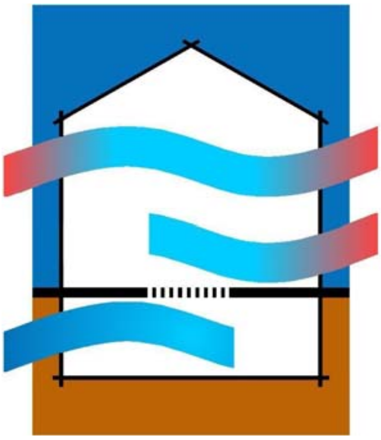
# Coolhouse



# Final Technical Report

## January 2000– December 2003

Energie Demonstration Project NNE5 –1999 -193

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*The National and Kapodistrian University of Athens*

## Summary

The COOLHOUSE project demonstrates the use of passive cooling techniques in southern regions of Europe which are aimed at giving comfortable summer conditions in domestic scale buildings without the use of mechanical cooling systems. The project focussed on three sites, a private development of houses for sale in south west Portugal, an old people's home in south France and a community centre in mid Italy. All are new buildings and were designed to provide cool internal conditions by passive means such as using solar shading and thermal mass, with the addition in all three cases of ground cooling pipes, through which external air is drawn, cooled by the ground and delivered to the buildings when cooling is needed. This combination of measures was designed, constructed and monitored as part of the project. The ground pipe systems used PVC pipes buried 2-3 metres below ground with air drawn through using electric fans. The results demonstrate that the whole package of measures is successful in providing summer comfort, particularly the ground pipes in the Portuguese and French cases, where cool air was always available when external temperatures were high. There is also benefits to the heating of the buildings in winter if the preheated air is used. The project concludes that there are no architectural difficulties in buried pipe system or providing and using internal thermal mass and that the COOLHOUSE package of measures could be replicated in different building types across all southern Europe, and possibly in more northern regions as global warming advances making the requirement for cooling of buildings more common in the future.

## Abbreviations Used

| | |
|---|---|
| AHU | Air handling unit |
| PVC | Poly vinyl chloride |
| OAT | Outdoor air temperature |
| HVAC | Heating, ventilating and air conditioning |
| CPF | Contract preparation form |
| $CO_2$ | Carbon dioxide |
| DT | Temperature difference |

# Contents list

# 1. Project details

**Project Number: NNE5-1999-193**

Title of Project:

**Cooling houses in Southern Europe using innovative ventilation and cooling strategies - COOLHOUSE**

**Final Technical Report**

Period covered: from *1/1/2000* to *31/12/2003*

Date of report: *29/2/2004*

**SESAME-Sheet** enclosed: *yes*

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## *An important note about the COOLHOUSE project*

The project brought together 3 different sites, in three different countries, with 3 different building types to be built, 3 different designers, etc. It is not possible to bring all the final reporting into one set of conclusions. Thus this report has general, and specific descriptions about each site. We think this is important as many readers may be particularly interested in one situation only. Different situations call for very different technical solutions and there is certainly no one set of answers. There are communal conclusions – on thermal mass and the general effects of ground cooling pipes – but for any specific situation consideration must be given to a whole range of issues – ground conditions, temperatures maximum and diurnal, building occupant behaviour (very important), other mechanical systems associated, building design in general, and so on. The project shows tremendous general, and specific potential for improving summer comfort by natural means in south Europe but it is a small project and the range of application is we believe wide. Not all the answers are here.

# 2. Aim and general description

## *Overall COOLHOUSE project*

### 2.1 Aim of the project

The project aims to test the viability of alternatives to air conditioning using passive and low energy construction, cooling and ventilating techniques in Mediterranean and coastal climates and to demonstrate that such strategies can be practical and provide comfortable internal conditions for the occupants. One objective of the Coolhouse project is to reduce the energy demand and the environmental impact of the developments. Another is to provide economic and environmental arguments to justify the cost of the systems and to design and construct ground cooling systems that are easy to replicate at reasonable cost.

The design phase aimed to examine several natural ventilation and cooling strategies, including passive architecture, wind catchers, wind towers, ground pipes, and rock stores. However, the concept of ground cooling systems was common to all three sites. The Coolhouse project finally aimed at the construction, monitoring and publicity of the architectural integration of ground cooling systems with passive architecture in new domestic type developments.

### 2.2 Description of the sites

Three sites were finally included in COOLHOUSE. A new housing development in south west Portugal (Alma Verde), a nursing home in southern France (Frejus) and a community centre in central Italy (Aler Pavia). The developers in each country worked in partnership with energy consultants to achieve the project aims. Each site is described in the sections below.

A fourth housing site, in Crete was included in the original contract, but was never built and the contractor was removed from the project by the European Commission in early 2002 (the advance payment was returned to the Commission by the bank guarantee). The design work on the project was carried out in 2000 by the University of Athens but no further action was taken by the Contractor ElGreco. A search was made for a substitute site in Greece and although a couple were originally identified and contract amendments prepared, it was not finally possible to bring one into the project within the timescale.

### 2.3 Description of the installations

The three sites are different in both location and building type and use and the details of the components and systems finally incorporated into the buildings varies greatly. Each site used its own designers and consultants, though all sites and installations were discussed between the design teams at the regular six monthly meetings. The purpose of these meetings was to exchange ideas, experience and design proposals but not to make the designs similar. The responsibility for the design stayed with the design team on each project, as is necessary for professional liability in each case. This variety also demonstrates that design of passive cooling systems can take on a number of different forms and the results demonstrate that each can be successful.

