SQUARE - A System for Quality Assurance when Retrofitting Existing Buildings to Energy Efficient Buildings

Energy Improvement Measures and their Effect on the Indoor Environment

Supported by

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SQUARE

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Energy Improvement Measures and their Effect on the Indoor Environment

Work Package 5 Energy Improvement Measures,
Deliverable 5.1 report

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Preface

This report is part of the work carried out within the SQUARE project (EIE/07/093/SI2.466701), which stands for A System for Quality Assurance when Retrofitting Existing Buildings to Energy Efficient Buildings. The project is co-funded by the European Commission, supported by its Programme Intelligent Energy Europe (IEE). The SQUARE project aims to assure energy efficient retrofitting of social housing with good indoor environment, in a systematic and controlled way.

The partners of the SQUARE project are:

- AEE Institute for Sustainable Technologies, Austria
- EAP Energy Agency of Plovdiv, Bulgaria
- TKK Helsinki University of Technology, Finland
- Trecodome, Netherlands
- TTA Trama Tecno Ambiental S.L, Spain
- Poma Arquitectura S.L., Spain
- SP Technical Research Institute of Sweden, Sweden
- AB Alingsåshem, Sweden

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Summary

Energy efficient measures for the European residential building stock, mainly of the period 1960 to 1980, should lead to at least 50% energy savings. Ambitious and high performance retrofit, carried out in the SQUARE pilot projects, lead to much more savings, to 80 or 90%. To reach these goals, it is important to know more about energy improvement measures that have a great reduction potential and are easy to accomplish.

Work package 5 focuses on energy efficient solutions that are basic for the retrofit of residential buildings and at the same time raise indoor environmental issues. Since the climate varies in the European countries it was decided to suggest measures for three different European climates to meet special requirements in several countries.

So this report describes 10 important energy improvement measures, leading to satisfying building performance, also during operation phase. The description of each measure includes information about values, their verification systems, their effect on indoor environment and “best practise” examples and links.

Additionally one short list and a presentation of these 10 measures have been developed, targeted to housing associations, planers and architects to give a simple and understandable view on those measures. The information material is available at the SQUARE project website.

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Appendices

1 Introduction

This work package describes sustainable **energy efficient solutions for retrofit** of social and multi-family housing with different conditions in several countries. These renovation solutions are specified with respect to the indoor air quality and thermal comfort, but also to climate and building traditions.

1.1 Description of task, methods

First step is to evaluate the potential for saving energy when retrofitting multi-family and social housing in different countries.

Second step is at one hand to evaluate the energy efficiency measures that have high potential with respect to renovation need, building tradition, climate and resources; at the other hand to show their effect on the indoor environment.

Third step is to evaluate how these technical, building related improvement measures are useful for keeping the required building performance during the whole operation phase - another potential and other priorities are shown here.

1.2 Objectives and target groups

Main objective is to show that it is worth having an action plan or a general list with different measures to improve energy efficiency when retrofitting residential buildings. The measures should not only focus on the renovation process itself, but also on the "use of the building" after renovation like indoor climate and operation needs.

Another objective is to create information material on energy efficient renovation measures with references to different climates and the relevant types of social housing. The information is adapted to fit the needs of housing associations, developers, building managers, architects and residents (all listed in SQUARE work package 3).

1.3 Scope and limits

The following contents are focused on the results of SQUARE investigations and the most relevant energy improvement measures, easily usable for our target groups. It is very important to give a quick and feasible overview. The decision was not to go in details regarding different types of buildings or different building traditions and

Picture 1: Social housing at Makartstraße, Linz - Austria; AEE INTEC

resources, but to make evident, what kind of measures are really important both for the building renovation and operation regarding energy efficiency and indoor environment (thermal comfort, air quality,...).

The measures have been selected with reference to the building stock of the period 1960 to 1980 (see Picture 1), because all over Europe this was the period with the highest building activity, setting up dwellings with the highest energy demand (SQUARE work package 2).

2 Background

If we talk about energy efficiency of building's retrofit, there is one key objective: very low primary and final energy input during planning, construction and operation stage. This should be defined for both the retrofit actions and the building services.

For energy analyses of the building(s) we need their final energy performance before and after renovation (see appendix A). If we roughly want to investigate the thermal comfort inside the dwellings we should at least have U-values of the relevant building components, also important for the calculations of ISO 7730. But there is much more to consider. A lot of investigations are necessary to get a comprehensive impression of the building's energy performance.

There are different energy efficient solutions following different climates or climate zones. In the SQUARE project it was decided to work with three different climates within the EU, with characteristics shown in table 1. It is not made from a scientific view on climates but for a quick and short overview on different parameters influencing climate conditions relevant to energy efficient solutions.

Table 1. *Characteristics of the three different European climates used for specifying energy improvement measures of buildings' retrofit within SQUARE (suggested by AEE INTEC, verified by SQUARE partners)*

CLIMATE/ CHARACTERISTICS	W warm	T temperate	C cool
Lowest standard outside temperature during heating period [°C]	0 to -10	-10 to -16	-12 to -25
Outside average temperature during heating period [°C]	+8 to +10	+2 to +4	+2 to -10
Outside average temperature during summer [°C]	+20 to +24	+17 to +22	+10 to +16
Heating degree days 20/12 [K.d]	1.200 – 3.000	3.000 - 4.500	4.500 – 7.000
Solar radiation [kWh/m²a]	1.200 – 1.500	1.000 - 1.200	Up to 1.000

Additionally there are a few parameters that characterize the minimum requirements of the indoor environmental quality and which can easily be measured, such as given in table 2.

There are different requirements for the room temperature in each country, dependent on individual national principles. There are also traditional methods how indoor air quality is measured and assessed by different European countries. The northern countries use the ventilation rate, middle and southern European countries sometimes use the CO_2-concentration too. For example in Spain there is a mandatory air change rate for new buildings with mechanical fans as a method to assess a certain indoor air quality. CO_2 sensors are not mandatory, but high efficiency projects use CO_2 sensors to reduce the ventilation rate when it is too high.

Table 2. Values of indoor environment parameters due to different climates (suggested by AEE INTEC, verified by SQUARE partners)

CLIMATE	**W** warm	**T** temperate	**C** cool
Room-Temperature Winter/Summer [°C]	21/<26	20/<26	20/<26
Ventilation rate [ACH] *or*	0,35-0,4	≥ 0,3	0,2-0,35
CO_2-concentration [ppm]	<1.000	800	900-1.000

The SQUARE pilot projects use different kinds of measurements to analyze the indoor air and environmental quality - see also the guide to QA from WP4 [6].

3 Methods and accomplishment

The investigation of the European residential building stock and its energy and indoor environmental performance was a first step to go into the topic of energy saving potential, carried out in collaboration with work package 2 (see table 3.).

Table 3. *Average energy saving potential of residential building stock (Reference: SQUARE-Internal report on work package 2, additional information of SQUARE partners, delivered 2009)*

	Energy demand for heating [kWh/m²a]	Energy saving potential [%]
Austria	210	50-60
Bulgaria	> 170	40
Finland	> 170	50
Spain	55 to 100	60
Sweden	210	50-60

One approach was to collect energy improvement measures for different building components and services, mainly used for the SQUARE-pilot projects in different countries (see Appendix A). For indoor environment quality there was developed an excel tool consistent with ISO 7730 (see appendix B).

Second approach was to focus the task not only on the SQUARE pilot projects but on energy improvement measures important for every retrofitting project adapted to different climates and building traditions. If it should be easy for stakeholders to decide whether energy improvement is worth to invest in, it is crucial to make it implementable and easy understandable. The following 10 measures presented in this report are the synopsis of this consideration.

The energy efficient solutions have been sorted out by evaluating the energy improvement potential in different types of residential buildings. The evaluation was made mainly with respect to different climates (heating load and cooling load), but also includes building traditions, local resources and regulations in different countries. Additionally the influence (advantages and disadvantages) of the energy efficiency measures on indoor environment (thermal comfort, air quality) in different types of buildings was investigated within WP5.

Enquiries within the national pilot projects, described in SQUARE work package 6, experiences of AEE INTEC and other SQUARE partners, different information and studies on energy consulting and energy savings (see chapter 7.) completed the task of WP 5.

4 Two different types of measures

Energy improvement measures can be defined by different levels of energy input or demand (figure 1.).

