5808

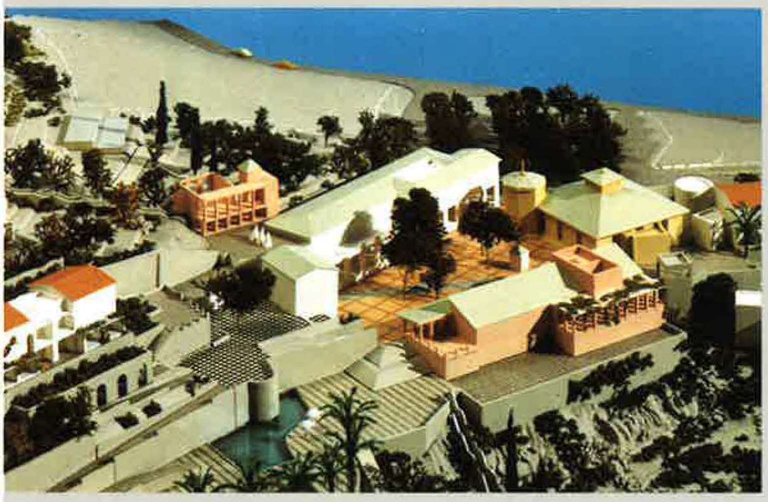
BUILDING 2000

Commission of the European Communities

- Luxury tourist complex with approximately 550 beds, reception, administration offices, multi-purpose hall, restaurants, lounge, shops, theatre, swimming pools, gym and saunas
- Complex is built around secluded bay in series of small-scale buildings, some of which are partly buried in the slope of the land
- In summer, outdoor living is the norm and extensive landscaping has been used to create a comfortable microclimate
- Summer-time overheating has been prevented by cross and night ventilation, shading, evaporative cooling and air-to-ground heat exchangers
- Daylighting is used carefully, for practical reasons and to enhance the architecture
- The annual contribution of passive solar systems to the heating requirements of the complex is 82%. Their contribution to the cooling load is 52%.

TOURIST COMPLEX

AGIOS NICOLAS/CRETE/GREECE



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 Crete

Building Type

This scheme, known as Hellas Holiday Hotels, is a luxury tourist complex containing 237 double rooms and 28 suites, reception and administration offices, a multi-purpose hall for conferences and exhibitions, restaurants, a lounge, shops, a theatre, a health centre with gym and saunas and indoor and outdoor swimming pools.

Location

The complex is located in Lasithi County (latitude 35° N), south of the town of Agios Nicolaos in Crete (see Figure 1). It is adjacent to the bay, which runs east-west (see Figure 4). The site is approximately 180,000 m^2 in area and has a 20-30% slope to the north. There are views to the east and to the open sea to the north.

Sunshine hours	1131
Global irradiation on a horizontal plane	
Jan-Dec	1743 kWh/m^2
(Jan-Dec	6275 MJ/m^2)
Oct-Apr	713 kWh/m^2
(Oct-Apr	2567 MJ/m^2)

Table 1. Some key climate data. (Source: Solar radiation atlas of Greece.)

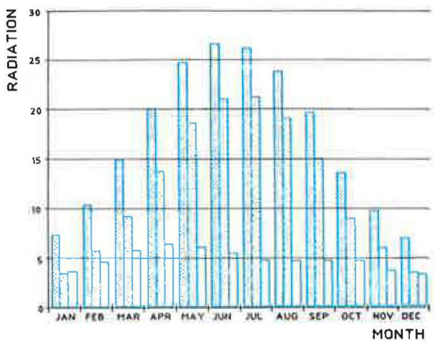
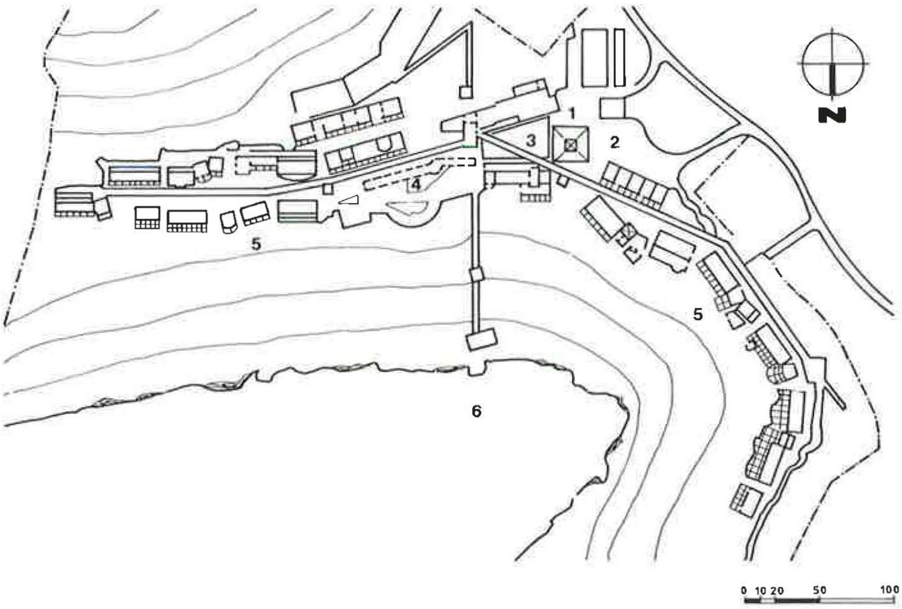


Figure 2. Mean daily global, direct and diffuse solar irradiation per month (MJ/m^2)



Key:

1. main entrance
2. service yard
3. main square and public facilities
4. swimming pools
5. guest rooms
6. sea

Figure 4. Site plan

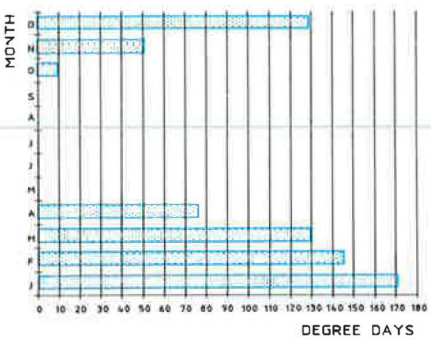


Figure 3. Degree days per month

Site Microclimate

Details of the site climate are given in Table 1 and Figures 2 and 3.

