ENERGETIC EFFECTS OF DEMAND – CONTROLLED VENTILATION RETROFITTING IN A BIOCHEMICAL LABORATORY BUILDING

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ABSTRACT

The main objective of the demonstration project “LabSan” is the innovative energetic retrofitting of a research laboratory building (3724 m² net floor area) which can serve as an outstanding and guiding example for a large number of existing laboratory buildings.
A scientific monitoring programme, supported by German Ministry of Economics and Labour, is carried out by the Solar-Institut Jülich and the research group STE of Forschungszentrum Jülich. Researchers will analyse the energetic building and HVAC system performance, optimize the operating parameters based on dynamic building simulation, and analyse the retrofitting potential of similar laboratory buildings in Germany. A guide for the retrofitting of laboratory buildings will result.
Due to the high air change rate (25 m³/m²h), and high electric loads of laboratory equipment, the original building consumed about 1235 kWh/m²a primary energy, 65 % of which were due to air heating, air cooling and transport of air. Therefore the largest energy saving potential is related to the ventilation and air conditioning system. The project goal is a 50 % reduction of primary energy consumption, i.e. 600 kWh/m²a, 300 kWh/m²a of which are caused by electricity consumption due to scientific equipment.
First measurements indicate a reduction in primary energy consumption by about 60 %.

KEYWORDS

laboratory building, retrofitting, energy efficiency, variable volume flow, air heat recovery, Air-flow-reduction

INTRODUCTION

Research laboratories belong to the big consumers, even under the energy-intensive buildings for educational facilities. This particularly is because of the high power requirement for the ventilation, the electricity consumption of scientific equipment and lighting. Often operators are missing exact information how much energy is consumed by their laboratory and which possibilities they have to reduce the energy consumption. Many laboratory buildings were established during the creation of research centres in Germany between 1950 – 1980. The use of the buildings for many decades can be recognized: the building structures exhibit numerous defects and the technical equipment is often outdated. In addition, according to changing scientific activities, office space was converted into laboratories and vice versa.

New devices with high heat emissions were added. The retrofitting project serves as an example that will reduce technical and financial uncertainties for future laboratory retrofitting projects.

THE ORIGINAL BUILDING

The building had been established in the middle of the 1960s as chemistry laboratory and had to be modernized in 2002 for a future use by the Institut for Phytosphaerenforschung (see Figure 1 and Figure 2).

Figure 1: Before retrofitting

Figure 2: After retrofitting

After a survey and several short-time consumption measurements a reorganization concept was developed and implemented. The original building needed about 1,200 kWh/m²a primary energy. See Table 1 for some selected building data.

TABLE 1
Selected building data

<table>
<tr><td>Building construction style</td><td colspan="2">Concrete carcass structure</td></tr>
<tr><td>Gross floor area</td><td colspan="2">3,720 m²</td></tr>
<tr><td>Heated floor area</td><td colspan="2">3,380 m²</td></tr>
<tr><td>Gross volume</td><td colspan="2">11,420 m³</td></tr>
<tr><td>A/V ratio</td><td colspan="2">0.30 m^{-1}</td></tr>
<tr><td>Thermal insulation of external Wall before retrofitting</td><td colspan="2">5 cm polystyrol bonded-system for heat-insulation</td></tr>
<tr><td>Thermal insulation of external Wall after retrofitting</td><td colspan="2">Rear-ventilated cladding with 17 cm heat-insulation</td></tr>
<tr><td></td><td>Before retrofitting</td><td>After retrofitting</td></tr>
<tr><td>Wall</td><td>0.4 – 4.6</td><td>0.22</td></tr>
<tr><td>Window</td><td>3.4</td><td>1.0</td></tr>
<tr><td>Roof</td><td>0.6</td><td>0.15</td></tr>
</table>

In a chemistry laboratory safety and health aspects are of highest importance. Therefore the minimum air exchange rates must comply with DIN 1946-7. Exhaust air was extracted by 55 decentralized ventilation systems without heat recovery. The building was constantly supplied with 45,400 m³/h of fully air-conditioned fresh air. The old ventilation system exhibited function deficits in parts, so that for the evaluation of the possible saving effects a second scenario with values for a fully functional condition of the ventilation system (50,300 m³/h air change) was developed.

