Integrated Building Concepts – Current IEA Trends and Monitoring Results

E. Blümel and J. Krail
Fachhochschulstudiengänge Burgenland GmbH - University of Applied Science
Steinamangerstraße 21, A-7423 Pinkafeld, Austria

D. Jähnig and W. Wagner
AEE – Institute for Sustainable Technologies
Feldgasse 19, A-8200 Gleisdorf, Austria

ABSTRACT

Subtask B of the IEA-ECBS Annex 44 “Integrating Environmentally Responsive Elements in Buildings” deals with the development and the optimisation of integrated building elements. The results of two model buildings exemplify the impact of building concepts and user behaviour on the operation of the building. The analysis shows that innovative building concepts and elements, which to some extent are being realised at the moment, need to take into account system integration and intelligent planning in order to achieve satisfactory results.

1. INTRODUCTION

Due to increased demand for comfort and sustainability an enhanced performance of individual components and systems no longer suffices. One of the greatest future potentials for the improvement of a building’s energy performance lies in technologies – so called responsive building elements - that promote the integration of “dynamic” building elements in building design, building services and renewable energy technologies.

To understand and even to improve building concepts and building elements, the International Energy Agency (IEA) has created within its program “Energy Conservation in Buildings and Community Systems (ECBCS)” the Annex 44 “Integrating Environmentally Responsive Elements in Buildings”.

2. INTEGRATED BUILDING CONCEPTS WITHIN THE IEA-ECBCS ANNEX 44

IEA-ECBCS Annex 44 is an international co-operation of 24 researchers from 12 countries and focuses on the research and development of innovative building elements that dynamically respond to changes in climate and user demands and are designed and applied in integrated building concepts.

The objectives of IEA Annex 44 are to improve and optimize responsive building elements, to develop and optimize new building concepts with the integration of responsive building elements and to develop guidelines and procedures for estimating the environmental performance of responsive building elements and integrated building concepts. To reach these objectives, the working programme of the Annex 44 is divided into three subtasks and is shown together with the expected results in Figure 1.

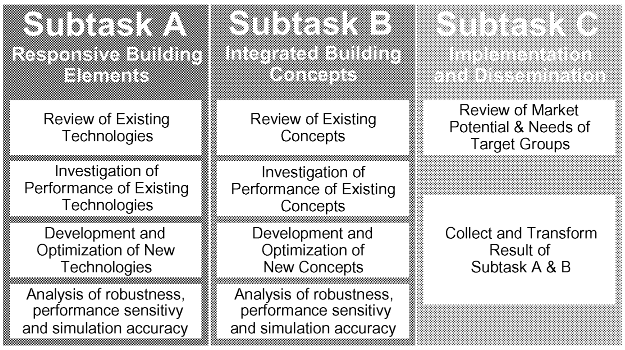

Figure 1 – Working programme and expected results of the IEA-ECBCS Annex 44

With the integration of responsive building elements and building services, building design completely changes from the design of individual systems to integrated building concepts (as shown in Figure 2), which allow for the best possible use of natural energy strategies as well as for the integration of renewable energy. Besides this, the integrated design approach also achieves an improvement in the environmental sustainability of the building.

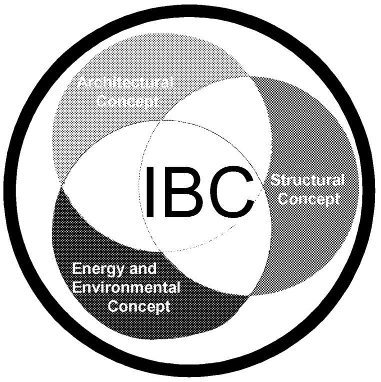

Figure 2 – Integrated Building Concepts

3. MONITORING OF RESPONSIVE BUILDINGS IN MODERATE CLIMATE

Subtask B contains an overview of 22 case study buildings from 9 countries with integrated building concepts. On the one hand, innovative concepts, building components and planning ideas are described. On the other hand, planning and monitoring data are compared in order to analyse the performance of planning tools and proposals as well as innovative building elements. The results will subsequently be summarised in an experts guide.

In order to provide an overview of the data collected, the measurement results of the projects "Christophorus Building" (office building) and "Kindergarten Ziersdorf" (municipal building) will be presented below.