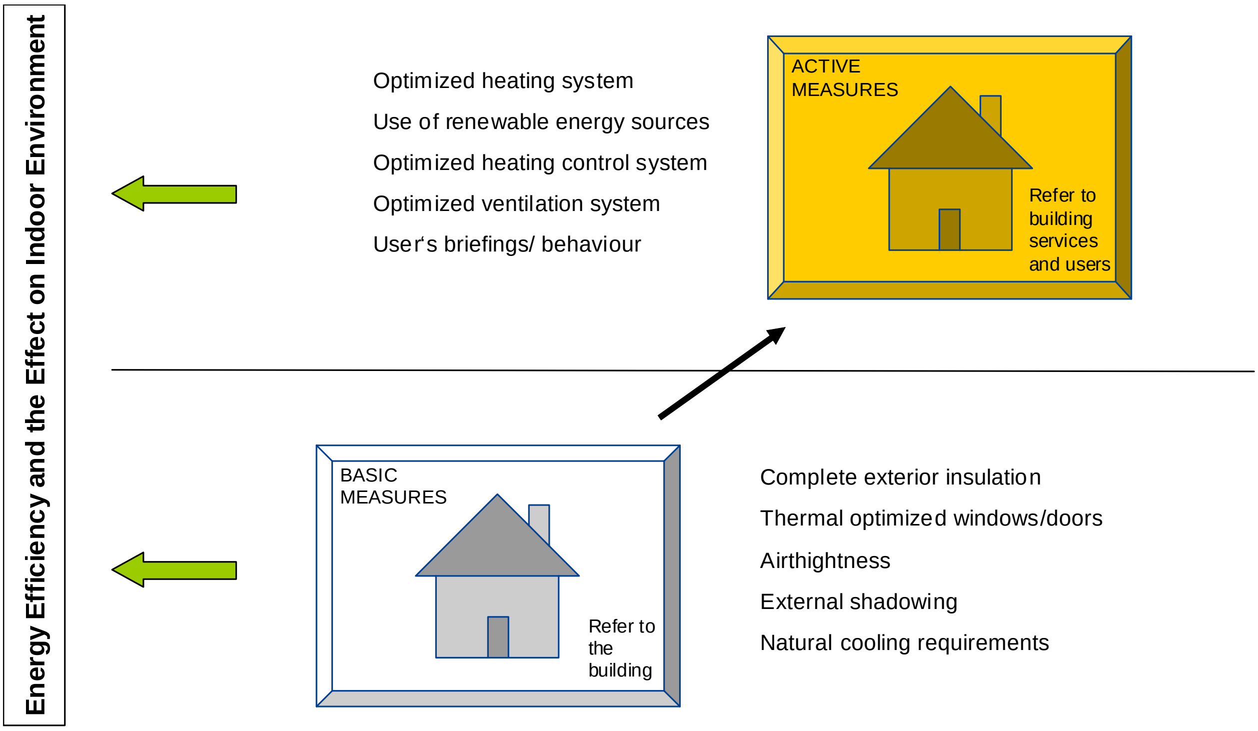


Figure 1. Two levels of improvement measures – BASIC and ACTIVE MEASURES are leading to energy efficiency and good indoor environment (AEE INTEC)

BASIC (energy improvement) MEASURES are meant to be the basic requirements for an energy efficient building with good indoor environment before optimizing the building services. These measures refer to the building constructions and components. The energy demand to set up these measures is definitely lower than their effect on energy savings. The optimization takes place at the "passive components" of the building system.

ACTIVE (energy improvement) MEASURES are meant to be supply and maintenance measures for optimizing parts of the building services, to bring them to a better performance or renew them. This optimization takes place after the building was adapted to highest energy efficiency standards. Considered for a long term and compared to the BASIC MEASURES their energy saving potential is important but generally lower and the energy and resource input to set up these measures is higher, because they mostly have a short estimated service life, for example boilers, heat exchangers or sensors. The optimization takes place at the "active components" of the building system.

Following this classification - two relevant levels of energy improvement measures for the retrofit of residential buildings can be described, 5 measures are the BASIC ones and 5 measures the ACTIVE ones (see figure 1. and chapter 6.).

5 Prior measures for each climate

Although there are different energy and (re)source relevant "levels" of measures, one small package of measures is typical for each climate regarding heating and cooling. The following figure 2. aims to give a very brief and clear, but of course short and insufficiently view on the essential measures carried out in work package 5.

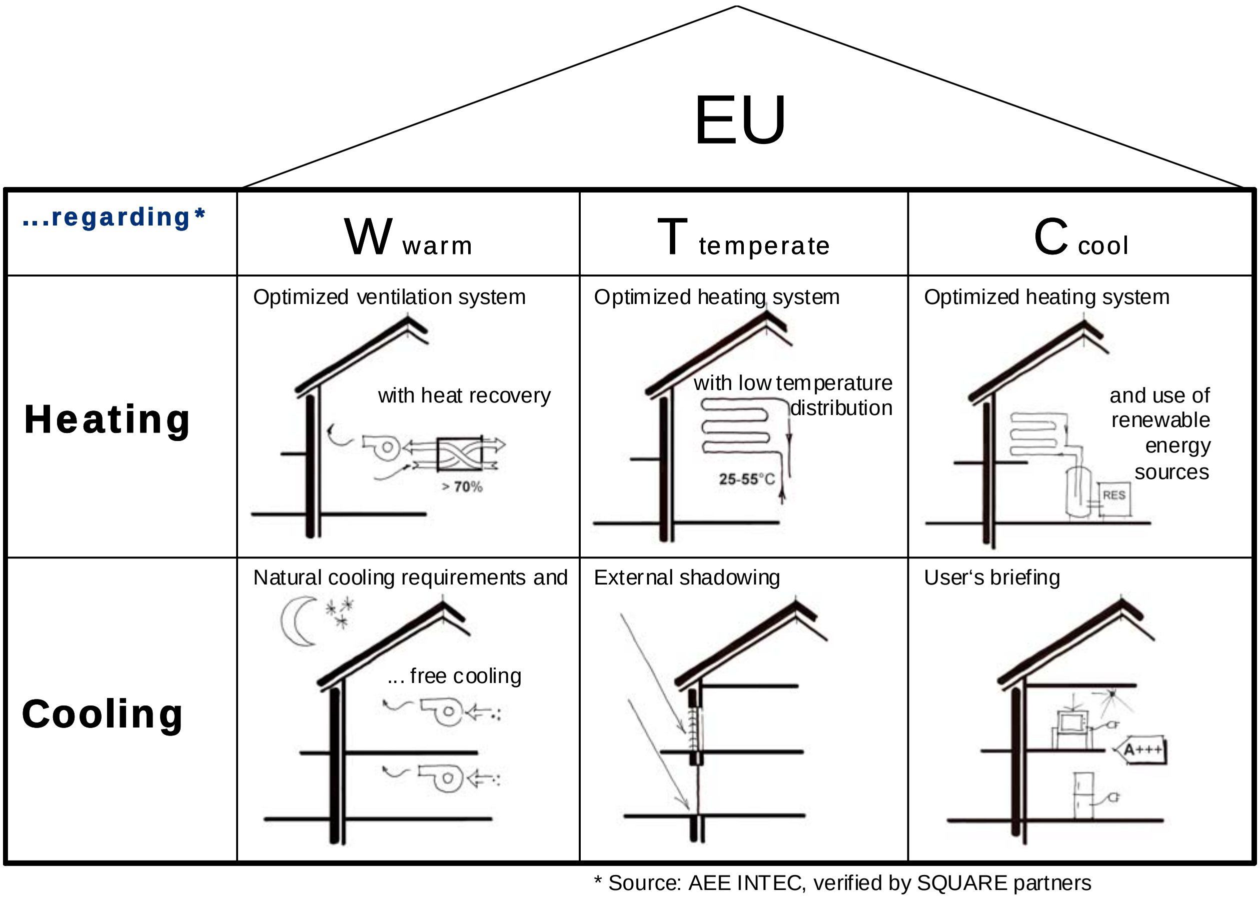


Figure 2. Most relevant energy efficient measures for heating and cooling of renovated residential buildings in three European climates (AEE INTEC)

6 10 Energy Improvement Measures

6.1 Complete exterior insulation

In all climates we have the need for insulated buildings, the thickness of the layer is ranging from 5 cm in the South to 40 cm in the North part of Europe. Before insulation it is crucial to investigate building components (ground touching walls, ceilings,...) thoroughly for capillary rising and absorbed moisture. If there is one it should be dehumidified immediately.

For building physical reasons the insulation layer should be positioned at the exterior side of the load bearing structure (see figure 3.). Hereafter it is easier to avoid thermal bridges, to cover window frames with insulation, to keep heat storage mass and humidity buffer of the building components inside the thermal building shell. Interior insulation is mainly used for historic buildings, but it is more difficult to manage the building physical challenges there.