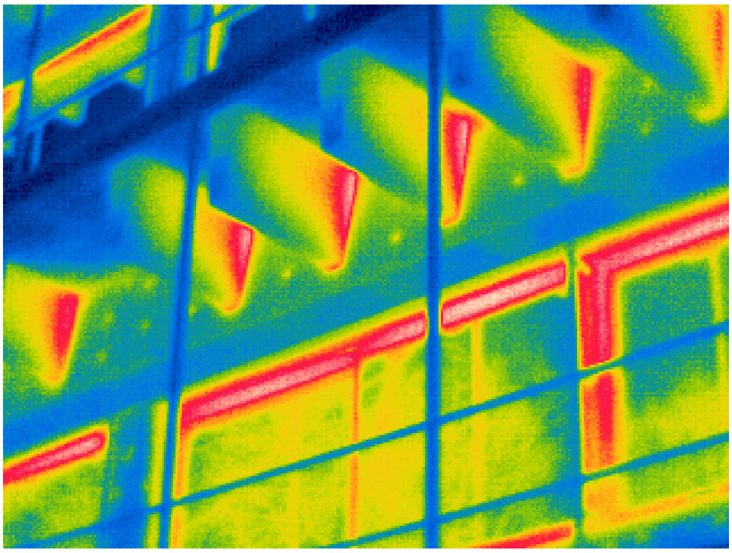

Figure 3: Thermography of the concrete balconies

Concrete balconies projecting from the building front and aluminium window frames formed heat bridges that worsened the energy balance of the building (see Figure 3).

Data basis for the energy consumption were the current consumption measurements of the last six months, individual current consumption diurnal variations, individual measurements of all fans, detailed volumetric air flow measurements and short time heat consumption measurements in the heating season. The annual energy consumption was calculated with the software LACASA under Matlab/Simulink, based on short-time measurements.

An important aspect in a research lab are the internal heat loads. Internal loads were assumed to be up to 15 W/m² by lighting (after the reorganization 9 W/m²), 10 W/m² by office equipment and up to 125 W/m² by scientific equipment. In the simulation computations it was assumed that during the day 2/3 and at night 1/3 of the maximum equipment load was consumed.

THE RETROFITTING CONCEPT

An important aspect were the reorganisation of the space use, the demand-controlled ventilation system with air heat recovery and a differentiated individual room regulation, a complete retrofitting of the building cover and a better daylight use in connection with a lighting system controlled by presence detectors. Supplies of fresh air and cold were completely separated. For the first time a cooling ceiling system was used for the cooling of physical measurement rooms. The sensitivity analysis based on the simulations showed that the largest energy-saving potentials are opened by the reduction of air volumes and the employment of an effective heat recovery system. The past consumption data and the underlying user behavior showed that it is of high importance to optimize the building operation and its usage. Planned energy data are summarized below in table 2.

Restructuring the rooms in use depended groups

Functions as chemical or physical laboratory, office or seminar room were assigned to the individual areas and they were combined within the building into groups, assuring short installation paths. Handling of toxic materials is only allowed in chemical laboratory rooms, thus reducing the number of rooms with increased air change. Areas with high internal loads were positioned at the north-east side of the building.

Centralization of air flow

85% of the exhaust air is led across a central exhaust air system with heat recovery, which can recycle under full load up to 50% of the contained heat. In addition, four decentralized ventilation systems are used for harmful exhaust air.

System separation

In former times laboratory areas were cooled by increasing the air flow. After the reorganization separate cooling systems were installed, either as a recirculating cooler, cooling ceiling or a gravity cooling system. . All systems are appropriate for high inlet temperatures. Cold can be provided either by outside air radiators, river water or a district cooling network.

Volume flow reduction

Variable flow rate controllers are used and provide a single room air balance. The air exchange is reduced at night and on weekends. With the usual laboratory departures a Opening of the front slide gate of extractor hoods leads automatically to an increased exhaust and supply air rate. Only energy-saving, frequency-controlled fans are used.

