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DEMOHOUSE

Design and Management Options for improving the energy performance of Housing

SPECIFIC TARGETED RESEARCH OR INNOVATION PROJECT

Thematic Priority 6

Deliverable 6 Catalogue of best available technologies

Due date of deliverable: xxx
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Executive Summary

The EU- Demohouse project is a specific targeted research and innovation project supported by the EU – 6th Framework programme. It started in October 2004 and is ongoing for 4 years until October 2008. Demohouse is here an acronym for Design and Management Options for Improving the Energy Performance of Housing. ECN from Holland is coordinator and there are realised demonstration projects in 5 countries – Denmark, Austria, Hungary, Spain and Greece, with main focus on housing renovation.

The main goal of WP2 is: "Generation of solutions and technical designs", which is coordinated by Cenergia from Denmark, is to assist on the development of a new quality and value oriented design process in connection to renovation projects in the housing sector. And to do this in connection to the demonstration projects which are realised in the EU- Demohouse project.

This report includes a catalogue of best available techniques in relation to renovation of housing projects. The information is based on the Green Catalogue which was developed until 2004, based on an EU-save project.

This report is an introduction to relevant best practice technologies you can utilise in connection to energy efficient construction.

The energy use for heating can be reduced by use of extra insulation of walls, floors and roofs. Here it is also important to focus on possible cold bridges and limit the effect of these. E.g. in concrete housing blocks you often have a balcony where the concrete is direct connected without any insulation to the interior of the dwelling. A solution here could be to mouth new balconies which are insulated towards the building or you can equip the balcony with insulation using a hard insulation material. Besides it is optimal to use energy optimised windows especially windows with low frame losses. Finally as one of the most important future solutions it is necessary also to consider energy savings in connection to ventilation which can be a very considerable part of the total energy demand. Here new ventilation solutions with low cost and high-efficiency heat recovery are important, also to improve the indoor air climate.

An important issue is how to reduce the energy consumption for heating domestic hot water DHW, and electricity use for operation of fans and pumps as much as possible. Also water savings are relevant in general since it affects the DHW use. Besides needs for circulation of DHW should be reduced / optimised.

Furthermore it is obvious also to use renewables like solar heating or PV electricity to cover part of the reduced energy demand. And it is necessary to introduce an optimised general energy supply solution with reduced losses like e.g. district heating, gas heating or use of heat pumps. Here it is important to focus on a low level of heat losses from distribution of both heating and domestic hot water. Especially in low energy renovation projects there can be considerable heat losses compared to the reduced energy use.

The report is divided in 3 parts. The first part presents a thorough introduction to the above-mentioned best practice technologies while the second part quantifies the present state for Europe, the goals for 2011 (in relation to EPDB) and the state of the art – the best available technology. Rerences are here made to relevant standards and references.

In the last part of the report is shown an input from the EU-Demohouse demonstration countries, referring to performance requirements for different best practice technologies. Detailed country specific information on what kind of technologies were considered and applied (or rejected) in the Demohouse renovation projects and why is discussed in deliverables D14 (for the reference projects) and D16 (for the pilot projects).

European standards as well as best practice on energy saving technologies for buildings are presented. The technologies are:

- Insulation
- Windows
- Air tight constructions
- Heat recovery ventilation
- Condensing gas boilers
- District heating systems
- Combined heat and power production
- Heat pumps
- Natural, hybrid and PV-assisted ventilation
- Solar domestic hot water heating systems
- PV installations
- Energy Signature monitoring and follow-up system

A considerable saving potential is found. The current Best Available Technologies offer better performance than the demands that are expected to be implemented in 2011 based on the EPBD. Even in mature technologies like insulation and windows, a substantial potential exist. Newer technologies like PV, heat recovery ventilations systems, heat pumps and air tightness show even larger potentials.

Special attention should be given to optimise building installation systems so that the energy supply systems (e.g. district heating and solar thermal systems) match the house-systems (e.g. heating system, DHW system and ventilation system).

Detailed technical information concerning best practice technologies used in the different Demohouse partner countries can be found in Deliverable 14 report concerning reference project and in the Deliverable 16 report concerning pilot projects.

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1 Introduction

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2 Best practice technologies

In the following single technologies suitable for renovation are presented. The examples are based on the Green Catalogue project.

- Insulation
- Low-energy Windows
- Air-tight Constructions
- Heat Recovery Ventilation system
- Condensing boiler
- District heating systems with low losses
- Combined heat and power
- Heat pumps
- Natural, Hybrid and PV-assisted Ventilation
- Solar DHW Heating System
- PV-installations
- Energy Signatures by help of Energy management System Survey

2.1 Insulation

The most efficient strategy of energy saving in buildings is optimisation of heat insulation. Thermal insulation reduces the heat losses due to transmission and is therefore the condition for a low heating energy demand.

The extra insulation can be added from the outside or the inside. Both will have different consequences, e.g. insulation on the outside will change the appearance of the building facade, and insulation on the inside will decrease the living area. In addition, with internal insulation, care must be taken to avoid the risk of condensation in the outer building envelope.

Insulating the roof is a very important measure, which should be given special attention in every building. As warm air goes up, the temperature in the upper air layers of heated rooms is always a bit higher. That is the reason why a lot of heat can be lost through the roof.

The insulation of a steep roof can be implemented in two ways: by insulating the ceiling of the top floor if the attic is not heated and by insulating the roof construction itself in case of a heated attic. If the last mentioned kind of insulating the roof is applied, five constructional principles have to be differentiated: insulation between the rafters, over the rafters, between and over the rafters, between and under the rafters and an insulation lying outside.

It is also important to insulate the cellar. The insulating material can be implemented either on the ceiling of the cellar or under the ceiling of the cellar. In most cases an additional insulation is used to reduce the sound propagation due to subsonic noise. Another aspect to be aware of when isolating is avoiding cold bridges and airtight constructions in order to avoid draught and unnecessary heat losses.

A measure for a material to transmit heat is the heat conductivity (λ), a value that is characteristic for a specific material, independent of the thickness and the integration of the component. The unit of the heat conductivity is therefore W/mK, i. e. it indicates how much heat (W) passes a component of 1 m² with a thickness of 1 m and a temperature difference of 1 Kelvin (K). The lower the heat conductivity of a material is, the better is its efficiency of insulation.

The quantitative heat losses through a component are measured by the coefficient of thermal transfer, the U-value. Similar to the heat conductivity λ it describes the amount of heat that goes through a component of 1 m², when the temperature difference between the inside and

the outside is 1 K. Its unit is W/m²K.
Insulating materials are such materials that a characterised by a heat conductivity below 0,1 W/mK. The best available insulating materials have λ-Values of 0,025. However, the materials that are mostly used have λ-values of 0,04 or 0,035. They are fixed as a thermal envelope around the area that should be kept warm. Materials that are on the market have very different consistencies. Only few products are completely made of a single raw material. In general, insulating materials can be differentiated in inorganic and organic raw materials, whereas those can again be partitioned in synthetic and natural materials.

Based on the λ-value, the U-value or heat loss coefficient can be calculated as:

U- value (W/m²c°) = λ- value (W/m c°) / Insulation thickness (m)

2.2 Low energy windows

Similar to the insulation of the external wall, the roof and the floor, the insulation of windows has a big impact on the thermal protection of a building. Although the development of the last years is characterised by a big improvement of the energetic quality, windows still have the lowest level of insulation of all external components of a building.

The reduction of the thermal transfer of windows has been reached, as especially the thermal properties of the glazing, which has the highest impact on the heat losses, were improved. Generally there are the following kinds of glazing:

Glazing	U-value for Glazing (W/m²K)	U-value for Window (including frame) (W/m²K)
Single	5,8	3-4
Double	3,2	2,8
Double low-Energy	1,1	1,5-1,7
Triple	2,5	2,2
Triple low-Energy	0,7	1,0-1,2
Passiv House (with insulated frame)	0,7	0,8

Table. 2.2.1: Overview of U-values for different types of glazing and for the whole window –including frame. The values are for standard windows (app. 1x0,7m).

Single glazing (U-values up to 5,8 W/m²K) are no longer common. In old buildings they might though be found and here it can be efficient to apply a secondary removable window – a so called double window or winter window – on the inside.

Efficient glazing consists of two or three layers pane, which are separated from each other by a layer of air. The heat losses due to transmission are reduced to the half of a single glazing, but they are still very high. That is for example the reason why since 1995 efficient glazing is not allowed any more in Germany to be implemented in a new building. A substantial improvement is the high-efficient glazing with U-values between 0,4 and 1,6 W/m²K. The insulating properties are again 50 - 60 percent better than those of the efficient glazing. On the inner layer there is a very thin emission-reducing metal coating, which reflects the long-wave heat back to the room and lets the short-wave sunrays pass through the glazing. Moreover the space between the two layers of glazing is not filled with air but with a rare gas, which has lower heat conductivity. The gas used in most cases is Argon. The difference to the triple high-efficient glazing is, that here the heat losses can be reduced even more through the implementation of a third layer pane and a metal coating on two inner layers. The best thermal insulation can be reached, if one of the even better insulating rare gases Krypton or Xenon is used instead of Argon. Altogether the heat loss through a triple high-efficient glazing is only one eighth of the value of a single glazing. According to the Passive hous Institute, because of solar gains, the net heat losses through triple high-efficient glazing (south orientation) are the same as those through a wall.

As typical measures of windows consist to 15 – 35 percent of frame, the heat losses due to transmission in the frame are important to consider. Here it is both heat losses through the frame (this is not the case for plastic windows) and heat losses through edges and thermal bridges in the frame. Frames are typically made of wood, synthetic material or aluminium. In new types of insulated frames the heat losses has been reduced by help of integrated parts of the construction which breaks the cold bridges.

Wood is the material, which is characterised by the longest lifespan and is best durability against influences from the outside. Usually, frames made of wood have very good thermal insulating properties. The kinds of wood that are used in most cases are spruce, pine and oak.

Frames made of synthetic material are mostly made of polyvinylchloride or polyurethane and can reach values of thermal insulation similar to wood-frames. All in all wood and synthetic materials are those that with a market share of 80 percent are sold in most of the cases.