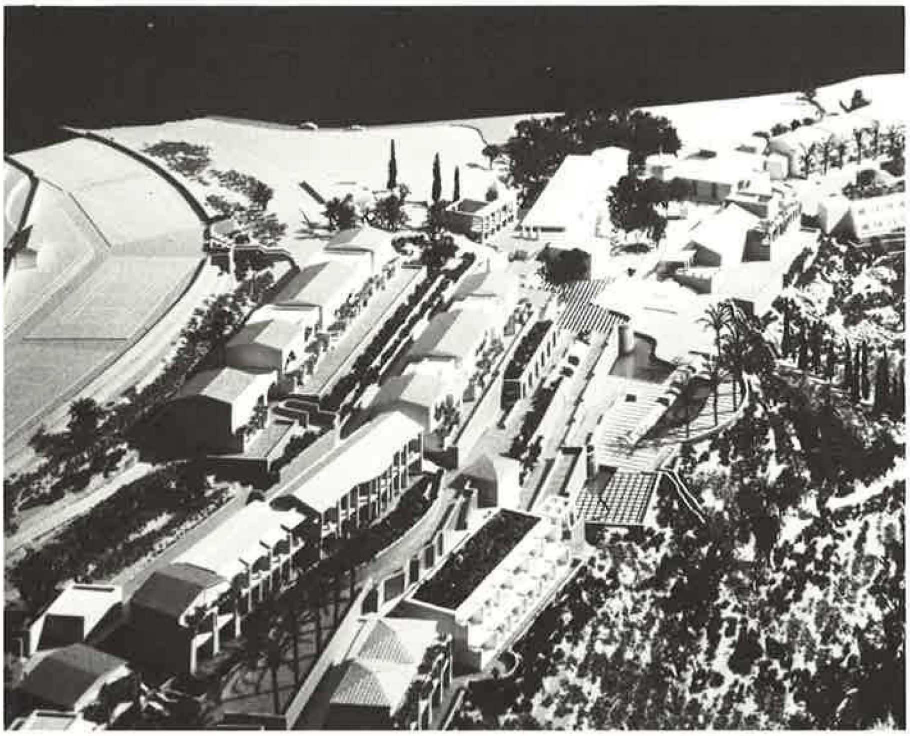


Figure 5. General view of model of site showing the linear building layout following the shape of the bay

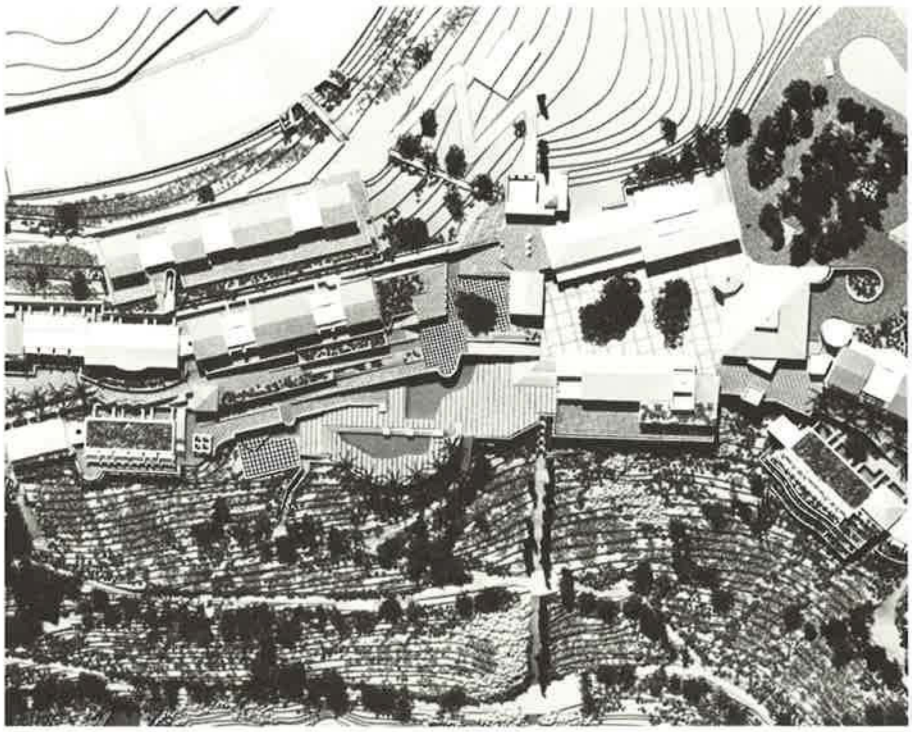


Figure 6. General view of the central part of the model

Design and Construction Details

General Layout

The complex has been developed along the lines of a traditional village and individual buildings are based on forms which have been close to the hearts of people in Crete for generations.

Indoor and outdoor communal facilities are at the site centre and the guest rooms are on the edges so they are quiet and secluded. The layout makes full use of the views and exploits the slope of the land.

The individual buildings are positioned to follow the shape of the bay (Figure 5). Between them they have a floor area of 21,859 m^2 and a volume of 100,514 m^3. Most face north with their main axis running east-west so that in summer they receive the sun in the late evening. The U-values of some key building elements are given in Table 2.

There are two entrances to the site at the uncovered parking lot and service yard. Vehicles are not allowed beyond this point. The site is designed to encourage outdoor living and the main pedestrian pathway, which runs parallel to the seashore, and main square form an open-air promenade with sitting and recreation areas.

roof	0.32-0.34
floor	0.82-0.83
external walls	0.33-0.56

Table 2. U-values of some building elements (W/m^2 K)

Main Square

The main square is in the centre of the complex adjacent to the main entrance (see Figures 6 and 7). It provides a focus for activities in the day and, especially, evening.

The elevations of the public buildings around the main square are shown in Figure 8. On two sides there are arcades for sitting-out, paved with white marble strips and red brick to absorb heat in winter and shaded by large deciduous trees in summer. A water fountain provides evaporative cooling.

On the south side are the reception and administration offices. This is a long two-storey building with an east-west axis. The reception lobby and some administration offices are on the ground floor. More offices and top management accommodation is on the top floor. The building is cross ventilated and naturally lit from the south and north. The ground floor has a high ceiling both as an architectural feature and to provide cooling.

On the western side of the main square is a square building on the ground floor of which is located the multi-purpose hall. The latter can be divided and is used for conferences, exhibitions and games. Service facilities are in the basement. The building is daylit from all sides through deeply recessed doors-windows and from the top by a glazed turret on the wooden roof.

On the north side of the main square is a two-storey restaurant building. In the upper level there is a speciality restaurant which opens out into an open-air eating area under a covered porch at the edge of the square. On the north side of this restaurant is a terrace with a view of the sea. Crossventilation keeps the central area cool in summer. Daylight enters from both sides.

