BUILDING 2000

Commission of the European Communities

- Multi-use laboratory suitable for high tech projects
- Low energy design with passive solar features to appeal to young innovative firms
- Solar walls, internal atria and conservatory provide buffer spaces which in winter preheat incoming air for mechanical ventilation and reduce heat losses. They also allow good daylight penetration.
- Thermal mass of building and convection ventilation in buffer spaces provide free cooling in summer

HIGH TECH LABORATORY

LEUVEN/BELGIUM

Building 2000 is a series of design studies illustrating passive solar architecture in buildings in the European Community.

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2 PROJECT DESCRIPTION

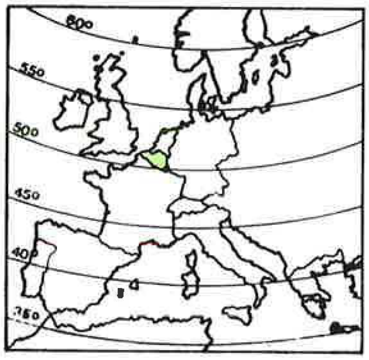


Figure 1. Location

Building Type

This is a building suitable for the development of research-based or innovative prototype projects in high tech fields such as microelectronics, robotics or biotechnology. The aim was to create a flexible laboratory building which could be used by a number of small or medium-sized companies of the type set up jointly by industry and the universities.

Location

The building is for the Catholic University of Leuven which is located in the middle of Belgium, about 20 km east of Brussels (Figure 1). The specific site marked for the building is between the approach to the E40 and E314 intersection and the university science campus (see Figure 4). It is a considerable distance from other buildings.

Degree days (base 15° C) over heating period of 269 days 2080	
Sunshine hours heating season	
(Oct-Apr)	617
Jan-Dec	1555
Mean daily temperatures	
Jul max.	21.6° C
Jan min.	-0.3° C

Table 1. Some key climate data

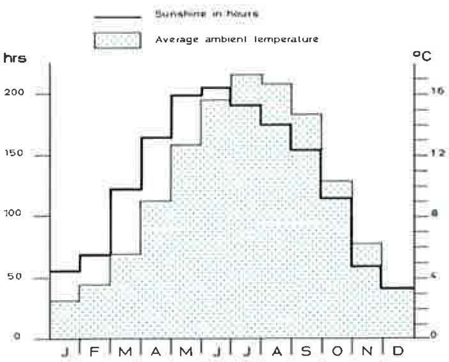


Figure 2. Sunshine hours and average ambient temperatures

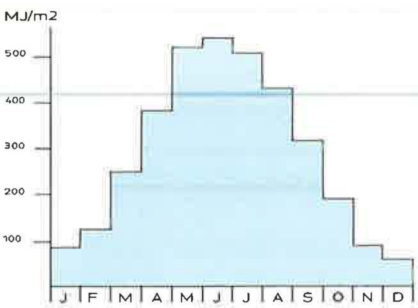


Figure 3. Solar irradiation on horizontal plan

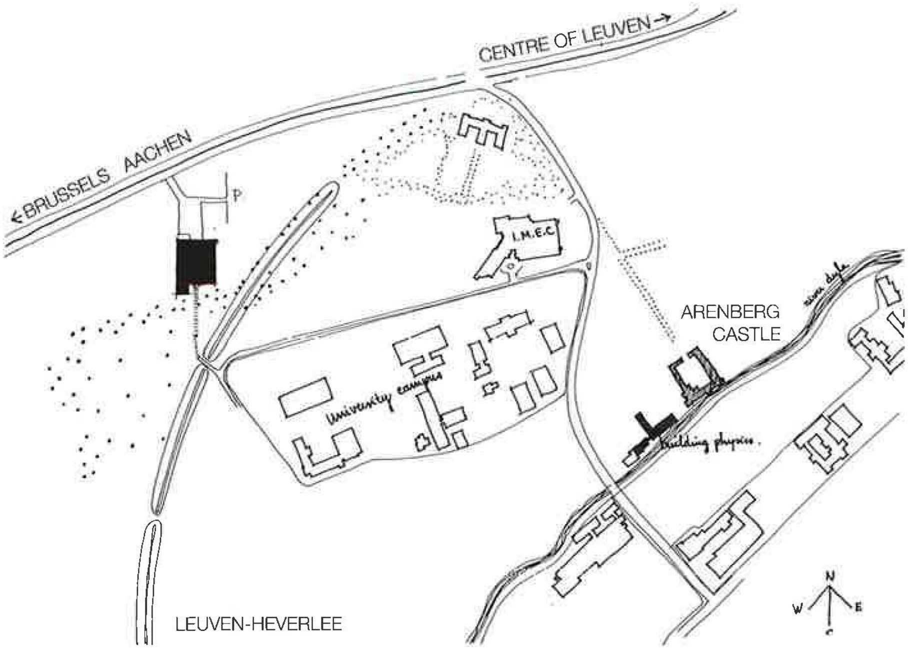


Figure 4. Site plan

Site Microclimate

The site is flat and fairly open, apart from some tall trees to the south which provide shelter against the prevailing wind and summer overheating. Some climate data are given in Table 1 and Figures 2 and 3.