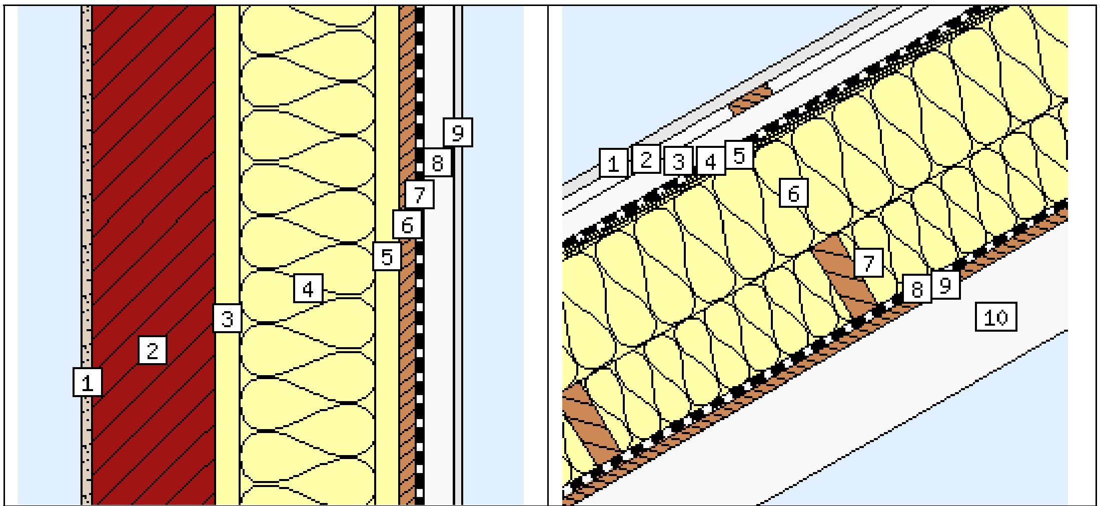


Figure 3. Details of exterior insulated wall and roof – the numbers show the different layers. ***Wall*** *1 Lime cement plaster, 2 Brick chipping concrete wall, 3-4-5 Mineral wool or Flax between different thick wood C-posts, 6 Wood shuttering with 1mm gaps between boards, 7 Open diffusion PE wind sealing with windproof glued joints, 8 Rear ventilation between upright wood lathes, insect screen, 9 Fiber cement panels.* ***Roof:*** *1 Covering, 2 Lathes 3/5, Ventilation between cross lathing 5/5, 4 Open diffusion roofing sheet, sealed (windtight), 5 Porous wood fiber inside roofing layer, 6 and 7 Mineral wool or Flax insulation panels between vertical and horizontal lathes, 8 PE vapour barrier, 9 Exposed shuttering - tongue and groove, 10 Freely visible rafters (Reference: IBO - Austrian Institute for Healthy and Ecological Building, 2009)*

6.1.1 Impact on energy efficiency

Exterior insulation reduces heat transmission losses and avoids thermal bridges.

6.1.2 Other advantages/disadvantages and influence on indoor environment

Insulation gains high thermal comfort because it raises the temperature of the inner surface of the building (components). It avoids damage of building components and mould caused by condensate through thermal bridges. Heat storage mass is effectively keeping heat or cool, only if the insulation layer is situated at the exterior of a building (see also 6.5).

6.1.3 Values

The characteristic value for the effect of insulation is the U-value, thermal transmission or heat transfer coefficient (unit: W/m^2K). It defines vertical heat transfer in watts (W) through 1 m^2 of a construction segment if the temperature difference of the bordering air layers is 1 Kelvin (K = 1 °C) [1]. It is ranging from < 0,2 W/m^2K (or passive house standard) for cool to < 0,5 W/m^2K for warm climates.

The characteristic value for the effect of thermal bridges is the linear thermal bridge coefficient ▯ (unit: W/mK). It defines the extra heat transfer in watts along 1 m of construction due to joints or corners if the temperature difference of the bordering air layers is 1 Kelvin (K = 1 °C). It is difficult to put a recommended value on the thermal bridge because it depends on the thickness of connecting insulation. Thick insulation close to the thermal bridge is necessary but gives a high value on ▯. A low value on ▯ indicates that there is only little difference between the thermal bridge and connecting construction. To obtain an even surface temperature it is important to reach as low value as possible. It should be possible to reach values below 0,05 W/mK [2].

6.1.4 Verification

The following international and European/national standards represent the state of the art or calculation and measuring procedures of insulation specifics and values:

- EN ISO 6946 - Building components and building elements - Thermal resistance and thermal transmittance - Calculation method (U-value)
- EN 15251 - Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics
- EN ISO 7730 - Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria (thermal comfort) – Excel tool available from SQUARE project (see appendix B)
- EN ISO 10211 - Thermal bridges in building construction - Calculation of heat flows and surface temperatures, e.g. Part 2: Linear thermal bridges (thermal bridges)
- Detailed engineering drawings are useful to identify and describe thermal bridges

6.1.5 "Best practice" and information

All the SQUARE pilot projects use some types of exterior insulation as an important measure (see picture 2, figure 4. and national reports [3]).

Austrian and German Links:
http://www.ibo.at/en/index.htm and http://www.baubook.info/PHBTK/:
Details for Passive Houses - A Catalogue of Ecologically Rated Constructions
http://www.impulsprogramm.de:
List of drawing details regarding insulated buildir

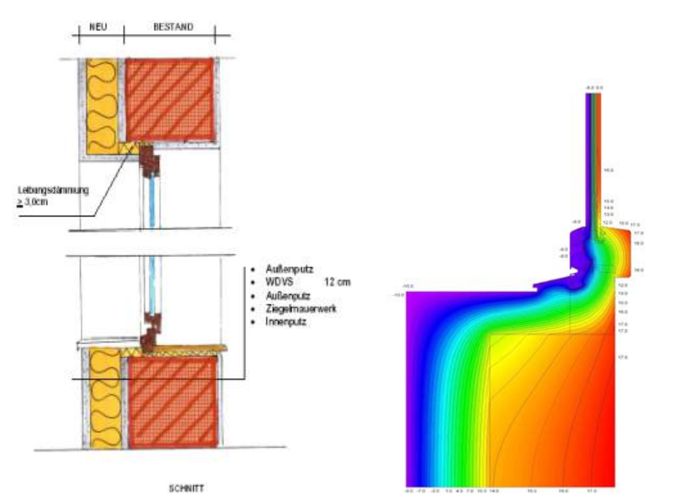
Picture 2: Pre fabricated and insulated modules at Dieselweg, Graz; AEE INTEC

Figure 4. Additional insulation and new façade material at Brogården/Sweden (left picture) and the same on the inside of the external wall due to restrictions of changing the exterior façade at a historic building in San Juan de Malta/Spain (References: SP and TTA)

6.2 Thermal optimized windows/doors

In all European climates we have the need for better insulated glazing, windows and doors. This is very important for the temperate and cool climates, but also getting more common in the warm climates.

Not only the value of insulation of windows and doors itself is very important to improve the energy efficiency of buildings, but also the fixing of them into the cladding – the exterior insulation layer should cover a big part of the window frame (on site) to make it more heat protected and the joints more draught-proofed, etc. (see figure 5.).



Condensation, followed by mould

Figure 5. Well (left pictures) and wrong insulated window reveal with potential of condensate and mould (right picture) (References: AEE INTEC; Hochschule für Architektur, Bau und Holz HSB; "die umweltberatung")

6.2.1 Impact on energy efficiency

Thermal optimized windows, doors and other transparent building components reduce heat transmission losses and gain "passive" solar energy.

6.2.2 Other advantages/disadvantages and influence on indoor environment

Insulated windows and doors lower the energy input from glazing during summer; in some cases it is worth to downsize the glazing area to reduce transmission losses during heating period and overheating during summer (see also 6.4).

6.2.3 Values

U-values for windows and doors are ranging from < 1 W/m²K (or passive house standard) for cool up to 3 W/m²K for warm climates.
The characteristic value for the energy gains by windows and doors is called g-value. It ranges from 0,4 (very good insulated windows) to 0,75 (double glazing windows) [4], saying that 40 to 75% of the energy from the outside radiation goes trough the window/door.

6.2.4 Verification

The following international and European/national standards represent the state of the art or calculation and measuring procedures of window/doors specifics and values:

- EN ISO 10077 - Thermal performance of windows, doors and shutters - Calculation of thermal transmittance (U-value)
- EN 410 - Glass in building - Determination of luminous and solar characteristics of glazing (g-value)
- DIN 4108 – Thermal protection in building construction (fixing windows; „RAL-mounting“)
- ÖNORM B 5320 - Connection joints for windows, French doors and doors in external construction elements – Principles for design and execution of work (fixing windows)

6.2.5 “Best practice” and information

All the SQUARE pilot projects use insulated windows/doors [3]. The pilot project Dieselweg Graz/ Austria, used pre-fabricated insulated façade modules, where the windows have been integrated into the modules (figure 6.).

