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Buildings
a TechnologyPortrait

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1 INTRODUCTION

Approximately 40 per cent of final energy in Austria is used in the sectors of construction and habitation (i.e. in heating and lighting rooms as well as providing the appropriate hot water supply systems). The building and construction industry is regarded as consuming some of the highest resources in the industrial branch due to the masses of building materials transported and used, and it is also responsible for creating a major part of the antropogen emissions that have a detrimental effect on the climate.

A building can be regarded as a success when its construction is linked to a sensible and conscious approach towards energy as well as meeting numerous other requirements (quality of life, health, social aspects, affordability, future property value etc.).. Architecturally creative and technical solutions thus have to be created and realised in view of all these specific requirements.

“Good Architecture” has to fulfil many requirements – and a sensible approach towards energy is definitely one of them. Some buildings, however, seem more like “Energy Machines” than building constructions, and the main aim of saving energy is often forfeited in return for basic building development plan requirements. “Form, Function, Construction” – these are the three regular criteria used to judge the architectural quality of buildings. There is no need to create a further criterion entitled “Energy Consumption” as this is completely incorporated in the criterion “Function” criterion. Buildings that fail to deal with the question of energy consumption have undeniable shortcomings in functionality in view of the well-known global problems we are all now facing. (Peter Holzer, Center for Architecture, Construction and Environment, Danube University, Krems)

The building and construction industry records an extremely high turn-over from an economic point of view and helps create many jobs in Austria:

- 57,000 living units were constructed in Austria in 1999, thus signifying newly created property assets of approximately EURO 9,8 billion.
- EURO 5,5 million were spent on residential building costs (not including basic costs) in Austria in 1997.
- The building and construction industry (building and civil engineering) employs 8.8 million people (8 per cent of all employed persons in Austria) and is thus the largest employer in the EU. A further 26 million are employed in jobs connected with the building and construction industry.
- The building and construction industry is responsible for using 43 per cent of all materials produced in Austria and for building on 47 per cent of all open spaces in the country. These percentages are based on figures from the overall national economy.

Source: Österreichisches Wohnhandbuch 2000 - Austrian Habitation Guide for 2000 by K. Lugger – available only in German; Indikators for Sustainable Land Use, H. Haberl et.al., Wien 1999.

The acquisition of living space is normally the largest financial expenditure/burden in people’s lives, and affordability, economical operating costs and future property value all become important in the search for the right place to live.

This presentation describes the technological options available for dealing sensibly with energy and focuses on the important areas of new building constructions and of building refurbishment together with its specific energy requirements. energytech.at also deals with other technology sectors in the building and construction industry such as the thermal and electrical utilisation of solar energy and wood heating systems.

There are numerous methods of planning – the approach shown here is just one of many and has been chosen to meet the aim of this presentation.

Further information, additional references and sources:

- energytech.at Thermal Solar Energy
- energytech.at Photovoltaics
- energytech.at Solid Biomass
- energytech.at Publications on Building Refurbishment
- Nachhaltiges Bauen und Wohnen - Sustainable Construction and Habitation, atsd: Brochure “Energy in Buildings”, Federal Ministry of Transport, Innovation & Technology (unpublished)
- Thermische Solarenergienutzung an Gebäuden (für Ingenieure und Architekten) - Thermal Solar Energy Use in Buildings (for engineers and architects); Marko, Braun; Springer Publishing House 1997 – available only in German

2 THE BUILDING – A COMPLEX SYSTEM

New building constructions are becoming more complex and equally diverse in design due to the increasing use of innovative materials, technologies and construction methods nowadays. The amount of chemical substances used in the building and construction industry has, for example, increased a thousandfold within the last century, and architecture is constantly endeavouring to incorporate these innovations in the design of new buildings.

Fig. 1: „Plabutsch“ solar housing, apartment buildings, designed and constructed by the “Neue Heimat”, housing association in Graz, Styria

(Source: energytech.at Pictures)

Numerous challenges arise in connection with this new complexity and diversity. A basic social obligation can be seen in every architectural era and it now focuses on the topic of sustainable development – i.e. an all-round economic, ecological and social approach. The search is on for systemic solutions and this often leads to conflicts in the realisation of concrete development programs. The whole topic of sustainability requires a systemic approach. A change in user behaviour in the office and residential building sector has also left its mark on new building constructions, thus requiring the total integration of ever-changing user needs when employing a systematic approach.

The basic pre-requisites for sustainable building constructions are a long period of occupancy and the prolonged use of building components. It is, for example, worth spending the maximum period of occupancy possible in a passive house with low operating energy requirements and low costs for operating materials (i.e. for maintenance) in comparison to some existing buildings with bad standards of thermal comfort conditions, which should undergo extensive renewal or building refurbishment as soon as possible. A sustainable building should have a total period of occupancy of at least one century, which correlates with the average demolition rate of approximately 1%/a.

The operating energy expenditures clearly exceed the production energy expenditures in existing buildings, and the production expenditures (like, for example, the extremely low primary energy demand for the heating) only start to correlate in solar low energy houses and passive houses. Extra expenses for production and renewal are more than reduced due to the savings made during the whole period of occupancy.

The following factors are usually included in a sensible and conscious approach towards energy in building:

The construction plan, type of building envelope and appropriate heating, ventilation and air conditioning system are all chosen according to user needs and location factors, and these decisions are then tested by employing static or dynamic methods and corrected, if necessary.

See chapter “Planning” for further information on the planning stages.

See chapter 8 for the specific requirements to be met when carrying out building refurbishment.

3 PLANNING

Users (building owners), planners (architects) and domestic engineers all have to work together from the very beginning of a project in order to obtain high-quality solutions.

Fig. 2: "Aspern an der Sonne" site plan, Müllnermaisgasse/Wulzendorferstraße (1220 Vienna)

(Source & Copyright: Arch. G. W. Reinberg)

3.1 Choice of location, development planning

Important parameters for subsequent energy consumption can also be seen in the choice of location and development planning:

- Solar Radiation: The intensity, duration and direction of direct solar insolation are all-important factors to be considered when attempting to provide high standards of thermal comfort at low energy prices with environmentally-friendly solutions. (For further information, see energytech.at: Thermal Solar Energy – Preconditions for the utilisation of solar energy),
- Air temperature,
- Wind intensity and wind direction,
- Easy access to public transport facilities as well as only short distances to the work place and leisure amenities.

3.2 Type of development and building shape

Energy-inefficient development plans or building shapes lead to increases in energy consumption during occupancy, which can only (if at all) be reduced by introducing additional measures.

The surface-area-to-volume ratio measures the "compactness" of a building and is, at 0.7 per cent, extremely energy-inefficient in a detached house in comparison to 0.25 per cent for block-edge developments (e.g. in inner cities).

Fig. 3: Blocks of flats in flats in Feldkirch, Vorarlberg

The orientation of a building to the south is not absolutely necessary in terms of energy, especially if it would be contradictory to the surrounding area. There are a number of existing buildings, which are energy efficient, although not oriented to the south. (For further information see: "Building of Tomorrow".)

The concept of "thermal zoning" and the use of buffer spaces is of the utmost importance for the energy demand of a building. Thermal zoning means the sensible distribution of rooms with different energy demands, in order to create rational distribution of the heat and reduce heat flows as much as possible. Unheated buffer spaces such as the stairs and storerooms provide additional heat conservation when they are located along the north-side or towards shaded exterior walls. Glazed buffer spaces and sun-spaces on the other hand are oriented to the south, in order to provide additional heat gains.

3.3 Optimising the gains – The building as an energy-efficient system

Internal gains (waste heat of appliances, metabolic gains from occupants) and solar gains have to be compared with the heat losses (ventilation heat loss or heat loss through the building envelope). The difference between heat gains and heat losses must be provided by the heating or the air conditioning system, which is especially relevant for office buildings in our part of the world in the summertime. Gains must be maximised and losses minimised in order to obtain high energy efficiency and high thermal comfort in buildings.

3.3.1 Energy indicators

The energy efficiency of buildings is measured by calculating energy indicators. The basis being not only Austrian Standards (ON), but also German (Heat Insulation Ordinance), Swiss (SIA 380-1) and International Standards (EN or ISO).

Table 1: Typical energy indicators

Unit	Passive House	Low energy house	Number of buildings < 1980
Heating demand kWh/m² (floor area).a	=< 15	=< 40	150-250
Final energy demand kWh/m² (floor area).a	=< 42	=< 70	
Primary energy demand kWh/m² (floor area).a	=< 120	=< 160	

(Source: ECO-Building Optimierung von Gebäuden durch Total Quality Assessment - Building Optimisation with Total Quality Assessment by Susanne Geissler, Manfred Bruck, Ökologie Institut - The Austrian Institute for Applied Ecology)

The **heating demand** is the amount of heat supplied to the interior space of a building during the heating period in order to maintain the required temperatures. The heating demand takes into consideration the characteristics of the building envelope, the specific utilisation (as residential building, school etc.) and the climatic site conditions.