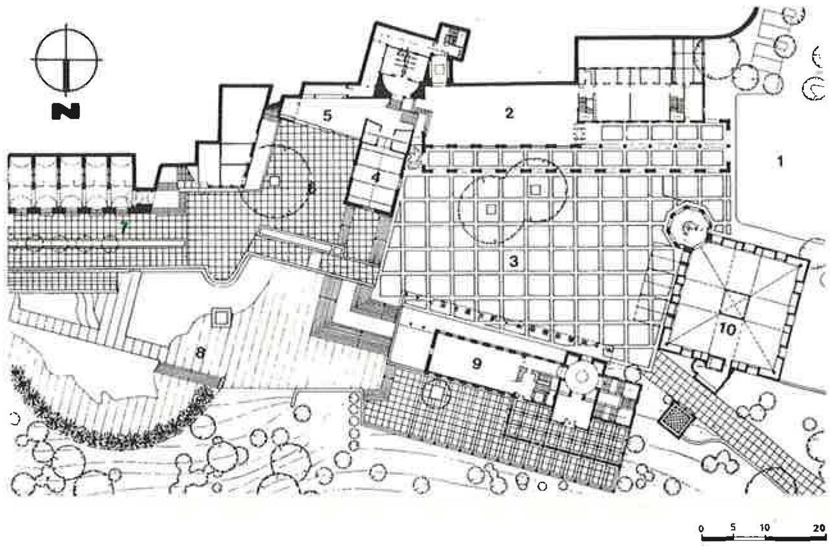
South-facing clerestory windows provide direct solar gain for heating the speciality restaurant in winter. The main entrance area to the restaurant building is covered with a cupola and is top lit. A stairway off this leads to the main restaurant, kitchen and laundry which are on the lower level. The main restaurant has a large terrace on the north side, shaded by deciduous creepers on trellis. Because it is single-sided, the main restaurant is cooled by overhead fans.

Secondary Square

To the east of the main square is a smaller, secondary square or piazza. The lounge, main bar, shopping mall and theatre are located around this. The lounge, which is for use on cool days, is enclosed and has a large fireplace. It is nearly square in plan and is cross lit and ventilated from the east and west. The main bar opens directly onto the square and provides an outdoor sitting area. The back of the bar is dug out of the slope of the land. In the shopping mall, small individual shops spill out onto the walkway. The indoor, multi-use three-sided stepped theatre with specially-designed top lighting is dug out of the hillside.

Swimming Pools and Health Centre

Below the secondary square, to the north, are grouped the swimming pools on terraces connected by waterfalls, a pool snack bar, the health centre with gym/sauna, an indoor pool and children's corner. This whole area is embedded in the hillside and, apart from the side which faces the sea, is provided with a variety of top lighting.



Key:
1. entrance
2. reception
3. main square
4. lounge
5. bar
6. secondary square
7. shops
8. swimming pools and terraces
9. restaurant with covered porch on one side and terraces on the other
10. multi-purpose hall