Austrian and German Links:
http://www.ift-rosenheim.de/: information, testing and certification of windows
http://www.ibo.at/en/index.htm and http://www.baubook.info/PHBTK/: Details for Passive Houses - A Catalogue of Ecologically Rated Constructions

Figure 6. Three pane windows with an U-value of 0,85 W/m²K, used in the pilot project Brogården/Sweden (left picture) and module-integrated passive house windows at Dieselweg Graz/Austria (References: SP and AEE INTEC)

6.3 Airtightness

In all European but mainly in cold and temperate climates, we have the need for an airtight building envelope. The most important thing is to decide where the airtight envelope will be situated (inner side of the exterior wall or between old and new façade, etc.) and how are windows, doors and building breaches integrated into that airtight envelope (see figure 7.).

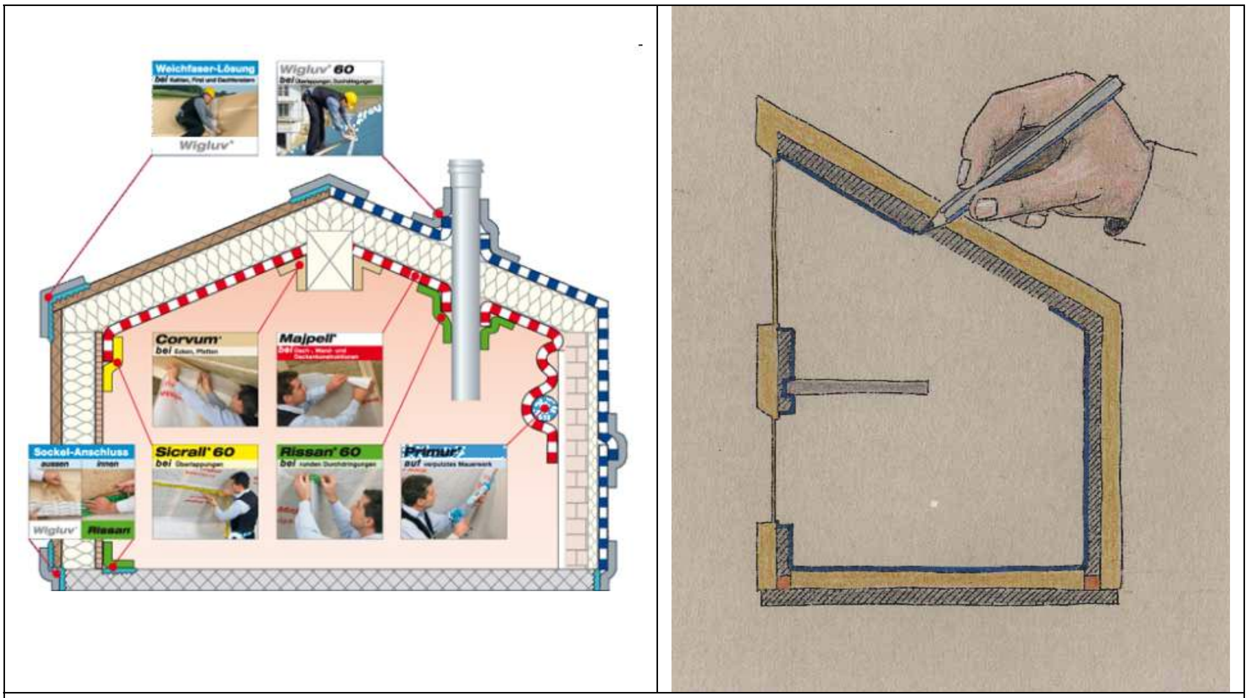


Figure 7. Airtight building envelope; pay attention on building breaches (References: Siga; PHI Darmstadt)

6.3.1 Impact on energy efficiency

Airtight building shell reduces infiltration and ventilation heat losses and avoids losses of heating up cool inner surfaces caused by draught.

6.3.2 Other advantages/disadvantages and influence on indoor environment

Airtightness avoids damage of building components and mould caused by condensate through leaks. Through a leak with 1 mm width and 1 m length the amount of 800 g of water per day infiltrates into the construction, if it is airtight it is only 0,5g/m²(!) [5].
Airtightness increases thermal comfort because it lowers the air velocity especially near windows, doors and other typical draughty points.

6.3.3 Values

The characteristic and measured value to prove airtightness is the n_{50}-value, measured by the so called "Blower Door Test". The test measures the air change rate (unit: per h) of one building or dwelling once with low and twice with overpressure of 50 pascal. The average of these two results gives the right n_{50}-value. For building renovation the n_{50}-value should be max. 1,5 /h (passive house standard $< 0{,}6$ /h) [2].

6.3.4 Verification

The following European standard represents the state of the art of measuring procedures of airtightness:

EN 13829 - Thermal performance of buildings - Determination of air permeability of buildings - Fan pressurization method (blower door test)

6.3.5 "Best practice" and information

It's one of the biggest challenges to get an airtight building shell, especially for the retrofit of buildings – investigate our SQUARE pilot projects (see figure 8. and reports [3]).

Useful German links:
http://www.passiv.de/: information to meet the requirements here

Figure 8. Blower door test in pilot project Brogården (left picture) and making the attic airtight at Dieselweg Graz (References: SP and AEE INTEC)

6.4 External shadowing

This measure is necessary to keep indoor thermal comfort during warm season.
Of course it is important in warm climates, but the importance for temperate and even cool climates is noticeably increasing. There are various reasons for that like higher inner heat load (technical equipment, lighting), big window areas without countable shading possibility, etc.

Figure 9. Two examples of external shading with outside blinds; the left picture shows light directing blinds - the upper part of the blind directs daylight into the room (Reference: AEE INTEC)

Figure 10. Wooden venetian blinds used in the Spanish pilot project (Reference: SP)

6.4.1 Impact on energy efficiency

External shadowing reduces cooling demand, thus lowers need for cooling devices. It lowers the current demand if daylight is used for lighting (see figure 9., left picture), but may sometime increase the current demand by using artificial light.

6.4.2 Other advantages/disadvantages and influence on indoor environment

Combined daylight use reduces power consumption for artificial lighting. If all blinds are closed without directing daylight into the rooms, more current might be needed. External shadowing protects residents from glare and reflection.

6.4.3 Values

The characteristic value to quantify the solar transmittance of a transparent building component is the Fc(z)- or Ts-value. It should range below 0,3 - that means maximum 30% of the solar radiation passes the glazed area.
In contrast to that the daylight-factor D is used to assess the indoor daylight conditions. It is a very common and easy to use measure for the subjective daylight quality in a room. It describes the ratio of outside over inside illuminance (unit %). The higher the D, the more natural light is available in the room; it should be higher than 4 in all rooms (4 % of the outside illuminance).

6.4.4 Verification

The following international and European (national) standards represent the state of the art or calculation and measuring procedures of shadowing and daylight specifics and values:

- EN 14501 - Blinds and shutters- Thermal and visual comfort- Performance characteristics and classification (solar transmittance)
- ASTM E1084 - 86(2009) - Standard Test Method for Solar Transmittance (Terrestrial) of Sheet Materials Using Sunlight (solar transmittance factor)
- ÖN B 8110-3 - Thermal protection in building construction - Heat storage and solar impact (solar transmittance values)
- DIN 5034 - Daylight in interiors- Part 4: Simplified determination of minimum window sizes for dwellings
- VDI 6011-1 - Optimisation of daylighting and artificial lighting – fundamentals (daylight)

6.4.5 "Best practice" and information

The SQUARE pilot projects use different types of blinds [3].

http://www.keep-cool.eu/CM.php: Keeping summer comfort in buildings
http://www.es-so.com/en/Solar-shading/types-of-shading-devices.html: Different types of shadowing (see figure 11.)

