BUILDING 2000

Commission of the European Communities

- Renovation of existing cottages and development of new building to form research and educational facilities for permaculture institute.
- Renovated building contains attached greenhouses which provide direct solar gains, preheated ventilation air and space for crop growing.
- Design for new building was developed by comparing performances of designs containing wrap-around greenhouses and atria.

RESEARCH AND EDUCATIONAL CENTRE

STEYERBERG/

FEDERAL REPUBLIC OF GERMANY

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

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PROJECT DESCRIPTION

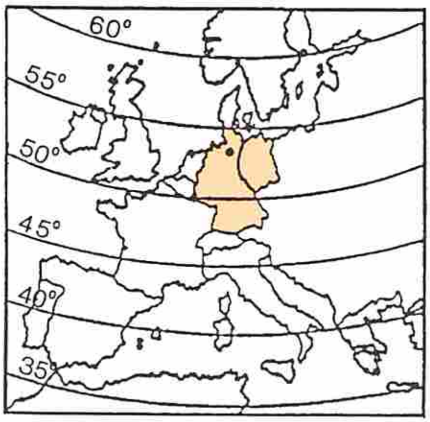


Figure 1. Location of Steyerberg

Sunshine hours per year	1600
Mean global irradiation per year	950 kWh/m^2
Sun as % of daylight time	
Nov-Feb	>25%
Mar, Apr and Oct	35%
May-Sep	45%
Mean temperature	
Jan	1.5 ° C
Jul	17.4 ° C
Annual average	9.1 ° C
Frost-free days per year	176
Rainfall per year	630mm
Relative humidity	85%

Table 1. Some climate data

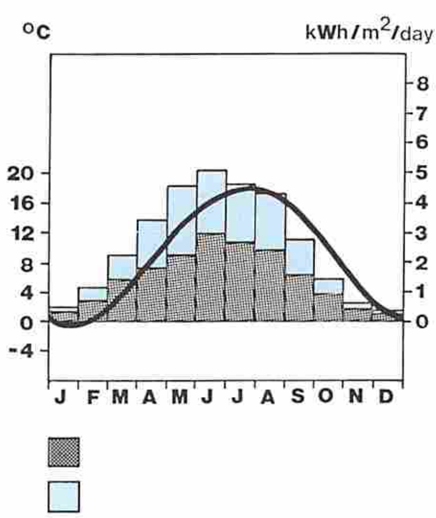


Figure 2. Mean solar irradiation and temperature data

Building Type

This project concerns the development of two separate buildings which together form a research and education centre for the Permaculture Institute of Europe. One building was formed by renovation of two existing cottages. The other is a new construction. Both buildings will house offices, seminar rooms and accommodation for staff, visiting lecturers, researchers, students and apprentices.The development is being carried out in two phases. Renovation of the cottages (Phase 1) took place over the period 1988-89. Construction of the new building (Phase 2) is expected to begin in 1991 and will take into account the results of the design studies described in this brochure and the lessons learned from constructing and monitoring the Phase 1 Building.

Location

The two sites, which are 600 m apart, are some 3 km outside the old village of Steyerberg (latitude 52 ° 3 ' N, longitude 9 ° 3 ' E) in Lower Saxony in the Federal Republic of Germany - see Figure 1. They are about an hour's drive from Hannover and two hours from Bremen and Hamburg.The sites are in the sandy hills of the west bank of the river Weser in the southern part of the county of Nienburg. The cottages are part of a community originally constructed in 1939 (see Figure 3). The new building is on a 2.6 ha site being developed as an example of permaculture for Northern European climates (see Figure 4). This site is unobstructed from the south-west round to the east. There is a larch tree plantation to the south but it is far enough away to let in even the lowest winter sun.

Site Microclimate

The climate is typical of that found in regions near the coast in north-west Germany. Over a year there are 100 days when the temperature is at least 20 ° C. Additional climate data are given in Table 1 and Figure 2.

