Exemplary retrofit concepts in Europe: Energy-efficient public buildings (results from IEA/EU-projects)

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***SUMMARY**:*
The Annex 36 of the International Energy Agency (IEA), under the management of the Fraunhofer Institute of Building Physics, dealt with energy-optimised retrofit measures for existing educational buildings (www.annex36.com). By comparing and analysing of more than 30 case study retrofits from 9 European countries and the USA, the team gained detailed experiences and exchanged knowledge. A software tool (Energy Concept Adviser) was developed to support the decision makers and their technical staff in designing energy efficient retrofit measures. This work on educational buildings is now extended to all public buildings by an EC-project. The integrated project „BRITA in PuBs" within the 6th Framework Programme is further developing the Energy Adviser by adding case studies of different public building types, summarising special energy-efficient retrofit measures and adding on benchmarks for different public building types (www.brita-in-pubs.com). The calculation engine of the Concept Adviser will be adapted to all public buildings in a new IEA Annex that is currently in the preparation phase.

1. Introduction

If we look at the building stock and the energy consumption for heating, cooling, ventilation and lighting in Europe with the focus on energy-efficient buildings, mostly built after 1980, we have to realise that these buildings represent about 20 % of the building stock but only 5 % of the energy consumption. In order to meet the objectives of the Kyoto Protocol we have to concentrate on improving the energy-unefficient building stock. The aim of improving the situation and of boosting the significance of energy conservation as one of the set-up of goals of decision makers in retrofit projects must be realised by increasing the knowledge of energy-efficient retrofit technologies and their intelligent application. One of the best ways to do that is to present best practice examples to show that the improvement of the comfort as the primary aim can be achieved together with measures for energy savings. Another promising way is to give the decision makers and their technical staff simple-to-use tools at hand that will support them in the first planning phase to make the right decisions towards energy saving retrofit measures.

2. Case studies of educational buildings out of IEA Annex 36

The IEA ECBCS Annex 36 dealt with the energy retrofit of educational buildings. Researchers from 10 participating countries from Europe and the US were 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 was also presented in a specific report.

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 were being or had recently been completed and data monitoring is still ongoing – were 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. 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).

2.1 Technologies

The energy retrofit technologies of the projects have been categorised in table 1 to present an overview of the distribution. 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.

TAB. 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

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. 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.

2.2 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.

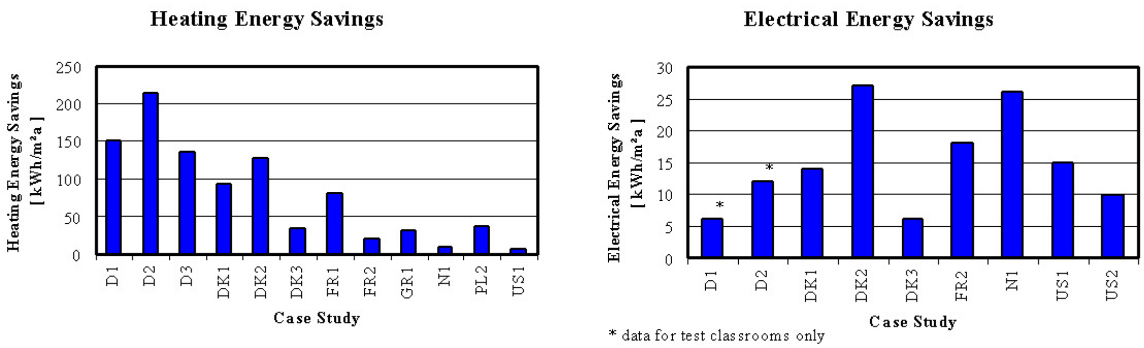

FIG. 1: Heating and electrical energy savings of the Annex 36 case studies.

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.

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.

2.3 Example Egebjerg School, Ballerup, Denmark

Of the 25 case studies one has been selected to be briefly presented in this paper. The object of the Danish demononstration 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 was 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 were combined with carefully chosen materials, natural ventilation and active solar heating. The project was completed in 1998.