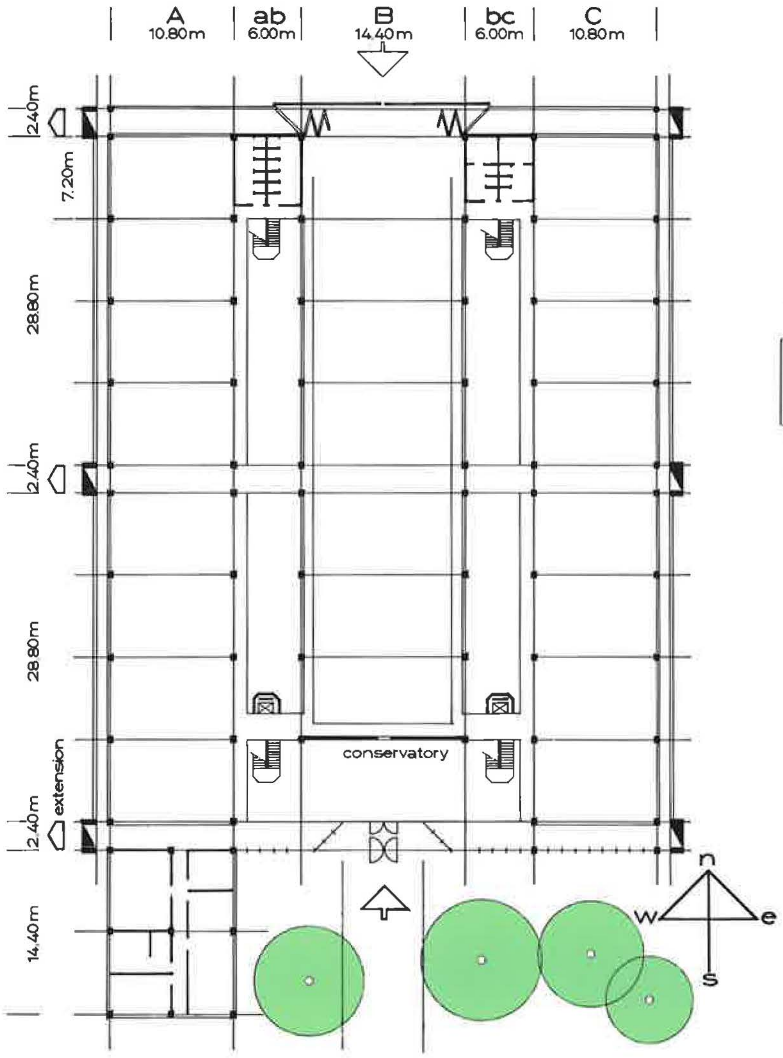


Figure 5. Plan of Leuven building

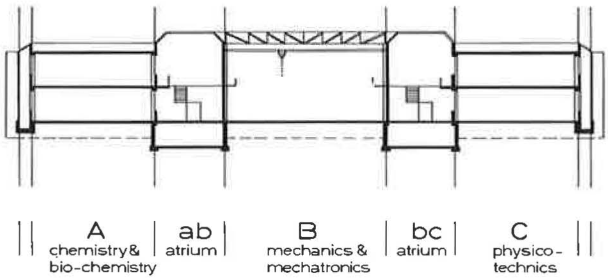


Figure 6. Section of Leuven building

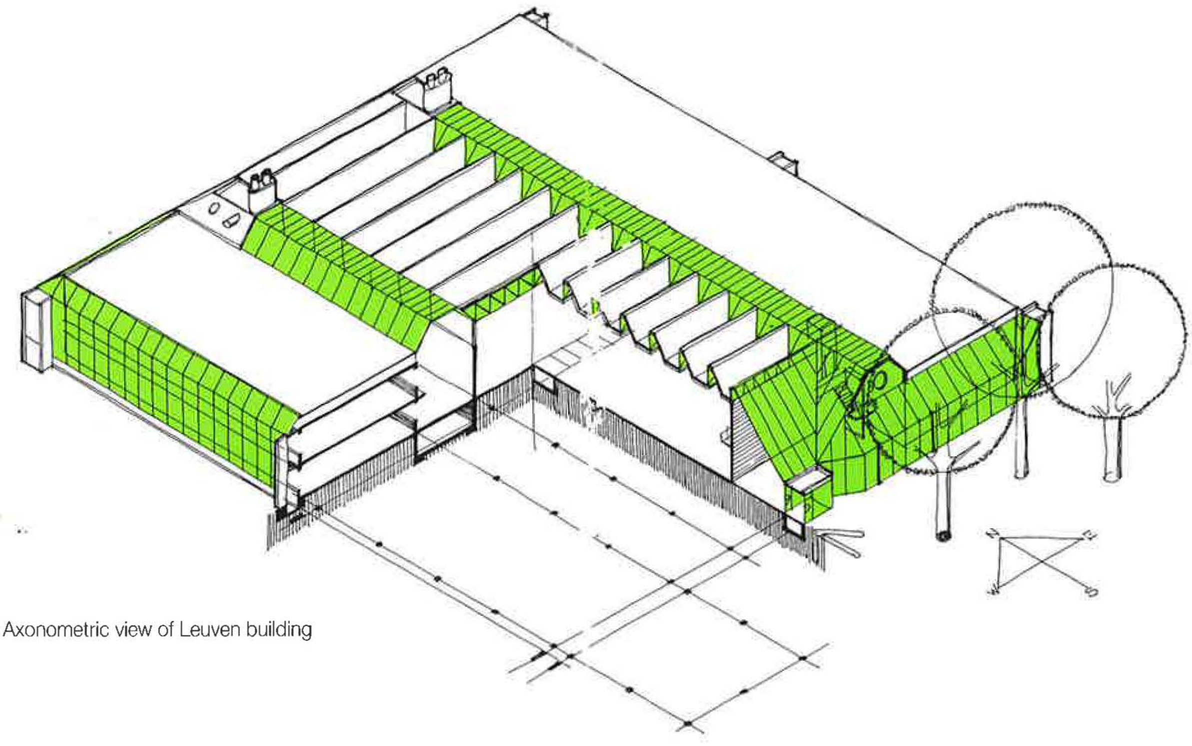


Figure 7. Axonometric view of Leuven building

Design and Construction Details

The central block (B) has a large rear entrance and a considerable amount of usable space (net height 5.4 m) under a pulley block to allow overhead movement of equipment.
The side spaces ab and bc are for circulation. They also permit future growth.
The modular nature of the building makes for easy construction and flexibility in use. Three large or eight small projects can be carried out simultaneously.

There is office space at the front; washrooms/cloakrooms are at the rear. These are topped by technical areas.
The building has a reinforced concrete frame with tinted glass cladding.

In front and behind the four standard bays are 2.4 m zones for circulation and service runs - ducts, pipes and cable trays.

