Energy Efficient Technologies in Buildings

Summarised Results of Advanced Targeted Projects Implemented in EU Countries in the Framework of THERMIE Programme of the European Commission

Preface:

Buildings (housing, offices, etc.) currently account for some 40% of the total, which presently represents the largest part of the final energy demand, and transport use 31% of the final energy, whereas industry accounts for the 29% balance. It represents an important sector for energy demand and consequently is associated to the man-caused environmental impacts. Of the approximately 3 billion tonnes of CO_2 emissions to the atmosphere per year in the E.U. Member States, households and small industries alone account for about one quarter (740 million tonnes), and depending on the climate conditions in the individual countries, the heating requirements account for 60 to 80 percent of these emissions.

Based on these facts, there is growing agreement that buildings must be incorporated into the general policy to cut energy consumption and, therefore, implement active measures that can reduce the use of fossll fuels. Like in other industrial sectors, "technology" has been nominated as the drlving engine to solve the problems. But at the contrary of other industrial sectors, buildings are not homogeneous, do not work in "standard" environment and are designed, constructed and operated by many milllon human belngs. Therefore "technology" becomes a complex medicine that has no universal appllcability, but one with many particular prescriptions.

The analysis that follows, represents a step towards the clarification of what measures have been implemented and how do they behave. It should help the building sector actors and decision- makers to limit the technical and economical risk associated to this process and therefore help their progressive implementation.

Envelope Materials and Passive Components

Envelope materials are those components of walls, ceilings and floors. They are considered from their capacity to control heat in and out the building; therefore envelope materials is a concept linked with insulation. Glass is a part of this concept but only when it is incorporated with a strong insulation approach, otherwise glazing is part of its own chapter "Window and Glazing".

Usually walls, floors and ceilings are not only structural components of buildings but part of the heat control and storage strategies of passive designers. In this case, the envelope materials are also passive solar component. In passive solar space heating the building itself acts as a heating system using the solar radiation as a heat source and the envelope materials as the storage and control media.

Building envelope materials are either the opaque and transparent components isolating the interior from the exterior. Depending on their composition they will slow the heat transfer in and/or out, from irrelevant to significant levels.

The following paragraphs focus on **the opaque part** as a technology objective and its behaviour linked to the insulation capacity. This property is not only a matter of extra insulation thickness, but also the conjunction of the good insulation capacity, the avoidance of thermal bridges and an airtight construction.

Only the global consideration of these three aspects means that the building can be labelled as highly insulated or super insulated.

Insulation is a material designed to slow down the flow of heat. In the building envelope, the primary function of insulation in most parts of the countries is to keep the heat in, but insulation also plays an important role in keeping heat out during the summer months in hot climates.

Heat flows by conduction, convection and radiation. Building insulation slows a11 three types of heat flow, though its greatest impact is on conduction. Most insulation materials are lightweight fibrous or cellular materials that enclose air or gas pockets.

A material resistance to heat flow is measured in R-values. The inverse of thermal resistance is conductance referred to the K or U value measured in units of W/m^2K, while the R-value is intuitively easier to understand (the higher the R-value, the better the insulation properties).

The U-value is more useful in calculations, since it describes the actual amount of heat that will move through the material for each degree difference in temperatures. Various types of insulation are available for application to the building fabric to reduce heat losses.

Transparent Insulation Materials (TIM) can be described as a mechanism which allows the harnessing of solar gains through controlled use of the greenhouse effects but which prevents most thermal losses in a manner similar to conventional (opaque) Insulation. TIM materials can be characterised by the following: high optical transmissivity achieved through the use of transparent/translucent construction materials such as low iron glass, thin wall polycarbonates or clear gels. Low thermal radiation transmissivity achieved through the use of coated glazing by low emissivity components, as thermal conductivity is achieved through the use of lightweight construction materials incorporating significant volume proportions of low conductivity gases or a vacuum

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good convection suppression achieved by compartmentalisation to avoid bulk movement of gaseous components.

Combinations of these properties have resulted in the design of various transparent insulation elements which have a U-value of less than 1 W/m²K, whilst retaining a solar transmittance above 70%.

Transparent insulation at Birmingham

Dynamic Insulation

Dynamic insulation (DI) is the combination, within a wall, of a conventional insulation and some hind of dynamic exchange between outside and inside temperatures. The typology of DI divides into: parieto dynamic insulation where a fluid (mostly air) circulates in a cavity which serves as heat exchanger and permeo dynamic insulation where a fluid circulates through a porous material.

DI is frequently coupled with ventilation thus offering an efficient way of pre-heating fresh air. **A** dynamic insulation construction can be given a variable U-value which is a function of the air velocity.