The heat losses through the windows are also measured by the U-value. The U-value of the complete window is calculated in dependency of the U-values of the frame and the glass, whereby the frame-U-value mostly is the higher one. Another important value is the g-value. It indicates how many percent of the sun-rays with a vertical direction go through the glazing into the room.

Below is showed an example of a questionnaire developed in Denmark and send to Danish window producers to obtain information on available best practice windows especially with respect to total U-value. The result of this is a list of best practice windows for the Danish market. A copy of this is included in annex 1 to this report.

Questionnaire from Cenergia and SBi concerning windows in Denmark made in relation to the Stenloese Syd low energy housing area near Copenhagen.

Please inform in the enclosed form the total U-value and other listed information concerning your window in the European standard size. 1230 X 1480 mm, when mounted with the following three types of glass:

- 2-layer low energy, Argon (typical U-value = 1.2 W/m² °C)
- 3-layer low energy, Argon (typical U-value = 0.7 W/m² °C)
- 3-layer low energy, Krypton (typical U-value = 0.5 W/m² °C).

(Please note that when you show the total U-value the frame losses of the window should be included).

The form can be copied, so it is possible to forward information about different frame constructions.

Manufacturer: **Window type:** **Date:**

Glass type:	**2-layer with Argon**	**3-layer with Argon**	**3-layer with Argon**	**Better alternatives / please specify**
Total U-value of window W/m² °C				

Glazed area U-value W/m² °C				
Frame area U-value W/m² °C				
G-value for the glazed area				
Glass %				
Hot perimeter of glazing YES/NO				
Opening (IN/OUT)				

Table2.2.2

2.3 Air tight constructions

There are several reasons, why an airtight implementation of the building envelope is very important:

- The reduction of heating demand: Especially during the winter the thermal lifting results in a high temperature difference between the inside and the outside of a building. Consequently, in the upper part of the building the warmed air flows through points of leakage to the outside (exfiltration), whilst in the lower part of the building cold air pours through untight locations to the inside (infiltration). There is also infiltration due to wind pressure to assure a convenient indoor climate, the cold air has to be warmed up, so that the unintentional air exchange results in a higher heating demand.

- Comfort: As a consequence of the thermal lifting, the inward flow of cold air into the building generates inconveniences. An airtight construction avoids infiltration.

- Prevention of structural damages: A high air humidity results in the creation of condense, which causes humid areas in the wall because of lower temperatures – and with it structural damages in the building envelope.

To assure an air tight building envelope, moisture brakes or even moisture barriers are attached in order to prevent humidity to get into the construction and the thermal insulation. It is very important, that these foils are fixed very accurately, because otherwise they do not have any effect. The following table shows values for air change pr. hour (ac/h):

Air change pr. hour (ac/h)	
International standard	0,5
Ordinary buildings	0,25-0,4
Low energy houses	0,05-0,1

Passiv houses	0,03 (0,6 at 50 Pa)
Note: the given values are for 0 pa. When testing air tightness with a blowerdoor each value has to be multiplied with a factor 20.	

Table.2.3.1: Air change pr. hour for different kinds of buildings.

To guarantee a construction without any leaks it is recommended to develop a leak tightness concept and to locate weak points in the envelop by a so-called Blower-Door-Test. In this test a ventilator creates a constant pressure of +/- 50 Pascal (Pa). Depending on the tightness of the building the ventilator has to work more or less strong to obtain a specific pressure in the building. Thus, the measure of untightness can be deduced with the help of artificial smoke and the untight points can be located.

The verification of an airtight construction can be done by the above mentioned Blower-Door-Test. The n_{50}-value indicates how often the complete air in a room is changed within one hour monitored at +/- 50 Pa. In case of a ventilation system applied, this value has to be smaller than in the case of window ventilation.

Fig. 2.3.1: Blower Door test in an apartment.

Fig. 2.3.2: Example of registration of white smoke movement to trace cracks and crevices in combination with the blower door test.

<u>Air tight constructions – Practical implementation</u>
The air-tightness should be ensured on the inside of external constructions by help of a vapour

barrier of e.g. aluminium foil or plastic film.
On the outside wind-tightness should be ensured to protect the building construction against bad weather conditions. The first thing one should do when ensuring the air-tightness of a building is to check the joints between the different parts of the external constructions, e.g. the windows/doors and walls. By sealing up joints between the different external constructions a good result can be achieved with low costs.

According to the German Passiv Haus Institut the most important rule for achieving good air-tightness is to seal the whole building with an air-tight layer (see Fig. 3.5).

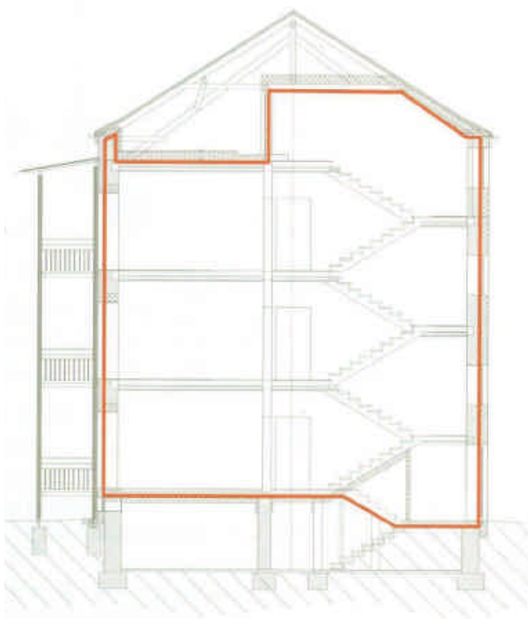

Fig. 2.3.3: Air tight layer (in red) wrapping the whole building.

See the report for Deliverable 5, Air tightness Guidelines, for detailed information on securing air tightness.

2.4 Heat recovery ventilation system

Because of the increased demands for low-energy ventilation systems in buildings there has been a great interest in development of heat recovery with mechanical ventilation systems, where outlet air is used for preheating of inlet air. To reach a low value for energy use and especially heat consumption in a building a heat recovery ventilation system with high efficiency is necessary. E.g. a passive house can only be realised with high effective heat recovery ventilation.

Fig. 2.4.1: Illustration of a heat recovery unit placed in connection to the ventilation system in a closet. This solution makes the maintenance easier.

Not only energy consumption is decreased by heat recovery ventilation systems with low electricity use, but also the indoor air quality is improved, which not only is a benefit for the tenants but will also prevent e.g. moisture damage in buildings.

To meet the demands for energy efficient ventilation system the following requirements should be satisfied:

- ✓ The dry efficiency of the heat recovery heat exchanger should be at least 80-90 %.
- ✓ Power consumption of the ventilation system should be only 30-40 W (0,24 W/($m^3/h_{air\ change}$)) (Danish Building Regulation demand is 87 W).
- ✓ The building should be complete air tight (natural infiltration should be 0,05 /h and never higher than 0,1 /h).
- ✓ The ventilation system should be installed inside the building envelope.
- ✓ The noise level should be less than 25 dB.
- ✓ For privately owned ventilation systems demand controlled operation f.ex. in min, mean, max as well as summer and winter is a normal demand.

In the Demohouse project, it has been aimed to develop a cost-effective heat recovery unit, with improved electricity efficiency and improved thermal efficiency in practice. In a new series of fans with backward curved blades the electricity consumption is decreased considerably from the former normal level. Also a DC engine has been developed where the electricity consumption incl. converter is 20 % below this level.

The main focus should be on individual heat recovery units for each apartment, due to risk of malfunction, more simple control and avoidance of heat losses in a cold loft room. Here there is a big need for solutions with a documented low electricity use and low noise. A solution with individual 15-25 cm thin air to air heat exchangers from the Danish company EcoVent has been developed. These can be integrated along the walls or loft in a simple way and with simple maintenance possibilities (e.g. change of filter). To make it possible to check the low electricity consumption for ventilation an easy check system for this is foreseen.

There will have to be ventilation with heat recovery if the aim is a total energy use below 65 kWh/m^2 per year for heating and hot water. In all cases a sufficient air change of 0,5 per hour shall be acquired. In case of mechanical ventilation max. 0,05 /h air change shall be through natural infiltration equal to 1,0 per hour at +/- 50 Pa blower door test.

User controlled ventilation can be 126 m^3/h or 0,5 /h at normal conditions and 65 m^3/h as a minimum value when you are away. There is a need for summer operation with a by pass function (to avoid overheating of the dwelling) and winter operation with a reduced fresh air amount when the temperature is below -5ºC (to reduce heat losses?). Relative humidity should not exceed 60 % and filtering is needed.

A reduction in energy consumption can best be obtained with a user controlled ventilation system and use of energy efficient components in optimal designed solutions. Also service and proper cleaning of the ventilation system is necessary (FK: how often?). The air velocity for ventilation shall be below 0,15 m/s in rooms to prevent draught problems for the tenants.

2.5 Condensing gas boiler

The condensing gas boilers are used both in single and central heating systems. An optimal use combines a condensing boiler, a heating solar panel and a low temperature heating system (floor heating) so as to achieve an optimal condensation and exchange of latent heat of exhaust gas fumes.

From a technical point of view the condensing gas boilers operate in two different fields of temperature with different efficiency: at 50/30°C (between sent and return temperature), they achieve a mean efficiency of 105% (Best available technology – BAT: 107%), while in the field between 80/60°C they achieve a mean efficiency of 96% (BAT 98%). The difference is due to the recovery of condensation heat in exhaust gas fumes.

The energy efficiency of the condensing gas boilers has been increased from the variable flame, where the variation of the air flow in the burner according to instantaneous needs, avoids low efficiency on-off cycles. From the ecological and waste emission point of view, the emissions are respectively: CO_2 9 mg/kWh NO_x 40-44 mg/kWh, CO 15-19 mg/kWh. The generators available on the market are of various sizes that cover all the requirements of a traditional heating system, but a higher initial investment is necessary.