The building consists of three parallel blocks (A, B and C) separated by side spaces (ab and bc). The plan and section and an axonometric view are shown in Figures 5, 6 and 7.
Block A is designed for chemical/biochemical projects. B is for mechanical work. C is for physico-technical projects. Blocks A and C are structurally identical but their building services differ. A has a mechanical ventilation supply and an exhaust with a large number of fume hoods together with a range of fluids supplies and drains. C has a number of different voltage electrical circuits and space for clean-air cubicles and closets.

At Leuven, the total floor area is 4,500 m^2 . Blocks A and C are 10.8 m wide; the central space (B) is 14.4 m wide; the side spaces ab and bc are 6.0 m wide.

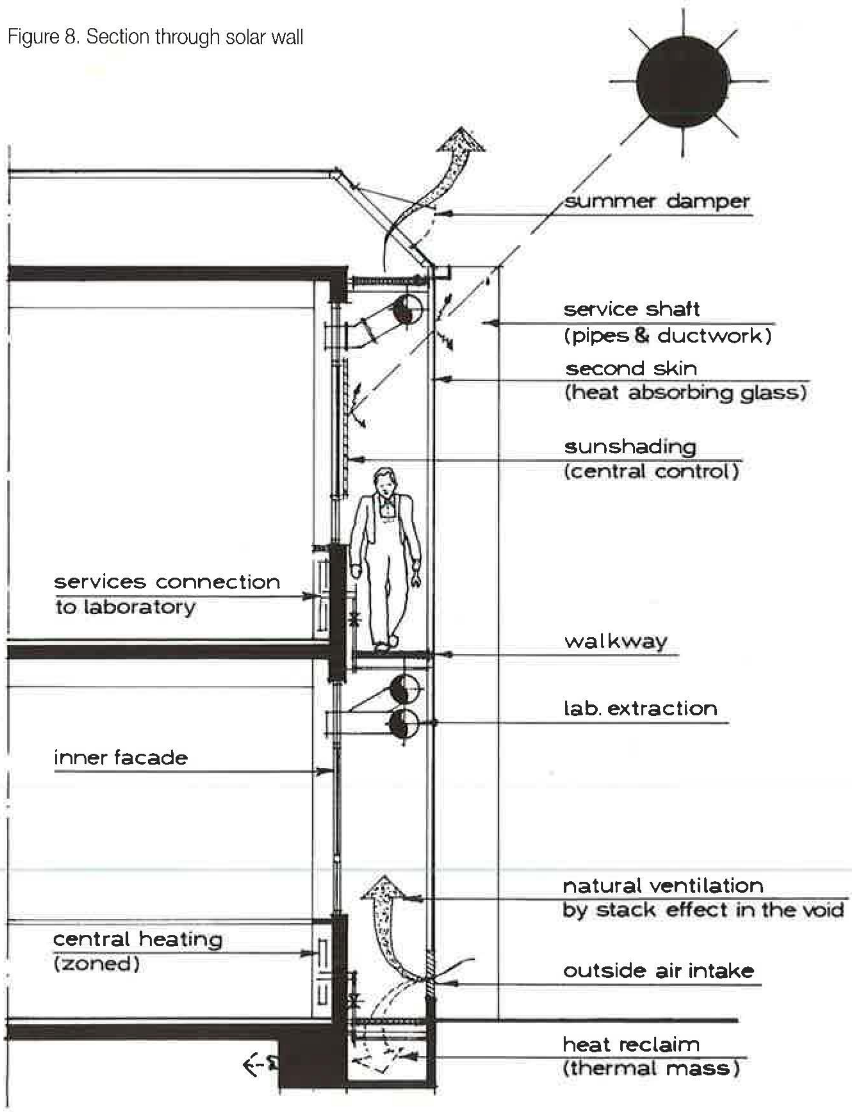
The crawl spaces under the intermediate zones are constructed of concrete and serve as air ducts.