3.1. Christophorus Building (Office Building)

Location: Stadl-Paura, Upper Austria, Austria
Sea level: 370 m
Situated: Countryside
Heating degree days: 3923 Kd (-15 °C norm data)
Energy concept: AEE - Institute for Sustainable Technologies

Figure 3 – Front view of the Christophorus Building

Description of the building

The office building with 1,215 m^2 is a work place for 40 persons. The building has a basement, a ground floor and two upper floors (see figure 3).

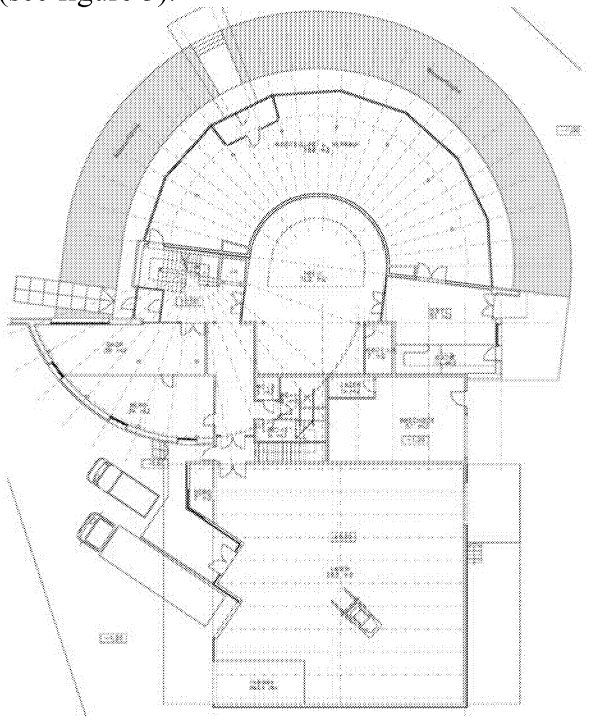

Figure 4 – Architectural plan view of the office building Christophorus Building (ground floor)

The goals of the planning team for the construction were:

- Multi functional application of the building (offices, events, mini shop, exhibition facilities and logistic central).
- Wooden construction
- Heating load < 15 kWh/m^{2}a
- Pressure test air change $n_{50} < 0.6\ h^{-1}$
- Primary energy consumption < 80 kWh/m^{2}a (including electricity for the domestic use)
- No compressor cooling machine
- Covering the remaining energy demand with renewable energy sources to a maximal extent
- Highest possible comfort for the employees with lowest possible running costs
- Building certified as "passive house quality" by the passive house institution in Darmstadt, Germany

These high ambitions were a challenge for the planning team and could be reached due to an integral planning process.

The essential components for the energy supply system are listed in table 1.

Table 1: Energy Supply of the Christophorus Building

Energy supply		
	Application	**Technical data**
Piles	Heating (heat pump) and Cooling ("direct cooling")	8 x 100 m Duplex – piles, (Double-U-pipes DN 32)
Heat pump	Heating	Nominal power 43 kW at COP 4.03
PV – system	Covers the yearly electricity demand of the heat pump	10 kW_{peak}
Solar thermal system	Domestic hot water supply	5 m² collector area
Energy demand		
	Application	**Technical data**
Ventilation system for the office building area	Fresh air supply Heating, Cooling	Nominal flow volume 2,800 m³/h, heat recovery rate 78%
Ventilation system for the seminar rooms	Fresh air supply Heating, Cooling	Nominal flow volume 1.000 m³/h, heat recovery rate 86%
Heating and cooling surface area	Heating, Cooling	"direct cooling" ~ 25 W/m²

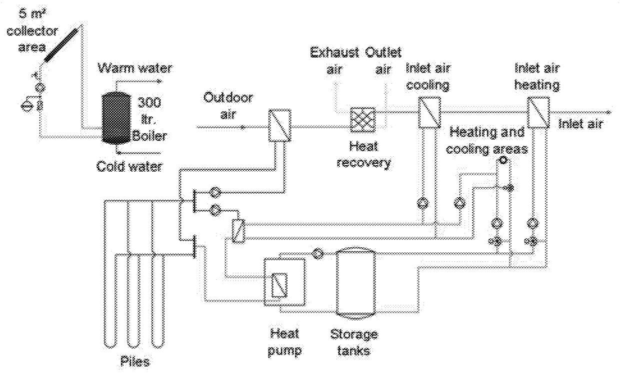

Figure 5 – Logic diagram showing the heat, cooling and ventilation concept for the office building

Measurement data acquisition

The measurement data acquisition of the building include an examination of comfort parameters (room temperature, humidity) as well as thermal and electric energy flows (heating, cooling, hot water) in relation to the whole building, individual office units as well as various load groups (heat pump, electricity for HVAC, etc.) In addition, the total solar radiation (onto the horizontal plane) and the outside air temperature were examined.