The characteristics of the envelope in this case not only include the heat conservation of exterior surfaces and compactness of the building, but also the orientation of the glazings (and their shading) and the airtightness of the envelope.

The **LEK value** results from the medium heat conservation of the building envelope, whereby the compactness is additionally taken into consideration. The LEK value of a building with a compactness of 1 is a hundred times the value of the medium U value (former K value), (see also chapter “Type of development and building shape”).

The **heating energy demand** is calculated from the heating demand – a building parameter - and the annual utilisation factor of the heating system. The annual utilisation factor represents the relation between the available energy and the used final energy over a period of one year. According to the Austrian Standard ON H 5056 it has to be calculated from the influences of the heat supply system (e. g. boiler), the heat distribution system and the heat regulation system.

Further information:

On the homepage of Österreichisches Institut für Bautechnik (OIB) - the Austrian Institute of Constructin Engineering - you will not only find a "Leitfaden für die Berechnung von Energiekennzahlen" - "Manual for the Calculation of Energy Indicators" and an "Muster für den Energieausweis" - "Energy Certification Sample", but also a calculation program for a fast and simple calculation of energy indicators, only available in German.

Table 2: Computer-based programs for calculating the heating demand:

Program	Producer
ArchiPhysik	A-Null EDV GmbH www.a-null.com
Ecotech	Ecotech Software GmbH www.ecotech.co.at
EPlan	AEE INTEC www.aee.at
G-e-Q, Buildings, Energy, Quality	Zehentmayer Software www.zet.at
Waebed	Vienna University of Technology www.tuwien.ac.at
Genbil	Energy Institute www.energie-institut.co.at/genbil.html
Handbuch Passivhaus (Passive house manual)	Passive House Institute www.passivhaus-institut.de

3.3.2 Thermal comfort

People's perception of thermal comfort in a building not only depends on their clothing and activities, but also on the following parameters:

- Operative temperature: This is made up of the surface and room temperature. The difference between the mean surface temperature, which constitutes the radiative contribution to the operative temperature and the air temperature should not amount to more than 4° C. The air temperature should have about 18 to 22 ° C in winter and about 22 to 25° C in summer – depending on the activity.
- Humidity: Relative humidity of 35 to 70 per cent, absolute humidity <12 g H2O/kg air
- Air velocity (draught): <0,15 m/s
- Air change: The air change rates in a residential building should measure between 0.4 and 0.7 per hour due to hygienic aspects.

- Thermal comfort in summer: Number of hours per year with a perceived indoor temperature above 26° C. This value should be kept as low as possible.

All values should be kept within the given limits in order to achieve thermal comfort.

3.3.3 Balancing and Simulation

A simple energy balance calculation can only be an estimation due to the extremely complicated physical interactions of solar insolation, shading, heating, ventilation, heat recovery, cooling, occupants, appliances, insulation and storage capacity of building components. The increased use of passive solar energy components do, however, require dynamic simulations during the planning phases as aspects like thermal comfort and overheating, as well as optimal economic efficiency can then be considered. It is also possible to regard storage capacities and create temperature profiles by employing dynamic methods. The use and interpretation of such methods do, however, require much training and know-how, and should thus be carried out by specialist planners.

Further information:

- A precise overview of available calculation programs for the computer-aided simulation of buildings is given in the brochure "Computer-aided Building Simulation", which was published as part of a research project carried out by the International Energy Agency.
- Another overview of more than two hundred software packages for building simulation can be found on the homepage of the Office of Building Technology, State and Community Program (BTS) of the U.S. Department of Energy (DOE).

Dynamic simulations in Austria are, for example, carried out by:

- Österreichisches Institut für Baubiologie und ökologie - Austrian Institute of Building Biology and Ecology, only in German. Also see innovative projects: Primary school in Grafenschlag, by Architect Johannes Kislinger.
- Energie-Institut

3.4 User behaviour

Some people talk about “user-deficient behaviour” and others about “user-unfriendly planning” depending on their approach towards the topic. It is, however, a fact that users have an extremely high influence on the actual amount of energy consumed. Tests have shown that the energy consumption can vary greatly in identically equipped living units.

Controlled ventilation systems and winter gardens are two building components that are often constructed in low-energy houses and have direct effects on the behaviour of users (ventilation behaviour, shading/use of winter gardens). A successful market deployment of low-energy houses also depends on the degree to which architects are able to adapt these building components to suit the needs of users by introducing further innovations. This step-by-step adaptation is a mutual learning process between producers and users (in this case not only occupants, but also building developers, architects or domestic engineers). (Source: H. Rohracher “The Acceptance and Improvement of Low-Energy House Components as a Mutual Learning Process for Users and Producers").

For further information:

Numerous projects on the topic of “User Behaviour” have been carried out by the Austrian Program on Technologies for Sustainable Development (Impulsgprogramm Nachhaltig Wirtschaften) in the subprogram “Building of Tomorrow” (Haus der Zukunft). The final reports can be read under the following addresses:

Subjective Housing Quality as Social Acceptance Test of Sustainability.

Experiences and Attitudes of Users as a Basis for the Development of Sustainable Housing Concepts with High Social Acceptance.

Acceptance and Improvement of Low-Energy House Components as a Mutual Learning Process for Users and Producers.

Analysis of User Behaviour and Post-Occupancy Experiences of Inhabitants of Pilot and Demonstration Housing Projects and Office Buildings.

Home Dreams: Practice-Based Criteria and Recommendations for Quality, User-Oriented Building Policies.

4 THE BUILDING – THE ENVELOPE

4.1 Building materials

The material input contributes greatly to the indoor air quality and energy consumption in a building. Insulation properties and heat storage capacity are both important energy factors, and clever dimensioning of new building constructions can also help:

- reduce energy consumption,
- even out fluctuations in temperature,
- prevent overheating in summer,
- shorten the warm-up period in a building.

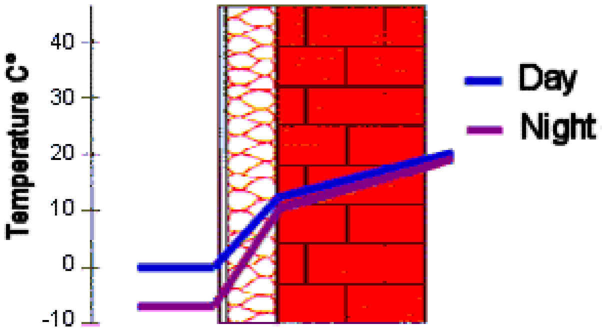

Fig. 4: Temperature flow in a wall with conventional thermal insulation

Savings of up to 20 per cent in heating costs and an improvement in thermal comfort during the summer can be achieved when there is a well-balanced ratio between solar gains and the storage capacity of a building. Transparent insulation materials not only reduce thermal heat lost through conventional insulation within the envelope but also benefit from solar gains, thus leading directly to a reduction in heating costs.

Remarkable results can be found under the Austrian Program on Technologies for Sustainable Development in the subprogram “Building of Tomorrow”:

Wall Systems made of Renewable Resources

Renewable Resources in the Building Sector

4.1.1 Heat insulation capacity

The heat insulation capacity of a building material is measured by its thermal conductivity (W/mK).

The thermal conductivity represents the amount of heat flow per second through 1m² of building material measuring 1m thickness with a 1 Kelvin difference in temperature between the inside and outside surfaces. The lower this value, the better the insulating effect of the building material. The U value (former K value) of a building material is gained by dividing thermal conductivity by the thickness of a building material.

Further information:

See chapter „Insulation systems with higher levels of material thickness“

The European Building Data Bank provides a Program for the Calculation of U values of building constructions

Basic research on fixing elements: drawing up universal design guidelines for high resilience mechanical jointing techniques for insulation products

Research work on outside sprayed-on cellulose insulation covered with plastering

4.1.2 Thermal storage and summer overheating protection

Heat insulation measures alter the heat storage capacity of building components. The storage mass does not have a strong influence on the heating energy demand in our Central European climate. Buildings should therefore have external insulation. Changes in the thermal storage capacity in buildings can occur when using internal insulation.

- The storage mass can store excess heat during periods of hot weather.
- A reduction of the storage mass will shorten the warm-up time.

The heat storage capacity of a building material is defined by its specific heat capacity c and expressed in storage mass per square metre of building component surface (kg/m²).