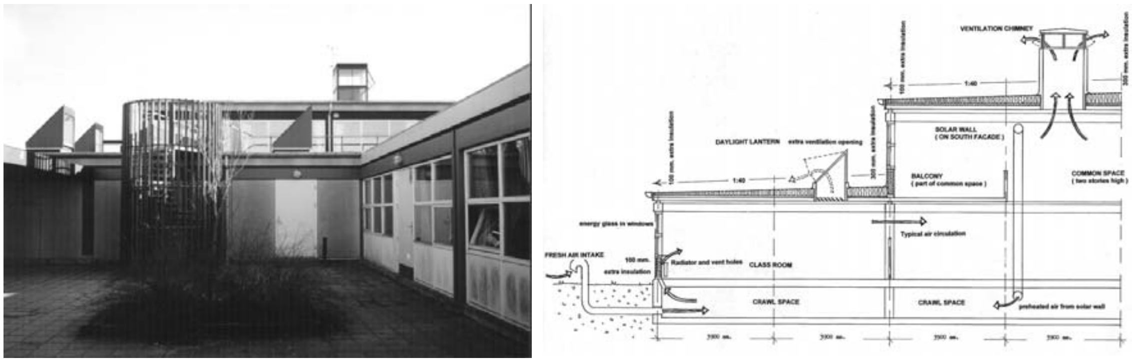

FIG. 2: Photo of the school (west view) and technical section of the school showing the ventilation system principle.

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. 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. 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 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.

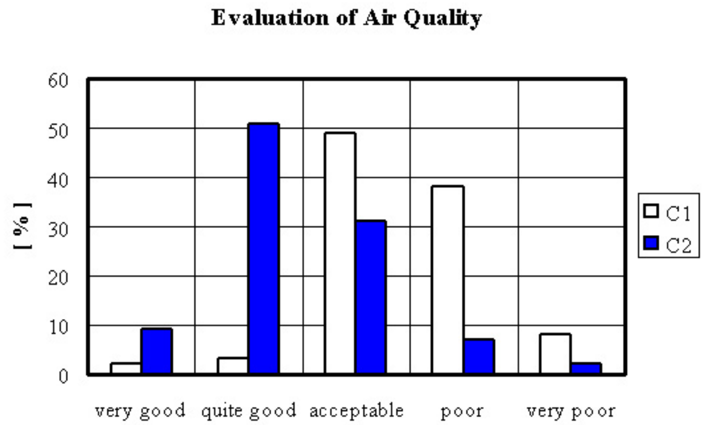

FIG. 3: Perceived air quality.

3. Energy Concept Adviser Tool of IEA Annex 36

As written in the second chapter, the ECBCS Annex 36 „Retrofitting of Educational Buildings – REDUCE – Energy Concept Adviser for Technical Retrofit Measures" of the International Energy Agency (IEA) dealt with the energy retrofit of educational buildings. The main result, besides several reports on case studies, retrofit measures and calculation tools, etc., is the "Energy Concept Adviser" that provides information on energy saving retrofits to decision makers in administrations and thereby supports them in the important first planning phase. Figure 4 shows the title page of the computer tool.

FIG. 4: Title page of the Energy Concept Adviser

3.1 Components of the Energy Concept Adviser

The Energy Concept Adviser consists of the following main parts:

3.1.1 Problem Related Recommendations

Here the decision maker can receive proposals for solution to specific problems in the buildings administered by him. The problems are sorted into groups: high energy consumptions for heating and electricity, high water consumptions, bad indoor air quality, untight building envelope, high humidity or mould problems, damages at different building or HVAC components, heat-start or control problems as well as asbetos in building components. For each solution payback times and best times for starting the retrofit are given. Additionally links to case studies with similar problems and to the detailed descriptions of suitable retrofit measures are provided.

3.1.2 Collection of case studies and retrofit measures

The database of retrofitted case study buildings and the description of suitable retrofit measures is created as matrix (see figure 5). The user is provided with information on more than 30 case studies and various retrofit measures. The case studies can be sorted according to country, and age. The retrofit measures include measures at the building envelope, the HVAC system, the lighting system, protection against overheating and no-cost measures such as further education of users, caretakers, etc. All information can be printed as pdf-report.

FIG. 5: Matrix as entrance to the information on case studies and retrofit measures.

3.1.3 Performance Rating

The user provides the input of the energy consumption for heating, electricity and the water consumption of a specific building. The programme then assesses these characteristic values by comparing them to the average national consumptions of the user country that are based on national studies.