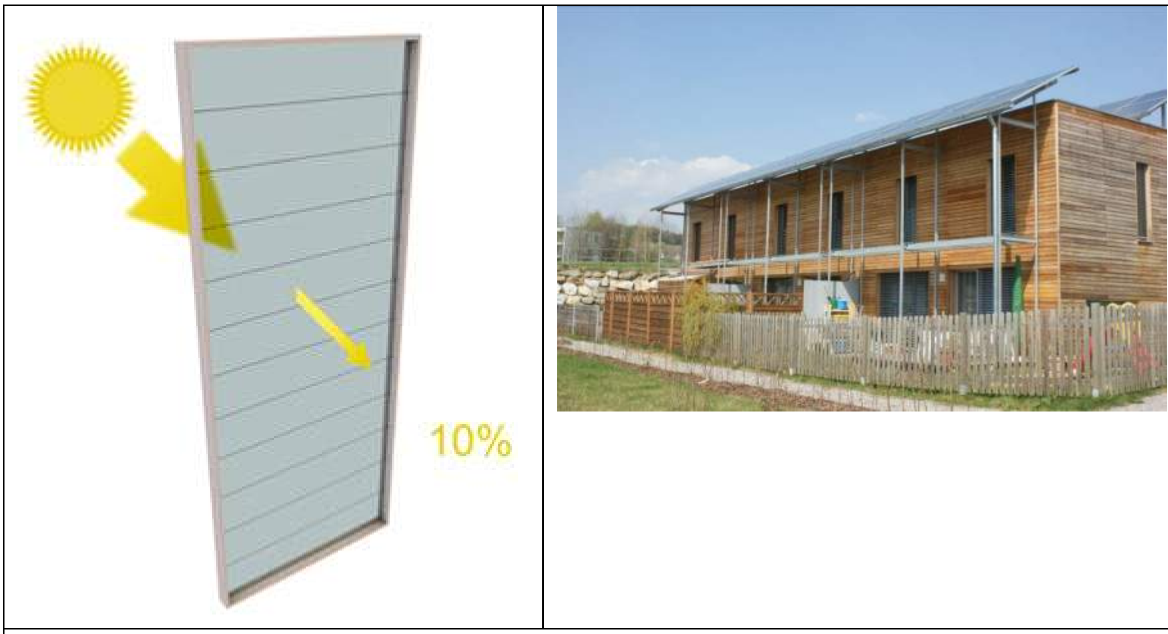


Figure 11. Shading foil solutions like MicroShade™ capture a market (left illustration), but there are more shading ideas like photovoltaic modules at the "Tanno-Row-Houses" in Weiz/Austria (References: PhotoSolar A/S and AEE INTEC)

6.5 Natural cooling requirements

In warm European climates vented roof (sketch in figure 12.) and light coloured roof and façade is very useful to protect the building from heat. Natural cross ventilation (figure 12.) and night free-cooling (see chapter 6.10), combined with external insulation and interior heat storage mass, are used to hold suitable indoor climate during summer season also in temperate climates.

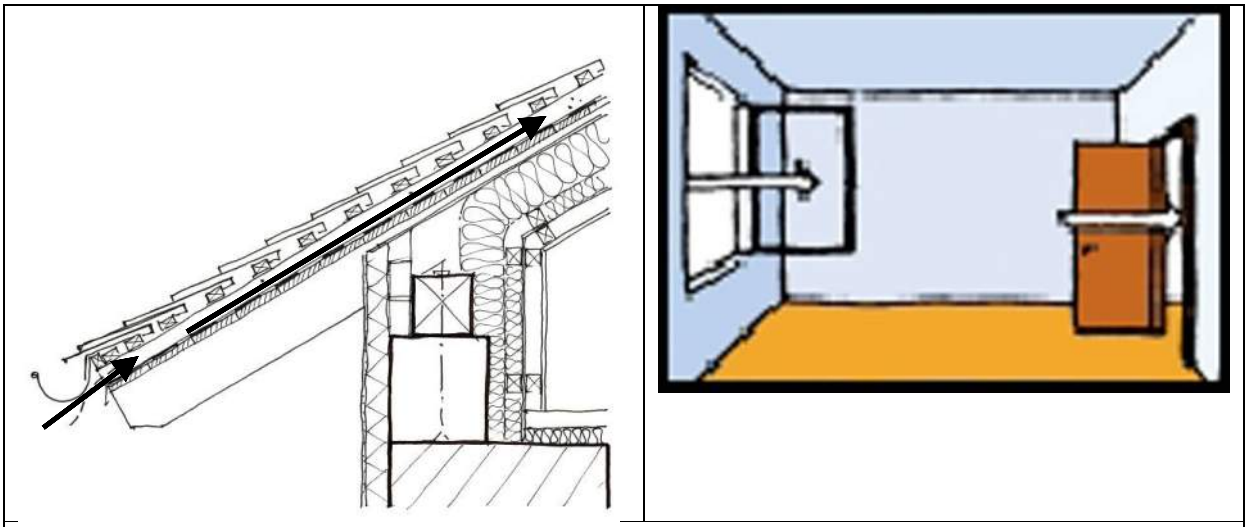


Figure 12. Vented roof and cross ventilation possibilities are basic cooling requirements (References: AEE INTEC)

6.5.1 Impact on energy efficiency

Natural cooling facilities of buildings reduce cooling demand.
It should be an exception or much better not be necessary to use active cooling systems in residential buildings.

6.5.2 Other advantages/disadvantages and influence on indoor environment

Light facade (exterior insulated or vented) and vented roof prevent material fatigue and damages because they reflect or reradiate most of the solar energy. Natural cross ventilation is an alternative to the mechanical ventilation system during the warm season, mostly used to cool down thermal mass during the night. So the heat storage mass helps to cool down the indoor air during summer and to keep rooms warm during winter.

6.5.3 Values

To keep the air flowing, a vented roof needs at least 2 cm of natural ventilated gap between inner insulated roof-layer and outer weatherproofed roof layer.
Cross ventilation is only possible with operable windows in opposite walls of one room or in opposite rooms. It is important to keep this option even using mechanical ventilation systems.

The heat storage mass of one room is very effective when it has the capacity of 1.500 to 5.000 kg per m² of south oriented glazing like windows and doors (immission area), through which the solar radiation incides (directly or indirectly) on heat storage materials.

6.5.4 Verification

The following international and European (national) standards represent the state of the art or calculation and measuring procedures, specifics and values:

- EN 12792 - Ventilation for buildings - Symbols, terminology and graphical symbols (cross ventilation)
- EN ISO 13786 - Thermal performance of building components - Dynamic thermal characteristics - Calculation methods (heat storage)
- DIN 4108 – Thermal protection in building construction (heat storage)
- ÖN B 8110-3 - Thermal protection in building construction - Heat storage and solar impact (heat storage)
- Simulations (heat storage, cross ventilation,...)

6.5.5 "Best practice" and information

The Spanish pilot project uses a vented, insulated roof with the aim to reduce the roof surface temperature during the summer. The roof collects rainwater (see picture 3 and [3]).

http://www.keep-cool.eu/CM.php: Keeping summer comfort in buildings

Picture 3: Vented roof of the Spanish pilot project St Joan de Malta/Barcelona; TTA

Austrian link for information:
http://www.ziegel.at/main.asp?content=technik/Waerme/waermesp.htm

6.6 User's briefing/ user's behaviour

Every retrofit process of residential buildings is first of all a technical and organisational effort, but also a social and communicational one, guiding residents (the users) to energy improvement and high indoor environment during the use and the operation of the building(s). The users' understanding of the actions during and the use of the building after renovation is very important for a comprehensive performance of the process.
It is very important to give residents tools and information so that they can learn what they are dealing with (building services, electricity demands of different devices, ventilation system, etc.). We speak about energy efficiency, so let's include user's interests and problems (see figure 13.).

Figure 13. Communication before renovation and guidance on site (References: AEE INTEC; Dir. Peter Friedl)

6.6.1 Impact on energy efficiency

Information and communication (indirectly) decrease final energy use of the residents when being aware of technical equipment, services and maintenance. This helps to "optimize" internal energy gains.

6.6.2 Other advantages/disadvantages and influence on indoor environment

User's briefings raise awareness of the retrofit and operational needs of an existing building. If the users change traditional behaviour in dealing with new ventilation and heating systems or current devices they contribute to the public attitude of energy saving households. User's briefings contribute to an active contact between the housing association and its tenants.

6.6.3 Values

Information and communication with residents should be held regularly before, during and after renovation (just as communication between partners within the project).
A technical example: If the building provides more natural light after renovation and the users are successfully introduced to use artificial lighting and equipment with energy efficiency class A or better (A+, A++). So current consumption can be reduced down to fifth and users will minimize overheating problems by lower internal loads during summer.

6.6.4 Verification

For example:

- User manuals
- Smart metering
- EU energy- and other labels

6.6.5 "Best practice" and information

All the SQUARE pilot projects tried to give numerous informations and use briefings for the residents, each of them in its own way (figure 14. and [3].

Background information about questionnaires and users' information is also given in the Guide of the SQUARE-system [6].

Some Austrian links:
www.topprodukte.at: Energy efficient equipment
www.hausderzukunft.at: Studies on residents' participation in renovations

Figure 14. An engineer explains the use of the ventilation device (left picture); meeting with tenants in Brogården (References: AEE INTEC; SP)

6.7 Optimized heating system

In cold and temperate climates there should be a very clear aim to minimize the heat losses of the heating system, wherever this is possible. Insulated heat pipes, low temperature (heat) grid, right dimensioned heat generation (heat load), latest boiler (see figure 15.) and heat storage technology, use of condensing boilers are examples that lead to an optimized performance of the heating system.