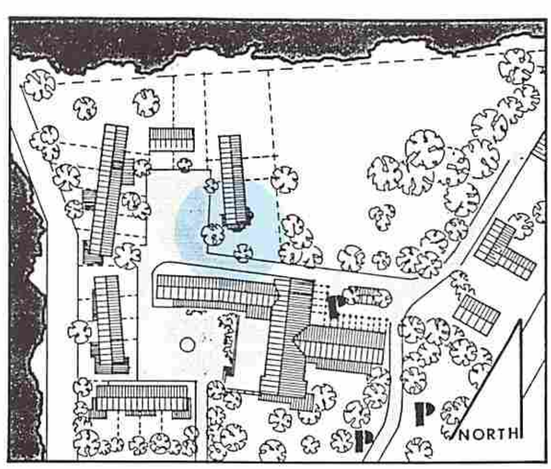


Figure 3. Site of the original cottages renovated in Phase 1 of the project

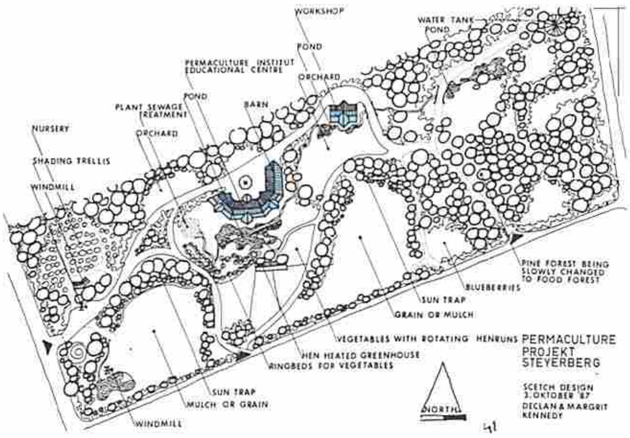


Figure 4. Site of the new building to be constructed as Phase 2 of the project

Design and Construction Details

Introduction

In developing the two buildings the objective has been to demonstrate the concepts of permaculture in a European cultural and social setting in a cold temperate climate. The term 'permaculture', originally formed from the phrase 'permanent agriculture', has now come to mean the planning and design of stable, self- supporting systems based on the principles of a sustainable ecology. It involves a holistic approach to life and includes the supply of wholesome food, energy and warmth and participation in good pursuits. The Permaculture Institute of Europe aims to support and develop these ideas by practicing them in different conditions and climates and disseminating the results of their work through seminars and workshops.

General Design Concepts

In both projects there are attached greenhouse or atrium areas for growing edible plants. The buildings and greenhouses are ventilated with pre-heated or cooled air to avoid temperature drops in winter and overheating in summer. The ventilation air for the main buildings is preheated in the greenhouses. In the Phase 1 building, the greenhouses are located on the south, east and west sides of the original cottages. In developing the Phase 2 building, the task has been to find out whether a building with a wrap-around greenhouse or one with an atrium would be the better choice for optimizing energy efficiency in the building and greenhouse areas. The buildings also incorporate the following ideas:- solar collectors to the south, with superinsulated water or magnesium tanks underground for long-term storage;- water-saving devices (e.g. humus toilets and used-water recycling systems) to save energy in treatment of waste water;- recycling of disposable wastes, preferably on site;- production of food (especially fruit and vegetables) under various conditions to ensure year-round supply and save energy on transport and storage;- wind energy for electricity and pumping ground water (for the Phase II building only);- photovoltaic cells for electricity, especially in summer;- wood-burning co-generation of heat and electricity in winter using wood grown on site in order to save energy and non-renewable sources;- shading and ventilation devices to prevent overheating in sunspaces and interior rooms and thus save energy for cooling in summer.

The Phase 1 Building

The original three-storey cottages are illustrated in Figure 5. A model of the renovated building showing the south-facing greenhouse is illustrated in Figure 6. The project as it looked on site in December 1988 is shown in Figure 7. The ground floor and first floor plans are given in Figures 8 and 9 and sections through the greenhouses in Figures 10 and 11. The two top storeys are within the 44 ° pitched roof. There is a basement under part of the building. The building contains four offices, a small seminar room containing information resources, one apartment and two single guest rooms. (One of these guest rooms will be turned into an office once the apartments in the Phase 2 Building have been completed.) The south-facing greenhouse is used as a seminar room for small group meetings from early spring to late autumn. Different climatic environments are produced in the different parts of the greenhouses, depending on whether they are oriented south, west or east. By using the various parts separately or in combination, many different types of plant can be grown throughout the year. The original cottages were built with a traditional brick and wood construction and a tile roof. The external walls on the ground floor are 360 mm thick. The roof slope has been insulated inside with 200 mm recycled paper impregnated with borax plus wood panelling. The outside of the south-facing gable has 120 mm insulation plus wood weatherboarding. The greenhouses are double glazed. The exterior walls up to cill level and the foundations to below frost level have 800 mm insulation so that heat is retained in the planting beds. Depending on the weather, roof and wall vents open automatically. Shading prevents overheating in summer. To ensure year-round growth, auxiliary underfloor heating (preheated by solar energy) has been installed to protect against temperatures below 5 ° C.

Figure 5. The original cottages in 1987

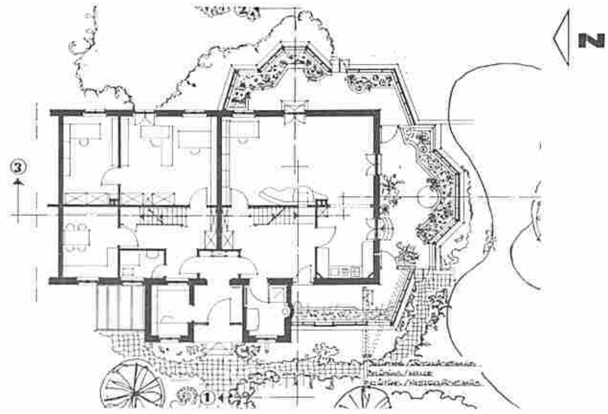


Figure 8. Ground floor plan of Phase 1 Building

Figure 6. Model of the renovated Phase 1 Building

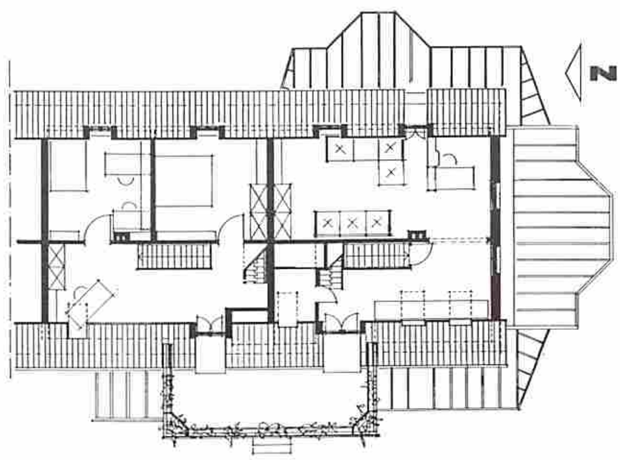


Figure 9. First floor plan of Phase 1 Building

Figure 7. Renovated Phase 1 Building during construction in December 1988.