2.6 District heating systems with low losses

District heating is a system that transfers and distributes heat from one or more heating plants to residential commercial and industrial consumers for space heating, hot water heating and industrial processes. A district heating system consists of heat production units, which could be a combination of heating-only plants, combined heat and power production plants, waste heat recovery plants, peaking and standby heat plants, primary heat distribution network, substations at the consumer connection points, end-users secondary networks and installations for space heating and domestic hot water.

The heat carrier in the heat distribution system can be either hot water or steam. The hot water in the distribution system can be generated in heating-only boiler plants, in combined heat and power production plants, from industrial waste heat recover, refuse incineration plants or sometimes from geothermal sources.

District heating is a natural solution for provision of heat in built-up areas. It helps keep the environment clean and increases housing comfort. District heating also helps conserve energy and the environment. This conservation is best realised in combined heat and power (CHP), which utilises 80–90 per cent of the energy value of fuel. When electricity is generated separately, the utilisation rate of fuel energy is a mere 40–50 per cent. Thanks to the efficiency of CHP, emissions to the environment are about 30 per cent less than in separate generation of electricity and heat (read more about CHP below). Heat is produced using a varied selection of fuels – natural gas, coal, peat, wood and waste wood, or oil – while also paying attention to overall economy and to the impact on the environment. Useable heat from industrial production can also be utilised for district heating

2.6.1 Heat supply

District heat is generated either together with electricity at combined heat and power plants (CHP) or solely as heat at heating plants. The temperature of district heating supply water varies depending on the country standards and weather, being for example 65-115° C. The temperature is at its highest in winter and lowest in summer, when heat is only needed for hot service water.

2.6.2 Heat distribution

District heat is transmitted from production plants to clients as hot water in a closed network consisting of two pipes (flow and return pipes). District heating pipes are laid in the ground, usually at a depth of 0.5 to 1 metre. The pipes have effective thermal insulation. On an average, heat losses in the distribution network account for less than 10 per cent of the energy transmitted in the pipes. Pump energy generally is in the order of x% of the heat transported.

The water circulating in the flow pipes releases its heat to clients via heat exchangers. The return pipe conveys the water back to the production plant for reheating. The temperature of return water from clients to the production plants ranges in best cases between 25 and 50 °C. The district heating water in general does not circulate in the space heating networks of buildings, but also direct connection variants to consumer equipment exist.

2.6.3 End users equipment

Clients receive the district heat in the substation, which includes the heat exchangers for heating and service water and possibly a heat exchanger also for air conditioning, control devices, pumps, expansion and safety equipment, thermometers and manometers and shut-off valves and energy metering. Substations are industrially manufactured units. Clients acquire their district heating equipment and the related installation work from heating contractors or, as comprehensive deliveries, from district heating suppliers. Heat is used in buildings for space heating, for providing hot tap water and for air conditioning. Also cooling of buildings by using district heating supply water in absorption chillers has been introduced lately.

2.6.4 Heat metering

The amount of heat consumed in the building is measured. The components of the heat meter are: a flow sensor, a temperature sensor pair, and a calculator. The flow sensor measures the volume of circulating district heating water. The temperature sensor pair constantly measures the temperatures of water going into the building and coming out of the building. Based on the readings of the flow sensor and the temperature sensor pair, the calculator calculates the thermal energy used for space heating and for hot service water. The calculator automatically takes into account the water density and specific heat corresponding to the temperature. The heat consumed is shown by the calculator as megawatt-hours (MWh).

Fig. 2.6.4.1: Metering device.

2.6.5 Reliability

Supply of district heat is very reliable (in Denmark, how about other countries?). On an average, in large DH-systems operation interruptions resulting from damages in the district heat network and the consequent repair work leave the individual client without heat as an average for only one hour a year. Thus, the reliability of supply in district heating is nearly 100%. District heating is also operation and maintenance free for clients – as the maintenance is included in the fee paid by the clients.

2.6.6 Potentials for development of district heating systems

Increased temperature difference/ low temperature systems: At low and medium load times a high temperature difference is desirable because it can save pumping energy and in many cases can reduce distribution heat losses. Low return temperatures improve also operating conditions and efficiency of CHP.

Heat driven district cooling

In a cold climate there are in summer months plenty of heating capacity available in district heating systems, e.g. for heat-driven cooling. The research issues are how the present one stage water/LiBr absorption process is operated with low temperature district heat. Another problem is the hydraulic restriction of maximum water flow in existing district heating transmission pipelines. The heating demand at wintertime limits the cooling load produced by absorption chillers to about 20% of wintertime maximum load. In warm climate the annual electric power peak occurs in summer, partly due to electric air-conditioning and refrigeration. If a part of the air-conditioning cooling demand would be covered with heat driven cooling machines, the power peak would be shaved off.

Incorporation of solar energy storage

Solar district heating with short-term and seasonal storage have been introduced, mostly in Denmark and Germany. Short-term storage systems are used mainly for the preparation of hot water and able to store heat for one or two days. Therefore the solar fraction of the total heat demand is limited to about 10-20%. The so called week storage system has relatively large collector area per living area (4-10 m^2/m^2) (FK: what do you mean with m^2/m^2?)and projected solar fraction 30-40%. An innovative solar–district heating system called pulse heating has several buffer tanks connected to solar panels and district heating network. The buffer tanks are heated by solar energy with district heating as backup. One tank in turn is filled with hot DH-water as a pulse and other times the DH circuit is closed for reduced pipe losses. The first experiences call for remarkably reduced heat losses and 40-70% annual solar fraction.

2.7 Combined heat and power

Combined heat and power (CHP), often referred as co-generation, is the joint production of heat (steam or hot water) and electricity from a single fuel source, which can result in the overall efficiency up to 70 – 90%. Some CHP systems produces also chilled water from the heat. This is often called tri-generation. Conventional electricity production plants convert about 30 to 40% of fuel energy into electricity, while the rest is lost as waste heat.

Combined heat and power systems can be implemented on many different levels. At the largest scale, utility heat production can cover a whole city through a district heating system and generated power is supplied into national electricity grid. Large scale CHP installations, typically hundreds of MWth and MWe, are found in process industry and in district heating of large cities, mainly in northern Europe. Small-scale CHP installations, typically below 1 MWe are installed within the buildings that they serve, are relative common in the middle and south Europe. Dimensioning of the CHP plat will be made according to the heating load. The electricity output will be used first in house and secondly sold to the electricity grid.

Power-generation technologies, which can be applied in small scale CHP systems, include advanced turbine systems, reciprocating engines (Otto and Diesel), micro turbines and fuel cells.

In large scale CHP systems back-pressure turbines, gas turbines and diesel engines are typically used in power generation. Practical uses for co-generated thermal energy include process heating, space heating, water heating, absorption chillers, engine driven chillers, desiccant dehumification, compressed air and industrial processes. In traditional CHP/DH plants heat is extracted from major power plants and supplied to city district heating networks or for industrial use.

2.8 Heat pumps

Heat pumps are used for transforming free heat from sustainable sources: air, water, ground and waste heat at a relatively low temperature (0-10 °C), to a useful temperature level (typically 30-50°C). They are used for residential and commercial rooms for heating, cooling and domestic hot water heating as well. A high number of different heat pumps exist and they vary in size, price and efficiency depending on its purpose. Most are electrically driven, but the latest developments include natural gas driven heat pumps.

Heat pumps for heating and cooling purposes in buildings can be divided into four main categories depending on their operational function:

- Heating-only heat pumps, providing space heating and/or water heating.
- Heating and cooling heat pumps, providing both space heating and cooling.
- Integrated heat pump systems, providing space heating, cooling, water heating and sometimes exhaust air heat recovery.
- Heat pump water heaters, fully dedicated to water heating.

It is considered that using heat pumps can significantly reduce CO2 emissions. In some European Countries heat pumps are treated as a renewable energy source. This allows obtaining some donation from environmental funding. A heat pump does not require chimneys or gas or oil installations, and it does not produce any pollutions or wastes in the nearby environment.

The heat pump is a machine, which can change heat from a low level of temperature to a higher one. As a low level temperature heat source the following are usually used: ground (vertical or horizontal heat exchangers), ground and surface water (open or close loop), outdoor and exhaust air. A good idea may be to use waste heat as a low temperature heat source, where the heat is transformed to a higher level of temperature by the heat pump. The heat is usually released to a central heating system or/and domestic hot water. It is also possible to make a reversible operation with the heat pump in cooling mode.

Below are shown two kinds of heat pumps: heat pump using heat from the ground and a heat pump using heat from the outside air. The last mentioned are popular in holiday cottages and patios. The one shown on the picture is connected to a small PV-plant producing the necessary electricity for running the pump.

Fig. 2.8.1: Heat pump producing heat for 8 apartments using heat from the ground.

In the heating mode, the external fluid returns from the ground and passes through the heat exchanger. Within the heat exchanger the internal fluid is allowed to expand and change state into a gas (vaporization) drawing the heat of vaporization from the external fluid. This gaseous fluid is then pumped to the compressor which compresses and liquefies the fluid releasing the heat of vaporization into the heat sink (heating system, domestic hot water etc.). The cooled external fluid is then pumped back into the pipes running outside the house, where its temperature is lower than the temperature of the surrounding soil. It once again absorbs the heat from the ground and the cycle repeats.

In the cooling mode, indoor air is drawn through a heat exchanger where the internal fluid is allowed to expand and evaporate absorbing the heat of vaporization from the air. The gaseous fluid is then pumped to the compressor where it is compressed back into a liquid releasing the heat of vaporization into the external pipes via a second heat exchanger. The fluid in the external pipes is then pumped out into the heat field where its temperature is higher than the temperature of the surrounding soil. The soil absorbs the heat and the cooled fluid returns to the house to repeat the cycle.

Nowadays there are also heat pumps with direct evaporation and accumulation in a vertical tank. This can reduce the number of heat exchangers, pipe's connections and length of installation. This type of heat pumps usually consume less energy for pumps and compressors, gives heat at higher temperature level and because of less cost became quite popular especially in single family houses.