The volumetric air flow can be reduced by these measures by more than 50%. For example, in former times in a 20 m² laboratory 1,100 m³/h air were exhausted constantly. With the new regulation air change is reduced to a value between the minimum 500 m³/h (as required by DIN 1946-7) up to 1,100 m³/h during the day, while at night and on weekends it is reduced to 340 m³/h. In the library, which serves also as seminar room, the ventilation system is controlled by an air quality sensor.

Building envelope

Concrete balconies (see figure 3) were cut off. Walls and roof were well insulated and windows were replaced with new frames and a double-pane glass with a U value of 1,0 W/m²K. A Blower Door test was carried out at the end of the building phase. The test reached a value of 0,98/h and thus exceeds the value of 1,5 / h as demanded by the German building code EnEV.

TABLE 2: Key building and energy data of retrofitting activity

Energy consumption data			
	Before retrofitting	**After retrofitting (planned)**	**Reduction**
Primary energy demand[#]	4,600 MWh/a*	2,074 MWh/a	
	1,235 kWh/m²a*	600 kWh/m²a	- 50%
Room heating (District heating)	400 kW	200 kW	
Air heating (District heating)	1,100 kW	246 kW	- 70%
Annual sum of transported air	440 Mio. m³	190 Mio. m³	- 57%
Primary energy demand per air volume	6.7 Wh/m³	3.5 Wh/m³	- 48%
Installed electrical achievement of the fans	41 kW	33 kW	- 20%
specific transmission heat losses [W/K]	4,030	2,030	- 50%
Net heated floor area	offices	ventilated area	other
m²	663	1,527	1,190

conversion factors primary energy: Electr. power = 3,0; district heating and cooling = 1,1
* according to ventilation scenario II – 50,300 m³/h constant air flow

Daylight use and lighting system

For an improved daylight use external blinds with reflecting coating were installed at the south-west facing offices. Corridor doors were equipped with daylight openings. The effect of the light guidance lamellas on the space impression and the appropriate shading situation was examined by Solar-Institut Juelich with daylight simulations. Also the distance of the escape balconies improved the daylight situation. The new lighting system is characterised by energy-savings lamps and a require-fair control with operational readiness level alarm units, stage circuits and automatic density of light regulation as a function of the external beam of light.

FIRST RESULTS

A summary of energy consumption data is given in table 3.

TABLE 3

Characteristic values and energy consumption

Details							
		Before retrofitting		**After retrofitting (planned)**		**After retrofitting[$] (measured)**	
		End-use energy MWh	**Primary energy[#] MWh**	**End-use energy MWh**	**Primary energy[#] MWh**	**End-use energy MWh**	**Primary energy[#] MWh**
Electricity	Fans	373	1,119	112	336	216	648
	Lighting	72	216	43	130	339	1,017
	Equipment	344	1,031	344	1,031		
Heat	space heating	350	385	140	154	209	230
	Central air preheating	1,298	1,428	220	242	195	215
Cooling	space cooling	0	0	119[§]	131[§]	§	§
	Central air conditioning	383	421	45[§]	50[§]	§	§
Sum		**2,820**	**4,600**	**1,023**	**2,074**	**1,123**	**2,291**
	Volume flow	**day**	**night/WE**	**day**	**night/WE**	**day**	**night/WE**
	m³/h	50,300	50,300	28,800-36,600	12,000	26,000 – 29,000	17,600

conversion factors primary energy: Electr. power = 3,0; Long-distance heating and cooling = 1,1
* after ventilation scenario II – 50,300 m³/h constant air flow
+ for the prognosis an identical equipment use in the laboratories and offices before and after the reorganization were assumed.
$ Annual energy requirement on the basis of G20 heating degree days and the test basis year TRY 02
§ at this time a computer forecast on the annual cooling demand is not possible)

First results of the heating season 2003/04 are available. The heating energy consumption (133 kWh/m²a) exceeds the expected value slightly. The ventilation system is not yet challenged to its full capacity. However, at night and on weekends, volume flow rates should be further reduced to reach the targeted values. 88,4% of the exhaust air passed through the central system with heat recovery. Statements about the actual cooling power requirement are only possible after the summer 2004.