The east and west external walls are solar walls. They are constructed from an outer wall of heat-absorbent single glazing and an inner wall made of clear glass and insulated solid panels. The average U-value of the solar wall is 2.4 W/m^2 K. The average U-value of the total envelope is 1.0 W/m^2 K.

The compactness of the building (i.e. the ratio of the volume to the total area of the envelope) is 2 - good for a low-rise building.

The overall thermal insulation level of the building is 70 which is in line with Belgian regulations (NBN B62-301) and European Community recommendations for the future.

Figure 8. Section through solar wall



DESCRIPTION OF PASSIVE SOLAR FEATURES/COMPONENTS

Passive Solar Features and their Operation in Winter and Summer

The solar walls, conservatory and atria shown in Figures 5, 6 and 8 are part of a passive solar system aimed at creating a comfortable environment in the building and reducing the amount of conventional energy needed to run it.

The system has two different operating modes, according to season.

Mode of Operation in Winter

In winter, the solar walls, the conservatory on the south side and the internal atria serve as buffer spaces between the outside environment and the building interior. Solar gain in the glazed areas is distributed evenly over the buffer spaces by fans. Fresh air is introduced into the bottom of the solar walls, prewarmed by passage through the concrete mass of the air ducts in the crawl space and then warmed further in the solar walls by solar radiation and conduction heat losses from the laboratories. The warmed air is taken into the air handling units to reduce the load on the heating plant.

With the louvres at the top of the solar wall shut, the double wall acts as additional insulation.

The solar wall and the glazed areas in the roof maximize daylight entry into the building. Automatic switching of the artificial lighting in the atria, conservatory spaces and external zones of the laboratory floors is achieved by means of photocells.

Mode of Operation in Summer

In summer, the conservatory is shaded by the existing high trees. Catwalks, ducts and service runs serve as a sunscreen in the solar walls. Natural stratification of warm air in the buffer zones prevents the laboratories from overheating. Motorized vents open at the top of the solar walls and atria so that unwanted heat can be vented to the outside by the stack effect.

The laboratories are ventilated mechanically. Air intake is through louvres in the north walls of the plant rooms. No mechanical cooling is required.

There is natural ventilation in a N-S direction through the atrium zones. Air intake is at the bottom of the conservatory. The air movement is reinforced by the prevailing wind from the SW.

At night, outside cold air is drawn in by fans through the cavity of the concrete floors and the solar walls.

Mechanical Features and Design Temperatures

The air handling units are on the north side of the building, in the ab and bc zones at the first floor level. The laboratory floors are mechanically ventilated with air change rates in the range 5-10 changes per hour. Central heating is via perimeter radiators. The building is zoned for better control.

The design temperatures during the heating season are 20° C ± 1° C in the laboratories and 18° C ± 2° C in the hall and circulation areas.
The summer internal design temperature is 23° C ± 3° C.

The air supply ducts run in zones ab and bc and extraction ducts run in the cavity of the solar walls. Reclaim of heat in the handling units is indirect so there is no contamination of the supply air.

The average lighting load in the laboratories is 400 lux.
The plant rooms for the laboratories' building services are on the north side in the basement in the ab and bc zones.

Pipes for water, sewage, compressed air, gases and electric cables run in the ab and bc zones and in the twin wall cavity and feed the laboratory equipment from the perimeter. This allows for growth and change in the laboratory without disturbance of the floor underneath.

Maintenance can be carried out in the twin wall cavity and in the ab and bc zones without interfering with laboratory activities.

ENERGY CALCULATIONS PERFORMED AND DESIGN TOOLS USED

Energy Performance of Leuven Laboratory

The predicted annual thermal performance of the Leuven laboratory is shown in Figure 9. Key points regarding heating and lighting energy consumption are as follows.

