IEA ECBCS Annex 36: Retrofitting in Educational Buildings – REDUCE 25 Case Study Reports from 10 different Countries

Heike Kluttig[1], Hans Erhorn[1], Ove Mørck[2]

[1] Fraunhofer Institute of Building Physics
(Head of the Institute: Univ.-Prof. Dr.-Ing. habil.Dr. sc. techn. h.c. Dr.-Ing. E.h. mult. Karl Gertis)
Nobelstr. 12, 70569 Stuttgart, Germany,
heike.kluttig@ibp.fhg.de
[2] Cenergia Energy Consultants
Sct. Jacobs Vej 4, Ballerup, 2750, Denmark,
ocm@cenergia.dk

ABSTRACT

The IEA ECBCS Annex 36 deals with the energy retrofit of educational buildings. Researchers from 10 participating countries from Europe and the US are collecting information on retrofit measures and case studies and are developing an energy concept adviser for technical retrofit measures. This internet-based computer tool for decision-makers is the main outcome of the annex. One of the most important inputs to the tool is the collection and assessment of case studies, which is also presented in a specific report. 25 case studies from Denmark, Finland, France, Germany, Greece, Italy, Norway, Poland, UK and the US are included into the collection. For each case study the report consists of a description of the state before the retrofit (geometry, construction and HVAC-system), the used retrofit measures, the resulted energy savings, the renovation costs and the experiences or lessons learned during the retrofit and the user feedback afterwards. The buildings are divided into different building types. A summary including a matrix on the used retrofit technologies per building and an overview on the reached energy savings are given. The paper for the AIVC BETEC 2003 gives an overview on all buildings and specifies on the used technologies with focus on energy and ventilation.

KEYWORDS

IEA ECBCS Annex 36, case studies, retrofit, educational buildings, retrofit technologies, energy saving.

1. INTRODUCTION

The collection of case studies is a means to provide and disseminate valuable inspiration, insight and experience from energy renovation projects carried out in different countries and under different constraints. This collection of case studies was identified as one of the subtasks of the IEA project. It was decided early on to collect the case studies in two rounds: existing and new case studies. This report presents the existing case studies. The new cases studies – identified by the fact that they are being or have recently been completed and data monitoring is still ongoing – will be collected, analysed and reported at the completion of the project. A format was developed according to which the existing case studies were reported.

Below is a list of all the case studies organised by country. Then follow an overview of the typologies represented by the case studies, the technologies and a synthesis on the aims and energy savings of the projects.

2. LIST OF CASE STUDIES

A total of 25 case studies have been reported: 5 from Germany (D) and the UK, 3 from Denmark (DK) and the US, 2 from Finland (SF), France (FR), Greece (GR) and Poland (PL) and 1 from Norway (N). The projects are listed below ordered country by country.

D1: Exemplary Retrofitting Of a School in Stuttgart (EROS)
D2: Bertolt-Brecht-School in Dresden
D3: Paul-Robeson-School in Leipzig
D4: University of Stuttgart
D5: University of Ulm

DK1: Egebjerg School, Ballerup
DK2: Enghøjskolen, Hvidovre
DK3: Vridsløselille School, Albertslund

SF1: Elementary School of Oulujoki
SF2: Vihaistenkari Day Care Centre

FR1: Louise LABE secondary school
FR2: GAMBETTA professional high school

GR1: Chemical Engineering building, N.T.U.A, Athens
GR2: University of Ioannina.

N1: Kampen School

PL1: Secondary School in Swarzedz
PL2: Poznan University of Technology

UK1: William Parker Community Secondary School
UK2: Hadley Junior School
UK3: Grove House Refurbishment
UK4: George Tomlinson School, Bolton, Lancashire
UK5: Ketley Town Junior School

US1: Wausau West High School, Wisconsin
US2: Akard Elem. School, Sullivan County, Tennessee
US3: University of New Hampshire

3. TECHNOLOGIES

The energy retrofit technologies of the projects have been categorised in a table to present an overview of the distribution, see table 1. The technologies have been categorised according to their main intended function: Improvement of the building envelope, ventilation, lighting, heating, cooling, solar, lighting and other. The number in the last column is a count-up of the number of applications among the case studies of a particular technology. The count shows, not surprisingly, that it is the traditional energy conservation technologies that have been applied most often. They are: Added insulation, low-E-coated windows, new efficient electrical lighting (and control thereof), renewal and control of the heating system. But also “newer” concepts such as natural (hybrid) ventilation and demand-controlled ventilation have been implemented in more than 30% of the projects. In approximately 1/3 of the projects daylighting principles and improved control of the artificial lighting systems have been applied. The rest of the technologies, that is: preheating of the ventilation air, innovative insulation systems, passive solar design, atria, a number of passive cooling technologies, active solar, PV and other principles have been implemented in a few projects.