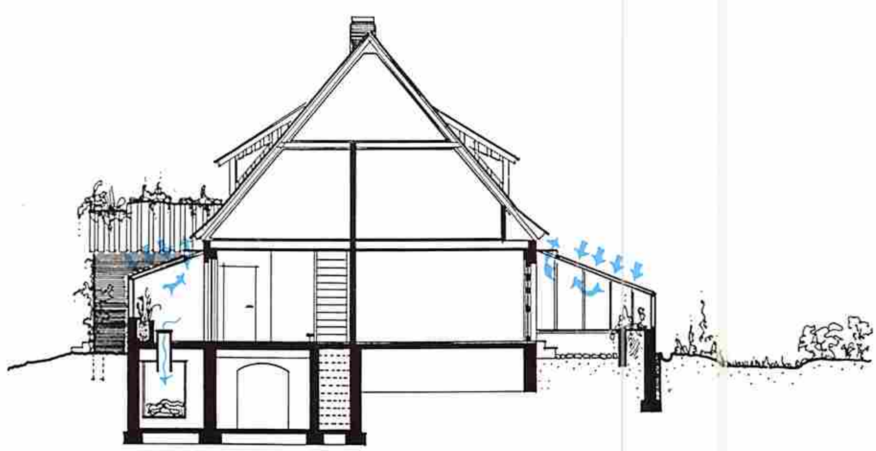


Figure 10. Cross-section through east and west greenhouses of Phase 1 Building

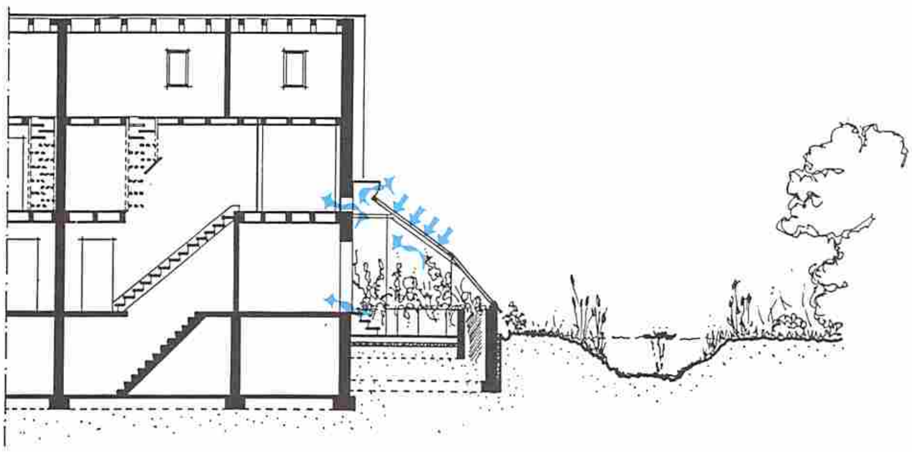


Figure 11. Section through south greenhouse and reflecting pond of Phase 1 Building

The Phase 2 Building

The new building will contain apartments (flats), offices, a large seminar room, kitchen and eating spaces and a barn. Two basic designs have been prepared. In Design I, greenhouses with $120\ m^2$ usable space are wrapped around the south, south-east and south-west sides of the main building. In Design II, the greenhouses have been pulled into the building to form atria with $130\ m^3$ usable space.