It can be formulated following limitation in heat pomp using:

- Because a heat pump operates most effectively when the temperature difference between the heat source and heat sink (distribution system) is small, the heat distribution temperature for space heating heat pumps should be kept as low as possible during the heating season. For example replacing conventional radiators (60/50°C) with floor heating (35/30°C) may increase COP (see 2.8.1) from 2.5 to 4.0. For more information see description of technology B.12. Low Temperature Heating System.
- It is quite difficult to control working of heat pumps. In most cases it is only possible to use an on/off kind(?) of control strategy. This is the reason for additional requirements for central heating and/or domestic hot water systems.
- Continuous access to low level temperature heat source should be provided. In some cases it may be difficult (large ground area for horizontal ground heat exchanger, lack of pond, river or lake) or expensive (cost of energy consumption of ground water pump, cost of constructing low level temperature heat exchanger).

Refrigerants should have as low environmental impact as possible - ozone depletion and global warm potential.

2.8.1 COP coefficient

The heat delivered by a heat pump is theoretically the sum of the heat extracted from the heat source and the energy needed to transform the heat from low temperature level to higher one. The steady-state performance of an electric compression heat pump at a given set of temperature conditions is referred to as the coefficient of performance (COP). It is defined as the ratio of heat delivered by the heat pump and the electricity supplied to the compressor (and shows how much heat is delivered by using one amount (kWh) of energy). The COP of a heat pump is closely related to the difference between the temperature of the heat source and the output temperature of the heat pump. The COP drops with the increasing of condensation temperature.
As the heat pump uses electricity it might be necessary also to take into account the amount of energy used for producing the electricity. With a factor 2,3 used for the production of electricity a heat pump with a COP of 3,0 will have a resulting energy efficiency of 1,3 (3,0/2,3). This number is called the PER or Primary Energy Ratio. This is an important aspect to consider when calculating the energy efficiency of the house and might be demanded by implementation of EPBD.

The COP of a (theoretical) ideal heat pump is determined by the condensation temperature and the difference between condensation and evaporation temperature. This number is theoretically the highest efficiency of any heat pump operating at these temperatures. The ratio of the actual COP of a heat pump and the ideal COP is defined as the Carnot-efficiency. The Carnot-efficiency varies from 0.30 to 0.5 for small electric heat pumps and 0.5 to 0.7 for large, very efficient electric heat pump systems.

2.8.2 Performance

The operating performance of an electric heat pump during the season is called the seasonal performance factor (SPF). It is defined as the ratio of the heat delivered and the total energy consumed over the season. It takes into account the variable heating and/or cooling demands, the variable heat source and difference in sink temperatures over year, and includes the energy demand, for example, for defrosting. The SPF also takes into account the energy use for pumps, fans, electronics etc. The SPF can be used for comparing heat pumps with conventional heating systems (e.g. boilers), with regards to primary energy saving and reduced CO_2 emissions. However SPF is very useful in practice it is quite difficult to obtain.

The performance of heat pumps is affected by a large number of factors. For heat pumps in buildings these include:

- the climate - annual heating and cooling demand and maximum peak loads;
- the temperatures of the heat source and heat distribution system;
- the auxiliary energy consumption (pumps, fans, supplementary heat from peak load heating system etc.);
- the technical standard of the heat pump;
- the sizing of the heat pump in relation to the heat demand and the operating characteristics of the heat pump;
- the heat pump control system.

2.9 Natural, hybrid, PV-assisted and demand controlled ventilation

With the high demands for ventilation systems, there is a great need for energy efficient ventilation systems. In connection with this natural, hybrid and PV-assisted ventilation systems are very interesting topics.
A Danish research project has shown that natural ventilation can work well and also be a good solution regarding indoor climate. The analyses show that natural ventilation can be sufficient as ventilation in e.g. row houses, if the design and function of building is integrated in an architectural way that optimises the natural ventilation, but it is at the same time clear that you can not obtain savings of the ventilation heat losses, so it is not so useful for real low energy buildings. Benefits of natural ventilation are listed below:

- Provides effective whole house ventilation without electricity use
- Prevents (?) condensation and mould growth
- Continuous gentle extraction
- Improved acoustic quality, < 25dBA
- Simple installation
- Unobtrusive
- Minimal maintenance

The most optimal solution for natural ventilation is where all rooms are located on the same side in a row house. In this way the ventilation will be dominated by thermal buoyancy because the outdoor air will enter through the windows to the rooms on south side, and exit through a tall chimney element on north side that has outlet from kitchen and bath room.

In an energy efficient demonstration project of a public school, Egebjerg School, in Ballerup in Denmark natural ventilation has been used. The implemented technologies connected with natural ventilation are:

- Advanced EMS-system with control of heat, ventilation and lighting.
- Combined use of natural and mechanical ventilation.
- Pre-heating of ventilation air through channels in ground and through a so called Canadian Solar Wall (with small holes for air inlet) and convectors in class rooms.

In the centre of the area that was chosen for renovation there is a space with double height compared with the rest of the building and on the roof of this space a ventilation chimney has been placed for natural ventilation. The primary drive force is the wind pressure. By help of an EMS-system the windows in ventilation chimneys can be opened in lee side. If there is no wind at all thermal drive forces are activated. The height is therefore an important factor. When the temperature difference between inside and outside in summer times is very low an absorber built in the ventilation chimney provides the necessary drive pressure by help of the so called chimney effect (hot air rises). The amount of ventilation is controlled on background of CO_2- and temperature sensors in class rooms.

The heat consumption with pre-heating of ventilation air is 97 kWh/m^2, and was 181 kWh/m^2 before the renovation and users are very satisfied with the improved indoor air climate.

The electricity saving with natural ventilation, electricity efficient ventilation and EMS control is 13,5 kWh/m^2 per year. Before renovation the electricity consumption was 36 kWh/m^2 per year. Also indoor air climate has been improved and the amount of CO_2 is satisfying.[1]

Regarding PV-assisted ventilation PV-VENT system has been developed. PV-VENT combines building integrated PV with high effective ventilation systems. The PV produces direct current (DC) which can run low consuming DC-engines in a new generation of effective counter flow heat exchanger. In this way energy loss and an expensive converter installation can be avoided.

Counter flow exchanger is run with an electricity consumption of only 20-30 W, equal to 150-200 kWh per year. 25-50 % of this electricity consumption can be covered by electricity from building integrated PV directly coupled to the ventilation fan, by help of a so called PV-mixer ISO supplemented electricity can be taken from the grid f.ex. during the night. Oriented to south an optimal PV area is assumed to be 0,7 m^2 per dwelling for crystalline panels and 2 m^2 per dwelling for amorphous panels. The ventilation system in a PV-VENT system shall be with low electricity consumption with counter flow heat recovery, where the outlet air is used for preheating of the inlet air. The heat recovery of outlet air shall be 80-90 %. Alternatively you can also utilize indirectly coupled PV-VENT systems where PV electricity is fed into the grid and is designed to match electricity use for ventilation on a yearly basis. Here PV-areas of 0,2 kWp – 0,25 equal to 2 – 2.5 m^2.
Crystalline modules can be used per dwelling (in Denmark approx.800 kWh/kWp can be gained from PV modules on a yearly basis). This is approx. 1000 kWh/kWp for Austria and Hungary while Spain and Greece will have 1200-1600 kWh/kWp.

Fig. 2.9.1: Small ventilation unit for sunspaces which is operated by help of a small PV-plant, which produces the needed electricity for operation of the fan. A operation the fan. A ventilation rate up to 400 m^3/h is possible. FK: The PV module is about ¼ m^2, so it generates about 25Wpeak, which is far too little to drive the heat pump.

[1]*Reference: Solar Energy and Urban Ecology, Peder Vejsig Pedersen, Ingeniøren|Bøger, 2002*

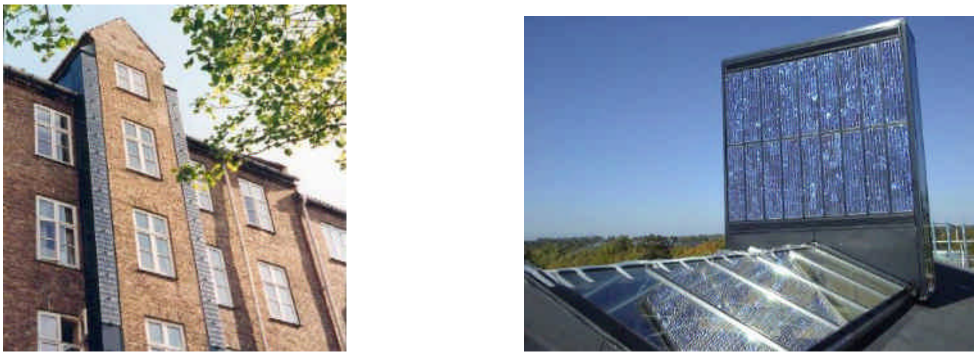

Fig. 2.9.2: PV-assisted solar ventilation towers and PV-chimney were PV modules are directly operating DC-fans.

In all cases it will be a good idea to include demand controlled ventilation, f.ex based as a humidity sensor or user input. At the same time a minimum ventilation should be secured f.ex aiming at an airchange of 0.5/hour.

2.10 Solar domestic hot water heating system

The European solar thermal market has shown substantial growth over the past decade, with solar collector sales amounting to about 2 million m^2 in 2005 (the total number of installed m^2 was in 2004 about 16 million and the EU target for 2010 is a total of 100 million m^2 (Estif 2005)). However, Germany, Greece and Austria account for 80% of the collector area in operation throughout Europe. When the glazed collector area is related to the population, the leading roles of Austria (about 275 m^2 per 1.000 capita) and Greece (about 270 m^2 per 1.000 capita) becomes even more evident, compared with the EU average of 24 m^2 (Estif 2006). In recent years the market for solar domestic hot water systems in Spain, Italy and France has been growing faster than the EU average, but the market is still largely dominated by the strength of the market in Germany.

Solar DHW systems can be successfully implemented at all latitudes. Some of the strongest markets (Germany, Austria) are not situated in particularly sunny regions, whereas for instance Spain and Italy are clearly lagging behind. Factors like general awareness of the environment; public support and the quality of the products/services offered by the industry have proven to be at least as important as climatic conditions. The potential for growth in the near future is therefore immense.