Figure 6 shows the monthly energy balance during the monitoring phase. The energy supplied for cooling is pictured in negative values, next to the energy supplied for the heating. The results can be seen as an interaction between load reduction (day light controlled shading) and passive cooling (piles, night ventilation), which functions very well.

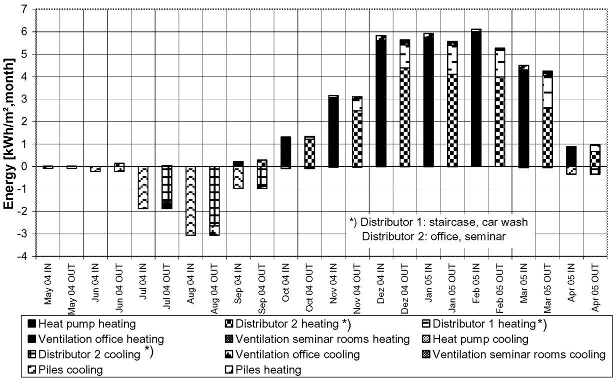

Figure 6 – Energy balance of cooling and heating for the office area.

The measured heating demand was 20 kWh/m²a and the maximal heat load was 13 W/m² for the winter operation. If you compare these data with the results of the planning phase (8 kWh/m²a for a very mild winter and 19 kWh/m²a for a very cold winter) it becomes apparent that the measured results are slightly higher than the planning data. The reason for this deviation is the low occupancy of the building (fewer people, fewer PCs than planned).

During the cooling period the measured cooling demand was 6.4 kWh/m²a and the maximal cooling load was 11 W/m². The cooling energy is provided only in the direct cooling mode. The measured data agree with the planning data, which are 4.5 kWh/m²a (mild summer) and 10 kWh/m²a (hot summer) depending on the set of climate data that were taken into account.

The graph in Figure 7 shows the room temperature during the summer and winter operation for periods of two weeks (average per hour). Concerning the operation in the summer it can be observed that the room temperature remains constant in spite of outside temperatures of over 30°C. The operation in winter also shows that in spite of low outside temperatures even over a longer period of time the room temperatures are constant and comfortable.

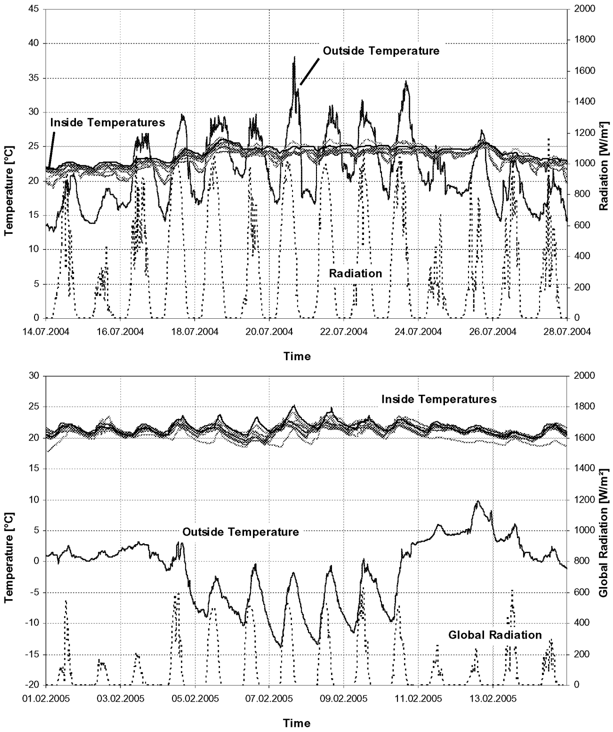

Figure 7 – Room temperature during two hot summer weeks (above) and two cold winter weeks (below)

Lessons learned

In spite of the difficult starting conditions which planning an office building entail (a high proportion of glass, the preference of a lightweight mode of construction, high internal loads, very different individual needs, a high rate of visitors and a great variety of occupants) the Christophorus Building shows successfully how it is possible to create a pleasant room climate with little energy input.