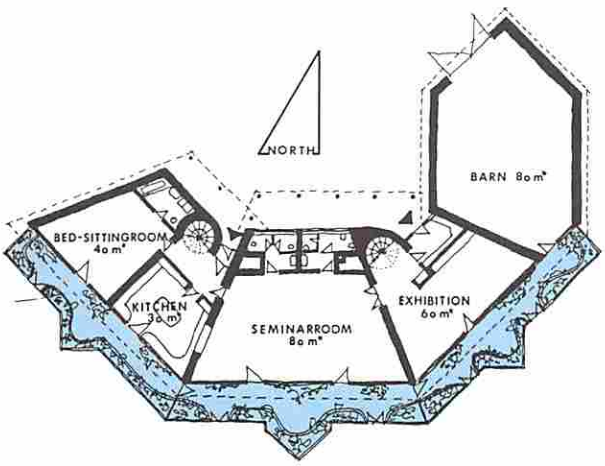


Figure 12. Ground floor plan of Phase 2 Building Design I

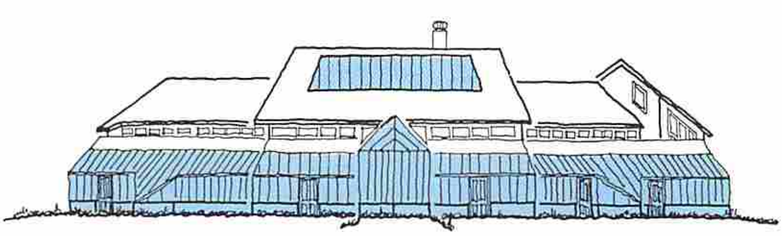


Figure 13. South elevation of Phase 2 Building Design I

Phase 2 Building - Design I

Design I is mostly two storeys high although there is an additional roof space in the middle section. There is a basement under part of the building. The ground and first floor plans, south elevation and north-south sections are shown in Figures 12-15. The main rooms face south, south- east or south-west and there is a narrow (2.5 m) greenhouse along the front. On the ground floor there is an exhibition room at the entrance which also serves as a foyer for the large seminar room. Eating takes place in the seminar room. The adjacent kitchen, with its basement and two flats, has a separate entrance from the outside. All the bathrooms, toilets and staircases are on the north side of the building so that they form buffer spaces for the main rooms. This buffer principle is also used on the first floor.Windows have been placed almost exclusively on the south side. This has been found to provide adequate daylighting for all rooms except the upstairs library. Here, to ensure good daylighting, the greenhouse (which is in general one-storey high) has been raised to two storeys and pulled back to the roof. A spiral staircase provides access from the library to an upper floor containing workspaces for apprentices and visiting researchers.The interior walls are mud-brick to add to the heat storage capacity of the building. All the outside walls of the greenhouse are highly insulated from below frost level to sill height. The glass wall between the greenhouse and the main part of the building will allow a high degree of heat transfer between the sunspace and the interior. All the glass roofs have shading devices which are also air collectors to provide hot water (up to 85 ° C) through an air-to-water heat exchanger. The surplus hot water is stored in tanks two storeys high and used to preheat water for the auxiliary heating system.

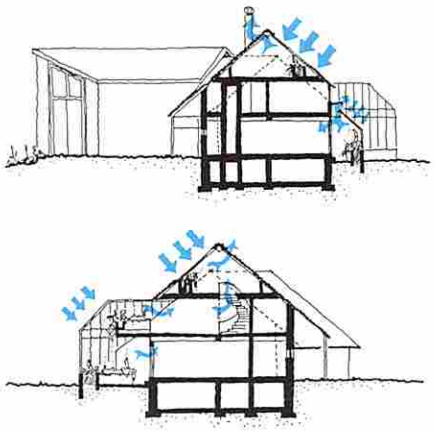


Figure 14. North-south and south- north cross sections of Phase 2 Building Design I

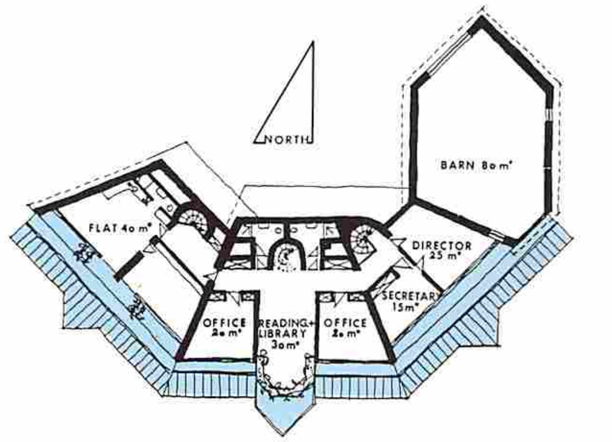


Figure 15. Phase 2 Building Design I first floor plan

Phase 2 Building - Design II

The ground floor, first floor and basement plans, south elevation and north-south sections of Design II are shown in Figures 16-20. The building has three atria, facing south, south-east and south-west. They have much the same area as the wrap-around greenhouses of Design I but seem more spacious and give occupants direct contact with plants and the outside world. The atrium facing south is for potted plants. Those facing south-east and south-west have direct contact with the earth so fruit trees from southern climates can be grown there. The atrium roofs are higher than the roof of the main building to ensure optimum ventilation. The main entrance is from the north, on a split level between the basement and ground floor. The entrance hall forms an exhibition area. The foyer for seminars is one floor below. The south-facing atrium is partly used as a dining area. The large seminar room is situated under it in a half-basement and obtains its daylight through the atrium facade. A second entrance from the north provides access to the kitchen, its basement store and two staff flats. The first floor contains the library and offices which are connected by galleries overlooking the atria. All the atria are fitted with shading devices/air collectors similar to those in Design I.