The electricity consumption of the building is a major concern as it contributes to about 50 % of the primary energy consumption. At present the building is not yet fully equipped with scientific equipment. Therefore the present peak consumption (average of laboratory area) is only 13 W/m². The electricity consumption of laboratories is displayed in a sorted graph in Figure 4. The total peak power based on hourly averages is 78 % of the sum of the single maximum values of the single sub-grids in the different floors (Ground floor: EGUV1 and EGUV2, First Floor: 1OGUV1 and 1OGUV2, Second Floor: 2OGUV1 and 2OGUV2). As can be seen in Figure 4, there is not yet any single consumer which dominates the electricity consumption.

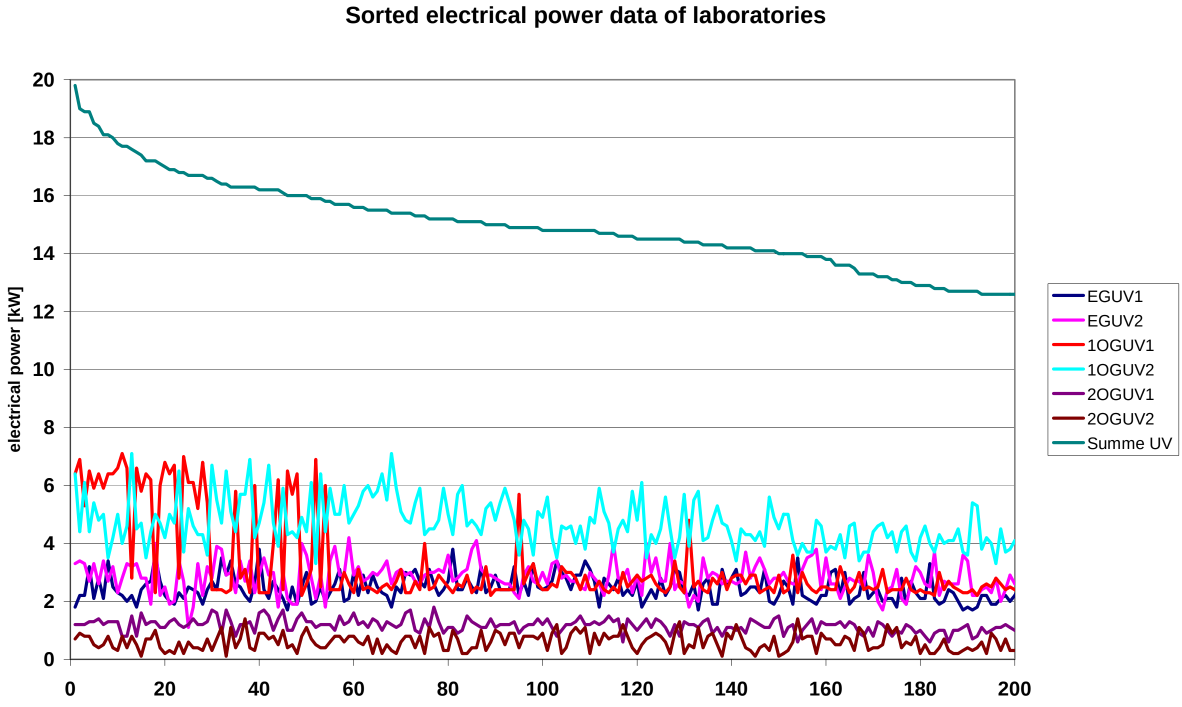

Figure 4: Electricity consumption data of laboratories, sorted by sum value ("Summe UV")

CONCLUSION

A laboratory building with a primary energy consumption of 1,200 kWh/m² was retrofitted with the aim of 50 % reduction of energy consumption. An intensive monitoring programme was carried out by Solar-Institut Juelich. According to extrapolated measured data, this aim has just been achieved. Further optimization will be necessary when the laboratory usage is intensified and data of cooling energy consumption is available. For example, the optimization of supply air temperature may result in a 27 % reduction of total energy consumption /2/.

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