The effective storage mass depends on specific heat capacity, bulk density, limit depth and thermal conductivity of each building material. There is no further notable increase in heat storage capacity at the limit depth. This value amounts to approx. 20 cm with solid brick, hollow brick or light-weight concrete. The uppermost 5 to 10 cm of material thickness are important for a typical one-day period of heat storage. Further factors considerably contributing to the overall storage capacity are ceilings, floors, interior walls and furniture.

The room temperature in living spaces should be at least 3K but no more than 6K below the maximum external temperature on hot summer days and especially on humid days.

A simplified procedure published by the Austrian Standards Institute (ÖNORM B8110-3) can be used to calculate overheating levels. It takes into consideration the following factors, regarding the warm-up time of buildings in summer:

- size of transparent surfaces (glazings)
- effect of sun protection
- amount of natural ventilation in the interior space
- storage mass.

The higher the contribution of solar energy to interior space heating during winter, the more important it is to calculate it in advance.

4.1.3 Airtight constructions

Airtightness is becoming an important consideration in the construction of both new buildings and the thermal refurbishment of existing buildings. Current building standards state that roofs should be airtight, but this can rarely be realised in practice.

Measures to achieve airtightness (and moisture barrier) are always positioned on the warm side of the roof construction facing the interior, whereas measures to achieve windtightness are always positioned on the cold side of the construction. Non-airtight sections in the building envelope, like, for example, in the moisture barrier or window constructions result in

- large-scale thermal losses,
- the risk of building damage due to moisture build-up,
- a too dry indoor room quality in winter,
- less overheating protection in summer,
- poor sound insulation and
- uncontrolled air change.

4.1.3.1 Thermal loss through air gaps

Insulation can drop to 4.8 times its initial value when there’s an air gap measuring 1 mm in width and 1 m in length. Up to 800 g moisture can get into the roof construction through such an air gap per day and square metre – in comparison to only 0.5 g with an airtight moisture barrier.

General conditions:
Room temperature +20 ° C,
External temperature –10 ° C
Pressure difference 20 Pa = Wind velocity 2 - 3

Measuring values:
Without air gap: U value = 0.3 W/m2K,
With 1 mm air gap: U value = 1.44 W/m2K

Source: Thermal losses with a 1 mm air gap (Measurements carried out by the Fraunhofer Institute for Building Physics in Stuttgart)

4.1.4 Vapour diffusion

An important pre-requisite for the correct functioning of thermal insulation is to avoid humidity penetration. Vapour usually diffuses from the warm to the cold side of a building or from the side with a higher level of humidity to the side with the lower level of humidity. This means that the vapour diffuses from the interior to the exterior of the building envelope in winter. The resistance offered by a building component to the vapour being transported through the thermal insulation is shown in relation to the resistance in the air (=1) and regarded as the vapour-diffusion resistance indicator.

Table 3: Vapour diffusion resistance of building materials

Air	1
Sheep’s wool, Flax, Mineral Wool	1
Cork	5 - 10
Polystyrene Rigid Foam	30 - 60
Wood	15 - 35
Brick	5 - 15
Concrete	100
PE-foil	100.000
Aluminium foil	vapour-tight

The diffuion resistance of a complete building component is defined by the equivalent diffused air space thickness, which shows the thickness of air spaces with the same diffusion resistance in m. The eqiuvalent diffused air space thickness is calculated by multiplying the thickness of the building components with the diffusion resistance.

Equivalent diffused air space thickness (sd) = Thickness of Building Components (in m) x Diffusion Resistance

Example:
Masonry 30 cm, Hollow Brick: *sd = 0,3 x 10 = 3 m*
PE-Foil 0.2 mm: *sd = 0,0002 x 100.000 = 20 m*

4.1.5 Grey energy

The energy consumption connected with the manufacture of these building materials is known as the “Grey Energy” of building materials. A more elaborate definition of grey energy also takes into consideration the energy consumption used in the transport, construction, demolition and disposal of building materials. The level of this type of energy consumption in low-energy houses is comparable to the amount of energy consumed throughout the whole period of occupancy.

Further information:

More data can, for example, be found in the IBO-Bauteilkatalog - IBO Catalogue of Building Components at Österreichisches Institut für Baubiologie und –ökologie - the Austrian Institute for Building Biology and Ecology.

4.2 Windows/ Daylighting

Windows and window frames usually represent the weakest point in an energy-efficient building (not even the most innovative window construction can compete with an insulated wall that meets the current building standards considering the U value). Correctly sized windows are, however, able to make optimal use of natural daylight and benefit from solar gains (thermal comfort in summer also has to be taken into consideration).

The dew-point temperature amounts to up to 9.3°C at an indoor temperature of 20 °C and relative humidity of 50 per cent. A temperature of 8.4°C is reached on the interior surface of double-insulating glazings at an exterior temperature of –10°C. Condensation thus forms on the whole window pane, and the result is that condensation forms in the corner sections of the window pane at external temperatures that do not even have to be extremely low due to the fact that the frame is one of the weakest points in the construction.

Table 4: Different types of glazings and their savings potential, as well as the surface temperature of interior window panes:

	U value	Interior surface temperature of window pane at -10°C outside and 20°C inside of the building
Single glazing	5,6	- 1,0°C
Double insulating glazing	2,9 – 3,1	+ 8,4°C
Triple insulating glazing	2,1	+ 12,1°C
Double heat protection glazing	1,1 – 1,6	+ 13,8 - 15,5°C
Triple heat protection glazing	0,4 – 0,8	+ 16,8 - 17,3°C

The glazing systems of passive houses usually have triple heat protection glazings, which are filled with an inert gas and have a special coating on the inside of the window pane. Net energy gains can be made in the heating period when using such south-facing, non-shaded glazing systems. The U value should thus at least amount to 0.8 W/m²K and the G value (overall transmission coefficient) 50 per cent.

4.2.1 Window frame

The U value of windows is based on the value in the centre of the window and does not take into consideration the window frame, a weak point in terms of energy. The U value will amount to about 15 to 20 per cent above the “normal” value when calculating the conventional aluminium window frame depending on the size of the window.

- a larger overlap of the window frame with the window pane will reduce this "thermal bridge".
- “Warm Edge”- thermo-edges made out of high-performance plastics, e.g. TS-Thermo Spacer, will help to minimize the problem of the frame. The additional expenses may be relatively low, but the effect is extremely high. The insulation of the windows is definitely improved and the formation of condensation is almost completely excluded.

Table 5: Producers of window components for passive houses:

(Uw<0,8 W/m²K, according to the European Window Standard EN 100 77)

Components	Enterprises
Heat-mirror-glazings (foils)	Mayer Glastechnik GmbH mgt@mgt.at
Climatop Solar (triple glazing)	GlasMarte http://www.glasmarte.at/
Thermally separated spacer	Thermix GmbH
Drei3Holz	Freisinger Bau+Möbeltischlerei http://www.freisinger.at/
Buhl Warm window	Buhl (Tel. 02985 2113-288)
“Building of Tomorrow” window	Sigg

The table may not be complete. Further products will be added in future.

4.2.2 Daylighting

Daylight systems make use of specular systems, prismatic elements and Venetian-blinds do not only divert and shade solar insolation, but also to optimise the use of natural light and lower the use of artificial light.

Innovative daylight systems have also been designed for various different uses and help:

- transport daylight into greater depths of the rooms.
- bring more daylight into rooms in cloudy climatic zones.
- use more daylight in extremely hot and sunny climatic zones where sun protection is required.
- increase the use of daylight in buildings where the solar insolation cannot directly enter the building.
- transport daylight into rooms without windows.

Fig. 5: Optimised use of natural daylight with the help of sun protection screens in the "Design-Center" in Linz (Foto: Bartenbach)

Further information:

- Research Forum 3/2000
- IEA Solar Heating & Cooling Programme - Task 21 Daylighting
- Bartenbach Lichtlabor

4.3 Thermal bridges and the airtightness of the building envelope

Thermal bridges are areas in the external building envelope with a notably increased heat flow. Geometric thermal bridges are created due to the building shape, whereas constructive thermal bridges are created out of special constructions within the external building envelope. The importance of heat losses due to thermal bridges increases with the better insulation of the building. These areas are also at more risk of getting damp.

Thermal bridges usually occur where an exterior wall meets the uppermost ceiling of a building, at the window flannings (window head, side parts, window sill) or at the connection between an exterior wall and a ceiling (especially with overhanging balconies).

4.4 Quality control

The comparison between the actual and calculated energy requirements for heating provides rather late and unreliable results on the incorrect use of energy systems in buildings. The following methods can be used to localise weak spots in energy systems, which are either created by the incorrect use of energy systems or bad planning in the construction of the building:

- Thermal Imaging: Thermal imaging registers the distribution of the surface temperature in a building and evaluates the thermal properties (thermal bridges, tightness) without coming into contact with the surface area.
- "Blower Door" tests the airtightness of the building envelope by using tests based on the differential pressure method.