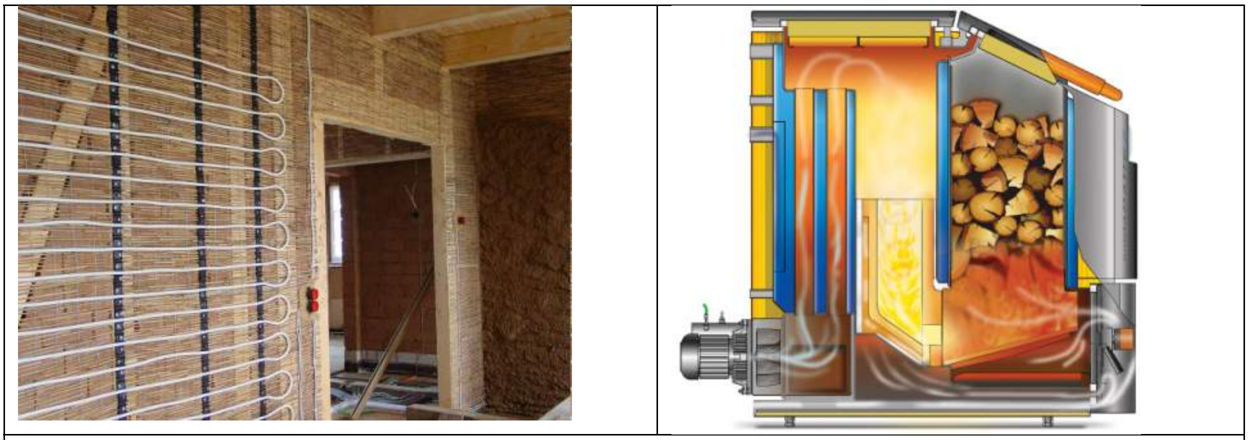


Figure 15. Wall heating (= low temperature) heating system and latest boiler technology, here a log firing boiler, raises the annual use efficiency of the heating system (References: natürlich bauen gmbh; Guntamatic)

6.7.1 Impact on energy efficiency

An optimized heating system reduces energy consumption for heating.

6.7.2 Other advantages/disadvantages and influence on indoor environment

The coefficient of performance of low temperature energy generation such as solar thermal energy is much better by using radiant floor heating or wall heating systems (see figure 15., left picture, and picture 4.). Even in winter it is possible to get 40° or 50°C of flow temperature from solar collectors, but not high temperatures like 60° or 70°C. These systems yield high indoor thermal comfort through heat radiation instead of heat convection.

6.7.3 Values

If boilers are more than 15 years old they should be changed to new ones, which must run with high coefficient of performance (COP min. 90%).
The heating system must run with a high annual use efficiency (wood min. 75%, heat pumps >4, solar thermal systems >35%).
For the hot water distribution pumps have to be energy efficient, heating pipes have to be insulated and flow temperatures from 25 to 55°C should be supplied (low temperature heat distribution).

6.7.4 Verification

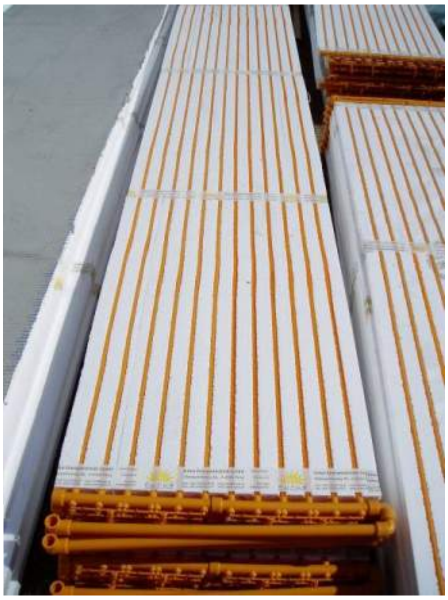
The following international and European (national) standards represent the state of the art, calculation and measuring procedures of heating specifics and values:

- EN 12831 - Heating systems in buildings - Method for calculation of the design heat load
- ON H 5056 - Energy performance of buildings - Energy use for heating systems

- ÖN M 7753, 7755, 7760 and 7763 – national standards for different heat pumps
- Producer's certificates (COPs)
- Measurements to show the annual use efficiency

6.7.5 "Best practice" and information

All the SQUARE pilot projects optimize(d) the heating system and install(ed) latest boiler technology. The systems changed to use heat radiation or heat by ventilation. Pipes were insulated and some use latest solar technology. [3]



Picture 4: Wall heating system used between old and new exterior wall at Dieselweg, Graz; AEE INTEC

6.8 Use of renewable energy sources

In all European climates we should increase the share of renewable energy sources. Except deep geothermal energy, they all have its origin in the sun. In cooler climates it will be better to use water and biomass like wood (see figure 16.), more than solar thermal and photovoltaic energy which is mainly used in warm and temperate climates. Wind, biomass like biogas and deep geothermal energy can be used in all climates, only if there is local supply.
To know about the local sources for decentralized energy generation is crucial to get independent from fossil fuels, to force the local economy and to reduce greenhouse gas emissions for long term perspective.

Energy from heat pumps such as ground coupled, water-water or air to water, can only be considered as renewable energy if the current which is used for the operation of the heat pump comes out of ecological energy sources like wind, biomass, water or deep geothermal energy.

Figure 16. Logs from the woodpile and wood chips boiler (Reference: AEE INTEC)

6.8.1 Impact on energy efficiency

Renewable energy sources replace fossil fuels and -energy sources, and lower the primary energy consumption.

6.8.2 Other advantages/disadvantages and influence on indoor environment

The use of efficient renewable energy technology is crucial to decrease GHG-emissions and to increase regional added value.
At a very subjective level: It is much more comfort to "feel" the sun heating water for the shower or to look at a wood fire place than smelling fuel oil out of the cellar...

6.8.3 Values

The focus is to cover 100% of final energy demand of a building with renewable energy sources.
The primary energy demand should be limited (like 120 kWh/m²a for passive houses, defined by PHI Darmstadt, Germany) as well as the CO_2-emissions.

6.8.4 "Best practice" and information

The Austrian SQUARE pilot project uses solar thermal energy and heat pumps combined with big heat storage tanks (see picture 5 and [3]).

Picture 5: Solar thermal façade collectors at Dieselweg, Graz; AEE INTEC

International links (see also the guide to QA [6]):
www.estif.org: For solar heating and cooling technologies and products
www.epia.org: For Solar PV
www.heatpumpcentre.org: Heat pump technologies

6.9 Optimized heating control system

The best heating control system is the one that offers the right amount of heat at the right place and the right time!
So every single room should have its own heating circuit or ventilation vent in order to control it separately. A high quality control system is every time connected with the outside temperature, the room temperature and the boiler or the flow temperature of the heating system.
New future linked systems like individual (smart) metering are able to control even single devices or parts of the system, and make them run when it is favourable both for energy supply times and the users' budget.

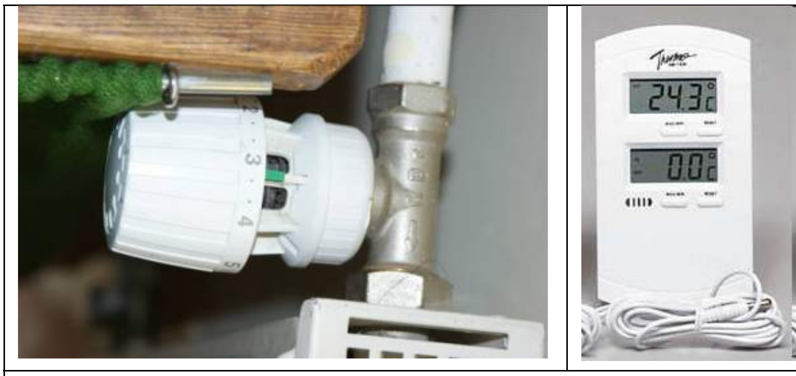


Figure 17. Thermostatic valve and outside temperature sensor (References: AEE INTEC; Star)

6.9.1 Impact on energy consumption

An optimized heating control system reduces energy consumption for heating by strongly raising the annual use efficiency of the supply system.

6.9.2 Other advantages/disadvantages and influence on indoor environment

The control system raises thermal comfort by optimizing the time of heat supply inside the different parts of a dwelling. It avoids overheating (particularly in south situated rooms) and the cool down of adverse situated rooms.