The room temperatures and room humidities are consistently pleasant; the building is cooled passively through geothermal piles. The room humidity is a little too low only on extremely cold days in winter. When the humidity is experienced as too low it can be improved by using local humidifiers or by reducing the air change during these periods.

The heating energy demand as well as the cooling energy demand do not exceed the range for various climate conditions that was allowed for and expected when planning the building.

3.2. Ziersdorf Kindergarten
(Municipal building)

Location: Ziersdorf, Upper Austria, Austria
Sea level: 227 m
Situated: Countryside
Heating degree days: 3575 Kd

Description of the building

The Kindergarten Ziersdorf (see figure 8) is a passive house and consists of four classrooms, one exercise room and one staff room. In addition, there is a big entrance area, where a pellet stove has been installed. The total floor space is approx. 750 m².

Figure 8 – Outside view of the Ziersdorf Kindergarten.

The building is equipped with a controlled domestic space ventilation system with heat recovery and is heated by means of a pellet stove combined with a wall heating system. The ventilation device is a so-called regenerative energy exchanger. The heat recovery is accomplished not through a classic heat exchanger but through two chambers with thermal mass, through which fresh air and exhaust air pass alternately. The fresh air is drawn in through a ground-coupled heat exchanger.

The solar system with 8 m² of flat-plate collectors loads a latent-heat storage tank with a volume of 500l. The solar system is primarily used for domestic hot water heating; excess energy can be supplied to the heating system.

Figure 9 – Pellets burning stove

The pellet stove, which can be seen in Figure 8, is manually filled with sacks of pellets. The idea behind the pellet stove is to make the heating process a tangible and understandable experience for the children.

Measurement data acquisition

Figure 10 shows the room temperatures (average per day), room humidity and outside temperatures as well as the total solar radiation per day for the first measurement year. During the first winter the room temperatures were sometimes below 20°C. As a consequence, the automatic control was readjusted. In addition, due to the effort it takes to manually fill the pellet stove a gas boiler was installed. In summer the temperatures rose to more than 25°C only during the holidays when the ventilation system was not in operation.

With a value of 35% r.H. in winter the humidities were rather low. It became apparent that the humidity recovery was clearly not sufficient.

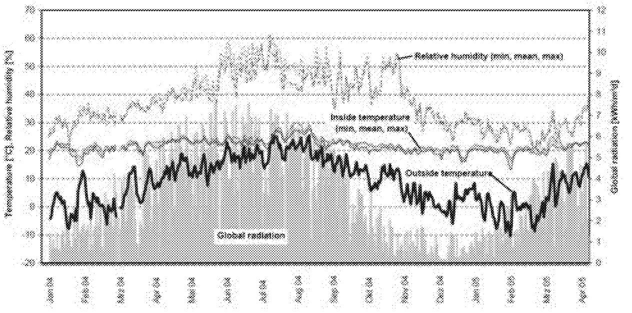

Figure 10 – Comfort parameters in the Kindergarten Ziersdorf on average per day for the first measurement year March 2004 – February 2005

Figure 11 gives an overview of the entire energy consumption including heat as well as electricity. The energy consumption is compared to the yield of the solar system.

In the first measurement year the thermal heat demand was 21.1 kWh/(m² a). Based on a design room temperature of 20°C this value is 18.1 kWh/(m² a), which is only slightly above the passive house limit of 15 kWh/(m² a).

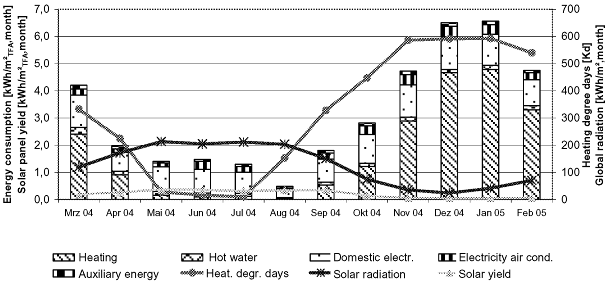

Figure 11 – Monthly energy consumption Kindergarten Ziersdorf, first measurement year.