Selected case-studies

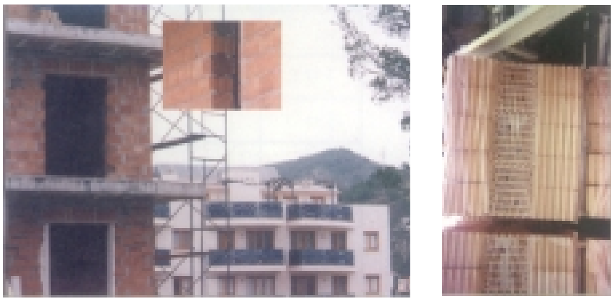
Case-study 1: In the Aalborg case the minimum U-value of the roof is 0.1 W/m²K achieved by using 350 mm mineral insulation material. The walls are constructed with two different types of outer surfaces with insulating, medium density, lightweight, concrete panels as bearing inner walls. For the lower part, light-weight concrete blocks and 125 mm mineral insulation with U-value of 0.25 W/m²K are used and for the upper part, wooden cladding and 200 mm mineral insulation with U-.value of 0.18 W/m²K. The external doors are made of soft wood with high performance insulated value of 1.77 W/m²K overall. For the ground floor slab, 300 mm expanded clay nuggets and cold bridge stopping insulation achieve U-values of 0.2 W/m²K.

In this building, sustainable building materials were considered. The materials used for the construction of the outer walls for instance, have been calculated to embody 49% the energy of a standard brick wall and the construction of the outer walls emits 35% the $C0_2$ of a standard brick wall. The wood used on the upper cladding is untreated North American Red-Wood. In connection with the reduction of the risk of allergy, the surfaces must be easily cleaned.

Following the above-mentioned demands new "light", water based, "plastic" paint was chosen both on walls and on indoor wood, steel, gypsum boards and concrete panels.

Case-study 2: A low thermal conductivity brick, also called "low-k-brick"with a U-value of 0,4 W/m²K was used in the construction of the building of Barcelona. It is a low density ceramic material made from a mixture of clay, polystyrene foam spheres and other granular materials which gasify during firing at over 900°C, producing no residues and giving good, uniform porosity to the ceramic material of the brick.

Low-k-bricks used at Sitges (Barcelona)



Case-study 3: The Rokingham case (Bristol) envelope recycled materlals arising from the demolition of the former buildings. Here also attention is paid to design and construction to achieve a good degree of air tightness of the whole structure. The limitss of infiltratlon were specifled as <3m?/hm? at 25 Pa. The insulatlon of roof is deslgned to have a minimum U value of 0.15 W/m?K and to achieve using a 175-200 mm thickness of "Warmcel" recycled paper insulatlon. The high thermal mass structure was reduced to a inimum U-value of 0.17 W/m?K for the maln body of the external cavlty wall construction with no thermal bridges greater than l.2 W/m?K in any part of the structure. This has been achieved with cavity 200 mm wlde filled with '"Dritherm" fibre mineral wool cavity slabs. The ground floor slab has been insulated with minlmum U-value of.0.25W/m?K and avoidance of thermal bridging.

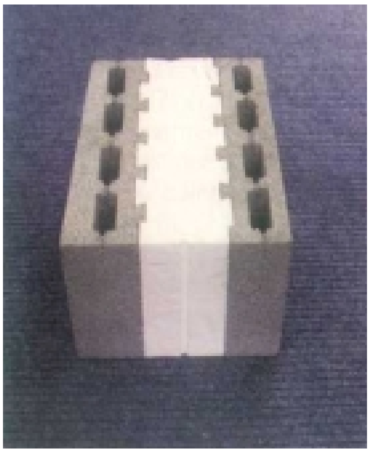
Insulation in between the two elements of external walls at Rokingham Place (Bristol)

Case-study 4: At Dublin the following strategies have been implemented:

- Pre-insulated concrete wall blocks with a U-value for the whole wall of 0.31 W/m²K;
- Pre-cast hollow concrete floors giving excellent fire proofing; structural strength and soundproofing..

• The house is air tightened using a damp-proof membrane under the floor and a vapour barrier fixed to the inside of the walls. The house has no open chimney.

Pre-insulated concrete blocks with a polystyrene core that provide a U-value of 0.31 W/m²K



Windows and Glazing

Any window lets the solar radiation come in while stopping the internal heat escaping. This standard element becomes a noticeable technology when the heat transfer value is 1.5 W/m²K at maximum.

To achieve this goal both the glass and the frame need to be carefully selected. The glass panes are responsible for the bulk of the heat transfer migration. The two principal phenomena to be controlled are radiative and conductive losses.

Radiative heat is controlled by means of Low Emissivity coatings. These are coatings applied to several or all the glass panes that reduce the glass emissivity by a minimum of five times compared with the normal values of glass. New emerging technologies are also appearing in the market such as the so-called "smart windows". These materials have variable solar-optical properties, which can be passively or actively altered. Their Summary of application in architectural glass allows dynamic regulation of solar energy transfer through the fenestration for visual comfort, thermal comfort, peak load management, the control of glare, privacy and daylight.

The convective losses are diminished by replacing the air in between the panes with an inert gas (Argon, Krypton or Xenon). But some other new ideas have been developed to help diminish these kinds of losses. In general they are labelled as transparent insulation (TIM).

There are two main types of TIM, which allow a further reduction of the U-value. They are typically used as fill in a double-pane glazing assembly:

Aerogel:

Silica aerogel is a microporous material that traps air in tiny holes. It has excellent insulating properties, good optical clarity and relatively high solar transmittance.