3.1.4 Retrofit Concept Development

This core part of the tool supports the user with an assessment method on energy savings and the necessary investments and running costs for various retrofit measures. The starting point is either a typology building suitable to the own building, or the adaptation of the geometry and systems default values to the real building. After defining the existing status, first single retrofit measures for each building and system component are assessed financially and according to the energy savings. The next step is to combine the best measures of each component to up to 5 retrofit concepts that are compared against each other. An additional paper by Simon Wössner will give detailed insights in the retrofit concept development part.

3.2 How to acquire the Energy Concept Adviser?

The Energy Concept Adviser is currently in English language at www.annex36.com available, but can be additionally ordered as free of charge CD-Rom at Fraunhofer Institute of Building Physics (to order at: Fraunhofer-Institut für Bauphysik, Mr. Hans Erhorn, Nobelstr. 12, D-70569 Stuttgart, fax: +49-711-970-3399). The translation to German is planned within a short time frame. The translation to other languages such as Finnish, Italian and Danish are also currently under way.

4. EU 6th Framework Programme IP „BRITA in PUBs"

The BRITA in PuBs Integrated Project with 23 European partners from public administration, research, design and consultancies aims to increase the market penetration of innovative and effective retrofit solutions to improve energy efficiency and implement renewables, with moderate additional costs. In the first place, this will be realised by the exemplary retrofit of 9 demonstration public buildings in the four participating European regions, see figure 7. By choosing public buildings of different types such as colleges, cultural centres, nursery homes, student houses, churches etc. for implementing the measures it will be easier to reach groups of differing age and social origin. The energy-efficient retrofit measures are funded by 35 % by the EU. Secondly, the research work packages will include socio-economic research such as the identification of real project-planning needs and financing strategies, the assessment of design guidelines, the further development of an internet-based knowledge tool on retrofit measures and case studies (extension of the ECA of IEA Annex 36 to all public buildings) and a quality control tool-box to secure a good long-term performance of the building and the systems. The third main pillar of the BRITA in PuBs project is dissemination, divided into a minor part, the training of users and maintenance personnel, and a larger section on publishing the research and demonstration work to different target groups. The Fraunhofer Institute of Building Physics coordinates the project. Figure 8 shows the project structure and the planned activities.

The technology applications include measures at the building envelope like improved insulation and high-efficient windows, advanced ventilation concepts like hybrid systems, integrated supply technologies like combined heat and power units, energy-efficient lighting and integrated solar application. The overall goal of the 9 different demonstration buildings is the decrease of the primary energy demand for heating, cooling, ventilation, domestic hot water and lighting by at least 50 %. Additionally the comfort in the buildings shall be improved, so that the percentage of the dissatisfied users (investigated by questionnaires before and after the retrofit) shall be halved. The retrofit concepts of all buildings will be evaluated through monitoring of at least a one-year period.