The distribution of the implemented technologies shows that the technologies traditionally accepted as economically viable are dominating in numbers. However, the newer, less established technologies that are demonstrated in the case studies, add important knowledge with respect to the design, construction and control of these technologies.

TABLE 1
Energy technology by case study overview.

Energy Technologies		Total
Building Envelope	Windows	15
	Insulation materials & systems	13
	Over-cladding systems	1
	Doors	6
Heating Systems	Heating Installations	8
	Domestic Hot Water Installations	5
	Energy Sources	11
	Control Systems	14
Ventilation Systems	Natural Ventilation Systems	10
	Mechanical Ventilation Systems	8
	Hybrid Ventilations Systems	7
	Control & Information Systems	12
Solar Control & Cooling	Shading & Glare Protections	8
	Cooling Systems	5
	Air-Conditioning Systems	3
	Control Systems	5
Light & Electr. Appliances	Lighting Systems	11
	Electrical Appliances	7
	Daylighting Technologies	8
	Control Systems	10
Management	Energy Auditing Techniques	6
	Commissioning	1
	Education & Training	2
	Non-Investment Measures	2

4. PROJECT AIMS, ENERGY SAVINGS AND VENTILATION STRATEGIES

The projects showing higher savings are generally demonstration projects, in which several energy saving technologies have been implemented in a form of holistic approach, where relative long payback times have played a secondary role. In contrast, the projects showing relatively smaller savings are projects where fewer technologies have been implemented and more emphasis has been on a cost-effective approach resulting in fairly low payback times of the order of 5 years. In some projects the main emphasis has been on the improvement of indoor comfort, air quality or lighting comfort and the energy savings have been considered as a positive side-effect.

The energy savings reported are for some project quite considerable. For example heating energy consumption for the German and Danish projects before retrofit were 200-280 kWh/m²/year and after the retrofit these were reduced to 50-90 kWh/m²/year. The saving percentages of the different projects range from 75% heating and 100% electricity to 0% heating and 15% electricity. A number of projects (primarily from Denmark and Germany) report quite large savings 55-75% heating and 30-40% electricity. At the other end of the scale the projects in UK and the US report rather modest savings of 8-20% heating and around 15% electricity savings.

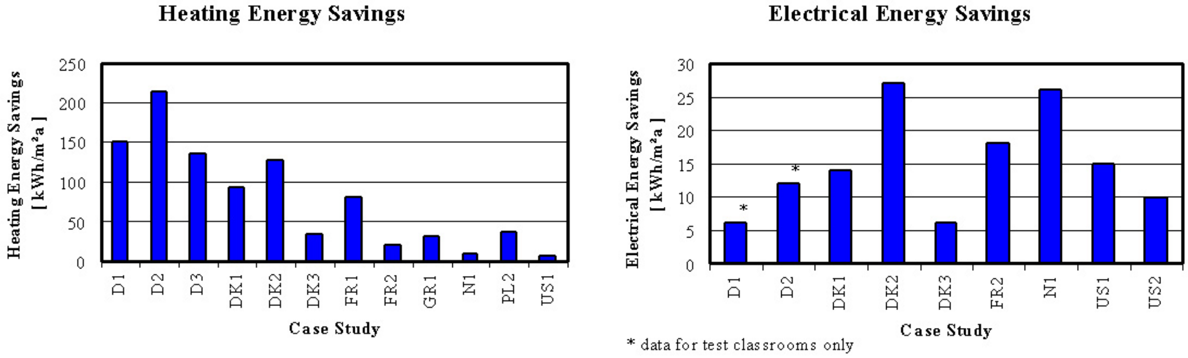

Figure 1: Heating and electrical energy savings of the Annex 36 case studies.