Heating

The total annual consumption of fuel for heating the 4,500 m² building is 405 kWh/m². Over half of this is required for mechanical ventilation.

Useful solar gains amount to about 70 kWh/m² a year and compensate for most of the efficiency losses of the heating system.

Lighting

Electricity consumption for artificial lighting is estimated to be 17 kWh/m2 a year. This is low because, although the building is quite compact, each block (A, B and C) has good natural lighting from the solar walls and the rooflights in zones ab and bc.

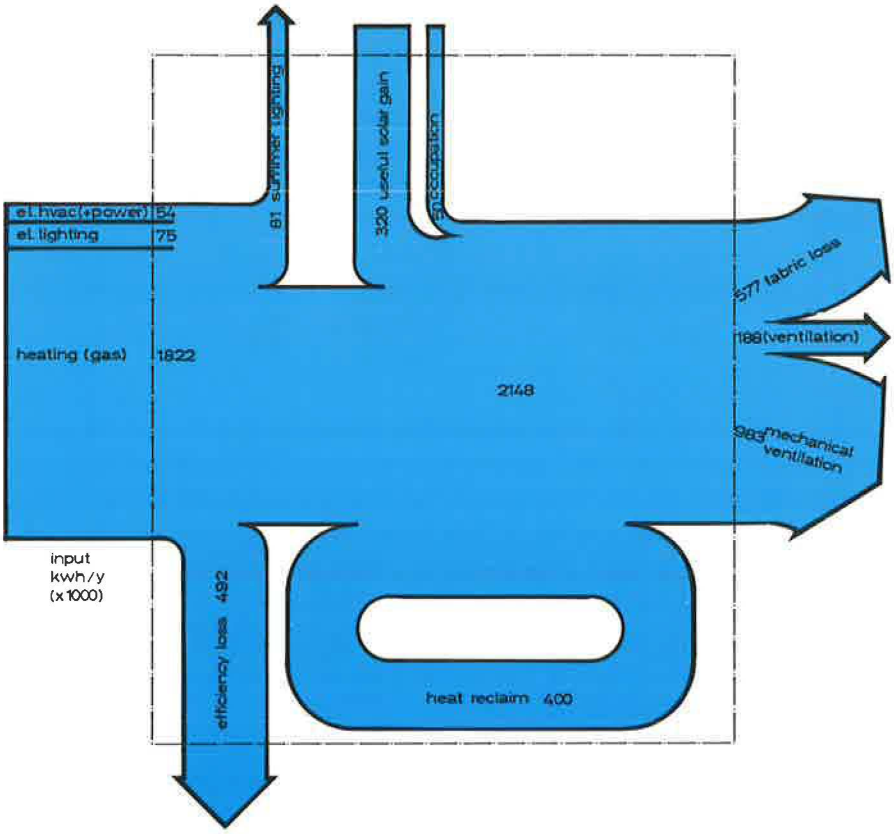


Figure 9. Sankey diagram of energy flows in Leuven laboratory

Case Study on Conversion Project

To gain experience of the thermal performance and use of solar walls in laboratory buildings before embarking on the design of the Leuven project, studies were carried out on a recently- completed project involving conversion of a five-storey 5,000 m² building into new research laboratories and offices with a total floor area greater than that of the original facilities.

The original building is shown in Figure 10. It was put up in the 1960s before the energy crisis and had single glazing and precast concrete external walls of poor construction. Vertical risers for air ducts and pipes were at 3 m centres on the inside perimeter walls, just in front of the windows. In winter the building had been uncomfortable because of excessive ventilation and heat loss by conduction through the external walls. In summer, it was subject to overheating.

The converted building is shown in Figure 11. The building has been given a new glazed skin, placed some 900 mm outside the original facade. The extract ducts, feeder pipes and cables for laboratory services have been put in the cavity between the twin walls (see Figure 12). The top of the cavity is surmounted by a new roof structure which houses the extract fans. Integrated into the roof structure are motorized louvres operated by temperature sensors in the cavity. There are catwalks for maintenance access at each floor in the cavity.