Figure 7. Plan of central squares and public facilities

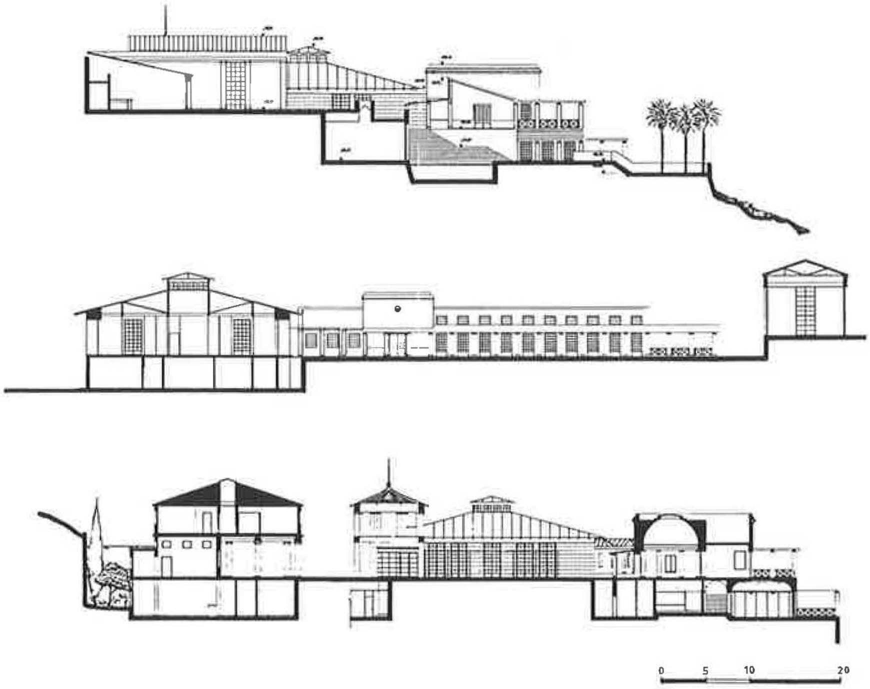


Figure 8. Elevations of the public buildings round the main square

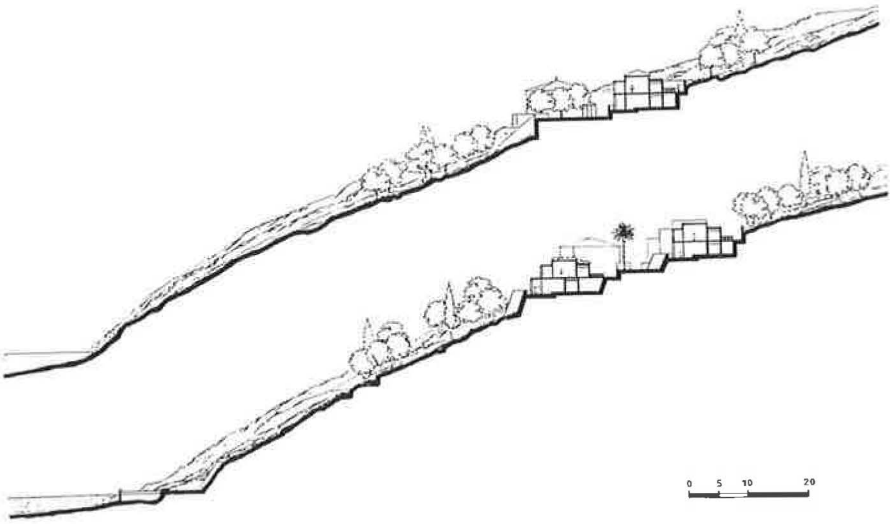


Figure 9. Typical sections through guest rooms

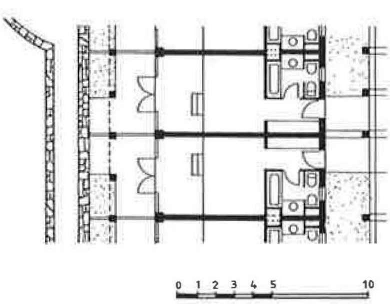


Figure 10. Plan of guest room module

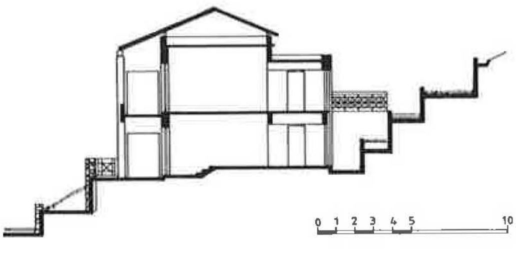


Figure 11. Section of guest room module

There are 237 double guest rooms of four basic types and 28 suites. They are located in small two-storey buildings around the bay along the natural contours of the land (see Figure 9). All have a linear plan with an east-west axis. A plan and section of a typical module are shown in Figures 10 and 11.

All the guest rooms have an entrance and bathroom on the south side and a spacious private veranda on the north, looking towards the sea. Access to the lower-storey rooms is via an exterior pathway on the lower level. Access to the upper rooms is through little wooden bridges built in pairs from the high ground behind the buildings. Thus, even though the site is steeply sloped, all the rooms have openings on front and back and are cross ventilated and cross lit. Some of the upper rooms have south-facing clerestories.

Pathways and walks covered with trellises and climbing plants interlink the buildings and give access to the bay from different parts of the complex. A few seats are arranged in secluded corners or points with a special view. Running water provides cooling and environmental features in the form of gullies, pools, fountains and waterfalls. Wooden gangways, jetties and sundecks run out from the paths along the seashore. Floating decks and gangways stretch out into the shallow bay providing areas (shaded by awnings) for use in daytime and at night, when they will be lit up.

DESCRIPTION OF PASSIVE SOLAR FEATURES/COMPONENTS

Introduction

The complex's main occupancy period is from April to October. Most of the passive solar and other energy-saving features, therefore, are aimed at cooling and daylighting. High levels of insulation have been incorporated in the buildings to improve their performance in summer and winter.

Cooling Systems

Ventilation

Nocturnal cross and fan-forced ventilation is used to reduce cooling loads at times when there is a large difference in interior and ambient temperatures. The cross ventilation systems in the multi-purpose hall, restaurants and guest rooms are shown in Figures 12-15.

Minimizing Direct Solar Gain

Small areas of glazing on the buildings' south side minimize solar gains while large areas of north-facing glazing aid heat loss as well as provide excellent views over the bay.

Shading devices - some fixed, some adjustable - cut out direct solar radiation at times when overheating in likely. Planting on pergolas and the use of deciduous trees also minimize the possibility of excess solar gain.

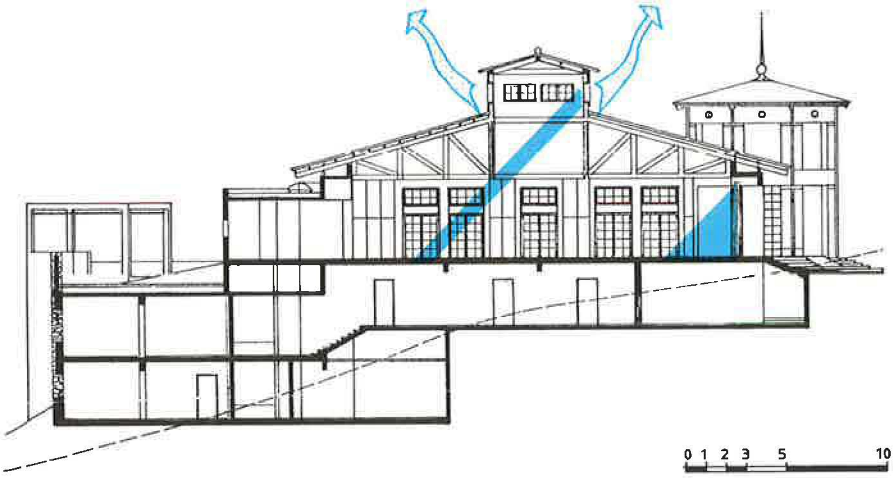


Figure 12. Section through multi-purpose hall showing cross ventilation and daylighting

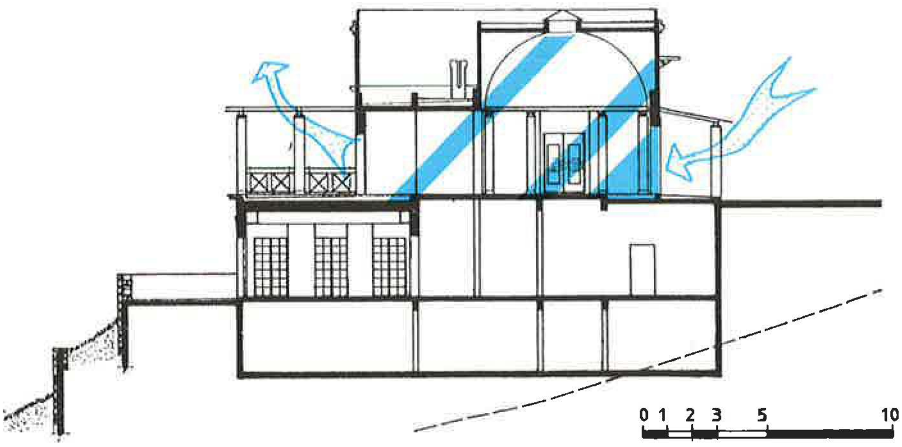


Figure 13. Section through restaurants showing cross ventilation and daylighting

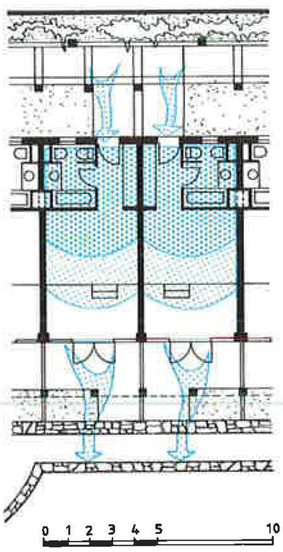


Figure 14. Plan of guest room module showing cross ventilation and daylighting

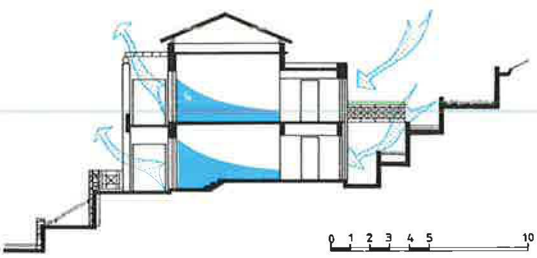


Figure 15. Section of guest room module showing cross ventilation and daylighting