6.9.3 Values

As an example a well planned heating control system allows you to drawdown the room-temperature of every single room during night or times of absence. A decrease of 1 degree (room temperature) means a reduction of energy consumption up to 6%.
A flexible control for every room or heating circuit would be suitable: Outside temperature sensor combined with thermostatic valves at the heaters or room thermostats (see figure 17.).

6.9.4 Verification

The following international and European (national) standards represent the state of the art of control specifics and values:

- EN 215 - Thermostatic radiator valves; requirements and test methods
- EN 60730 - Automatic electrical controls for household and similar use

6.9.5 "Best practice" and information

All the SQUARE pilot projects use control systems [3].

Ask organisations offering energy consulting – they mostly have a lot of know-how about control systems.

Picture 6: Heat distribution and integrated control system; AEE INTEC

6.10 Optimized ventilation system

A well planned and carefully installed ventilation system is the best assurance for high indoor air quality. In all European climates there is the need for an excellent ventilation system that runs hygienically and energetically satisfying. For energy efficiency the ventilation system uses heat recovery by applying an air heat exchanger. In cool and temperate climate it is common to use a ground-air heat exchanger in addition to the heat recovery to pre-warm the outside air.

In warm but also in temperate climates it is common to use the ventilation for cooling down rooms during the hot season: The rooms are supplied with the "cooler" outside air usually at night (free-cooling), because they are heated up by inner loads. In this case the heat recovery is turned off, the cooler air comes in via air-bypass.

Figure 18. Ventilation device with integrated heat recovery and insulated ventilation pipes (References: AIT; AEE INTEC)

6.10.1 Impact on energy consumption

If the ventilation system is equipped with heat recovery, it reduces heat losses. Ventilation such as free-cooling helps to reduce the cooling demand, especially in warm climates if there is relatively high heat storage mass.

6.10.2 Other advantages/disadvantages and influence on indoor environment

The controlled, mechanical ventilation system raises indoor comfort by constant change of air. It avoids construction damages concerning condensation and moist building components, offers possibilities to filter out allergy germs, pollen and air pollutants. If the indoor air gets too dry caused by the ventilation system during cold season, humidity recovery or plants can solve this problem.

6.10.3 Values

The air flow specific electrical power consumption of the ventilation system should range below 0,4 Wh/m^3.
The supplied air change rate (ACH) should exceed 0,3 1/h to meet comfortable indoor air quality; that means 30% of the room volume should be changed per hour.
Some countries use the CO_2-concentration as characteristic value assessing the indoor air quality. It should range below 800 ppm.
Other quality criteria of the mechanical ventilation system are: temperature of room-supplied air higher than 16,5°C, air velocity below 0,15 m/s.
The relative air humidity inside the dwellings during the heating period should range from 45 to 60% (during summer beneath 55%) – an important criterion especially in warm and temperate climates!
The heat recovery should have an effective recovery performance of more than 70%.
The air heat exchanger shouldn't freeze – so there is the possibility to use a ground-coupled-air heat exchanger to prewarm the outside air with a performance of 20% or more.

6.10.4 Verification

The following international and European (national) standards represent the state of the art or calculation and measuring procedures of ventilation specifics and values:

- EN 13141 - Ventilation for buildings - Performance testing of components/products for residential ventilation (mechanical ventilation)
- EN 12599 - Ventilation for buildings - Test procedures and measuring methods for handing over installed ventilation and air conditioning systems (mechanical ventilation)
- EN 13053 - Ventilation for buildings - Air handling units - Rating and performance for units, components and sections (mechanical ventilation)
- ANSI/ASHRAE-standards no. 62 and many others (mechanical ventilation)
- VDI 2071 - Heat recovery in heating, ventilation and air conditioning plants
- Producer's certificate (heat recovery)
- Spanish standards CTE and RITE (ventilation, free-cooling)

6.10.5 "Best practice" and information

All the SQUARE pilot projects use ventilation systems with heat recovery as an important energy improvement and indoor quality relevant measure [3].

www.komfortlüftung.at: Quality criteria for ventilation systems in multifamily buildings
http://www.engineeringtoolbox.com/ventilation-systems-t_37.html: One example of technical information

Picture 7: Big ventilation device with integrated heat recovery; AEE INTEC

7 Conclusions and further information

The SQUARE pilot projects show that there is a big range of measures leading to energy improvement and tried to collect most efficient and important measures that should be considered for every retrofitting action.

Table 4. summarizes the classification of basic and active measures to improve energy efficiency for different SQUARE climates.

Table 4. *Most relevant basic and active measures regarding different climates (suggested by AEE INTEC, verified by SQUARE partners)*

	W warm	T temperate	C cool
BASIC MEASURES	External shadowing and natural cooling requirements	Complete exterior insulation and airtightness	Complete exterior insulation and thermal optimized windows/doors
	Complete exterior insulation and heat storage mass	Thermal optimized windows/doors and external shadowing	Airtightness
ACTIVE MEASURES	Optimized ventilation system with free-cooling during summer	Optimized ventilation system with heat recovery (ground heat exchanger)	Optimized heating system and use of renewable sources
	And with heat recovery during winter	Optimized heating- and control system, use of renewable sources	Ventilation system with heat recovery

We learned that energy improvement is more than to reduce energy input. As long as it influences indoor environment and the well-being of residents it is worth to go into details and to spend time on establishing requirements for the renovation process both for the construction and the operational stage of the process.

Some more information:

Please have a look at some useful Austrian websites, concerning the aims of energy efficiency for retrofitted buildings:
http://www.hausderzukunft.at/ (Austrian studies on different building aspects)
http://energytech.at/ (Austrian platform for innovative technologies in

Picture 8: A very efficient measure: exterior insulation; Arch. Kaltenegger.

the area of energy efficiency and the use of renewable energy sources)
http://www.energyagency.at/ (Austrian energy agency with lot of information in the area of energy efficient buildings, consulting organisations and subsidies)
http://www.oegnb.net/ (Austrian total quality assessment platform, offering an assessment guideline [7])

8 References

[1] IBO - Austrian Institute for Healthy and Ecological Building (2009): Details for Passive Houses - A Catalogue of Ecologically Rated Constructions. Vienna/Springer-Verlag

[2] Energieinstitut Vorarlberg in Zusammenarbeit mit IBO im Auftrag des BMLFUW (16.02.2009): Technische Erläuterungen. Kriterien zum klima:aktiv haus für Wohngebäudesanierungen. Version 1.1, Austria

[3] SQUARE partners (2009): National pilot project reports. Deliverable 6:1 - SQUARE work package 6 Pilot Projects. Internal reports and information given during the SQUARE meetings

[4] Forschungsgesellschaft Joanneum – Institut für Energieforschung, K. Frey, J. Haas, K. Könighofer (Ausgabe 1994): Handbuch für Energieberater. Graz, Austria

[5] Umweltschutzverein Bürger und Umwelt, "die umweltberatung", Manfred Sonnleithner (2006): Passiv- und Niedrigenergiehäuser, Seite 20, 3. überarbeitete Auflage. St. Pölten, Austria

[6] SP Technical Research Institute of Sweden, Peter Kovacs and Kristina Mjörnell (2009): A guide to quality assurance for improvement of indoor environment and energy performance when retrofitting multifamily houses, SQUARE work package 4. Borås, Sweden

[7] Österreichisches Ökologie-Institut, Susanne Geissler, und Kanzlei Dr. Bruck, Manfred Bruck (2002): Leitfaden für die TQ Bewertung, Version 2.0. Vienna, Austria

A Energy efficient measures - documentation

SQUARE

Object / country:

Evaluation of energy improvement measures by the terms of the Directive 2002/91/EC (on the energy performance of buildings) and the ISO 7730 (Ergonomics of the thermal environment)

	before retrofit		after retrofit		national target	(if there is)
Comparison of CALCULATED values:						
U-values / structures of building components						
Outer walls		[W/m²K]; structure to be delivered		[W/m²K]; structure to be delivered		[W/m²K]; structure to be delivered
Top ceiling						
Ground floor or floor towards cellar						
Window pane						
Window frame						
Operative temperature:						
Standard outside temperature:		[°C]				
Internal surface temperatures of						
Outer walls		[°C]		[°C]		[°C]
Top ceiling						
Ground floor or floor towards cellar						
Windows						
Heat bridges (option I)						
Internal surface temperatures		[°C]		[°C]		[°C]
Linear thermal transmittance Y		[W/mK]		[W/mK]		[W/mK]
Comparison of CALCULATED OR MEASURED values:						
Energy demand for heating						
Calculated energy demand for heating (EPBD)		[kWh/m²a]		[kWh/m²a]		[kWh/m²a]
Measured energy demand for heating (bills)*		[kWh/m²a]		[kWh/m²a]		
(*not possible in the case of combined DHWC and heating systems)						
Fuel for heat production		to be declared		to be declared		
Comparison of MEASURED values (if available):						
CO_2 - concentration of indoor air		[ppm]		[ppm]		[ppm]
Indoor air humidity R.H.		[%]		[%]		[%]
Air temperature		[°C]		[°C]		[°C]
Internal surface temperatures						
Outer walls		[°C]		[°C]		[°C]
Top ceiling						
Ground floor or floor towards cellar						
Windows						
Air tightness (n_{50})		h^{-1}		h^{-1}		h^{-1}
Air flow rate ensured by ventilation system		h^{-1}		h^{-1}		h^{-1}
Heat recovery rate of ventilation system		%		%		%
Thermographic views		to be delivered		to be delivered		
PLANS, DRAWINGS to be delivered:						
Radiation asymmetry						
Floor plans		to be delivered		to be delivered		
Section view						
Heat bridges (option II)						
Detail drawings		to be delivered		to be delivered		
Exterior shading elements against overheating in summer						
Detail drawings		to be delivered		to be delivered		
Night ventilation system						
Concept description		to be delivered		to be delivered		

Figure 19. *Template for calculated and measured values of the different SQUARE pilot projects (Reference: AEE INTEC)*

The above shown figure 19. was elaborated as "DATA FORM A" and developed to compile calculated and measured values of the pilot projects.