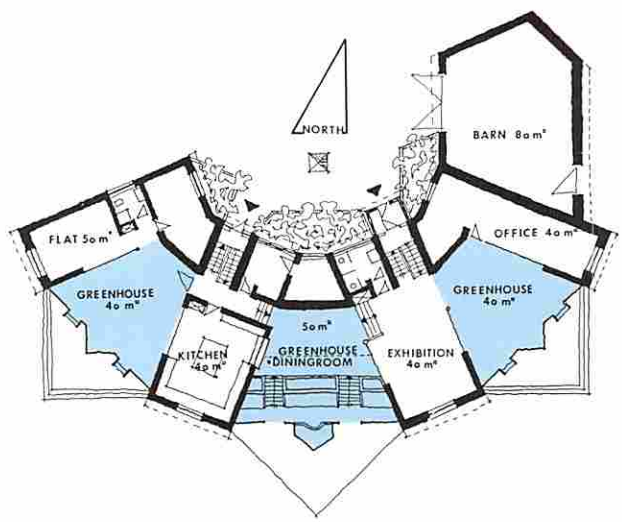


Figure 16. Phase 2 Building Design II ground floor plan

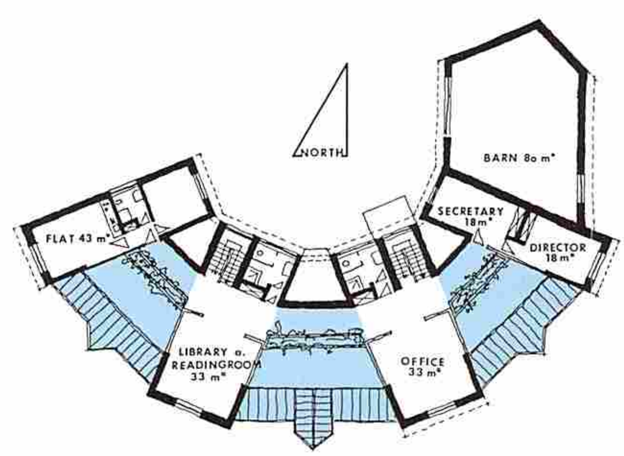


Figure 17. Phase 2 Building Design II first floor plan

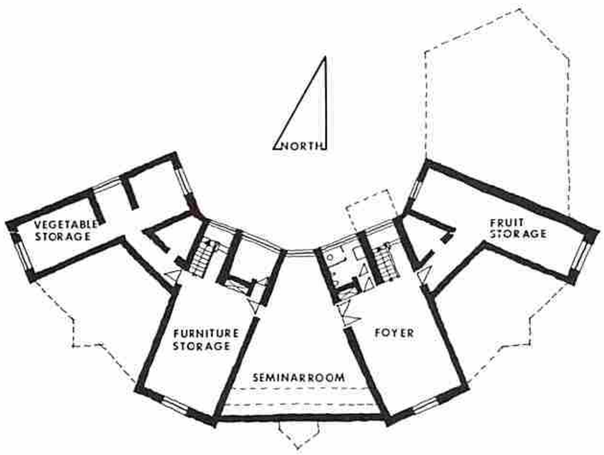


Figure 18. Phase 2 Building Design II basement plan

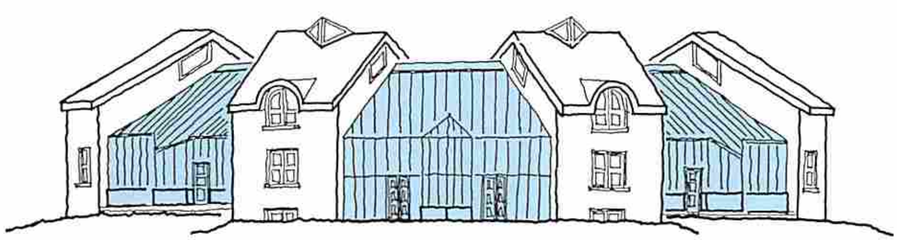


Figure 19. South elevation of Phase 2 Building Design II

	m^2	greenhouse/ atria	m^3
Design I	510	120	1400
Design II	584	130	1459

Table 2. Comparison of usable floor area and volume of the two Phase 2 Building designs

	volume m^3	costs/m^3 (DM)	total costs (DM)
Main building	1,400	800	1,120,000
Barn	560	500	280,000
Greenhouse	48	500	24,000
Glazing	305	480	146,400
Total			1,570,000

Table 3. Estimated construction costs of Phase 2 Building Design I

	volume m^3	costs/m^3 (DM)	total costs (DM)
Main building	1,459	800	1,167,200
Barn	560	500	280,000
Atria	52	500	26,000
Glazing	258	480	123,840
Total			1,597,040

Table 4. Estimated construction costs of Phase 2 Building Design II

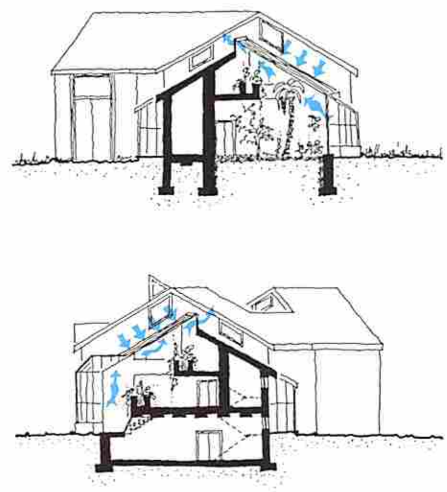


Figure 20. North-south and south- north cross sections of Phase 2 Building Design II

Comparison of Area and Construction Costs of the Two Phase 2 Building Designs

The floor area and volume of the two designs are compared in Table 2. Design II has more usable floor area because it has greater circulation space. In Design II the roof office space is omitted. It could, however, be added without altering the results of the costs and performance evaluations described below.At first thought, it seemed likely that the atrium design (Design II) would be much more costly to build. However, when the costs were estimated from the actual costs of the Phase 1 Building it was found that Design II would be less than 2% more expensive to construct (see Tables 3 and 4). Design II has the advantage of providing glasshouses where the height, width and orientation are more suited to growing plants in accordance with the principles of permaculture.