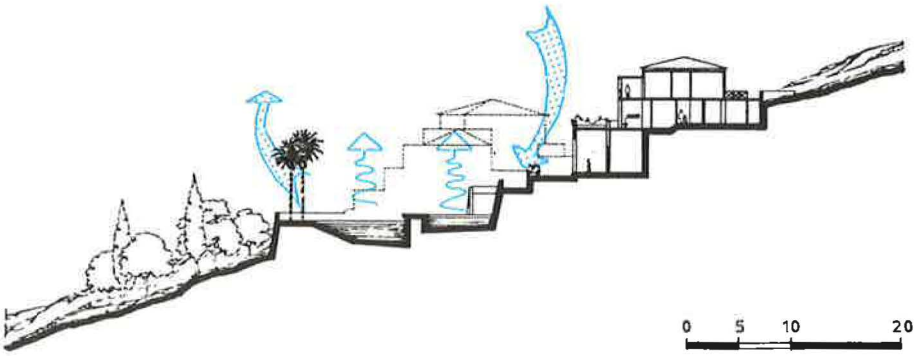


Figure 16. Section through swimming pool area showing evaporative cooling effect

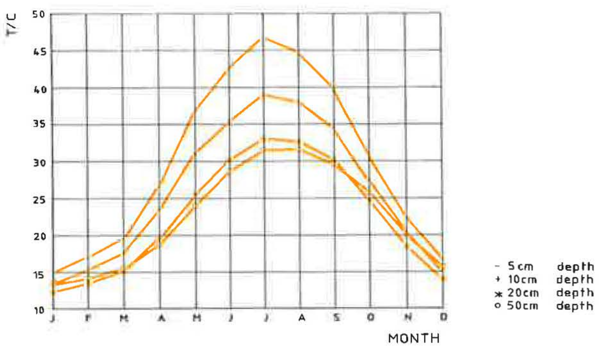


Figure 17. Mean soil temperatures

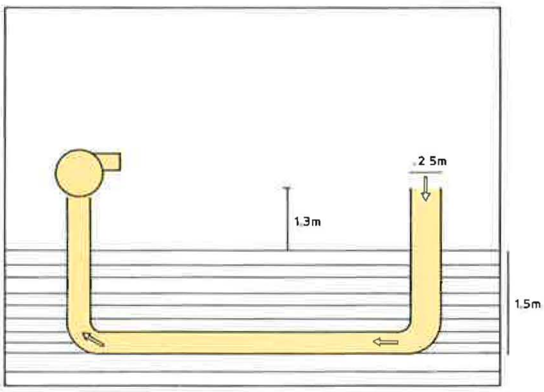


Figure 18. Buried pipes

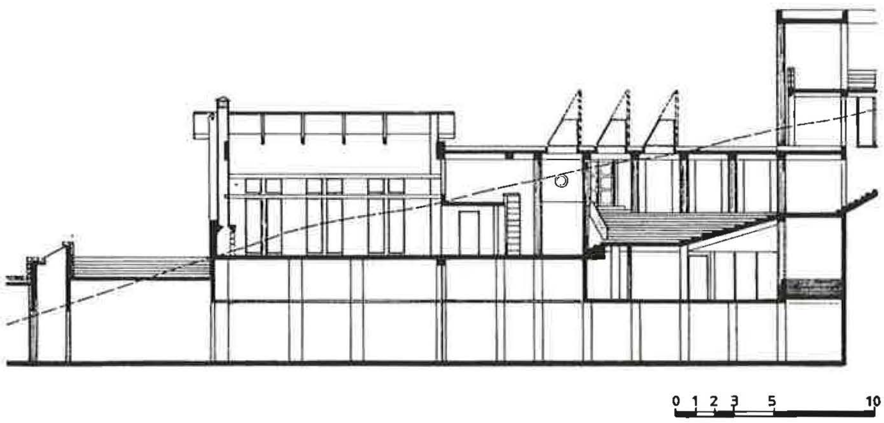


Figure 19. Section through the entrance reception and bar showing daylighting

Evaporative Cooling

Evaporative cooling results from the proximity of the sea and the swimming pools in the centre of the complex (see Figure 16). Fountains and streams of water near the buildings increase this effect.

Air-to-Ground Heat Exchangers

These are used for cooling and heating. The system is based on the difference in temperature between the ground and the air. Figure 17 shows the variation in temperature at different ground depths. The principle of the system is illustrated in Figure 18. Pipes are buried underground and air circulated through them. The air loses or gains heat according to the season.

Auxiliary Cooling and Heating Systems

Conventional air conditioning and fan coil units have been installed in the communal buildings. Auxiliary heating in the guest rooms is supplied by split electrical resistance units.

Daylighting

North daylighting provides uniform natural light in the living spaces (see Figures 14 and 15). Rooflights allow natural light to penetrate into deep and otherwise unlit spaces such as the centre of the multi-purpose hall, speciality restaurant, and the reception and bar areas (see Figures 12, 13 and 19).

ENERGY CALCULATIONS PERFORMED AND DESIGN TOOLS USED

The design of the passive solar and other energy-saving systems was carried out with the help of studies using a number of design tools. The thermal performances of the heated or cooled spaces were calculated using the admittance method (a simplified thermal network method) developed by Building Research Establishment in the UK. This calculates the heating and/or cooling loads, the contribution of the passive systems to heating or cooling and the daily temperature variations. The performance of the air-to-ground heat exchangers and the effect of night ventilation were determined using the PASCOOL computer program for simulating passive solar cooling components. Calculation of daylight factors inside all the spaces was carried out using MICROLIT 1.0, a computer program developed in the USA. Thermal comfort was evaluated using the COMFORT computer program developed at the Technical University of Denmark. This determines the predicted mean vote (PMV) which indicates how close to comfort conditions a space is, taking into account indoor air temperature, mean radiant temperature, relative air velocity, water vapour pressure, clothing, metabolic rate and external work.