4.4.1 Thermal imaging

Thermal imaging is a measuring technique that changes the invisible thermal infra-red radiation an object sends out into a visible diagram – known as a thermal imaging diagram. A thermal imaging diagram of a building construction thus registers the distribution of the surface temperature in a building and evaluates the thermal properties (thermal bridges, tightness) without coming into contact with the surface area. Thermal imaging tests should be carried out before renovation work or building extensions and provide information about weak points and critical areas as well as presenting new material on the history of the construction. Measuring techniques can be carried out in combination with the blower-door-test. These mainly show non-airtight sections in light-weight building constructions, roof extensions, window and door casings. Ideal conditions for carrying out these measurements are provided at night-time and by an external temperature of under 5°C (bearing in mind that there should not have been major fluctuations in temperature prior to measuring).

The following factors have to be taken into consideration when evaluating a thermal imaging diagram: Fluctuations in temperature, solar insolation, different capacities of material emission, wind velocity, thermal reflections.

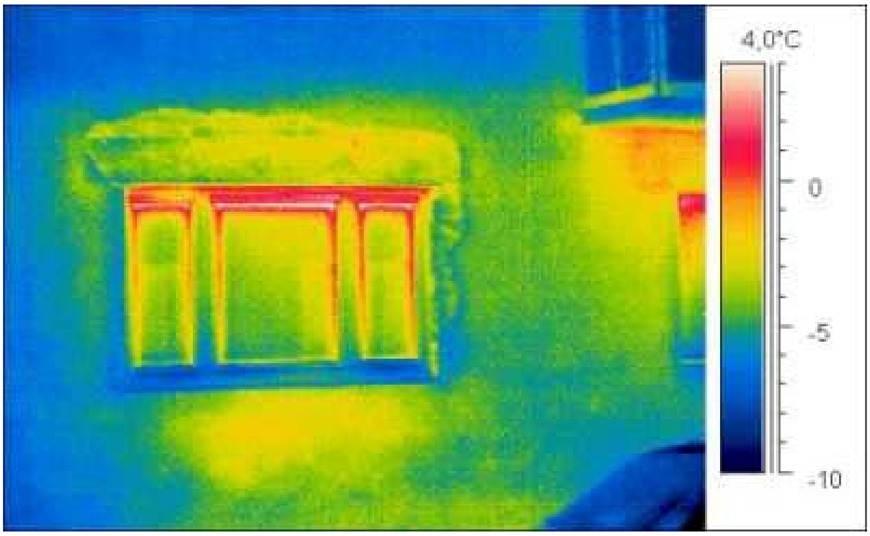

Fig. 6: Thermal imaging picture of a building construction in need of thermal refurbishment

(Source: Grazer Energieagentur)

Thermal imaging pictures show the critical areas – window flannings and lintels.

Red, yellow and green till light blue are all colours that signify high thermal loss.

Further information:

arsenal research is one of many companies to provide thermal imaging measuring techniques.

4.4.2 Blower-Door-Test

Airtightness is state-of-the-art in the technology of today (Austrian Standards: ON B 8110 Part 1). The airtightness of the building envelope can be tested by carrying out the blower-door-test, according to ISO 9972. This test is carried out prior to the installment of interior panelling, as improvements to the vapour barrier could otherwise not be made.

Air in non-airtight sections of roof constructions flows from the interior to the exterior of the building envelope in the winter due to the fact that the warm air rises. The normally humid indoor air temperature cools off quickly in these non-airtight sections. Condensation then forms and is deposited in the neighbouring building component (convection) – and damage to the building structure is inevitable.

Further information:

The following companies provide blower-door-tests:

- arsenal research, Vienna
- Fa. Isocell, Neumarkt/Wallersee
- Fa. Hofer&Weratschnig, Wels

5 HEATING, VENTILATION AND AIR-CONDITIONING WITH SUITABLE POWER SYSTEMS

5.1 Heating, ventilation and air-conditioning

Low-temperature radiators and low-temperature distribution systems contribute to the reduction of losses in heating systems. The temperature in the heating cycle should not exceed 45°C. Heat is then supplied to the interior space of a building through the appropriate heaters, floor or wall heating.

Heat can also be supplied by introducing supply air (i.e. via controlled ventilation with heat recovery) in a building with only low heat requirements. The supply air temperature can measure up to 50°C due to the charring of dust particles. Charring can also be avoided by using an air supply filter on the fresh air side of the building.

Air-conditioning or cooling mainly takes place through the appropriate size of openings (windows, winter garden, etc.), the correct shading system and storage mass as well as ventilation. Air-conditioning systems (principle of heat pumps) can also be used in order to provide additional active cooling. There are many innovative solar-assisted air-conditioning systems on the market at present.

Further information:

- Austria participates in the International Energy Agency’s research project “Solar Assisted Air Conditioning of Buildings”.
- The technology profile on thermal solar energy provides more information on the topic of solar cooling.

5.2 Appropriate energy supply systems

Efficient building systems require innovative, energy-efficient solutions: low thermal losses require heating systems in a lower power-range than those in conventional buildings. Energy-efficient and ecological criteria should also continue to be included when choosing the power supply system for providing heat and electricity.

A large amount of power supply systems are available in varying stages of development. energytech.at not only provides these technologies, but also further information on the appropriate technology sectors.

Heating and hot water supply

- Thermal solar energy
- Biomass
- Heat pumps
- Efficient use of conventional sources of energy
- etc.

Power generation

- Photovoltaics

Combined heat and power generation

- Cogeneration (microturbine, decentral CHP)
- Fuel cells
- etc.

Thermal solar energy & photovoltaics

The thermal use of the heat carriers air and water in active solar energy use presents an special ecological alternative to water heating and (solar assisted) room heating. High quality photovoltaic systems integrated into the building constructions turn the solar insolation striking the building envelope directly into electrical power.

Fig. 7: The “Sonnenpark” photovoltaic housing estate in Dornbirn in the province of Vorarlberg, Austria

(Source: stromaufwärts Photovoltaik GmbH)

Further information:

- energytech.at – Thermal Solar Energy, technology sector
- energytech.at – Photovoltaics, technology sector

Biomass

Modern and comfortable wood heating systems have been perfected and are now available as an alternative method of heating. These systems provide excellent emission values, are run on wood pellets, wood chips or pieces of cut wood and have already gained a clear share of the market.

Further information:

energytech.at – Solid Biomass, technology sector

Heat pumps

A heat pump makes use of "free" and existing ambient energy from the soil, air and water. High seasonal performance factors (SPF, expressing the relationship between heat created and final energy used for operating heat pumps) are essential for the sensible and successful use of this technology. Today's heat pump heating systems also represent an SPF of 3.0 and above when correctly planned, installed and run. Annual rates of operation of 4.0 have even been recorded in heat pump heating systems that are actually being run in buildings today.

Further information:

- Austria is a member of the International Energy Agency's Heatpumpcenter.

Conventional sources of energy

Major improvements and developments have been made to the efficiency of oil-fired and gas boilers (i.e. condensing boilers) and pollutant emissions.

Thermal storage

Heat has to be stored for a minimum of some hours to a maximum of some days (for the whole heating season in the case of seasonal storage) in order to match the difference between energy provided and energy needed for heating and hot water supply. The following principles can be seen:

1. Sensible thermal storage by warming a heat-storage medium – i.e. "classic" hot water storage appliances/boilers.
2. Latent heat storage, which makes use of the change between the solid and liquid form of a heat-storage medium (i.e. dissolved salts, paraffin).
3. Thermo-chemical heat-storage mediums like, for example, sorption storage (silica gel) or the storage of hydrogen in combination with a fuel cell.

The storage within the soil in connection with a heat pump, which is a combination of 1 and 2.

Further information:

See chapter on Storage Technology in the section – Thermal Solar Energy, at energytech.at

6 ENERGY-EFFICIENT BUILDING APPLIANCES

Electrical appliances and occupants represent heat sources, which have to be integrated in the planning phases. These additional heat sources can make up a considerable amount of heat input especially in buildings designed to have low heat requirements (e.g. passive houses). Furthermore they increase the cooling performance costs necessary for additional air conditioning in summer. Summer overheating is especially likely to occur in office buildings where there are a great many working people and computers in small spaces.

Further information:

E.V.A. - the Austrian Energy Agency, which deals among other things with energy efficient domestic and office appliances

6.1 EU label for lamps

The EU Directive 98/11/EG became a part of the national legislation as of September, 1999 and is the legal basis for classifying the energy efficiency of domestic lamps.