DESCRIPTION OF PASSIVE SOLAR FEATURES/COMPONENTS

The Phase 1 Building

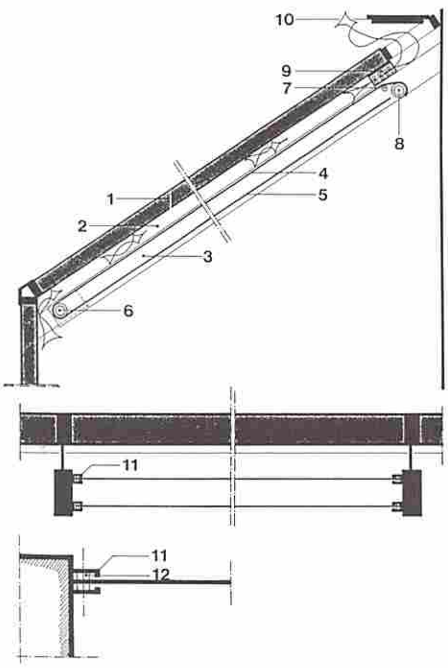


Figure 21. The greenhouse shades/solar collectors

Auxiliary Heating

Auxiliary space heating is provided by a natural gas-fired furnace/low temperature radiator system with thermostats on the individual radiators and an earthen wood- burning stove installed on the ground floor.

The Greenhouses

The main passive solar features in the Phase 1 Building are the greenhouses. The south-facing greenhouse serves as a sunspace which collects and stores solar heat. The east- and west-facing greenhouses act as buffer areas to reduce heat loss from the main building and utilize heat from the main building for plant growing.In winter, the greenhouses preheat ventilation air for the parent building. Calculations show that almost 60% of the solar gain is used for this purpose. The air is circulated throughout the building by means of vents, entering the upper floor at the gable end. Fresh air is brought into the greenhouses through pipes set 2.5 m below ground. The temperature of this air is 10 ° C and thus is pre-cooled in summer and pre-heated in winter.The 360 mm brick walls of the original building act as short-term primary heat stores. These help warm the building and assist the growth of plants by retaining some of the heat collected during the day well into the night. A reflecting pond has been constructed in front of the south greenhouse to reflect solar radiation into the greenhouse in winter. The insulation on the outer walls and foundations allows reflected solar radiation to be retained in the greenhouses and enables the plant beds to serve as secondary heat stores.Overheating of the greenhouses is prevented by shading and by ventilation through top-hung windows and roof-top flaps which automatically open at 35 ° C and close at 24 ° C. The top flaps also close automatically in case of rain.The performance of the greenhouses is being monitored over the period 1989 to 1991, prior to the construction of the Phase 2 Building.Greenhouse

Shades/Solar Collectors for Domestic Hot Water

Shading in the south-facing greenhouse is provided by a movable sheet membrane installed under the double-glazed roof. This prevents overheating. It also allows the layer of hot air between the membrane and glass to act as an air collector (see Figure 21) which is transformed by a heat exchanger into domestic hot water. The electricity for this and for the compressor for the automatic vents is run on a 12 volt circuit provided by photovoltaic cells on the south facade.

Other Energy-Saving Features

For the humus toilet in the bathroom on the west side, a large tank (Clivius Multrum) has been built underneath the west greenhouse, the floor of which has been constructed so that conductive heat is let through to allow composting to take place at 18 ° C.At the most northern part of the annex, a glass-covered open air wood stove has been constructed to dry new wood for the earthen stove and store it under cover.Under this structure is a new basement with a packed earth floor to provide an ideal storage temperature for vegetables throughout the winter.

The Phase 2 Building

Greenhouses/Atria and Other Energy-Saving Features

The main passive solar features in the Phase 2 Building are the greenhouses or atria. These and other energy-saving features will be constructed and operated in a similar way to those in the Phase 1 Building. However, there is in a new building the advantage of being able to place all the different components in the right place from the start. For instance, heat storage in interior walls and in large one-storey high water tanks can be better integrated. The hot air flow from the greenhouses to the upper floors can be placed all along the south walls to provide a better distribution than in Phase 1. To obtain the best energy-saving from the greenhouses, natural air flows from them to the heated occupied spaces can be encouraged by extracting air from heavily occupied spaces using the stack effect and taking it to the highest part of the building. The north side of the building should be airtight and highly insulated. In winter in northern Germany solar gains from the global reflection of the sky are higher than those from the direct sun. As a result, the angle of the glass roof should be as flat as possible - but not so flat that snow cannot slide off. In addition, the Phase 2 Building will take into account points learned in Phase 1. For instance:

- buffer zones and longer roof overhangs on the north side can reduce heat loss and serve for drying firewood;
- orientation and conductivity and storage capacity of materials all have to be taken into account in the overall building design;
- the walls of the main building need not all be built of the same materials or have the same thickness. Depending on orientation, they can be built of materials found on or near the site, thus reducing transport costs;
- roof ridge dormer windows can improve daylighting and reduce the necessity of north windows, thereby cutting heat loss;
- rather than having a grass sod covering, the roof should be covered with tiles made in a nearby brickyard to enable rainwater to be collected and stored in cisterns underground.

