cost electricity during times of peak demand;
- PV panels can provide revenue by selling excess electricity in times of low demand (local policy);
- Noise free operation.

Limitations (Disadvantages):

- High installation costs;

- High embodied energy of PV cells and requirement of rare metals;
- PV panels require regular cleaning;
- Associated inverters may cause reliability and energy consumption (if not properly designed) issues because they heat up during operation;
- Requires careful positioning to obtain optimum performance;
- The efficiency is in direct relation with the climate zone;
- Solar energy is not available during night and is less available during cloudy days;
- Energy storage is necessary, in the case of a stand-alone system.

References:

Publications

ASHRAE GreenGuide: Design, Construction, and Operation of Sustainable Buildings, 4th Edition, 2013
Energy Efficiency Guides for Existing Commercial Buildings, ASHRAE, 2012
Environmental design, CIBSE Guide A, 2006, 7th edition
Ground-Source Heat Pumps - Design of Geothermal Systems for Commercial and Institutional Buildings, ASHRAE, 1997
HVAC in Sustainable Office Buildings, Virta-Hovorka-Kurnitski-Litiu, REHVA GB 16, 2012
Low Temperature Heating and High Temperature Cooling. J. Babiak (ed.), B.W. Olesen, D. Petráš, REHVA Guidebook No 7.
REHVA European HVAC Journal, http://www.rehva.eu/publications-and-resources/hvac-journal/
Renewable energy sources for buildings, CIBSE TM³8, 2006
Renewable energy technologies: Key factors for successful installations - Set of 5 BRE Information Papers
Solar Shading. W. Beck (ed.), D. Dolmans, G. Dutoo, A. Hall, O. Seppänen, REHVA Guidebook No 12.
The Illustrated Guide to Mechanical Cooling, BRE, BG 1/2010
The Illustrated Guide to Renewable Technologies, BRE, BG 1/2008

Online resources

Hotel Energy Solutions - H.E.S.: http://hotelenergysolutions.net/en
Inspection of HVAC Systems through continuous monitoring and benchmarking - iSERVcmb project: http://www.iservcmb.info/
REHVA HVAC Terminology: http://www.rehva.eu/publications-and-resources/hvac-terminology/?L=0#c440
REHVA HVAC Dictionary: http://www.rehva.eu/publications-and-resources/hvac-dictionary/?L=0%27%20and%20char%28124%29%20user%20char%28124%29%3D0%20and%20%27%27%3D%27

neZEH TEAM

Project Coordinator
Technical University of Crete, School of Environmental Engineering
Renewable and Sustainable Energy Systems Lab, Greece

United Nations World Tourism Organization

Network of European Regions for a Sustainable and Competitive Tourism

Federation of European Heating, Ventilation and Air-conditioning Associations

Agency of Braşov for Energy Management and Environment Protection, Romania

Creara Consultores S.L., Spain

ENERGIES 2050, France

Energy Institute Hrvoje Požar, Croatia

Istituto Superiore sui Sistemi Territoriali per l'Innovazione, Italy

Sustainable Innovation, Sweden

CONTACTS

PROJECT COORDINATOR:
Technical University of Crete, Renewable and Sustainable Energy Systems Lab
Ms Stavroula Tournaki • stavroula.tournaki@enveng.tuc.gr • +30 28210 37861 • www.nezeh.eu

AUTHOR:

REHVA
Anita Derjanecz • ad@rehva.eu, Zoltan Magyar • zmagyar@invitel.hu, Andrei Lițiu • al@rehva.eu

Co-funded by the Intelligent Energy Europe
Programme of the European Union