The CO2 concentration is a significant comfort parameter in educational institutions. In order not to exceed permitted CO2 levels the ventilation system was controlled by a CO2 sensor.

Figure 11 shows the time dependant CO2 concentration in the classrooms and the volume flow of the ventilation system. Basically a CO2 dependant regulation of the air volume flow in periodically used buildings or classrooms makes sense and can lead to energy savings through the reduction of air change rates at times when rooms are empty.

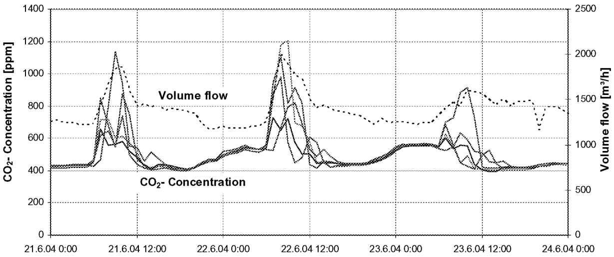

Figure 12 – Time dependant CO_2 concentration in class rooms and ventilation volume flow (15 min – average values) in June 2006.

Lessons learned

The monitoring of this showcase project has shown not only the importance of careful technical planning and execution but also the need to involve future occupants as early as possible during the planning phase. Since kindergartens of this size do not normally have their own caretaker, the kindergarten teachers have to manually fill the pellet stoves, which adds to their work load. Furthermore, they have to recognise and forward potential problems and disturbances of the system. As a consequence, when starting to plan the building it has to be clarified to what extent members of staff are prepared to take on this extra responsibility and what training they might need.

From a purely technical point of view, after a continuous optimisation process during the first winter the performance of the heating system is satisfactory. Room temperatures that were occasionally too low after a long weekend could be improved through higher flow temperatures. The energy consumption of the air conditioning appliance could be reduced and the comfort increased by adapting the operating times and the volume flows to the opening hours of the kindergarten.

The heating energy demand corresponds in the two years lasting monitoring phase the planning data very well.

4. CONCLUSION & OUTLOOK

Passive and low-energy houses are becoming more and more popular worldwide. Due to intensive research and development efforts during the past few years excellent building and energy concepts have become available. However, the professional implementation for a comfortable operation is still a challenge. It is therefore essential to include the whole planning team from the very beginning of the planning process and to clearly define the aims as well as the requirements for the building. It is therefore important to take into account the actual occupancy (residential building, office, educational institution) because solutions and concepts have to be based on a concrete analysis of needs.

Frequent measurements of the showcase project have shown that when there are deviations between the planning and the operation a detailed analysis makes more sense than acting on a “gut feeling”. Furthermore, it has become apparent that the monitoring of buildings is a good tool for quality assurance and should be used more often, for example as a prerequisite for the granting of subsidies.

The Annex 44 project is still ongoing and will be finished at the end of 2008. Results of the project will be an expert and a design guide for manufacturers, designers, planners and architects.

5. ACKNOWLEDGEMENTS

This paper summarises the activity done in subtask A and B of Annex 44. The full report on the state of the art can be requested over the Annex 44 website. This paper is the joint effort of different researchers participating in the Annex 44 programme.

Annex 44 Website: www.civil.aau.dk/Annex44

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REFERENCES

AEE Intec (2007), Annex 44 – State-of-the-art report: Subtask B1 – Office Building “Christophorus Building” – Austria

AEE Intec (2007), Final report within the “building of tomorrow” project of the Federal Ministry of Transport, Innovation and Technology: „Monitoring of the Kindergarten Ziersdorf“ – Austria.

Andresen, I., et al. (2006), Integrated Building Concepts – State-of-the-Art Review – Working Report, International Energy Agency (IEA).

Bluemel, E. (2008), Overview of existing integrated building concepts, Presentation at the Annex 44 symposium “Responsive + Building + Elements”, May 14th 2008, Delft (NE).

Perino, M. (2008), Opportunities for RBE in a developing building market, Presentation at the Annex 44 symposium “Responsive + Building + Elements”, May 14th 2008, Delft (NE).

Perino, M., et al. (2007), State of the Art Review of Responsive Building Elements – Volume II, International Energy Agency (IEA).