Honeycomb or capillary structures

Honeycomb or capillary structures made of plastics or glass have a high solar.transmittance and reduce heat losses by suppression of convection and infrared radiatlon. No clear view through is possible; however, through redirecting solar radiation a good illumination of the room behind can be reached.

There are a number of configurations depending on the number of.glass panes, the coatings and the filling gas. There are even windows where some special films are included in between the glass layers to control heat gains. In average, however, the buildings do not have other configurations than two layer Argon filled glass in Southern climate projects while; central and northern European energy-efficient buildings use triple glazing, also Argon or even Xenon gas-filled.

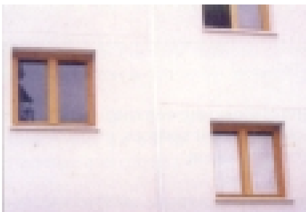
However, depending on the window quality and the climate, the frame may account for as much energy loss as the glass. Frames are responsible for the infiltration and noticeable amounts of conductive losses. Therefore, efficient windows have incorporated building technologies to break the thermal bridges when the frame is made of aluminium, and most recently new models are using lower conductivity materials as wood or Fiberglas.

As it is a highly deployed and commercially available technology, a general application is observed at all sites, the general approach being to use multi-glazed units leading to a U-value reduction down to below 2 W/m²K The U-values achieved by the distinct projects are:

- Southern climates: 1.8 W/m²K;
- Northern climates: 1.2 W/m²K.

Case-study: An advanced concept, the "Solar-Acoustic-Ventilated" (SAV) window has been introduced at the Barcelona, Sabadell, Lisbon sites (REMMA) and Sitges (SUNH). The concept includes two-glass panes 8 cm apart and with a Venetian blind in between, with air flowing through this space. The combined effect of double glazing and internal blind produces an accumulation of heat in the inner space between the panes that is conveniently forced inside or outside the building depending on the season, thus acting as a small sunroom.

External and internal views of the SAV window system



Source: *A brochure on "Guidance for Energy Saving Technologies in the Building Sector – Targeted Projects" published under THERMIE Programme by a consortium coordinated by Geohabitat company*

Projects for Energy Efficiency Improvements in Existing Buildings: Summarised Results of Measures Implemented in the Building Envelope within PHARE Project "Demonstration Project for Energy Efficiency in Multi-dwelling Houses with Individual Heating"

The above project was executed in a complex of 6 standard pre-fabricated panel type buildings in the town of Radomir, Bulgaria, and the following measured have been implemented for improving energy performance of the building shell:

Thermal insulation of the building envelope: more than 3600 m^3 of thermal insulation have been applied on the walls, roofs and basement ceilings, including:

- Exterior wall insulation has been implemented in three buildings using extruded polystyrene board produced by the Greek company FIBRAN. The insulation material features good thermal insulation properties, low water absorption and high compressive strength. Insulation boards of 6 cm, 4 cm and 3 cm thickness have been applied for facade external walls, to balconies and staircases respectively. The insulation boards on external walls have been glued to the old plaster and nailed with plastic couplings, then a thin layer of plaster and a fibre-glass grid (for reinforcement of the plaster), external layer of plaster with special additives for elasticy and final finishing have been applied.
- Thermal insulation and water proofing of the roof;
- Thermal insulation of the basement ceiling
- Restriction of air circulation in the joints between buildings;
- Carpentry replacement (wooden windows and doors) with aluminum ones in one of the demo buildings;
- Repair of existing wooden carpentry in two of the buildings;
- Replacement of the main entrances
- Thermal insulation and glazing of balconies in one of the demo buildings (where carpentry replacements was executed)

As a result of the above measures the thermal characteristics of the buildings have been significantly improved and the inhabitants have enjoyed increased thermal comfort in comparison with the non-insulated buildings. It should be noted, however, that the implemented measures are relatively expensive. The following table presents the unit prices of different energy efficient measures on the building envelope.

THERMAL RETROFITTING WORK OF THE "BUILDING ENVELOPE"	**Total Unit Cost (ECU/ m^2)**
Thermal insulation of exterior walls (façade)	**23.5**
Water proofing of the second external roof slab	**14.0**
Thermal insulation of the first roof slab	**6.3**
Basement ceiling insulation	**14.9**
Carpentry replacement	**129.8**
Repair of existing wooden carpentry	**8.5**
Replacement of main entrances	**54.0**
Thermal insulation and glazing of balconies	**60.0**

It's evident, that the highest is the price of carpentry replacement - 129,8 Euro/m^2 (pay-back period of about 20 years), but it is a measure that can be individually applied, while thermal insulation on the external walls costs 23,5 Euro/m^2 with a pay-back period of about 8 years, but its application requires the agreement of all co-owners of the building. The average pay-back of the building envelope measures is about 9 years. The economic calculations have been made based on 1998 prices in Bulgaria.

Radomir façade before and after the retrofitting

The present bulletin is issued by Sofia Energy Centre, Coordinator of Balkan OPET, within the framework of Energy Information Network at Local and Municipal Level

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