The functionality of a solar system is a result of two factors: the quality of its components (collectors, tank, control units etc.) and the quality of the system design and installation.

Solar collectors can also be used for space heating water. This kind of system is mainly used in the northern and central part of Europe: In Austria they have a market share of 35% (Estif 2005).

2.11 PV-installations

Photovoltaic means the direct transformation of sunlight into electric current. In general, two types of PV-systems can be identified: there are systems with mains connection and isolated operated systems and these are the type of PV-systems standing-alone, which means that they have no connection to the public power supply system and therefore need a battery for storage.

PV installations constitute a long-term and relatively expensive investment. Therefore, it is essential that an exact design of a certain PV installation is carried out.

In order to be able to design a PV installation extensive and precise information of a wide range of parameters are required, e.g. climatic data, characteristics for PV-modules, configuration of PV-panels, placing of PV-panels, load on PV-panels, current inverter data, the wanted electricity production over a year etc.

On basis of this information it will be possible, via a computer and relevant software, with considerable accuracy to simulate the yield of a certain PV installation. Simulations like this can be calculated by knowledge centres and consulting engineers.

The technique of a PV-installation is based on the photovoltaic effect: if light (photons) hits a solar cell, electrons are released out of the crystal structure of the semiconductor material. This process results in an electrical current.

The main components of a PV-system are the solar cell, the solar module and the inverter. The solar cell is the part of the installation, in which the transformation of light into electric current takes place. More than 95 per cent of all solar cells that are produced in the world are made of Silicium. In order to get a useful performance, mostly 30 – 36 solar cells are put together to a solar module. The totality of the modules is called solar generator. The voltage of the PV-installation depends on the number of modules connected in series, whilst the number of modules connected parallel determines the electrical current.

The inverter creates the connection between the solar generator and the distribution net. As the produced electric is direct current, the inverter has to transfer it to alternating current, in order to deliver it to the public power supply system.

The performance (measured in %) of a PV-installation depends on different factors. These factors are apart from the position the slope, the orientation, the performance ratio and the efficiency of the inverter.

Estimated actual efficiency of modules (modules with silicon cells)	Standard	High-efficiency
Monocrystalline, close-packed	12%	15%
Polycrystalline, close-packed	10%	13%
Amorphous /thin film	5%	9%

Table. 2.11.1: Estimated actual efficiency of modules

The performance ratio is the measure of the system efficiency of the PV-installation. With the help of this factor, PV-systems at different positions can be compared with each other. It is the relation of the actually produced current to the theoretically expected current of the solar generator. The actually produced current is lesser than the theoretically expected, because it includes occurring losses. The higher the performance ratio of a PV-installation is, the better the proceeds of current will be.

Estimation of system coefficient	Detached	Building integrated
Optimal installation with high-efficient	0,8	0,75

current inverter		
Average installation with standard current inverter	0,7	0,65
Less optimum installation, e.g. some shadows	0,6	0,55

Table 2.11.2. Estimation of system coefficient

Other factors which characterise the energy efficiency of a PV-system are the night-consumption, the energy use in stand-by modus and the input start. All of these factors are measured in Watt (W). The lower these values are the less energy is used by the installation.

2.12 Energy Signatures by help of Energy Management System Survery

Energy Signatures like a heat consumption characteristics has been used to evaluate effect and energy use as a function of ambient temperatures. This means a 3-4 month monitoring period is enough for an energy performance evaluation, see Fig. 1.13 below.

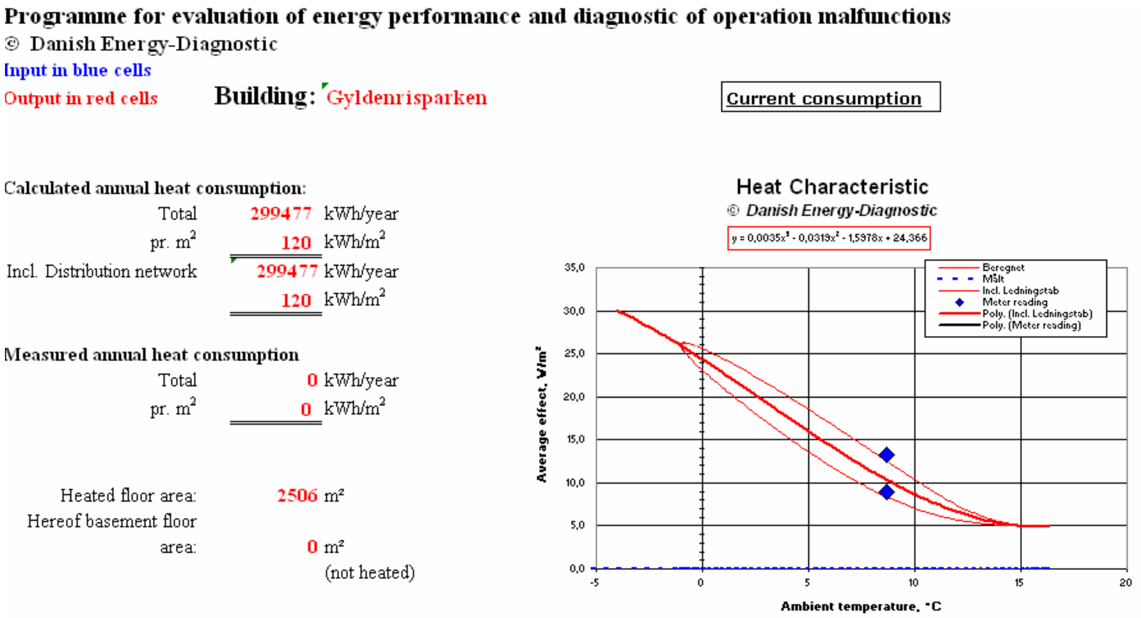

Fig. 2.12.1: Energy Signature for a building project

The energy signature will typically show the effect demand f.ex. in (W/m^2) as a function of the ambient temperature in C°. Here a graph can be presented based on calculations and when you have monitoring results, you can compare to these and see if the operation is according to what was expected. More information can be found in deliverable D4, D5 and D17 of the Demohouse project as well as in D22, the Common Evaluation Protocol.

3 Best Practice Overview

The tables below quantify the current Best Practice for Europe, divided into 3 geographical regions. For each technology, the relevant performance indicators are given, and values are listed. Values for 3 situations are given:

1. The present state in 2006 where the EPBD is implemented.
2. The expected values (target/goal values) for 2011, where stricter requirements are expected based on the EPBD
3. The current Best Available Technology.

The geographical zones in which Europe is divided are based on climatic regions. Countries within a zone may not have exactly the same requirements or best practice, but using the3 zones gives a good overview. Where relevant, country specific information is given. The zones are (bold names indicate a country participating in Demohouse):

Zone I: Finland, United Kingdom, **Denmark** France
Zone II: Germany, France, **Austria, Hungary**
Zone III: **Greece**, **Spain**, Italy

In chapter 3.1 following the tables is supplementary information, specific to the countries participating in the Demohouse project. Detailed country specific information on what kind of technologies were considered and applied (or rejected) in the Demohouse renovation projects and why is discussed in deliverables D14 (for the reference projects) and D16 (for the pilot projects).

Technology	Relevant Indicators	Performance Requirements			Check Systems and standards
		2006 (Present situation)	Goal for next EPBD in 2011	BAT (Best Available Technology)	
A. BUILDINGS					
1. Insulation	U-value [W/m²K] External Wall:	I: 0,2-0,6 II: 0,25-0,45 III: 0,15-0,7	I: 0,1-0,6 II: 0,11-0,4 III: 0,1 GR: N/A	I: 0,1-0,2 II: 0,1-0,3 III: 0,1-0,35	EnEV Passivhaus-Institut SAP RATING Building Regs
	Roof:	I: 0,13-0,6 II: 0,2-0,25 III: 0,1-0,5	I: 0,08-0,6 II: 0,11-0,2 III: 0,08-0,1 GR: N/A	I: 0,1-0,12 II:0,1-0,2 III: 0,1-0,4	STYROFOAM NBE-CT 79; UNE 92115/97 for XPS (extruded)
	Floor (ground/ unheated rooms):	I: 0,12-0,6 II: 0,35-0,45 III: 0,2-2 GR: 0,7-3.0	I: 0,09-0,6 II: 0,15-0,4 III: 0,1 GR: N/A	I: 0,12-0,18 II: 0,1-0,3 III: 0,12-1,2	Stamp INCE-AENOR (www.dow.com)

Technology	Relevant Indicators	Performance Requirements			Check Systems and standards
		2006 (Present situation)	Goal for next EPBD in 2011	BAT (Best Available Technology)	
2 Energy Windows	U-value [W/m²K] Total:	I: 1,0-1,8 II: 0,8-1,5 III: 1,1-3,2	I: 1,0-1,8 II: 0,5-1,2 III: 2,8	I: 1,0-1,7 II: 0,6-1,2 III: 1,1-2,8	Windows: DIN EN ISO 10077-1:2000-11; DIN 4108-4 Passivhaus-Institut FENSA Glass: DIN EN 673:2001-1; DIN EN 410:1998-12 Cold bridge coefficient: DIN EN 10211 + DIN 4108-2
	Glass:	I: II: 0,5-1,2 III:	I: II: 0,4-1,1 III:	I: II: 0,5-1,1 III:	
	Frame:	I: II: 0,85-1,5 III:	I: II: 0,75-1,3 III:	I: II: 0,64-1,07 III:	
	g-value [%]	I: II: 60-71 III: 58 GR: 77	I: II: 25-67 III:	I: II: 50-58 III: 55-58 GR: 77	
	Cold bridge coefficient glass: ψ [W/mK]	I: II: 0,06 III:	I: II: 0,034 III:	I: II: 0,017-0,022 III: 0,0-0,65	