Figure 10. Case study building before conversion

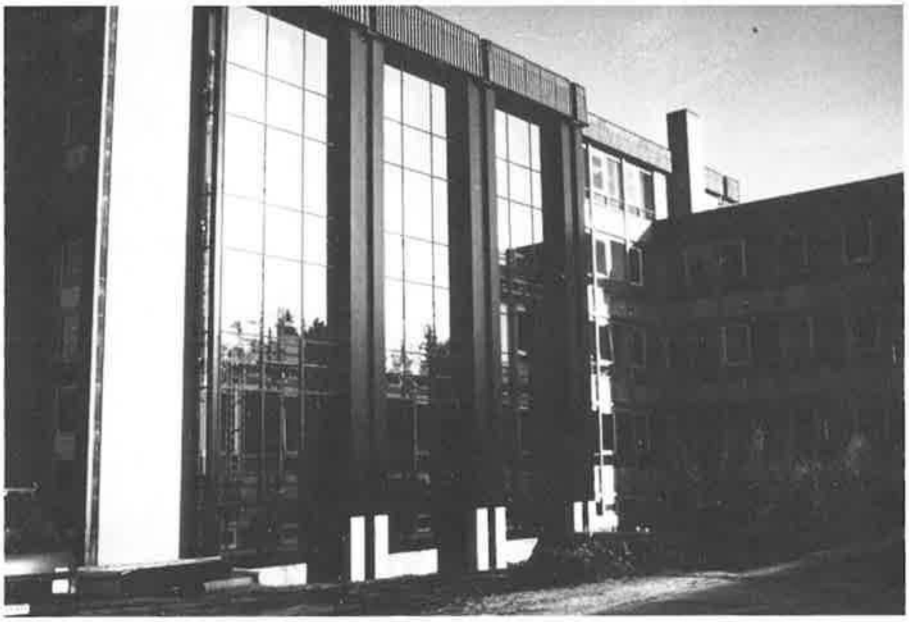


Figure 11. Case study building after conversion

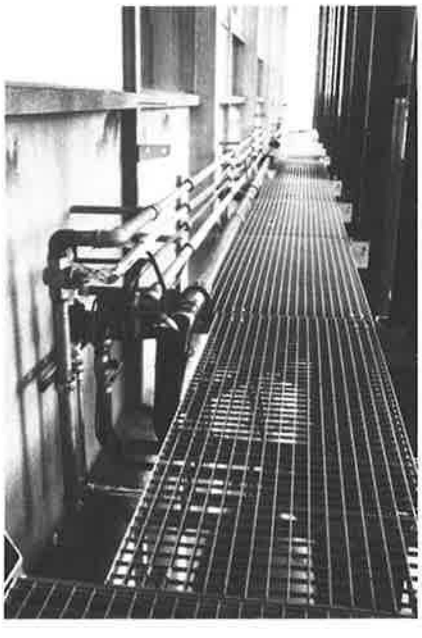


Figure 12. View inside cavity of solar wall

The aim of the double skin is to achieve:

- a lower U-value of the facade - 2.4 W/m^2 K compared with the existing 5 W/m^2 K;
- reduced ventilation losses and less draught from winds;
- protection of the existing facade against rain and environmental degradation;
- avoidance of cold bridges and condensation problems;
- solar gain in winter by closing the roof louvres;
- avoidance of overheating in summer by opening the roof louvres. A solar chimney is created by reflected and trapped heat. The heat is vented before it reaches the laboratory spaces.
- less glare and more equal distribution of daylight in the laboratories;
- an increase in net usable floor area by placing vertical ducts and risers outside the laboratory floor.

Energy Performance of Case Study Building Before and After Conversion

Energy performance calculations were carried out for a module of the case study building with floor area 22 m² and external wall area 12 m² before and after conversion. Two cases were taken: (a) when the module was designed for use as office space and (b) when it was used as a laboratory. Because the offices are not mechanically ventilated, their external wall construction differs from that of the laboratories.

The results are shown in Tables 2 and 3. In the Tables, Q is the annual heat loss in W/m² floor area when the external temperature is -8° C. E is the annual energy consumption for heating and ventilating in kWh per m² floor area. F gives the annual fuel consumption in l/m².

OFFICE MODULE	Fabric loss	Mechanical ventilation	Solar gain	Total	Saving	Total in %
Before reconversion						
Q	130	–		130		100
E	303	–		303		100
F	22,6	–		22,6		100
After reconversion						
Q	52	–		52	78	40
E	122	–	–26	96	207	32
F	9,2	–	– 1,9	7,3	15,3	32

Table 2. Comparison of annual energy consumption of office module before and after conversion. (For explanation of symbols and units, see main text opposite.)

LAB MODULE	Fabric loss	Mechanical ventilation	Solar gain	Total	Saving	Total in %
Before reconversion						
Q	130	300		430		100
E	303	698		1.001		100
F	22,6	52,1		74,7		100
After reconversion						
Q	52	281		333	97	77
E	122	654	–61	715	286	71
F	9,2	49	– 4,6	53,6	21,3	71

Table 3. Comparison of annual energy consumption of laboratory module before and after conversion. (For explanation of symbols and units, see main text opposite.)

From the Tables it can be seen that the conversion measures have reduced energy consumption by over 65% in the office module and nearly 30% in the laboratory module.

Solar gains amount to over 20% of the total heating load in the office module and nearly 8% in the laboratory module.

If the incoming fresh air is taken through the solar wall cavity into the air handling units in winter, the average temperature inside the cavity is some 4° C lower than if the cavity is closed. This results in a greater heat loss through the internal skin but the extra heat together with the solar gains is used to prewarm the air supply for the mechanical ventilation. Thus the efficiency in using the solar energy increases without loss of comfort.