The comparison between the 25 retrofit approaches showed that different countries follow different ventilation strategies in schools. Finland emphasizes on indoor air quality and tries to improve this with mechanical ventilation with heat recovery. Norway and Denmark have a tendency to remove mechanical ventilation and replace it with natural hybrid ventilation strategies that can by supported if necessary with fans. Germany showed in its three retrofitted schools three different ways of ventilation. First natural ventilation by simply opening the windows, which can be supported by an indoor air quality visualisation, second natural ventilation with pre-heating/pre-cooling by atria and third natural ventilation through shafts into the classroom and from there to corridors, supported by fans. France either works with a minimum air change rate provided by a mechanical ventilation system and additional ventilation by opening the windows or only natural ventilation through the windows. UK's retrofit project dealt not with ventilation strategies but the schools presented are mainly ventilated by opening the windows with sometimes mechanical ventilation by fans or draft support. The Polish school is ventilated by opening of the windows. The two US schools are mainly ventilated through the windows and in one case by an additional mechanical system with heat recovery.

5. EXAMPLE: EGEBJERG SCHOOL, BALLERUP, DENMARK

Of the 25 case studies one has been selected to be briefly presented in this paper for the AIVC conference. The project illustrates the implementation of ventilation technologies as part of the total retrofit concept. The object of the Danish MEDUCA project is the refurbishment of a school built in the seventies in the municipality of Ballerup, Egebjerg School, see figure 2. The overall aim of the project is to demonstrate that an energy efficient and ecological refurbishment of a common school of the seventies, can be carried through to obtain a healthy indoor climate at a reasonable cost. Modern building technology, heating and ventilation technology will be combined with carefully chosen materials, natural ventilation and active solar heating. The project at Egebjerg School concerns a selected part of the school, C2 and C1, containing classrooms, connecting corridors and two double height common area rooms. The project was completed in 1998.

The design concept focused on replacing the existing mechanical ventilation system with a natural ventilation system and reducing heat losses through reduced U-values in roof, façades and windows. A completely new sloped roof construction replaced the original flat roof. An average of 20 cm of mineral wool was added, giving 30 cm thick insulation overall. All façades were completely renewed including 20 cm of mineral wool insulation. All windows in the selected sections of the school were replaced by new low energy windows with a U-value of 1.7 W/m²K.

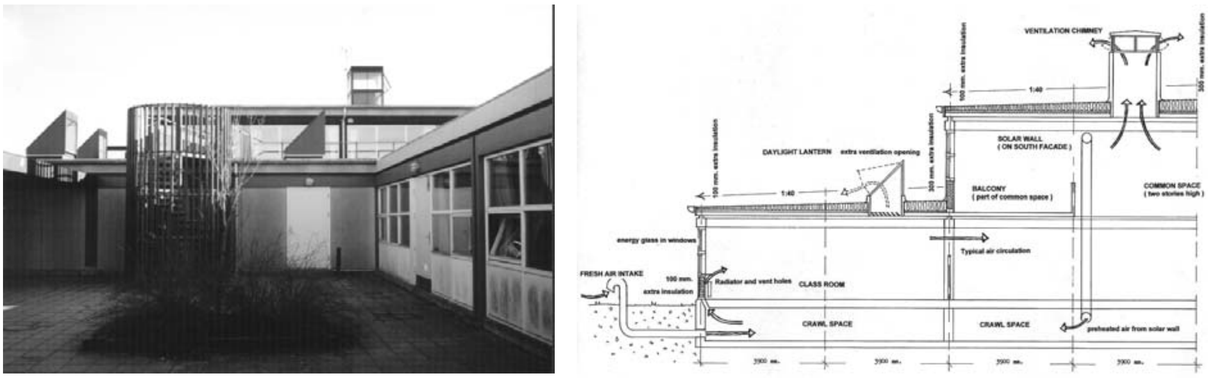

Figure 2: Photo of the school (west view) and technical section of the school showing the ventilation system principle.