It applies to domestic lamps that run on mains voltage such as electric light bulbs and flourescent lamps with an integrated ballast. Furthermore it applies to domestic light bulbs, lamps which comprise single-capped and double-capped lamps and lamps without an integrated ballast.

According to a standardized calculation method within the guideline lamps are classified in different levels of energy efficiency ranging from level A (high energy efficiency) to G (low energy efficiency). This calculation method considers parameters like lighting current and lighting consumption. It aims at illustrating the energy efficiency of the lamps to consumers and thus making it easier for buyers to choose the best and most energy efficient product.

The following lamps are taken into account in the EU Directive :

- Electric light bulbs
- Halogen lamps running on mains voltage
- Compact flourescent lamps
- Flourescent lamps

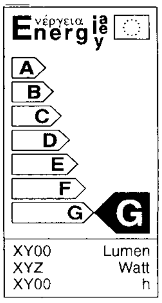

Fig. 8: EU label for lamps

7 THE PASSIVE HOUSE – A CONCEPT FOR SUSTAINABLE BUILDING

The term "Passive House" describes a building construction with a comfortable level of indoor air quality in summer and winter that is gained by employing energy-efficient measures and without conventional heating systems.

The three pillars of the passive house concept

The passive house concept is the result of the constant developments that have been made to the low-energy house concept: “Passive" building and technical measures ensure that very little heat is lost and that heat gains are optimally used, thus resulting in improvements to thermal comfort and a reduction in the energy requirements.

Insulation: Heat conservation of the external building components is the most effective measure for energy efficiency in buildings in Central Europe. The majority of insulating materials used in the building and construction industry make use of the low thermal conductivity in still air and try to avoid creating thermal bridges. The supporting structure of the insulating materials does not play an important role – and a wide range of suitable products is thus available on the market. Passive houses require a compact layer of insulation, which guarantees for both low heat losses and a high level of thermal comfort.

Highly insulating windows: State-of-the-art coating technology has enabled the development of high-quality glazings which still have internal surface temperatures of over 17°C at low external temperatures of -10°C. Highly insulating windows let in such high amounts of radiation energy that heat losses are more than compensated for by the solar heat gains even in the depths of winter and at ±30° south orientation. High-performance window frames that are especially-designed for passive houses are perfect to complete the extremely tight building envelope.

Ventilation systems with heat recovery: Fresh air is essential for the “well-being” of building occupants – the highest standards of luxury and comfort are achieved by introducing controlled ventilation with heat recovery; health and thermal comfort being once again the most significant factors for planning a project. The incoming air can also heat the rooms in the passive house, thus resulting in technically simple solutions for heat supply systems. And all this is what makes the passive house concept so attractive.

The three decisive pillars of the passive house concept are based on a significant improvement to the quality of building components, which are nonetheless essential in all building constructions:

- Every house needs a building envelope with a ground floor, exterior walls and roof; the passive house focuses on drastic improvements to these building components – high-quality heat insulation is thus added.
- The passive house requires high-quality windows, which boast such low heat losses at good levels of lighting that thermal comfort is reached without having to have radiators right next to the windows.
- Every flat needs fresh air, but only a controlled ventilation system can guarantee for this in our climate with its constantly changing wind pressure ratio.

The passive house thus provides us with the opportunity to reach extremely low levels of energy consumption by employing high-quality, cost-efficient measures to general building components – such measures are in turn of advantage to the ecology and economy sector. Additional measures mean more building materials and money instead of improvements to components that are necessary in any case.

The first passive house housing estate boasting 22 units was completed and put into operation in Wiesbaden in 1997. Research results have now shown that users consume approximately 13.4 kWh/(m²a) for room heating and 15.5 kWh/(m²a) for domestic hot water supply. Optimal energy indicators for passive houses can be found in chapter “Energy indicators”.

The passive house is no new, innovative product that is manufactured by a concern in a pre-fabricated form and then sold on the market. It consists moreover of a non-patented building standard, which enables many architects and building developers to realise high-quality building demands and gives manufacturers the opportunity of providing the appropriate, highly efficient individual building components. There have already been many significant synergistic effects in the past where, for example, the manufacturers of glazings suitable for passive houses have had to rely on the manufacturers of suitable window frames and vice versa.

An extensive discussion was held concerning air pollution control requirements due to experiences made by passive house users of introducing a user-controlled ventilation system [Feist, 1994]. It could thus be seen that the interior air quality in the four flats in the passive house in Kranichstein actually met the targets set in regard to air pollution control. The controlled ventilation system thus meets its main requirement – the improvement of the indoor air quality.

The aim of the CEPHEUS project (Cost Efficient Passive Houses as European Standard) was to construct approximately 250 living units boasting passive house standards in five European countries with the help of experts and evaluation of the constructions. Regulated standards of quality for the cost-efficient planning and construction of passive houses should thus be developed and then a basis for a wide-ranging market promotion created.

Further information:

- energytech.at Links: Passivhaus

Reference Books: Project report – CEPHEUS: Thermal Comfort Without Conventional Heating Systems

8 THE CHALLENGE OF REFURBISHMENT

8.1 Energy savings potential of existing building constructions

The specific avoidance costs of all kinds of refurbishments are calculated on the basis of marginal costs so that the profitability of refurbishment measures can be better estimated. The amount of financial expenditure is thus presented in order to save one kWh per year. The costs of the individual systems were divided by each specific period of occupancy in order to come to an equal basis.

Specific Avoidance Costs = Investment Costs/ (Savings in Final Energy per year x Period of Occupancy)

Table 6: Specific costs of refurbishments:

Type of refurbishment	**Specific avoidance costs in cent/kWh:**
Face-lift of building	0,029
Refurbishment of top floor	0,022
Window refurbishment	0,058
Refurbishment of basement floor	0,011
Overall refurbishment	0,029

Source: Ecology of the Rehabilitation of Old Buildings – Guidelines for Subsidization with regard to Energy Consumption, Emissions and Optical Aspects. (Contact Point: Lower Austrian Provincial Academy – http://www.noe-lak.at) . Guidelines drawn up by the Austrian Energy Agency (E.V.A.)

8.1.1 Energy certification and energy indicators

The energy certification, which contains pre-stipulated energy indicators, is used in order to be able to calculate and compare the energy savings potential of existing buildings. The energy indicator, which is found in the housing subsidy regulations or in provincial building regulations and worked out according to calculations in the Austrian Intstitute for Building Technology manual, should be registered in the appropriate heat conservation class (A-G) and marked by an arrow, which points to the corresponding bar.

8.2 Evaluation – planning – quality control

This chapter focuses on the stages of refurbishing an existing building starting off with the evaluation and planning then leading up to the quality control measures afterwards.

8.2.1 General evaluation EPIQR

The “General Evaluation” for buildings was developed on the Swiss Program of “Innovative Building Constructions” in 1992 and presents a general overview of the conditions of a property and the costs of reinstatement work with limited expenses. The "General Evaluation" is based on the results of English and French research stating that the costs of reinstatement work can be estimated according to a limited amount of building components. Expenses incurred in diagnosing the condition of a property may fall, but there is still enough reliability for a general evaluation.

Seven European research laboratories developed the EPIQR computer program as part of the Joule Programme on the basis of this general evaluation. EPIQR stands for Energy Performance, Indoor Environment Quality and Retrofit (taking refurbishment measures in occupied existing buildings into consideration).

8.2.2 Energy consultants

Weak points in the building envelope and heating systems are pinpointed, documented and analysed by specially-trained energy consultants. Energy consultants are organised differently from province to province in Austria. Energy consultant training courses have been standardised in the Energy Consultants Consortium.

For further information

The Austrian Energy Agency (E.V.A.) provides an overview of energy consultants on provincial, federal and EU level under http://www.eva.ac.at/esf/

8.2.3 Integrated planning

Pre-planning aims at co-ordinating the individual components in a better manner so that less alterations have to be made in the later planning and implementation phases. This actually means that specialists have to co-operate on the most important aspects of thermal refurbishment early on in the project. The planning and preparations needed for an all-round thermal refurbishment stand out greatly from the normal procedures undergone during conventional refurbishment:

- Clear targets are developed alongside general planning aims and legal requirements.
- The standards of quality that have been agreed upon by users and architects are recorded in the contract specifications and presented in the quantity description.
- The building aims are put down on record in final tests.
- Users receive a detailed certificate of quality (energy certification, and building certificate in future).

The first planning stages are especially important as everything is still possible and no high costs have been incurred. It is worthwhile investing more in these stages of planning. Taking into account some additional solutions do not cost a great deal – "Planning during Construction" on the other hand often leads to extreme overspending.