GENERAL DESIGN GUIDELINES/POINTS OF INTEREST RESULTING FROM THIS PROJECT

Solar Walls

Experience shows that solar walls are very suitable for laboratory buildings. They have a range of advantages which are not available in a traditional type of construction. They can be used for both new buildings and rehabilitation projects.

As has been seen already, solar walls bring energy savings. In a refurbishment project such as that described in the case study, they can provide annual energy savings of 330 kWh/m² wall plus 50-100 kWh/m² from solar gain, depending on the quantity of preheated air used. This represents a yearly savings of around 40 l fuel per m² wall. As with most passive solar features, however, the saving is achieved only at some additional capital cost. In the case study the extra cost of the second skin amounted to 12,500 BF/m² (291 ECU/m²). At today's prices, it would take 20 years to repay this additional investment from the resulting energy savings. This cannot be justified on economic grounds. However, solar walls can bring additional benefits which, under particular circumstances, can make their incorporation in a building worthwhile. Examples of these advantages are listed opposite. A monetary value can be put on many of them so that the payback time for the additional capital cost of the wall can be reduced to 5-10 years.

Summary of Advantages of Solar Walls

Solar walls can offer:

- energy savings;
- good comfort control in winter; no cold radiation from large glazed areas;
- good comfort control in summer by removal of solar heat before it can reach the interior, extraction of heat by stack effect and avoidance of mechanical cooling;
- good technical detail in the external wall with no problem regarding cold bridges and wind infiltration;
- good daylighting without harming the U-value of the wall;
- good sound insulation against traffic noise;
- good architectural possibilities in, for example, the upgrading of existing buildings.

Advantages particularly relevant to laboratories include:

- extra space for service runs and ducts without cluttering up the interior;
- the ability to incorporate additional pipe couplings, etc., very easily through the external walls as laboratory activities grow or change;
- easy maintenance of service runs, valves, etc., via catwalks in the cavity.

Summary of Advantages of the Atrium

An atrium can bring the following advantages:

- energy savings because of good floor to wall ratio, the possibility of natural ventilation without mechanical cooling and useful solar gains;
- good comfort control in winter and summer because of the buffer zone;
- good daylighting;
- a low floor-to-floor height because there are fewer mechanical services in ceilings or floors;
- cheaper exterior wall construction in the courtyard because there is no need for protection from rain or wind, although these advantages can be lost by the need for fire precautions;
- very good land-use ratio;
- good architectural possibilities in, say, the upgrading of existing courtyard buildings;
- extra multi-purpose space and circulation routes.

The Atrium

The recent revival of interest in the atrium, like the solar wall, has resulted from the need to take a fresh look at energy use since the energy crisis.

As with the solar wall, the acceptability of the present-day atrium rests on a number of arguments and a summary of the advantages which the presence of such a feature can bring to a building is given opposite.

Building Form and Energy Use

In deciding whether or not incorporation of an atrium is useful in a particular case, it is important to take into account the relationship of building form and energy use. For instance, although development of a design with a good compactness ratio can bring low energy use in a small building like a house or a one- or two-storey pavilion-type building, it does not necessarily have energy significance in bigger or more complex projects.

Figure 14 illustrates a number of different building forms. Table 4 gives the predicted heat losses of some examples of each of these. It also indicates whether or not a particular building form is capable of making use of natural lighting or natural ventilation.

Figure 13. The 19th century St. Hubertus shopping gallery in Brussels.
An example of a first generation atrium building.

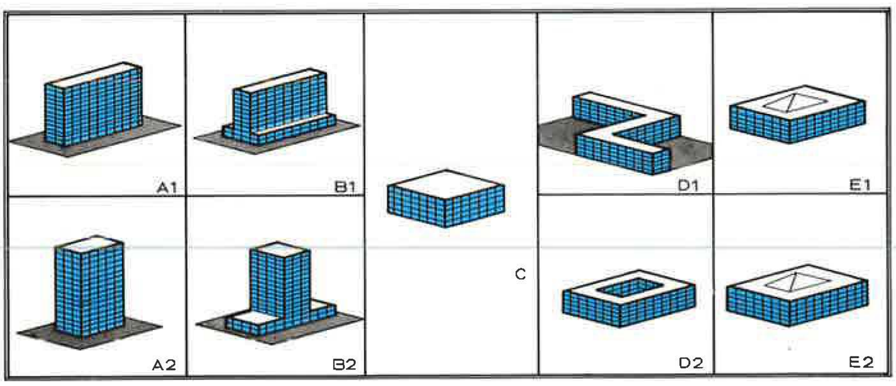


Figure 14. Some examples of different building forms

	A1	A2	B1	B2	C	D1	D2	E
totaal floor surface in modules (7,2 x 7,2 m)	240	240	240	240	240	240	240	240 +15
number of storeys	13	16	11	16	5	5	5	5
floor to floor distance can be kept low						x	x	x
total facade surface in modules (7,2 x 7,2 m)	146	149	132	145	80	130	120	80
total surface of the envelope in modules	183	179	205	216	176	226	216	191
heat losses by conduction in % referred to type C	136	138	136	147	100	142	134	112
natural lighting natural ventilation is possible	x					x x	x x	x x

Table 4. Building form and energy use

It is clear that the deep plan building type C has the best floor-to-wall ratio. The energy needed to compensate for the heat lost by conduction from the external envelope is 30-40% more for the high rise (types A and B) or narrow plan (type D) forms.