A completely new natural ventilation system has been designed. Fresh air is taken in through air ducts to a crawl space below the classrooms. From the crawl space the air is led into each classroom behind convector radiators, which have been designed to further preheat the air. Air leaves the classroom through corridors to the double height common assembly room, at the roof of which a combined stack effect, wind and solar chimney is placed. The chimney is designed to work by a combination of wind pressure and ordinary stack effect. Two separate chambers are heated as solar air collectors and are opened when the temperature increases to such a degree that a considerable driving force is established. This feature is primarily designed for summer operation. A fan is located in the crawl space to generate a slight over-pressure in case the natural driving forces are too weak to generate the necessary ventilation. A type of solar air collector called a “Canadian Solar Wall” is installed on the south façade of the double-height building. From the collector, air is taken into the crawl space instead of from the earth ducts, whenever it is preheated to a higher temperature.

Resulting energy savings

The energy consumption before and after were measured to be:
Heating: Before: 181 kWh/m², after: 87.3 kWh/m²
Electricity for ventilation and lighting:
Before: 36 kWh/m², after: 22 kWh/m²

The section of the school identified for the MEDUCA project was subdivided into two parts of equal size C1 and C2. C1 was defined as a reference case for the qualitative user evaluation of C2. All pupils and teachers in the two sections answered a questionnaire developed by the Stockholm office of statistics and research in Sweden. 8 teachers and 120 pupils from the C2 section and 9 teachers and 72 pupils from the C1 section participated. The questionnaire had 17 main questions and several sub-questions. Figure 3 shows the results of one of the main questions concerning air quality. The histogram very clearly shows a “shift” in perceived air quality from acceptable to quite good and from poor to acceptable as a result of the refurbishment of the school. The general picture of all questions is an overall improvement of the indoor comfort quality compared to the reference.

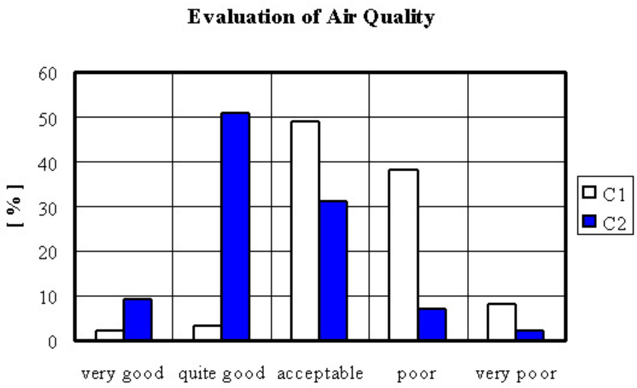

Figure 3: Perceived air quality.

6. CONCLUSIONS

A collection of 25 case studies of energy efficient renovation of educational buildings is presented in this report. 8 European countries: Denmark, Germany, Greece, France, Norway, Poland, the United Kingdom and the USA are represented. The case studies comprise 18 schools, 6 universities and one day care centre. Therefore the variety of climates, building types and energy conservation principles and technologies implemented are quite large, making generalisations and recommendations based on the experiences of these buildings a difficult if not impossible task. However, the descriptions of these case studies provide the reader with valuable inspiration and information on the experiences from the projects.

The energy savings reported range from 75% to 100% in the upper end to 8-10% in the lower. This can be interpreted as three different strategies:

1. to implement several technologies as part of a holistic approach aiming at high energy savings and accepting longer payback times,
2. to focus on the technologies with an immediate return of the investment resulting in less savings but obtaining very short payback periods, and
3. to focus on the improvement of indoor climate, air quality or lighting comfort and consider energy savings as additional benefits.

The case studies reported provide inspiration to decision makers who are seeking solutions for all three strategies.

This sample of case studies for energy efficient renovation of educational buildings presents new, advanced technologies, such as: Preheating of the ventilation air, innovative insulation systems, passive solar, atria, a number of passive cooling technologies, advanced HVAC, active solar and PV. It also includes the rather traditional technologies, such as: added insulation, low-E-coated windows, building energy management systems and new lighting systems. The latter technologies are represented in the majority of the case studies showing that there might still be a need for more demonstration projects implementing, testing and verifying the viability of the newer, less established technologies.

7. REFERENCES

1. www.annex36.bizland.com (website of Annex 36)
2. IEA ECBCS Annex 36: Case Study Reports, 2003, Ove Mørck (editor)
3. IEA ECBCS Annex 36: Energy Concept Advisor, 2003 (internet-based tool for decision makers), Hans Erhorn (editor).