Auxiliary Heating

In winter, auxiliary space and domestic hot water heating will be provided by a co-generation system using a Stirling motor. This will run on wood fuel found on site. The motor runs an electric generator. The heat from the exhaust will be channelled through ducts in the interior walls, creating radiant wall panels. The air is circulated back to the motor's cooler without entering the rooms. The co- generator will be supplemented by woodburning stoves as in the Phase 1 Building.

ENERGY CALCULATIONS PERFORMED AND DESIGN TOOLS USED

Design Tools

The performance of Designs I and II for the Phase 2 Building were evaluated using a number of design tools. A preliminary energy analysis was conducted using a simplified thermal network method developed in the UK by Dr Nick Baker. A more detailed comparison of energy performance characteristics was carried out using the ESP computer model developed at the University of Strathclyde in Scotland. An idea of the daylighting performance was obtained using a 1:50 scale model. The results of the energy analyses are given below.

	Ratio glass :	walls :	roof
Design I	4 :	3 :	3
Design II	3 :	4 :	3

Table 5. Ratio of glass to opaque surface areas in Designs I and II

Results of Preliminary Energy Analyses

Thermal Performance

The results of the preliminary calculations (which were based on rough U- values for the proposed materials and simplified sections for the building) are given in Table 6. Designs I and II require approximately the same amount of energy to run. There would, however, be a lower incidence of frost in the atria of Design II than in the wrap-around greenhouses of Design I. Furthermore, some parts of the atria would be virtually frost- free, permitting growth of perennial shrubs and trees from the Mediterranean region such as citrus fruit, melon, fig, etc. Conditions for such plants would be improved if a relative humidity of 70% and temperature of 5 ° C were maintained in the atria. This would require auxiliary heating at certain times - when, say, the external temperature was -20 ° C.

	Design I	Design II
Average January temperature in greenhouses or atria (° C)	4.0	7.2
Annual energy consumption (kWh) with no solar preheating of ventilation air	25,052	24,903
with preheating of ventilation air	21,225	20,902

Table 6. Preliminary comparison of the energy performance of Designs I and II for Phase 2 Building

Ratio of Areas of Glazed and Opaque Surfaces

It was found that Design II has not only a better energy performance but also a smaller proportion of glass (see Table 5). In traditional houses (including those which have been subject to modernization and renovation) in Lower Saxony, the ratio of openings:walls:roof is 2:4:4. In these buildings, only about half of the openings are filled with glass; the remainder consist of wooden doors, etc.

Additional Considerations

In addition to the above points, Design II would fit better into the local landscape because the glazing in the outside walls is less apparent. In addition, the opaque surfaces use local building materials and can be constructed with local labour.

Results of More Detailed Energy Analyses

Thermal Performance

The more detailed analyses of the Phase 2 Building were carried out for three different designs: one with wrap-around greenhouses where there is 72 m^2 single glazing between the greenhouses and the main part of the building (Design I); one with atria integrated into the building where there is no glazing between the atria and the rest of the building (a modification of Design II); and one where 10 m^2 glazed window has been introduced between each atrium and the parent building (a second modification of Design II).

It was found that the atrium designs consume less heating energy than Design I (see Figures 22 and 23). The total annual heating energy consumption for Design I is 43.1 kWh/m^3 building, that for the first modification of Design II (atrium type with no internal windows) 41.6 kWh/m^3 and for the second modification of Design II (atrium type with a total of 30 m^2 internal windows) 43.5 kWh/m^3 .

The atrium designs will, however, require auxiliary heating for frost protection whereas the wrap-around greenhouses will not need any additional heating. This is because the 72 m^2 single glazing between the greenhouses and building in Design I will allow heat loss from the parent building to the greenhouses. The required peak heating power for frost protection in the south atrium is 1.7 kW, for the west atrium 0.5 kW and for the east atrium 1.5 kW. For the complete building, the peak heating power is 23.6 kW for Design I and 25 kW for Design II.

The annual cumulative distribution of air temperature in the west and east atria is given in Figures 24 and 25. The west atrium generates a warmer climate so that it will have a temperature over 20 ° C for 35% of the year. In the east atrium, the temperature will be above 20 ° C for only 20% of the time. The yearly mean air temperature of the greenhouses/atria are given in Table 7.