Technology	Relevant Indicators	Performance Requirements			Check Systems and standards
		2006 (Present situation)	Goal for next EPBD in 2011	BAT (Best Available Technology)	
3. Air Tight Constructions	n_{50}-value [1/h]: (Air change per hour, monitored at +/- 50 Pa) Infiltration [1/h]: Permeability ($m^3/h/m^2$), Naturally ventilated dwelling: Dwelling with balanced whole house ventilation: Leakage factor, Air permeability of windows (three different classes) [m^3/hm^2Pa] A3: 0,35 A2: 1,00 A1: 2,50 Without classification: 5,00	≤ 2,5 ≤ 1,3 (in case of ventilation systems applied) 0,14 5 3 Class A3	≤ 2,2 ≤ 1,2 (in case of ventilation systems applied) 0,12 5 3 Class A3	≤ 0,6 0,04 10 5 Class A3	Blower door test DIN EN 13829:2001-02 DIN EN 832 Applied Pressure difference test of 50 Pascal (Pa) Building Regulations UNI 7979 UNI 10344
B. INSTALLATIONS					

Technology	Relevant Indicators	Performance Requirements			Check Systems and standards
		2006 (Present situation)	Goal for next EPBD in 2011	BAT (Best Available Technology)	
4. Heat Recovery Ventilation with Low Electricity Use (D, PO)	Electricity consumption: (See note below)	800-2000 W/(m^3/s) 25 W electricity use per dwelling (0,20 W/(m^3/h))	200-1.200 W/(m^3/s) 25 W electricity use per dwelling (0,20 W/(m^3/h))	Mech. vent.: 200-1.200 W/(m^3/s) 87 W per dwelling (0,28 W/(m^3/h); 0,15W/(m^3/h) for small local devices)	Electricity, temperature and noise monitoring. Efficiency is confirmed. VDI 2071 TZWL- European Test Centre for Heat recovery ventilation. VOB/C- DIN 18 379 (supply test) VDI 2088 VDI 2081 Electricity and noise monitoring
	Electricity use for ventilation [Wh/m³]:	0,41	0,39	0,26	
	Heat recovery:	80-92 %	85-95 %	70-99 %,	
	Volumetric current [m³/h]:			75 - 230	
	Noise level:	25-28 dB(A)	25 dB(A)	25 dB(A)	
	Exhaust only, Electricity consumption:	400-1000 W/(m^3/s))	100-600 W/(m^3/s))	100-600 W/(m^3/s))	
	Noise level:	28 dB(A)	25 dB(A)	25 dB(A)	

Note: In some cases also electricity use to avoid freezing problems. Alternatively a reduced inlet air volume can do the same. Dependant on pressure loss, here 20-300 Pa at 600-2.400 m^3/h:

Exhaust		SEL low-energy	SEL normal
2.400 m^3/h	300 Pa	517 J/m^3	1.350 J/m^3
1.500 m^3/h	120 Pa	272 J/m^3	1.086 J/m^3
600 m^3/h	20 Pa	107 J/m^3	1.036 J/m^3

Technology	Relevant Indicators	Performance Requirements			Check Systems and standards
		2006 (Present situation)	Goal for next EPBD in 2011	BAT (Best Available Technology)	
B. INSTALLATIONS					
5. Natural, Hybrid and PV-assisted Ventilation	CO_2 conc. in air CO_2 concentration [%]: Humidity: Temperature, inlet: Air change/hour: Heat recovery: Noise level:	< 1000 ppm CO_2 GR: 600 20-70 % 21-26 °C ES: 21-25 °C GR: 20-26 °C 0,5 25 % < 25 dB(A) ES: < 30 dB(A)	< 1000 ppm CO_2 20-70 % 21-26 °C ES: 21-25 °C 0,5 50 % < 25 dB(A) ES: < 30 dB(A)	< 1000 ppm CO_2 GR: 600 0,15 % 20-70 (30-65) % 21-26 °C ES: 21-25 °C GR: 20-26 °C 0,5 25 % GR: 75% < 25 dB(A) ES: < 30 dB(A)	CO_2-measures, Humidity, Temperature, Air tightness
E. SOLAR ENERGY					

Technology	Relevant Indicators	Performance Requirements			Check Systems and standards
		2006 (Present situation)	Goal for next EPBD in 2011	BAT (Best Available Technology)	
6. Solar Domestic Hot Water (DHW) Heating System	System efficiency (% of solar radiation) Solar fraction of DHW supply in %. **UK**: System Efficiency % watts/m^2 utilised. **FR**: Solar collector testing, solar DHW and combi system certification, collective systems, installer qualification. **GR**: Energy saving **AU**: % of coverage in the year different if only for hot water or additional for heating (combined systems are increasing!) solar gain. **D**: Efficiency solar pump	Solar Keymark used throughout Europe GR: 30 GR: 75-80	See note-2	**GR**: 500 kWh/m^{2}year for thermosiphonic compact to 700 kWh/m^{2}year for forced circulation with flat plate selective surface collectors **AU**: 60-80% of the domestic hot water a year. Solar gain 350 kWh/m²year **D**: 65% coverage: 40% system efficiency 25% coverage: 50% system efficiency, 0,32 solar pump eff.	**FR**: Inspector visit. Permanent monitoring for guarantee contract. Loss of "Qualisol" qualification if no solar installation during 2 years. **AU**: Table of values to be reached each month to achieve the 350 kWh/m² - attachment 1) **D**: Solar keymark

Technology	Relevant Indicators	Performance Requirements			Check Systems and standards
		2006 (Present situation)	Goal for next EPBD in 2011	BAT (Best Available Technology)	
Note-1: Collector testing by CSTB, following French and European standards. The Ademe certifies complete systems using tested collectors. This certification opens the right to subsidies. Subsidies collective solar systems must be covered by a Guaranteed Solar Results contract. "Qualisol" is a professional qualification required for the installation of solar systems. Note-2: In France, the national average energy needs for the supply of hot water in housing is 855 kWh/person/year and the average surface area is 34,5 m2/person. Therefore, the average energy needs for the supply of hot water in housing can be expressed as 24,8 kWh/m2/year. That is 24,8 kWh for every square meter of surface area used in the residential sector. A solar domestic hot water system, with a solar fraction of about 60 %. is considered to save an average 15 kWh/m2/year.					
7. PV Installations	Performance ratio [%] Inverter: Efficiency max. [%] < 10 kW > 10 kW night consumption [W] <10 kW >10 kW Stand By [W] <10 kW >10 kW Input start at [W] <10 kW >10 kW Annual kWh produced, Global Systems efficiency, Efficiency of the cells: Mono-cryst. Si Polychryst. Si	>85 >97 >97 <0,005 0 <9 <30 <15 <50 85% 15% 12%	>86 >97 >97 <0,005 0 <9 <30 <15 <50 20%	>85 >96 >96 <0,005 0 <9 <30 <15 <50 85% 15% 12%	IEC 61724 IEC 61727 UNE-EN 61215:1997

Technology	Relevant Indicators	Performance Requirements			Check Systems and standards
		2006 (Present situation)	Goal for next EPBD in 2011	BAT (Best Available Technology)	
Note from Gaia Solar (PV): *The most important thing is not the efficiency, but the price per Wp installed. This can be optimised by installing large scale systems with standard components and involve PV entrepreneurs early in building phase, so the system can be optimised in best possible way and e.g. the existing lift in site can be used.*					

3.1 Country-specific information

3.1.1 Insulation

3.1.1.1 Technique

Austria	In Styria the building regulation defines minimal U-values for new buildings and all building types. There are different levels of insulation depending on building components like outer walls, ceilings, windows, doors and roofs. U-values differ from 0,20 W/m^2/K (outer walls) to 1,90 W/m^2/K (windows). Most common materials are expanded polystyrene, followed by mineral wool. Ecological insulations are recycled expanded polystyrene, mineral foam board, cork, hemp and straw. Alternative insulations are also TWD (Transparent Heat Insulation) e.g. based on paperboard cells and glass or PCM (Phase Change Materials) elements. Market penetration of before mentioned alternatives is rather low.
Spain	External walls, roofs, floors and partitioning requires different levels of insulation (normative requirements described in the table). Usual insulating materials have conductivity values ranging from 0.035 to 0.040 W/mK. Main insulators employed in Spanish buildings are mineral wool, polyurethane and polysturene. Currently there are other new materials with □-values close to 0.005 W/mK, but they are not very introduced in the market yet.
Hungary	According to the new regulation, the maximum thermal transmittance of external walls is 0.45 W/m^{2}K, of attic floors 0.3 W/m^{2}K and of cellar floors 0.5 W/m^{2}K. The most common insulation material is expanded polystyrene, followed by mineral wool. Natural materials and innovative insulations have a low market share.
Greece	According to the Thermal Insulation Regulation dated on 1981 the building envelope of all structures including dwellings should comply with the follows criteria: *External Walls:* U-Value < 0.7 W/m^{2}K *Roofs and exposed horizontal surfaces i.e. Pilotis*: U-Value < 0.5 W/m^{2}K *Ground floors:* • Zone A : U-Value < 3.0 W/m^{2}K • Zone B: U-Value < 1.9 W/m^{2}K • Zone C: U-Value < 0.7 W/m^{2}K *Partitions to non-heated enclosed spaces:* • Zone A : U-Value < 3.0 W/m^{2}K • Zone B: U-Value < 1.9 W/m^{2}K • Zone C: U-Value < 0.7 W/m^{2}K A,B,C represent the three climatic zones of Greece, A represents the southern part, B the central part (i.e. Athens) and C the northern part of the country.

	The most common insulation materials for external walls, roofs and ground floors are expanded and extruded polystyrene, and mineral wool. Alternative insulation materials are not introduced in the Greek market.
Denmark	The following U-values are required for retrofit housing and extensions in Denmark according to Danish building regulations: U-value [W/m²K] External Wall: 0.20 Roof: 0.15 Floor (ground/ unheated rooms): 0.12-0.15 The minimum demands apply for rooms heated to at least 15 °C.