8.2.4 General contractors or individual contractors

The contracts placed are especially important on the refurbishment sector. Contracts placed with experienced general contractors are of especially great advantage to building contractors lacking in the relevant building experience. General contractors guarantee that a building construction is completed according to the plans shown and that users can move in straightaway. The planning is normally done by a general planner and this means that only one contractor is responsible for all trades. Further attractive factors being more rigid handling of the project, keeping to the deadlines and the price promise on agreeing to a fixed price. It may look as if there are higher costs when placing an order for a refurbishment project with a general contractor, but it's often more economical in the long run than placing a contract with various individual contractors.

8.2.5 Third Party Financing

Third Party Financing (TPF) means that measures and services for providing or efficiently using (saving) energy are dispersed to a third party – a distinction is made between installation contracting and energy-performance contracting.

There are no additional investment costs for users. Investments are financed using the difference between former energy costs and new reduced energy costs. Proprietors are usually offered the chance of paying reduced overhead expenses after the contractual time has expired (generally from 5 to 15 years).

Energy-Performance Contracting: Third parties carry out measures for reducing energy requirements and payment depends on the amount of energy saved. This model has proved successful in regard to the thermal refurbishment of public buildings like, for example, schools.

Installation Contracting: The contractor sets up, operates and finances an energy installation. The client pays for the energy actually supplied, the price of which is calculated from the amount of energy made available to users.

Further information:

Click here for an overview of Austrian contracting companies on the market and reference projects: http://www.eva.ac.at/contracting/

8.3 Specific measures

Specific measures used in the thermal refurbishment of existing buildings will be described in the following section.

8.3.1 Insulation systems with higher levels of insulation thickness

The thickness of insulation that has already been installed in building constructions usually can no longer be changed. The conventional thicknesses of 5-6 cm in the exterior wall sections and 10-15 cm in the roof sections, which are still used today, are neither cost-effective nor energy-efficient. The advantages of thicker insulation are:

* the long period of use (approx. 40 years),
* the increased standard of living due to the higher surface temperatures,
* the ratio between insulation costs and total investment costs,
* the low overall costs in comparison to the life cycle.

The Austrian Standards Institute has defined the standard or “good practice” of what we regard as “economic insulation“ in the ÖNORM B 8110-4. A cost-effective level of heat conservation is stipulated for a specific period of time (i.e. 30 or 60 years for residential buildings).

The insulation thickness should measure between 8 and 20 cm – lower levels should not be used. The dew-point temperature can occur in the walling component (in the case of good-quality insulating walling components) when the level of insulation thickness is too low. The cementing material layer gets wet and it can even happen that the façade of a building cracks when there's frost.

Table 7: U values of some wall constructions with and without insulation:

Present wall constructions including 1.5 cm interior plastering			Wall plus insulation lambda=0,4 W/mK	
Wall construction	Thickness (cm)	U value (W/m²K)	Thickness of insulation layer (cm)	U value (W/m²K)
Solid brick	38	1,37	6	0,45
			10	0,31
			12	0,27
			16	0,21
Hollow brick	30	0,89	6	0,38
			10	0,28
			12	0,25
			16	0,20
Reinforced concrete	20	3,70	6	(0,56)
			10	0,36
			12	0,31
			16	0,23

All-integrated insulation systems are normally installed alongside curtain walls with/without ventilation. The following insulation materials are available:

- Polystyrene EPS-F (Expanding Polystyrene Rigid Foam – Façade)
- Rock Wool Façade Panelling
- Agglomerated Cork Block
- Softboards
- Mineral wool block & board (STO Therm Cell, a new product made by the STO company)

All-integrated insulation systems can only work when the planning and realisation tally. The manufacturing standards have been set by the Austrian Standards Institute (Austrian Standards ÖNORM B 2259, B 6110, B 6135) and manufacturers' specifications.

8.3.2 Windows/doors

"Passive house windows" are not especially designed to be mounted in existing buildings, but they can be used in thermal refurbishments in certain circumstances. Calculations for a typical combination – an exterior wall measuring 30 cm and a passive house window – were made using the finite element method and the following results emerged:

- Thermal improvements to the wall flanning are essential.
- It is necessary that a frame be developed that can be mounted in passive houses.

Source: Mathias M. Stani, Head of the Institute of Thermal Engineering and Noise Control – at the TGM, Institue of Technology (technische Versuchsanstalt für Wärme und Schalltechnik am TGM)

Slim window constructions are usually required for the thermal refurbishment of existing buildings due to architectural demands and historical monument classifications, and that's what the "Building of Tomorrow" research program has been working on. The Austrian low-energy window with a U value of 0.9 W/m²K (including glazing heat losses) is extremely slim, its frame and window casements measuring just 88 mm, and was the starting point for research. The quality timber in the window casement frames was first replaced by a wood-purenit-wood sandwich construction. Special measures have to be introduced in order to avoid creating thermal bridges when the windows are mounted into the façade. The new window can now be mounted in passive houses (i.e. CEPHEUS-House in Wolfurt, Vorarlberg, by Architect Gerhard Zweier and three other buildings) due to the certificate of the quality timber construction together with the mathematical proof of improvements.

Quality timber windows suitable to be mounted in passive houses are now being developed on the basis of these experiences. These windows should combine the advantages of quality timber and the excellent insulation values of passive house windows. An initial batch was designed and certified after theoretical preliminary tests and scientific research, the aim being to bring certified passive house windows with the appropriate mounting suggestions on the market by the end of 2000. The Sigg company's project in the "Building of Tomorrow" subprogram has already managed to reach a U value of 0.79W/m2.K.

8.3.3 Solar refurbishments

Solar energy is not normally made use of in thermal refurbishments. Architects and planners may attempt to get the most out of the location, orientation and surface-area-to-volume ratio of a new low-energy building construction during the planning phase, but usually they can't change anything when it comes to existing buildings. Heat insulation and the renewal of windows and heating systems do not have to remain the only measures taken – passive or active solar energy can also be used in existing buildings with a bit of fantasy. Balcony glazings, glass curtain walls (which also provide technical improvements to sound insulation as well as a positive energy balance), the use of transparent insulation, solar water heating or space heating all make sense when refurbishing a building construction. A wall heating system can, for example, be installed when refurbishing the walls. This is the pre-requisite for the efficient running of solar (low-temperature) space heating. Daylighting should be planned especially when refurbishing roofs. Solar panels can act as a valuable alternative to conventional roof cladding. There are now many manufacturers on the solar energy power sector that provide photovoltaic roofing tiles.

8.3.3.1 Glazed extensions and sunspaces

A sunspace, which is a passive solar building component that contributes to energy gains, is defined as a loggia or veranda according to the Austrian Standard ÖNORM M7700. These sunspaces must show a positive energy balance as the thermal properties of the glazing mean that they can't be otherwise heated. Sunspaces that are built directly onto building constructions and have numerous storeys are energy and cost-efficient whereas jutting-out glass constructions get too hot in the summer and too cold in the winter.

Sunspaces' contributions to heating are often overestimated. Large-scale south-facing windows as a system making use of passive solar energy are more energy-efficient than sunspaces. It should also be considered that the light coming into the rooms behind the glazed construction is reduced by up to 20 per cent due to the construction and up to 30 per cent due to the glazing.

8.3.4 Heating, ventilation and air conditioning systems

The indoor air quality is often insufficient in buildings with ventilation systems and can thus lead to the Sick Building Syndrome. The energy efficiency of HVAC systems is far from perfect in many buildings and it is thus especially important to check out these systems in regard to the means of operation and system type. The requirements of the indoor air quality and the living space are laid down in standards and regulations.

Air change rates of 0.4 to 0.7 per hour are generally needed in order to meet the hygienic requirements of a building. Regular window ventilation is essential in order to get such values after a thermal refurbishment. The air change rates can reach values of 1-3 and this multiplies the energy requirements for air changes.

The heating load is lowered by the excellent thermal quality in modern buildings – so much so that the amount of air needed for hygienic requirements is enough to provide the space heating, too. This new concept of fresh air heating is optimally used in the passive house. Buildings that don't meet all the requirements of a passive house can also be fitted out with this system by adding domestic engineering technology. An wood-burning stove (logs, wood pellets) can, for example, be installed in the central living room and it only has to complement the fresh air heating at extremely low external temperatures.

A ground heat exchanger often helps pre-heat the fresh air prior to it entering the house during the heating period. The aim is to reach an exfiltration temperature of at least 0°C at a normal external temperature of -12°C. The following points should be taken into consideration:

- Laying Depth 1.5 - 2 m under the ground
- Length 25 - 35 m
- Pipe Diameter DN 160 (up to 125 m^3/h) or DN 200
- 1% Gradient
- Polythene Foil (PVC pipes should not be used).