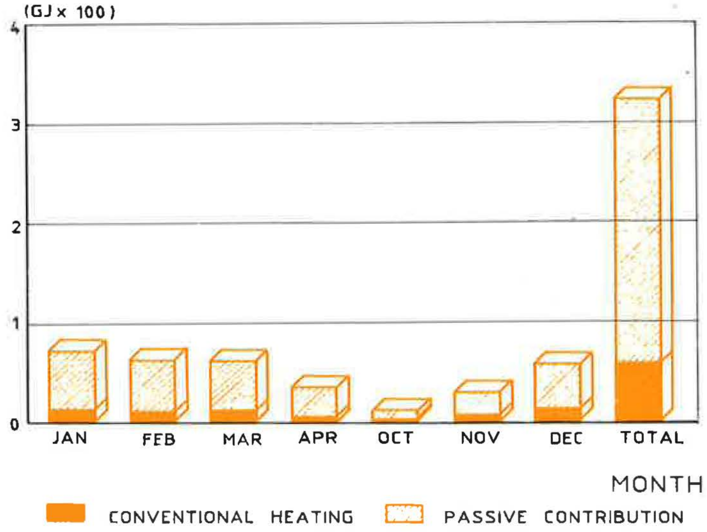


Figure 20. Heating load and contribution made by passive solar features

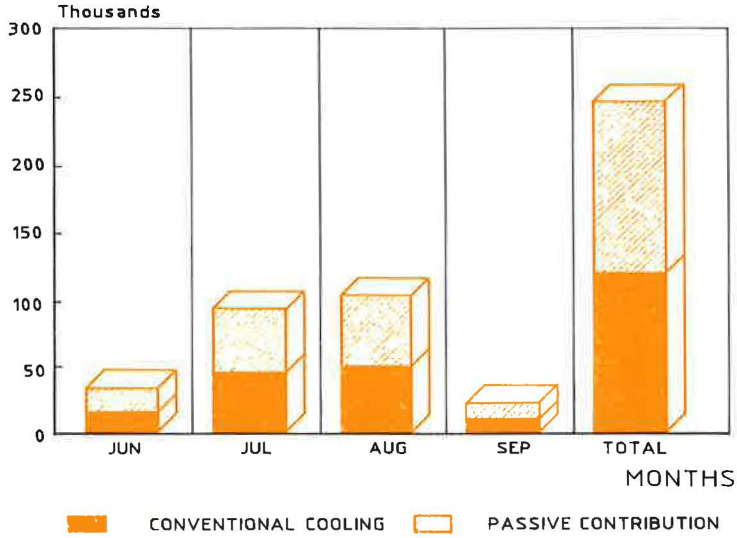
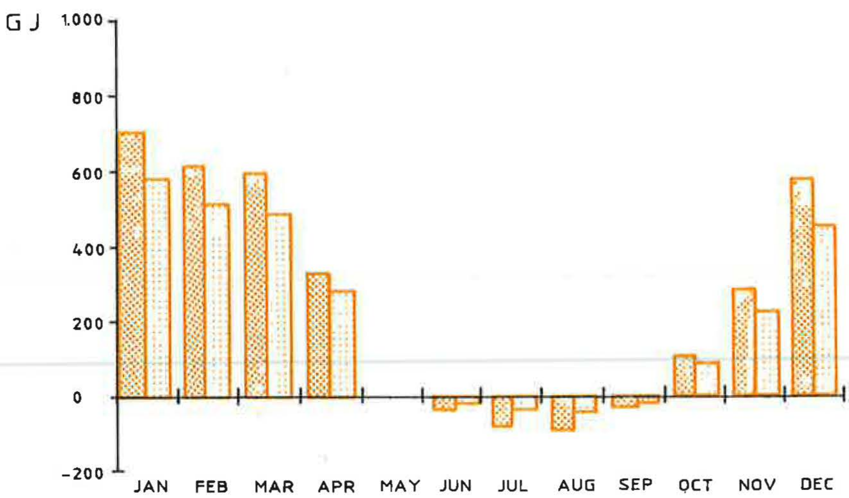


Figure 21. Cooling load and contribution made by passive solar features



Key:

load

contribution

Figure 22. Monthly heating and cooling loads and contribution made by passive systems

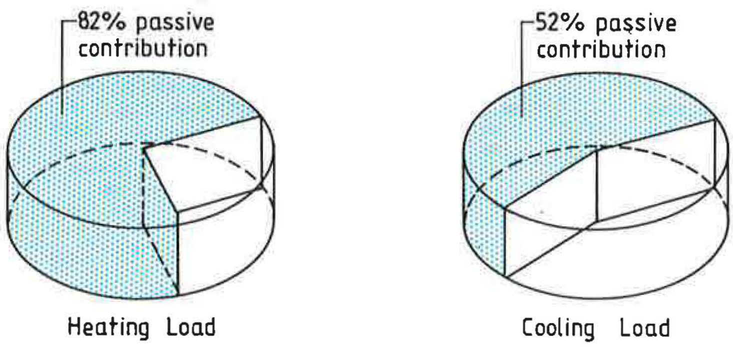


Figure 23. Annual contribution of passive solar systems to heating and cooling loads