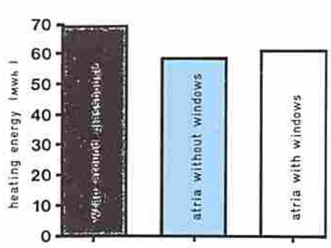


Figure 22. Annual heating energy consumption

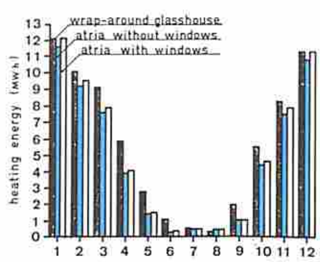


Figure 23. Monthly heating energy consumption

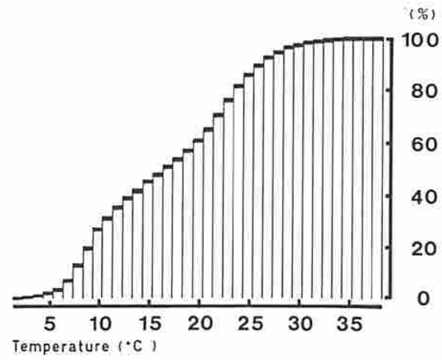


Figure 24. Annual cumulative distribution of air temperature in the west atrium

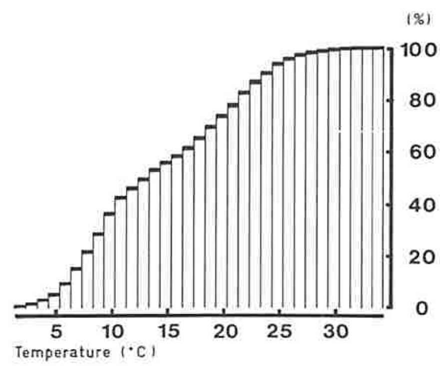


Figure 25. Annual cumulative distribution of air temperature in the east atrium

	°C
Wrap-around greenhouses	16.0
East atrium	14.6
South atrium	15.7
West atrium	17.0

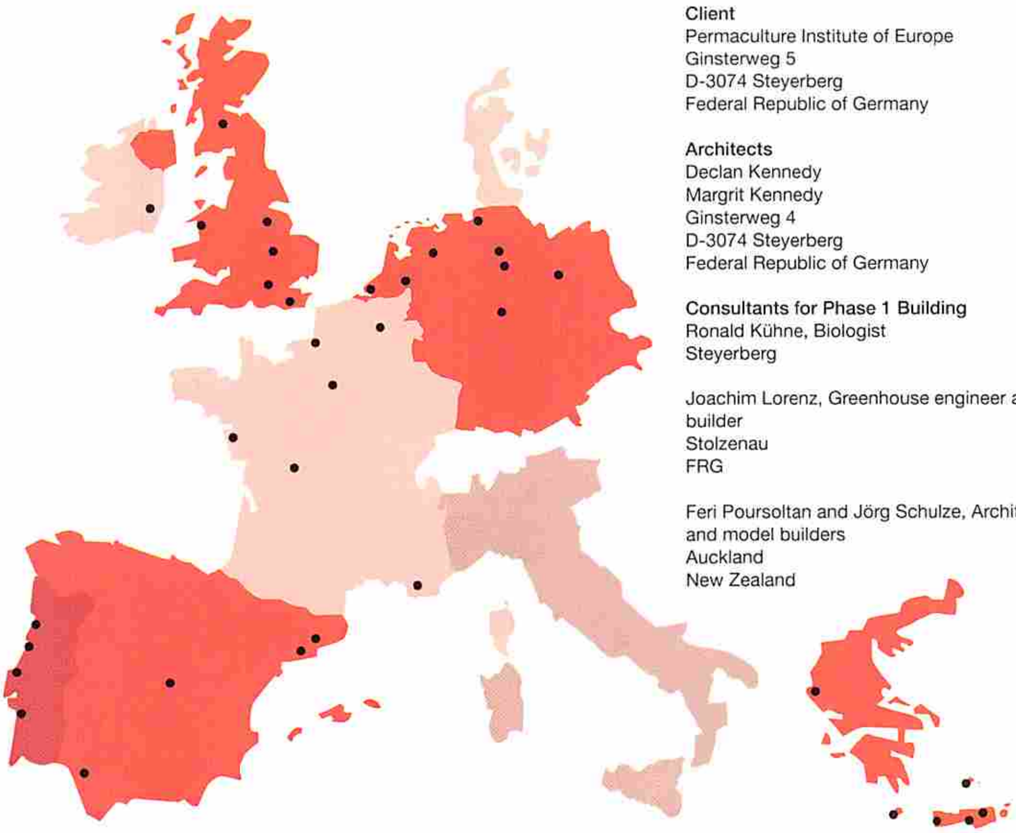
Table 7. Yearly mean air temperature of greenhouses or atria

Final Modifications to the Design

From the above results, it was concluded that the atrium design without internal glazing in the connecting wall is to be preferred to the other two solutions. The possibility was considered of pulling the atria out two metres beyond the facade of the building and joining them up using narrow buffer greenhouses. It was felt that this might provide a combination of the best attributes of all the designs considered earlier. Simulation studies showed, however, that the utilizability of solar gain diminished as the area of glazing increased.The Building 2000 experts, therefore, recommended that the final design combine just one atrium (built on the earth and south-facing with a larger area than the south-facing atrium in Design II) with east- and west-facing wrap-around greenhouses. This solution would generate all the different climate possibilities but at the same time minimize heat loss. The atrium and wrap-around greenhouses would need shading and top and bottom ventilation to prevent summer-time overheating. Shading collectors would also be included to provide insulation on winter nights.

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 of 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 Commision'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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