A high-quality filter is positioned at the inlet opening of the ground heat exchanger in order to eliminate any hygienic risks. A branch-line with a water outflow is connected to the exchanger on entering the building construction in order to enable cleaning. (Source: planning tips under http://www.drexelweis.at/ - only in German)

Ground heat exchangers should mainly be used in buildings where ventilation systems are standard applications like in warehouses, sports and leisure centres etc. – summer cooling loads and high levels of heat requirements are accrued here for the pre-heating of air.

8.3.5 Refurbishment of the heating system

Refurbishing the boiler can lead to energy savings of 25 to 30 per cent. This percentage also includes energy savings due to a lower boiler capacity. Source: Ecology of the Rehabilitation of Od Builidings – Guidelines for Subsidization with regard to Energy Consumption, Emissions and Optical Aspects (Contact Point: Lower Austrian Provincial Academy – http://www.noe-lak.at) Guidelines drawn up by the Austrian Energy Agency (E.V.A), page 52

The decision whether to carry out only a partial or overall refurbishment to the heating system depends on the following:

- period of boiler utilisation,
- size of the boiler and heating requirement,
- stack losses, fuel efficiency level,
- chimney inspection.

A change to an other energy source and the use of other thermal value equipment should be considered in the case of an overall refurbishment.

8.3.5.1 Heat supply

The size and type of the heating boiler should always be checked after improving the heat conservation. In the last few years there have been many improvements in boiler technology. Boilers that are over 20 years in age are, however, usually no longer economical, even if they fulfil the required limits. Modern low-temperature and condensing boilers are efficient even when working partial loads, while older boilers are always uneconomical with partial loads.

The efficiency of boilers has to amount to rated capacities of between 4 and 400 kW according to the European Efficiency Guideline 92/42/EWG of the European Commission.

Standard boiler: $\eta >= 84 + 2 \log Pn$

Low-temperature boiler: $\eta >= 87{,}5 + 1{,}5 \log Pn$

Condensing boiler: $\eta >= 97 + 1 \log Pn$

P_n ....Rated capacity

η......................Efficiency

The easiest way to check the over-dimensional boiler capacity of an old heating system is to calculate the full load hours per year. Fuel consumption (kWh/a) / power (kW) = full load hours (h/a).

The heating system works uneconomically (excluding low-temperature and condensing boilers) on full load hours of less then 1200 h/a (for space heating only) and 1400 h/a (for space heating and hot water supply).

The annual use efficiency is decisive for the heating energy demand and this has to be calculated by taking the energy values of the heat supply system (e.g. boiler), heat distribution system and heat regulation system according to the Austrian Standard ÖNORM H 5056.

Table 8: Evaluation of annual use efficiency etaH

High effiency according to ÖN H 5056	$eta_H >= 0,98$	
Inspection recommended	$0,92 <= eta_H <= 0,98$	*Reduced efficiency*
Improvement measures recommended	$0,82 <= eta_H <= 0,92$	*Reduced level of efficiency*
Improvement measures urgently recommended	$0,72 <= eta_H <= 0,82$	*Clear deficit in efficiency*
Inspection, as to whether the system works economicaly *Possibly renewal of heating system recommended*	$0,62 <= eta_H <= 0,72$	
Inspection of usefulness of heating system *Possibly instant renewal of heating system*	$0,62 < eta_H$	

Thermal insulation of pipes

The insulation of pipes in unheated rooms should measure at least two thirds of the pipe diameter. Hot water and circuit vents should be insulated according to their pipe diameter. Insulated hot water storage systems and fittings which feel hot should be refurbished.

Radiators

Radiators that are in good condition can still be used in some cases. Existing radiators give out the highest amount of radiation and the lowest amount of convection with smooth steel panel radiators that do not boast convector metals. The more a radiator is split into different panels the higher its level of convection. The heating systems can be kept at lower temperature levels after thermal insulation, which will lead to more thermal comfort due to a reduction in the circulation of air (convection).

Radiators that don’t get really warm or make streaming sounds require hydraulic alignment.

8.3.5.2 Active solar energy use

A building can only make use of active solar energy, if the condition and orientation of its roof surfaces are suitable. Check lists enable users to easily find out whether a building is suitable for the application of solar collectors or not.

8.3.5.3 Façade-integrated collectors

Façade-integrated wall collectors are flat-plate thermal collectors, which are mounted directly on façades without the need of a separate venting panel. The energy output in buildings with solar combi-systems can be increased by vertical collectors. There are, however, still problems on the sectors of building physics and heat distribution.

For further information

Current projects on wall collectors can be found in the framework of the "Building of Tomorrow" subprogram:

- Project „Façade-integrated collectors"
- Deployment and development of façade-integrated solar collectors for multy-storey residential and office buildings.
- Project: "Façade-integration of thermal solar collectors without the need of a separate venting panel on the basis of engineering and building physics".
- Project: "Integral 2000 – Neuartiger Systemkollektor mit kürzesten Montagezeiten" – „Integral 2000 – State-of-the-art system-collector at shortest installation periods" only in German.
- Forschungsforum 3/01 Facade-Integrated Thermal Solar Installations http://www.forschungsforum.at/e/3_01.htm

8.3.6 Transparent thermal insulation

8.3.6.1 Function and use

Solar energy can not only be used via windows, but also via wall surfaces. Conventional insulation only reduces the heat loss from the inside of the building to the outside, but transparent insulation can also make use of heat gains. Sun light reaches the building envelope and is then converted into heat with this concept. The heat enters the interior of the building with a delay, whereby the wall acts as buffer storage. The net energy gains on south-facing walls amount to between 50 and 150 kWh/m²/a. Most systems still require overheating protection.

A transparent insulation system consists of an absorber, an framing element with glazing (not needed when using all-integrated insulation), a regulation system, a shading device and a mounting bracket on the façade.

Plastics and glass are often used as insulation materials.

A great deal of research has been carried out on the sector of transparent insulation systems over the last few years, but there has as yet not been a major breakthrough. Despite many developments in this sector the costs for a transparent insulation system are still quite high at approx. EURO 330,- per m² (including mounting), whereby the shading system takes up a large part of the expenses. The costs for the façade and thermal insulation, which are now no longer needed, can thus be gained.

Successes in the development of high-performance insulating windows have also contributed to the loss of interest in transparent insulation, particularly as the transparent insulation components only let diffuse light into the room. Furthermore some consumers have experienced the build-up of condensation.

A positive prospect for the future is the combination of transparent insulation with solar hot water supply, especially when there is a high material suitability for stagnation temperature.

Further subjects of research are self-adjusting shading devices, which change the light diffusion according to the change in temperature.

Transparent façade insulation systems have reached a stage where they can be used in different kinds of buildings – not only in new constructions, but also for refurbishing old buildings. Transparent insulation does not only present savings in heating costs, but it also increases the thermal comfort, as the wall temperature is often higher than the room temperature. Studies have shown that occupants of buildings with transparent insulation are extremely satisfied.

Transparent insulation should be primarily used in renovating old buildings, as their massive exterior walls are perfect for this method of refurbishment.

8.3.6.2 Façade systems

Curtain wall: Transparent insulation components consisting of two glass window panes with pipes made out of glass or acrylic plastic are mounted in a wood or aluminium construction.

Products: Okalux (Kapilux), Röhm (multi-skin sheets), Schott (Helioran)

All-integrated transparent insulation system: Transparent insulation materials are mounted onto gaps made in a solid wall in a plastered façade by using black glue and plastered over with transparent glass plaster. The heat transmission lies at approx. 10 to 20 per cent below that of glazed systems. This systems fits perfectly into a building construction, and no sun protection is needed.

Products: Sto (ThermSolar), Caparol (Capatect)

Direct gain system: Lighting rows with transparent insulation are translucent not transparent, e. g. on the roof of industrial shed structures.

A system invented in Austria uses cardboard honeycombs: Solar radiation shines through a glass window pane onto a cardboard honeycomb and is then converted into heat. This type of construction is meant to reduce overheating by itself.

Product: Energy-Institute Linz und ESA-solar façade

8.4 Measures for the broad ecological refurbishment of existing buildings

In Austria 8.05 million inhabitants live in approx. 3 million flats with an overall floor area of 252 million m². 78 per cent of the buildings were constructed before 1981. The annual energy consumption of final energy for the heating and hot water supply in Austrian households comes up to 218 PJ. The annual energy costs for the heating and hot water supply amount approx 2,03 Mrd. EURO.