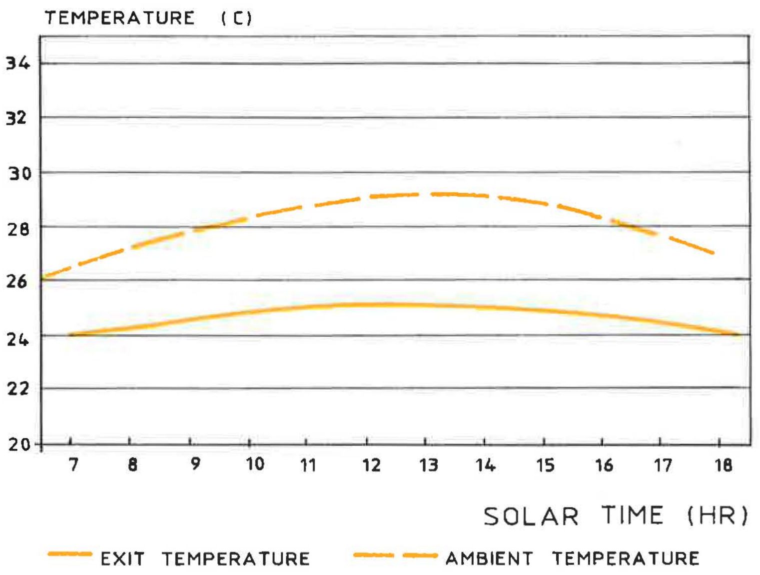
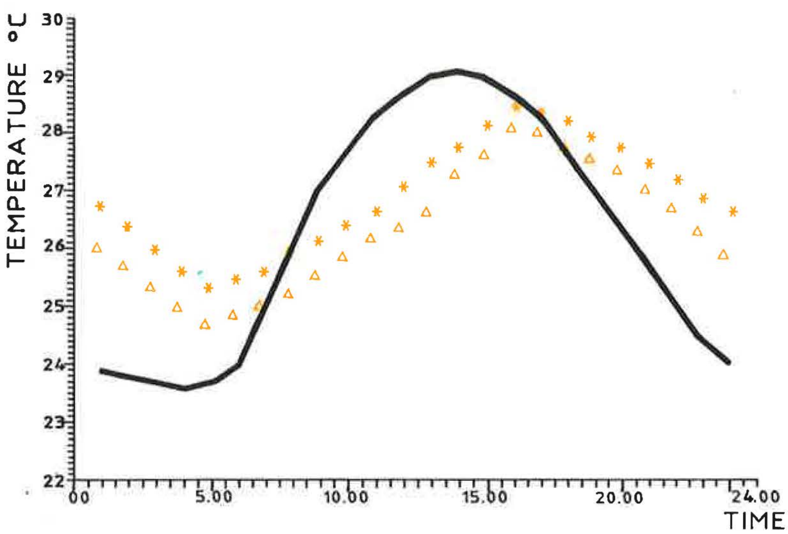


Figure 24. Performance of ground-to-air heat exchanger system in July



Key: 5 air changes per hour
1 air change per hour
ambient temperature

Figure 25. Indoor temperatures of a room in July with night ventilation

Thermal Performance Evaluations

The monthly heating and cooling loads and passive contribution to heating and cooling, together with the internal temperature, were calculated for all the buildings in the complex. Each room in the reception building was treated as a separate zone; the multi-purpose building was considered as one zone; the restaurant building was divided into three (each restaurant was treated separately); each room in the guest room buildings was considered separately. Auxiliary and non-heated spaces were not taken into account. Occupancy parameters for each building type were taken from ASHRAE data. U-values were assumed to be as follows (the units are W/m^2 K): single glazing 5.8; double glazing 3.7; external walls 0.58; floors 0.95; roofs 0.38-0.44. The results are given in Figures 20-23. The passive systems were found to contribute 82% of the total heating load and 52% of the total cooling load.

Performance of Ground-to-Air Heat Exchanger System

The outlet air temperatures likely to result from the tubes in July are given in Figure 24. The modelling showed that the air- to-ground heat exchanger system could provide 30% of the cooling load for the multi-purpose building in June, 37% in July and 43% in August.

Evaluation of Night Ventilation

The effect on room temperature of increasing ventilation rates at night was evaluated month-by-month. Figure 25 shows the results of increasing night ventilation in July from one to five air changes an hour. It can be seen that this technique would decrease the temperature throughout the 24 hours by nearly 1° C. The best contribution to cooling loads is achieved in June - a month when the performance of the ground cooling system is at its poorest. Thus night ventilation and ground cooling can be regarded as complementary techniques.

Daylighting Performance

The results of the daylighting studies at a height 1.5 m above the floor in a 9.5 m² ground floor bedroom with north-facing glazing at 12 noon on 21 December with an overcast sky are shown in Figures 26 and 27. Under these conditions daylighting is independent of orientation. It can be seen that the daylighting is uniform with daylight factors in the range 3% to 9%, except for the zone near the glazing where higher values are reached. Similar calculations for offices produced daylight factors in the range 5% to 13%. The studies showed that daylighting performance is good in bedrooms and offices alike.

Thermal Comfort Evaluation

The results of thermal comfort studies in a bedroom without auxiliary heating or cooling in January and July are given in Figures 28 and 29. In each case, the predicted mean vote (PMV) is perfectly satisfactory, being slightly below the optimum in January and slightly above it in July.