3.1.1.2 Verification and Check Systems

Austria	Specifications for thermal quality, fire protection and acoustic requirements of insulation materials are regulated by European (CEN) and Austrian (ÖNORM) standards. Calculation of the energy demand and bench marks for the energy consumption are regulated by OIB-Richtline 6 (Directive of the Austrian Institute of Construction Engineering), following the requirements of the EPBD. There is one calculation method for all Austrian provinces. Calculation can be done by approved software tools (Archiphysik, Ecotech, GEQ….).
Spain	When dealing with insulating materials thermal characterization is required according to standard laboratory procedures such as ISO-8302 and ISO-8990. For the calculation of thermal transmittance of constructive elements, the methodology described in ISO-6946 is applied. In addition, Spanish normative is supported by an specific software (LIDER) for the calculation of the energy demand of the buildings (including thermal transmittance, infiltrations, shadings, etc.).
Hungary	For the classification of insulation materials and the calculation of the thermal transmittance European standards apply. The requirements on the thermal transmittance of building elements are set in the Hungarian decree TNM 7/2006, based on the EPBD. The calculations can be carried out with various software tools, etc. WinWatt or Archiphysik. European standards apply (e.g. ISO-8302 and ISO-8990, ISO-6946).
Greece	No verification systems apply for the classification of insulation materials and the calculation of their thermal transmittance.
Denmark	It is difficult to actually control the U-value of constructions in practice. In the Danish building regulations and in guidelines from the Danish Building Research laboratory (SBi) there is shown how to obtain a good insulation quality and linelosses are indicated. The influence of this can be analysed in calculation programmes like Be06 (introducing EU-EPBD demands). Thermofotyography is often used to control possible cold bridges.

3.1.2 Windows

3.1.2.1 Technique:

Austria	Following the Styrian building regulation the max. U-values of windows has to be 1,90 W/m²/K. Double glazed windows with U-values of 1,10 W/m²/K for glass and 1,50 W/m²/K for frames are typical for the Austrian situation. Nearly all producers of windows offer products meeting the passive house standard, with U_w-Values (averaged) of 0,80 W/m²/K, but they are not very introduced in the market yet.
Spain	Windows are one of the main ways for heat exchange (heat losses) with exterior, so good insulating systems should be implemented. Typical systems in Spain are double glazing with different frame materials: aluminium, wood or PVC (not recently). Best available systems in this moment are double glazing (6/16/4) low-emissivity windows with U-values around 1.1 W/m²K (argon gap).
Hungary	The maximum average thermal transmittance is 1.6 W/m²K for wooden/vinyl windows and 2 W/m²K for aluminium frame windows. This can be fulfilled with double glazing, low-emissivity coating and argon infill gas.
Greece	From statistical data only 2.1% of the existing dwellings have double glazing. These buildings usually date back to 1980s. For new built construction typical systems are double glazing usually with aluminium frames with a target thermal transmittance of 1.8 W/m²K. Thermal breaks and glazing with argon is met only in prestigious constructions.
Denmark	For windows the following U-values apply for retrofit housing and extentions: U-value [W/m²K] Total: 1.5 Frame: 1.1 Pane: 1.1 – 1.2 g-value, Pane: approx. 0.6-0.63 Total: 0.50 Ψ-value [W/m]: 0.06

3.1.2.2 Verification and Check Systems:

Austria	EN-673, ISO-10077, EN-410, EN-10211
Spain	Standard procedures for thermal assessment of windows in Spain involve EN-673, ISO-10077, EN-410, EN-10211.
Hungary	European standards apply (e.g. EN-673, ISO-10077, EN-410, EN-10211)
Greece	No verification systems apply for the thermal assessment of windows
Denmark	European standards apply (e.g. EN-673, ISO-10077, EN-410, EN-10211)

3.1.3 Air tight constructions

3.1.3.1 Technique

Austria	There are no benchmarks in the Styrian building law, air tightness is regulated by ÖNORM, an Austrian norm. Measured air change rates by a reference pressure difference of 50 Pa must not exceed the following values: > Low energy buildings without mechanical ventilation n50 < 3,0 h^{-1} > Low energy buildings with mechanical ventilation without heat recovery n50 < 1,5 h^{-1} > Lowest energy buildings with mechanical ventilation with heat recovery n50 < 0,6 h^{-1} Air passage coefficient for well sealed windows and doors should be less than 0,2 m3/m.h.Pa2/3.
Spain	Spanish normative involves a minimum measured air renovation of 27 or 50 $m^3/h·m^2$ (100 Pa). In addition, in order to maintain equilibrium between indoor healthy conditions and energy savings a natural infiltration value between 0.4 and 0.6 ACH is recommended.
Hungary	There are no national requirements on air- tightness level. An air change rate of $n_{50} < 2\ h^{-1}$ is recommended.
Greece	There are no national requirements on air- tightness level
Denmark	There is a demand for airtightness in new buildings which is 1.5 l/sec,m² at +/- 50 Pa. This can also be followed for retrofit but is not a demand.

3.1.3.2 Verification and Check Systems

Austria	The Styrian housing subsidy for new built multi-storey buildings requires the same values for air change rates as ÖNORM 8110-5. Measurements have to be done by a Blower Door test according ÖNORM EN 13829. For new buildings up to 10 living units every third flat, from 10 living units on every fifth flat has to be measured.
Spain	Air tightness analysis is carried out according to ISO-9972, EN-12207 and EN-1026 standards.
Hungary	European standards apply (e.g. ISO-9972, EN-12207, EN-1026)
Greece	European standards apply (**EN 13829**)
Denmark	European standards is used here. Using blowerdoor tests at +/- 50 Pa and leak detection by smoke test.

3.1.4 Heat recovery Ventilation

3.1.4.1 Technique

Austria	There are no requirements especially for retrofit housing, but in the Austrian "klima:aktiv Haus" standard (most common quality label in Austria) following demands are defined: Volume flow rate following the maximum values of:

	- ÖNORM H 6038 - Supply air for standard occupancy and an air volume flow of 30 m^3/h - Air change rate > $0,3h^{-1}$ Power input electricity exhaust-air plant: < 0,25 Wh/m^3 Power input electricity heat recovery ventilation: < 0,45 Wh/m^3 Heat recovery: > 75% Supply air temperature: > 16,5 °C (by an outdoor temperature of –10°C) Ambient temperature: 20 °C Noise level for living space, bedroom, bathroom, kitchen : max. 25 dB(A) Internal air leak flow: max. 3% (by 100 Pa)
Greece	No legislation exists for the use of heat recovery. The application of heat recovery relies on the will of the client. Usually this technique is applied in high standards constructions with a suggested performance varying between 65-85 %
Denmark	The following demand apply for retrofit housing if heat recovery ventilatiom is used Electricity consumption: 1.2 kJ/m^3 (SEL values [kJ/m^3]) Heat recovery: 65-85 % (see note below) Noise level: 30-35 dB(A)

3.1.4.2 Verification and Check Systems

Denmark	The quality is not checked normally except noise monitoring which is a requirement. Monitoring of electricity use and HRV efficiency can be close by installing an extra electricity meter and a sensor in the inlet air.
Greece	No verification and check system apply for heat recovery ventilation.

3.1.5 Natural, Hybrid and PV-assisted Ventilation

3.1.5.1 Technique

Austria	In ÖNORM B 8135 following air change rates are defined: > Historical buildings with large rooms and large ceiling heights: 0,5 h^{-1} –0,25 h^{-1} > Single and multi-family houses: 0,5 h^{-1} > Social housing and office buildings : 0,7 h^{-1} > Office buildings with high frequency of visitors: 1 h^{-1} Air change rates about 20 – 30 m^3/person are recommended for the residential buildings. Mechanical ventilation in the residential buildings is not state of the art.
Spain	As mentioned previously no mechanical systems for ventilation are usually employed in Spain. Normative addresses some minimum requirements for air change depending on the type of space (see table). Other parameters, such as temperature or humidity, are normative for working places (industrial buildings or offices), but only recommended for residential buildings.
Hungary	Air change rate of 20 m^3/h per person in general, 30 m^3/h per person for smoking areas. In new residential buildings, an air change rate of 0.5 1/h is recommended. In residential buildings, mechanical ventilation is uncommon.

Greece	According to the European Standards CEN/TC 156, 0.7 ach should apply for buildings of category A, 0.6 ach should apply for buildings of category B and 0.5 ach should apply for buildings of category C (D22, Common Evaluation Protocol) Natural ventilation is usually applied in residential buildings whereas mechanical ventilation is uncommon. Sometimes, demand control ventilation is applied with the control of the CO2 concentration.
Denmark	The normal solution for retrofit housing is exhaust ventilation aiming at the highest value of 0.5/arch. or 125 m³/hour. Old building have natural ventilation. In some cases demand based ventilation can be accepted . Balanced ventilation with heat recovery are not common in retrofit projects.

3.1.5.2 Verification and Check Systems

Austria	Measurements of CO_2 levels, temperature, humidity, etc.
Spain	Measurements of CO_2 levels, temperature, humidity, etc.
Hungary	Measurements of CO_2 levels, temperature, humidity etc.
Greece	Measurements of CO_2 levels, temperature, humidity etc.
Denmark	Measurements of CO_2 levels, temperature, humidity etc.

3.1.6 Solar heating system for domestic hot water (DHW)

3.1.6.1 Technique

Austria	Solar heating systems for DHW are a must for residential buildings in the social housing sector in Styria. Granting of a housing subsidy requires for single-family houses a minimum of 5 m^2 /house and for multi-story buildings 2 m^2/flat. Solar heating for DHW has become an interesting aspect for building owners in Austria. To reduce distribution losses in multi-story building a 2-pipe system (single distribution system for space heating and DHW) with local heat exchangers in the flats has proved to be best.
Spain	Spanish normative requires a minimum solar energy contribution to DHW depending on different parameters of the building: DHW demand, type of building, climatic zone, elements of the systems, etc. There are some requirements about maximum losses by tilt, orientation and shadows (see table).
Hungary	There is no normative requirement for the installation of solar collectors. The use of renewable energy is encouraged by the low (zero) primary energy factors in the calculation of the integrated energy performance. Solar heating systems are still very seldom, but solar DHW systems are becoming more and more widespread.
Greece	There is no normative requirement for the installation of solar collectors. The installation of solar systems for dhw relies on the will of the client. Solar systems for dhw are often met in the Greek market. From statistical data oil-burn boilers provide domestic hot water for approximately 26% dwellings. Electricity is used for the

	provision of domestic hot water in 78% dwellings and solar energy in 15.1 %. (WP1, D1, State of the Art report)
Denmark	Solar DHW heating is not normal in retrofit housing. When it is used around 2 m² solar collector pr apartment is common.