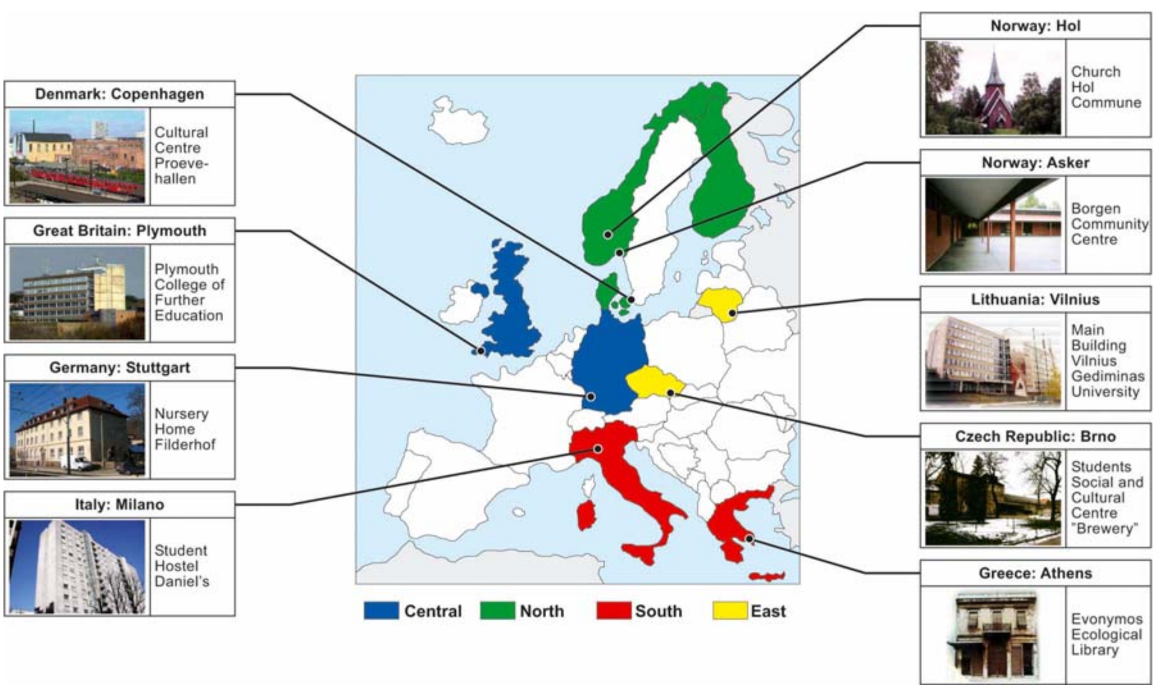

FIG. 7: Presentation of the 9 demonstration buildings in BRITA in PuBs .

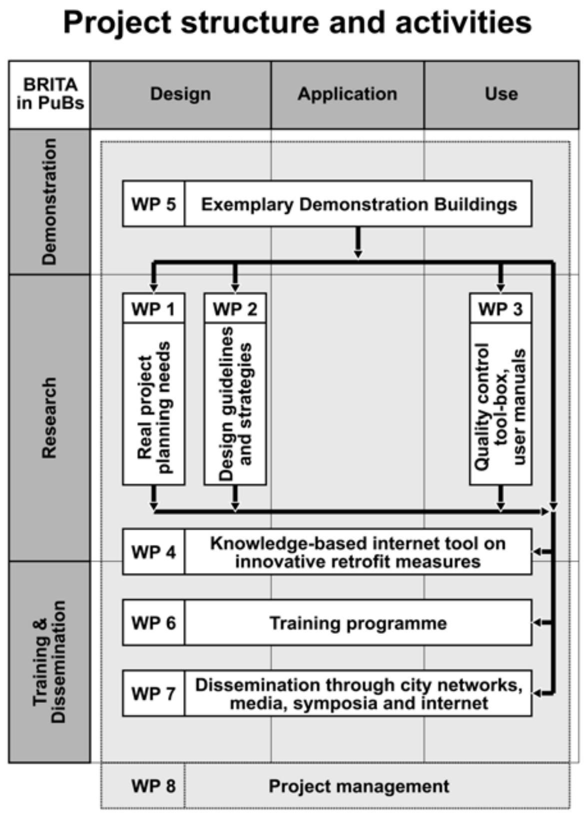

FIG. 8: Project structure and planned activities in the BRITA in PuBs project.

5. New Project IEA ECBCS Annex 46 – EnERGO

Based on the results of Annex 36 the International Energy Agency has started a new Annex, which includes the further development of the Energy Concept Adviser on public buildings. Whilst the work in BRITA in PuBs will mainly be to include new case studies, work on the retrofit measure part and add benchmarks for the whole group of public buildings, the Annex 46 will extend the calculation part to all public buildings. This is planned by using the new CEN codes for the implementation of the EPBD for the calculation of heating, cooling, ventilation, lighting and domestic hot water consumptions.

6. Conclusion

In this paper continuous work at different European and worldwide projects on bringing forward energy saving retrofit measures and therefore meeting the target of the Kyoto protocol is summarised. The focus in the projects is on two approaches: the presentation of best practice examples and the support of decision makers in the important first planning phase by a computer tool that gives valuable and reliable information on suitable retrofit measures, case studies, benchmarks and even the possibility to develop a rough energy saving retrofit concept. This tool was developed for educational buildings but will now be extended to all public building types in two actual follow-up projects.

7. References

www.annex36.com (website of Annex 36)

IEA ECBCS Annex 36: Case Study Reports, 2003, Ove Mørck (editor)

IEA ECBCS Annex 36: Energy Concept Advisor, 2003 (internet-based tool for decision makers), Hans Erhorn (editor).

www.brita-in-pubs.com (website of BRITA in PuBs)