Table 9: Summary of measures taken in Austria (excluding Vienna):

Measure	Final energy savings [TJ/a]	CO2 reduction [t/a]	Specific avoidance costs partial/marginal costs [cent/kWh]
Thermal refacing	13.005	767.882	0,012 / 0,018
Refurbishment of the topmost floor	12.743	752.256	0,011 / 0,014
Renewal of the windows	2.888	170.610	0,020 / 0,036
Reconstruction of the cellar floor	2.077	122.754	0,006 / 0,007
Change of boiler without changing energy source	14.147	723.945	0,052
Change to the energy source wood	8.365	1.065.304	0,084
Connection to existing decentralised biomass heating station	1.577	107.382	0,004
Solar water heating	8.762	1.111.576	0,085

Source: Guidelines drawn up the the Austrian Energy Agency (E.V.A.) in Ecology of the Rehabilitation of Old Buildings – Guidelines for Subsidization with regard to Energy Consumption, Emissions and Optical Aspects (Contact Point: Lower Austrian Provincial Academy – http://www.noe-lak.at)

The definition of measures is based on economic criteria. Mutual effects, such as an increased reduction in absolute energy consumption when changing a boiler after thermal refurbishments in comparison to individual measures, have been taken into consideration.

Table 10: Summary of packages of measures taken in Austria (excluding Vienna):

Package of measures	Final energy savings	CO2 reduction [t/a]	Economic period of amortisation
I: Thermal refurbishment and change of boiler	2.065	105.671	14
II: Thermal refurbishment and change to energy source wood	689	74.646	10
III: Thermal refurbishment and solar assisted space heating	527	26.979	39

Source: Guidelines drawn up the the Austrian Energy Agency (E.V.A.) in Ecology of the Rehabilitation of Old Buildings – Guidelines for Subsidization with regard to Energy Consumption, Emissions and Optical Aspects (Contact Point: Lower Austrian Provincial Academy – http://www.noe-lak.at)

Most important assumptions for the calculation of measures (for Austria, excluding Vienna):

I: Thermal refurbishment and change of boiler

Detached and semi-detached houses, doubling of the present exchange rate (36,000 flats per year); Calculation of the basis of marginal costs

II: Thermal refurbishment and change to energy source wood

Detached and semi-detached houses, 12,500 flats per year,

50 per cent total costs, 50 per cent marginal costs for change of boiler, refurbishment with marginal costs

III: Thermal refurbishment and solar assisted space heating

8,000 systems per year, 5 year limitation; 25 m² collecting surface per flat; expert installation

Overall assumptions: 4 per cent real interest rate, no increase in energy prices, normal average costs, marginal costs on the basis of a 5 year advance, 50 per cent energy savings due to thermal refurbishment.

Source: Ecology of the Rehabilitation of Old Buildings – Guidelines for Subsidization with regard to Energy Consumption, Emissions and Optical Aspects. (Contact Point: Lower Austrian Provincial Academy – http://www.noe-lak.at) . Guidelines drawn up by the Austrian Energy Agency (E.V.A.)

9 REGULATIONS AND SUBSIDIES

Heat conservation guidelines can be found in building regulations (resp. decrees on the basis of building regulations) and in the various housing subsidy conditions in the provinces of Austria. Building regulations may comprise, e. g. energy efficient rules, which must be applied to all new buildings (and recently in Vienna also for building renovation), while the regulations of housing subsidies are only valid for the construction and refurbishment of subsidised residential buildings. (Expenses for housing development subsidies in 1998 34,6 Milliarden Schilling; Source: Österreichisches Wohnhandbuch 2000 – Austrian Habitation Guide for 2000 by K. Lugger – available only in German). The housing subsidies not only influence the choice of heat conservation, energy source, heating and hot water supply system, but also building materials and other measures relevant to climate-protection.

Table 11: U value upper limit (W/m²K) according to building regulations in Austrian provinces of Burgenland (B), Carinthia (C), Lower Austria (LA), Upper Austria (UA), Salzburg (S), Styria (St), Tyrol (T), Vorarlberg (Vb) and Vienna (V).:

Date: 2/2000	**B**	**C**	**LA**	**UA***	**S**	**St**	**T**	**Vb**	**V***
Valid as of	**’98**	**‘97**	**‘96**	**‘99**	**1991**	**1997**	**‘98**	**‘96**	**‘01**
Exterior wall	0,45	0,40	0,40	0,50	0,47-0,56	Block of flats: 0.50 Detached and semi-detached house: 0.40	0,35	0,35	0,50
Boundary walls to unheated parts of building and party walls	0,70	0,70	0,70	0,70	0,70-0,83	0,70	0,50	0,50	0,50
Boundary walls to separated flats and offices	1,20	1,60	1,60	1,60	1,56	1,60	0,90	1,60	0,90
Boundary ceilings to exterior surfaces, attics or thoroughfares	0,25	0,25	0,22	0,25	0,26-0,30	0,20	0,20	0,25	0,25
Boundary ceilings to unheated building parts	0,40	0,40	0,40	0,45	0,37-0,43	0,40	0,40	0,40	0,45
Boundary walls to separated flats and offices	0,90	0,90	0,90	0,90	1,03	0,90	0,70	0,90	0,90
Windows	1,70	1,80	1,80	1,90	2,50	1.90	1,70	1,80	1,90
Exterior doors	1,70	1,80	1,80	1,90	2,50	1,70 / 1,90 (glass door)	1,70	1,90	1,90
Foundation walls	0,40	0,50	0,50	0,50	0,55-0,67	0,50	0,40	0,50	0,50
Foundation floors	0,40	0,50	0,50	0,50	0,39-0,47	0,50	0,40	0,50	0,45

(Source: E.V.A. Website)

*Further regulations have to be applied to the energy consumption of the whole building in Upper Austria and Vienna.

10 RESEARCH AND TECHNOLOGICAL DEVELOPMENT

Housing research

Housing research not only carries out activities within the EU, various research funds and federal ministries, but also provides subsidies for research and development in the field of energy efficient building constructions. Housing research has been decentralised since 1988 and is now run autonomously by each province in Austria. Since then subsidies have dropped from 7,3 Mio. EURO to approx. 1,8 Mio. EURO.

Further information:

The Internet platforms iswb (infoservice wohnen+bauen österreich) and "Forschungsgesellschaft für Wohnen, Bauen und Planen" (FGW) provide an overview of housing research projects in Austria.

Building of Tomorrow

Emphasis should be placed on the “Building of Tomorrow” initiative in the Austrian Program on Technologies for Sustainable Development, which is initiated and supported by the Federal Ministry of Transport, Innovation and Technology. The “Building of Tomorrow” subprogram concentrates on the two most important developments in the energy efficient and solar building construction industry – solar low-energy building constructions and the passive house. These energy-efficient innovations will furthermore comprise the ecological, economic and social aspects (see Fig. 14) in the “Building of Tomorrow” subprogram.

Energy efficient building components and types of residential and office buildings should undergo further development and market diffusion in this program.

Three calls for building proposals focussing on the construction of new buildings have been published since 1999. Approximately 60 projects have up to now been sponsored and financed at a total cost of 7,3 Mio. EURO.

The last call for proposals put an emphasis on ecological and energy efficient building refurbishments.

Further information:

The final reports of the projects in the “Building of Tomorrow” subprogram, which can, of course, be found on the energytech homepage:

Further information on project aims, background and results can be found on the energytech Website under “Building of Tomorrow”.

11 TRAINING COURSES AND FURTHER EDUCATION

There are many institutes which offer training and further education courses ranging from half-day workshops to full-time training courses.

AEE INTEC (Society for Renewable Energy, Institute for Sustainable Technologies)
Feldgasse 19, A 8200 Gleisdorf
Phone.: +43 3112 5886
Fax: 03112-5886-18
Email: office@aee.at
Website: http://www.aee.at/

Energy Institute Vorarlberg
Stadtstrasse 33 / CCD, A 6850 Dornbirn
Phone: +43 5572 31202-82
Fax: +43 5572 31202-182
Email: schlader.energieinstitut@ccd.vol.at
Website: http://www.energieinstitut.at/

Energie Tirol
Adamgasse 4, A 6020 Innsbruck
Phone: +43 512 589913
Fax: +43 512 589913-30
Email: office@energie-tirol.at
Website: http://www.energie-tirol.at/

Austrian Institute of Building Biology and Ecology
Alserbachstraße 5/8, A 1090 Wien
Phone: +43 1 319 20 05-0
Fax:+43 1 319 20 05-50
Email: ibo@ibo.at
Website: http://www.ibo.at und http://www.green-academy.at

Danube University Krems
Center for Architecture, Construction and Environment
Dr. Karl-Dorrek-Straße 30, A 3500 Krems
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Website: http://www.donau-uni.ac.at/organisation/zbau_einleitung.html