3.1.6.2 Verification and Check Systems

Austria	European standards apply (e.g. EN-12975, EN-124976, EN-12977, EN-806-1, EN-1717, EN-ISO-9488, EN-94002).
Spain	The methodology for solar energy contribution to DHW is supported in the normative by following standards: EN-12975, EN-124976, EN-12977, EN-806-1, EN-1717, EN-ISO-9488, EN-94002.
Hungary	European standards apply (e.g. EN-12975, EN-124976, EN-12977, EN-806-1, EN-1717, EN-ISO-9488, EN-94002).
Greece	No verification and check system apply for solar systems.
Denmark	Solar keywork

3.1.7 PV Installations

3.1.7.1 Technique

Austria	There are no requirements for PV energy production in the building sector. The Austrian Ökostromgesetz rules feed in of PV generated electricity into the grid by definition of contingents, capacity and remuneration. Because of the costs and a lower level of subsidy PV-systems are still very rare in Austria (about 0,3 per mille of the total Austrian electricity production).
Spain	National normative includes a minimum PV energy production for some building typologies (mainly commercial and industrial buildings). These requirements depend on type of building, climatic zone and gross area of the building.
Hungary	There is no normative requirement on the installation of PV-systems. PV-systems are still very rare, most installations serve demonstration and research purposes.
Greece	There is no requirement for the installation of PV-systems. PV-systems are still very rare, and their high investment cost does not encourage their implementation in the residential sector
Denmark	PV systems are only seldom used in retrofit housing. In some cases socalled PV-VENT solutions are used to match yearly electricity use for ventilation on a yearly basis. Typical yearly yield for a good orientation PV systems f.ex in roofs to mhe south: 800 kWh/kWp 80% system efficiency.

3.1.7.2 Verification and Check Systems

Austria	European standards apply (e.g. EN-61215, EN-61646).

Spain	The methodology and conditions of installation is collected in different documents: EN-61215, EN-61646 and several Royal Decrees.
Hungary	European standards apply (e.g. EN-61215, EN-61646).
Greece	No standards apply
Denmark	European standards apply (e.g. EN-61215, EN-61646).

4 ANNEX 1 List of best practice windows for the Danish market including information on total U-value incl. frame losses

The below list of best practice windows were developed based on a questionnaire send to Danish windows producers. A translated version of the questionnaire can be found in chapter 2.2, p. 8 of this report.

Danske vinduer til lavenergibyggeri

Nedenstående liste er et resultat af en undersøgelse af hvilke vinduer med s° rligt lave U-v° rdier, der er tilg° ngelige i Danmark. Undersøgelsen er sket ved at der i efteråret 2005 blev udsendt et spørgeskema til medlemmerne af VinduesIndustrien – og i 2007 er foretaget en opdatering af resultaterne fra 2005. Undersøgelsen af foretaget af EFP-gruppen tilknyttet udbygningen af Stenløse Syd.

Den nuv° rende liste vil løbende blive opdateret og skal betragtes som en dynamisk liste, der er åben for alle interesserede vinduesproducenter.

De angivne v° rdier i skemaet viser U- og g-v° rdier for den samlede vinduesløsningen af et standardvindue med målene 1230x1480 mm.

Producent Rev. 08.august 2007	**Typebetegnelse**	**Lag vinduer (antal)**	**Varm kant**	**g-værdi**	**U-værdi**
Bøjsø døre og vinduer A/S Højagervej 5-7 6623 Vorbasse Tlf.: 75333344 post@bejsoe.dk www.boejsoe.dk	SK-2-2 (koblet trævindue med integreret forsatsrude)	3	Nej	**0,66**	**1,35**
	T-1-1 (thermovindue i træ)	2	Ja	**0,74**	**1,41**
Glasalu Darumvej 87-89 6700 Esbjerg Tlf.: 75130322 www.glasalu.dk	Hansen Fenster (therm, fast felt)	3	Ja	**0,46**	**0,8**
HSHansen Bredgade 4 6940 Lem Tlf.: 96751100 www.hsh.dk	Hansen millennium (dreje/kip m. skjult ramme)	3	Ja	**0,46**	**0,9**
DFE – Dansk Facade Entreprise Hjortevej 3 7800 Skive Tlf.: 87509500 www.d-f-e.dk	Hansen Fenster (Therm, dreje/kip)	3	Ja	**0,46**	**0,9**
Vrøgum A/S	Klosterhede Ewitherm 0,8	3	Ja	**0,53**	**0,8**

Industrivej 1 6840 Oksbøl Tlf.: 76541111 www.vrogum.dk	Klosterhede 0-energi 1	3	Ja	**0,53**	**0,8**
	Klosterhede 0-energi 1	3	Ja	**0,53**	**0,91**
	Klosterhede 0-energi 1	3	Ja	**0,53**	**1,1**
KASTRUP Plastvinduet Mosevej 40 7500 Holstebro Tlf.: 97421500 Fax: 97423000 plast@kastrupvinduet.dk www.kastrupvinduet.dk	REHAU Clima-design *Hovedprofiler er udført i PVC og dette vindue kan derfor ikke anvendes i Stenløse Syd*	3	Ja	**0,50**	**0,79**
	REHAU Brillant Design *Hovedprofiler er udført i og dette vindue kan derfor ikke anvendes i Stenløse Syd*	3	Ja	**0,50**	**0,85**
	REHAU Brillant Design *Hovedprofiler er udført i PVC og dette vindue kan derfor ikke anvendes i Stenløse Syd*	3	Ja	**0,50**	**0,97**
	REHAU Brillant Design *Hovedprofiler er udført i PVC og dette vindue kan derfor ikke anvendes i Stenløse Syd*	2	Ja	**0,65**	**1,3**
VELFAC A/S Ribovej 5 6959 Ringkøbing Tlf.: 96755200 velfac@velfac.dk www.velfac.dk	V200 (med indvendig fortsatsramme) *Indvendig glasliste på ramme er udført i PVC og dette vindue kan derfor ikke anvendes i Stenløse Syd*	3 (+1)	Nej	**0,46**	**0,78**
	V200 *Indvendig glasliste på ramme er udført i PVC og dette vindue kan derfor ikke anvendes i Stenløse Syd*	3	Ja	**0,47**	**1,00**
	V200 *Indvendig glasliste på ramme er udført i PVC og dette vindue kan derfor ikke anvendes i Stenløse Syd*	3	Ja	**0,47**	**1,20**
	V200 *Indvendig glasliste på ramme er udført i PVC og dette vindue kan derfor ikke anvendes i Stenløse Syd*	2	Ja	**0,52**	**1,48**
Vildbjerg Vinduet Aps Bredgade 52A 7480 Vildbjerg	Vildbjerg Vinduet (Fast felt, fyr)	3	Ja	**0,47**	**0,77**
	Vildbjerg Vinduet (Fast felt, mahogni)	3	Ja	**0,47**	**0,87**

Tlf.: 97131823 www.vildbjerg-vinduet.dk	Vildbjerg Vinduet (Topstyret fyr)	3	Ja	**0,47**	**0,90**
	Vildbjerg Vinduet (Topstyret mahogni)	3	Ja	**0,47**	**0,96**
	Vildbjerg Vinduet (Topstyret fyr)	2	Ja	**0,61**	**1,35**
	Vildbjerg Vinduet (Topstyret mahogni)	2	Ja	**0,61**	**1,41**
PRO TEC vinduer Nybovej 34 7500 Holstebro Tel.: 97413077 Pro-tec@pro-tec.dk www.protecvinduer.com	Seven 36mm	3	Ja	**0,46**	**0,76**
	Seven 36mm	3	Nej	**0,46**	**1,00**
	Classic *Afstandsprofil mellem alu og træ i ramme er udført i PVC og dette vindue kan derfor ikke anvendes i Stenløse Syd*	3	Ja	**0,46**	**1,21**
	Seven 36mm	2	Nej	**0,50**	**1,25**
	Classic *Afstandsprofil mellem alu og træ i ramme er udført i PVC og dette vindue kan derfor ikke anvendes i Stenløse Syd*	3	Ja	**0,45**	**1,47**
	Classic *Afstandsprofil mellem alu og træ i ramme er udført i PVC og dette vindue kan derfor ikke anvendes i Stenløse Syd*	2	Ja	**0,50**	**1,53**
Vipo Vinduer A/S Håndværkervej 3 7770 Vestervig Tlf. 97941455 www.vipo.dk	TS1-11 Optiwin (fra Østrig)	3	Ja	**0,52**	**0,74**
	DK1-11 Vipo Vinduer	2	Ja	**0,63**	**1,4**
Krone Vinduer A/S Aalborgvej 570 Harken 9760 Vrå Tlf.: 96242860 kb@kronevinduer.dk www.kronevinduer.dk Beregninger er foretaget Jvf. ISO CE 10077-2	Super Lav energi Træ/Alu fast	3	Ja	**0,52**	**0,73**
	Super Lav energi Træ/Alu opluk	3	Ja	**0,52**	**0,84**
	Malet fyrretræ med fast karm	3	Ja	**0,52**	**0,82**
	Malet fyrretræ med fast karm	2	Ja	**0,63**	**1,25**
	Malet Fyrretræ med opluk	3	Ja	**0,52**	**0,93**
	Malet Fyrretræ med opluk	2	Ja	**0,63**	**1,30**

	Maghoni Fast	3	Ja	**0,52**	**0,85**
	Maghoni Fast	2	Ja	**0,63**	**1,28**
	STD. Træ/Alu vinduer med opluk	3	Ja	**0,52**	**1,15**
	STD. Træ/Alu vinduer med opluk	2	Ja	**0,63**	**1,45**