The documentation of the building envelope of the SQUARE pilot projects was one of the first tasks of WP 5. Following excel list (figure 20., first part of "DATA FORM B") was made to compile this information.

SQUARE
WP 5

Energy and indoor environment improvement measures catalogue

Please deliver data form B

- about your solutions for improvement of energy performance of building components
  - ☐ exterior walls
  - ☐ windows
  - ☐ top floors
  - ☐ Roofs
  - ☐ cellar ceilings
  - ☐ earth touching floors
  - ☐ ceilings to exterior air
  - ☐ walls to not heated building areas

- about your solutions for improvement of airtightness of connections between building components
  - ☐ connection between walls
  - ☐ connection between walls and ceilings
  - ☐ connection between walls and windows, doors
  - ☐ penetrations

- about your solutions for elemination of typical heat bridges
  - ☐ windows
  - ☐ balconies
  - ☐ Ceilings
  - ☐ attics of flat roofs
  - ☐ plinths (wall connections to cellar)

Figure 20. Excel sheet developed to compile information of the different SQUARE pilot projects (Reference: AEE INTEC)

The following figure 21. shows one example of an excel tool (second part of "DATA FORM B") developed for the analyse of retrofit actions regarding the building shell of the different SUQARE pilot projects.

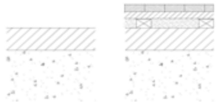
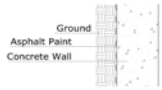
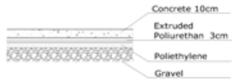
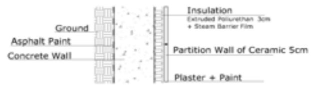
	Ground touching floor	Earth touching walls
Building stock (e.g. 1945 - 1980) in SPAIN		
Building component before retrofit (sketch)		
Structure of this building component before retrofit	Concrete floor with screed, without insulation	concrete
Typical U-value before retrofit	2,70	2,50
Percentage of heat losses through this building component	0,10	0,15
Requirements		
U-value for new buildings	0,65	1,22-0,74
U-value for passive house standard (recommended)	0,00	0,00
Retrofit measure		
Building component after retrofit (sketch)		
Description of retrofit measure	Insulation of ground touching floor	Insulation
Possible building materials	rock wool	rock wool
Comments, tipps		
Insulation thickness for new building standard	50 mm	40 mm
Insulation thickness for passive house standard		
Assessment of feasibility		
Economics		
Costs to achieve new building standard	67 € / m2	38 € / m2
Costs to achieve passive house standard		
Assessment of economics		
Indoor environment		
Relevance for the indoor environment		
	Moisture reduction	Moisture reduction

Figure 21. *Excel tool showing an extract of an energy relevant building components catalogue of the Spanish pilot project "St Joan de Malta" as a result of investigations within SQUARE WP5 (Reference: AEE INTEC)*

B ISO 7730 analysis

With the inputs of the SQUARE partners, an excel tool for simply investigating thermal comfort concerning ISO 7730 was developed (figures 22. and 23.).

Calculation of the mean radiation temperature of a room

Input data

Object: Dieselweg / Graz / EG Eckzimmer

BEFORE retrofit

Climatic parameters:

ta	Standard inside temperature	[°C]	20
te,1	Outside temperature in situation 1	[°C]	-12
te,2	Outside temperature in situation 2	[°C]	0
te,3	Outside temperature in situation 3	[°C]	10

Room to be evaluated:

			Floor	Ceiling	Wall 1	Window in wall 1	Wall 3	Window in wall 2	Wall 3	Window in wall 3	Wall 4	Window in wall 4
A	Size of surfaces	[m²]	12,16	12,16	8,51	1,56	8,48		10,07		8,48	
U	U-value	[W/m²K]	1,50		1,28	2,00	1,28					
x	**touches heated area** [cross if applicable]	[x]		x		-		-	x	-	x	-
Rsi	Heat transfer resistance	[m²K/W]	0,17	0,00	0,13	0,13	0,13	0,13	0,00	0,13	0,00	0,13

Surface temperatures of building components:

			Floor	Ceiling	Wall 1	Window in wall 1	Wall 3	Window in wall 2	Wall 3	Window in wall 3	Wall 4	Window in wall 4
tsi,1	Situation 1	[°C]	11,84	20,00	14,68	11,68	14,68	0,00	20,00	0,00	20,00	0,00
tsi,2	Situation 2	[°C]	14,90	20,00	16,67	14,80	16,67	0,00	20,00	0,00	20,00	0,00
tsi,3	Situation 3	[°C]	17,45	20,00	18,34	17,40	18,34	0,00	20,00	0,00	20,00	0,00

Mean radiation temperature:

tr,1	*Situation 1*	*[°C]*	*16,70*
tr,2	*Situation 2*	*[°C]*	*17,94*
tr,3	*Situation 3*	*[°C]*	*18,97*

Figure 22. Excel tool showing input data and requirements of ISO 7730-investigation within SQUARE project (Reference: AEE INTEC)

Object: [illegible]

BEFORE refurbishment **AFTER** refurbishment

Standard inside temperature ta	20	[°C]
Situation 1 BEFORE retrofit:		
Outside temperature te,1	-12	[°C]
PMV,1	-1,22	[-]
PPD,1	35,99	[%]
Situation 2 BEFORE retrofit:		
Outside temperature te,2	0	[°C]
PMV,2	-0,86	[-]
PPD,2	20,76	[%]
Situation 3 BEFORE retrofit:		
Outside temperature te,3	10	[°C]
PMV,3	-0,57	[-]
PPD,3	11,76	[%]
Situation 1 AFTER retrofit:		
Outside temperature te,1	-12	[°C]
PMV,1	-0,42	[-]
PPD,1	8,76	[%]
Situation 2 AFTER retrofit:		
Outside temperature te,2	0	[°C]
PMV,2	-0,37	[-]
PPD,2	7,80	[%]
Situation 3 AFTER retrofit:		
Outside temperature te,3	10	[°C]
PMV,3	-0,32	[-]
PPD,3	7,10	[%]

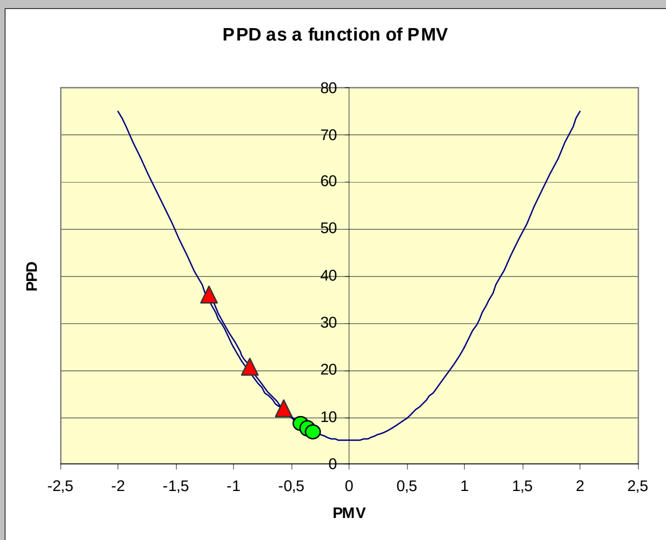


Figure 23. Excel tool showing results of ISO 7730-investigation within SQUARE project (Reference: AEE INTEC)

SQUARE - A System for Quality Assurance when Retrofitting Existing Buildings to Energy Efficient Buildings

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