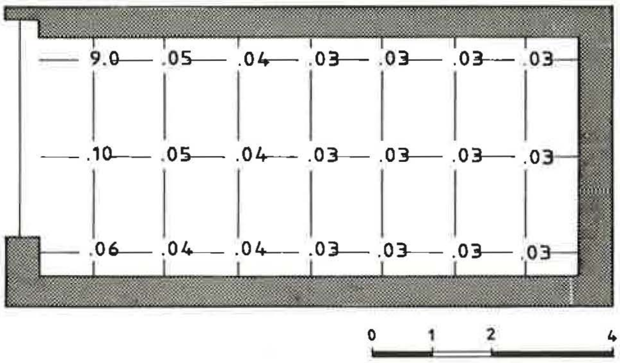


Figure 26. Daylight factor distribution in plan of typical guest room

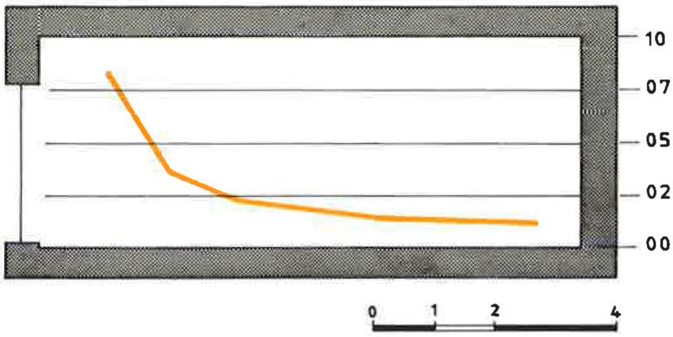


Figure 27. Daylight factor distribution in section of typical guest room

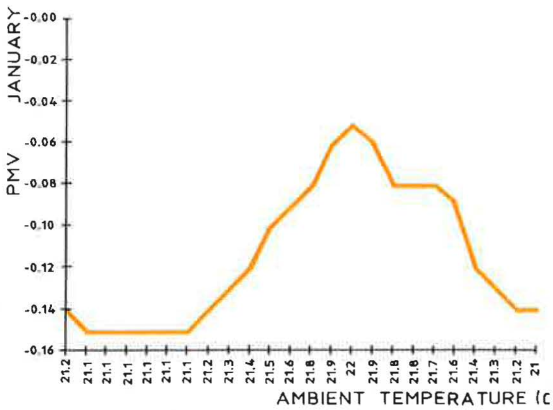


Figure 28. Values of PMV (predicted mean vote) in a typical bedroom in January

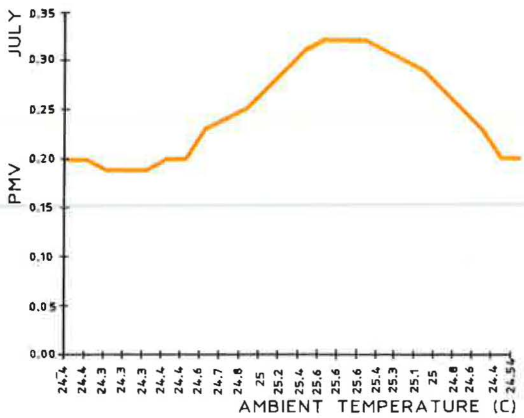


Figure 29. Values of PMV (predicted mean vote) in a typical bedroom in July

GENERAL DESIGN GUIDELINES/POINTS OF INTEREST RESULTING FROM THIS PROJECT

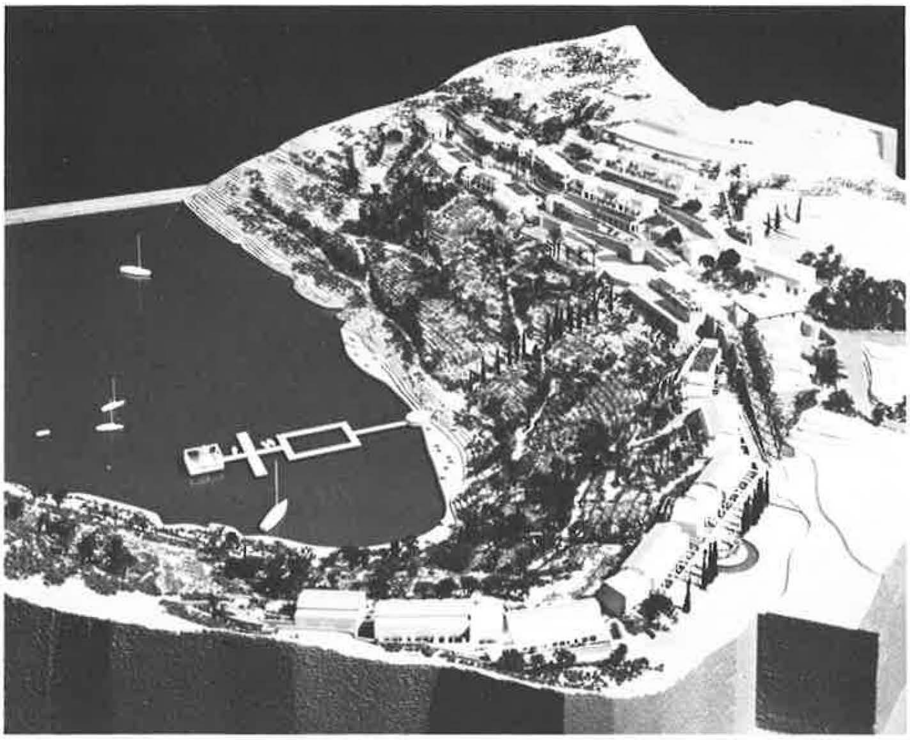


Figure 30. General view of the model of the site

This project showed that, in developing schemes of this sort, the following general guidelines can apply:

- provide a harmonious relationship between architecture, landscape, human intervention and nature, creating a dialogue between design and accident;

- improve the microclimate round each building by using evaporative cooling and shading;

- apply simple but innovative concepts for achieving cooling such as an air-to-ground heat exchange system;

- reduce the use of auxiliary heating, cooling and artificial lighting in comparison with similar conventional buildings;

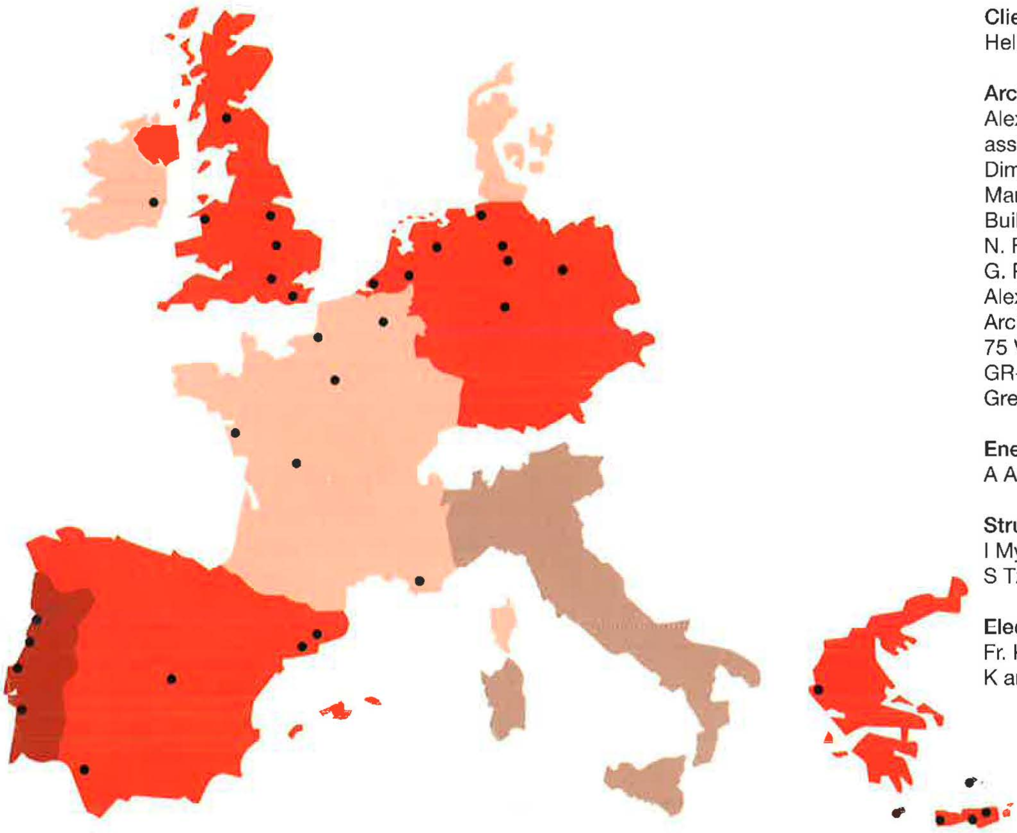
- passive solar features, no matter how important they are to the scheme, need not dominate architectural design;

- encourage social contact and outdoor living in a hierarchy of squares, terraces, secluded corners and open spaces;

- provide links with the past by using classical elements in the site organization and building form.

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 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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