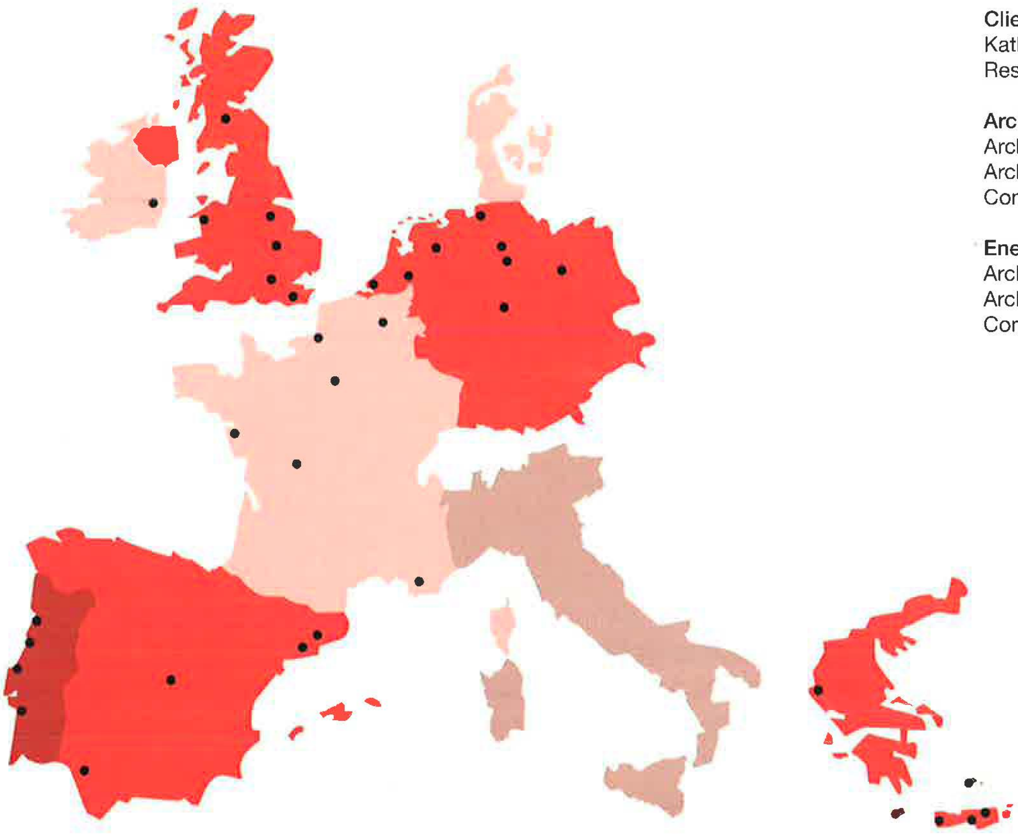
However, the deep plan building has a number of well known disadvantages relating to annual energy consumption. The large amount of electrical energy needed for lighting and ventilating the enclosed spaces can be higher than the energy saved from lower heat losses. Furthermore, the internal heat gains from the artificial lighting, people and equipment can necessitate cooling and air conditioning, with their accompanying energy consequences. In addition, the large package of building services/ducts which has to be brought into such a building results in an increase in floor-to-floor height which, in turn, brings additional external wall area and increased heat loss.

The advantage of the courtyard type of building is that it takes no more land than the deep plan type. By covering the courtyard with glass it is possible to combine the advantages of the narrow plan and deep plan type. Further, glazing the roof causes the courtyard walls to change from external to internal walls, producing a very compact building. In addition, the atrium provides a means of introducing natural light and natural ventilation into the rooms next to the courtyard. The atrium itself becomes an extra multi-purpose space in the building.

BUILDING 2000

Building 2000 brochures are published by Directorate General XII of the Commission of the European Communities to show how design studies can help architects and other building designers use passive solar principles to the best effect to produce attractive energy efficient buildings. Each brochure describes studies carried out with the support of the Commission during the design phase of one thirty-six non-domestic buildings in the EC Member States. The studies were on such topics as daylighting, heating, cooling, ventilation, comfort, control systems and urban design. They were carried out with the help of acknowledged European experts in these fields and drew heavily on lessons learned and techniques developed through the Commission's research and development programme on solar energy applications to buildings.

Commission of the European Communities/Directorate-General for Science, Research and Development



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This set of **Building 2000** brochures illustrates how architects and other building designers can successfully apply passive solar principles to produce energy-efficient buildings.

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