There is a general level of innovation in all the buildings which is that they are all designed to optimise the use of the local climate. The majority of new construction in hot countries is not designed to work with the climate and produce sustainable buildings, but rather ignores natural and passive design and, building to current regulations produces buildings that need heating in winter and cooling in summer to make them acceptable to occupants. This is very energy inefficient and very different from the COOLHOUSE building design.

The main technological innovation in all three projects is the use of buried pipes to cool external air and draw this into the buildings to provide cooling. This innovation avoids or at least reduces, the need for conventional active cooling using electrically driven compressor systems. The initial design studies showed that fans were necessary to draw the air through the buried pipes and this uses electricity, though considerable less than air-conditioning systems. It is also thought that buried pipes require less maintenance that air-conditioning systems and certainly have a much longer life.

Other building innovations are described in the separate sections, particularly important is the use of adobe internal walls in Portugal.

### 2.4 Description of the performance of the monitoring/measuring system

A monitoring system was designed and installed in each site to assess the energy and comfort performance of the systems, particularly the availability of cooling from the buried pipes and how this could be used in the buildings. Monitoring was carried out on all sites in the summer and autumn of 2003, a hot summer. Details are given for each site below.

## *Alma Verde, Portugal*

### 2.5 Aim of the project

The aim at Alma Verde has been to achieve zero or low-energy comfort cooling of single storey houses where conventional air conditioning might otherwise be installed. Techniques for making active use of the inherent cool and consistent temperatures within the ground have long been neglected as a simple and readily available source of cooling energy. Published estimates of the carbon emissions due to conventional air conditioning of residential buildings across Southern Europe suggest this is currently responsible for around 90 million tonnes of $CO_2$ per year. The aim at Alma Verde has been to research, develop and demonstrate methods of exploiting this available cooling energy by drawing air through ducts beneath the ground, where the low ground temperature cools the air within the ducts.

These aims are exactly as in the original project and contract. Details have been developed during the design process to support the aims (see section 2.7 below) – comfort by passive cooling, avoiding air conditioning, getting cooling from the ground (a renewable resource, zero $CO_2$ emissions), with fan powered ventilation. We believe that the aims have been fulfilled in this project.

### 2.6 Description of the site

Alma Verde is a 35.3 hectare new residential community with numerous public and private amenities located in the unspoiled western Algarve 8km west of Lagos, some 25km east of the tip of Europe. Set in undulating green and partly forested terrain to north, west and south the site is adjacent to the Costa Vicente Natural Park, with the Sierra da Monchique reaching 900m above sea level to the east. The site has for many years been abandoned as agricultural land.

The site is located 2km from the Atlantic coast rising from 12m to 56m above sea level over a water table at about 9m. Its Algarve location ensures winds of varying velocity from the northwest with 90% consistency (335° +/- 10°) which tend to blow from afternoon to evening. The winds relating to the site are affected by the surrounding hills and being in the lee of the Monchique mountains, and are location specific due to both the hilly terrain and the proximity of the Atlantic Ocean to south and west. Whilst the winds temper the heat from the high summer sun at this latitude, the 3000hrs pa of solar exposure can impose serious solar gains unless ameliorated by design. The area experiences very high levels of relative humidity during the winter months.

The site is being landscaped with indigenous varieties of drought resistant planting, and a shelter belt tree planting strategy moderates the effects at ground level of the consistent winds.

In practical terms, energy sources available on site are solar, electricity from the monopolized grid until deregulation, and LPG which is ducted to all plots. The latter is a common source of domestic energy in rural Portugal.

Originally when the project was submitted to the Commission, it was intended to apply the passive cooling measures to a block of 24 houses on the site (the whole development site being much more extensive including apartments, terraces and communal buildings) and the Work Plan in the contract was only designed very vaguely as nothing had been decided or designed. When site design started the first house to be built on the site were the set of 6 detached houses and it was decided to use these to demonstrate the COOLHOUSE principles. Design of the houses and cooling systems started in 2000 and the whole concept of passive cooling, together with the ground cooling systems was developed on a comprehensive basis compared with the original concept. Minutes and reporting at the time described progress.

As the description of the proposed works was defined only in general terms in the contract, the Commission was informed of the proposed changes in the six monthly reporting (approved and resulting in payments) and a meeting with the then project officer, but no formal contract amendment was thought to be necessary as the nature of the project was not changed. (A fuller description is included in our letter of February 2003).

The resulting six houses are an excellent advertisement for the development, one is used as the show house and it is though that this is the best advertisement of passive and ground cooling that could be possible. The subsequent development of the site reinforces this.

## 2.7 Description of the installation

The passive cooling measures were designed and built into the first six houses to be built on the development. These are prestigious detached houses built to a very high standard and were to be used to establish the site and for demonstration purposes. Many options for passive cooling as contained in the original contract were considered and explored for the site and the actual installation is described below.

Ground cooling system.

Standard PVCu drainage pipework was used for the ground pipes, with the widest readily and economically available diameter being 160mm. With this duct size taken into account, computational analysis showed that a duct air speed of 4m/s running through two ground tubes of 25m each would achieve an air temperature reduction of 8ºC at the ground tube outlets. This equates to 2500W of cooling energy. Further, computational fluid dynamic analysis showed internal air temperature reductions of 3ºC compared with outside temperatures, which under most circumstances is considered sufficient for thermal comfort. This would require an effective and simple strategy for cool air distribution within the building, and a thermally efficient building envelope.

It also became clear that direct wind power alone would not be adequate to achieve these duct velocities, and that fan assistance would be required. Also, with wind power only, the system would not operate on still days and these are the days when cooling would be most required.

For the heat sink effect of ground cooling to work, the ground must dissipate the heat accumulated from the cooling ducts. Again, analysis shows a separation between pipes of 2m allows heat dissipation and avoids the cumulative build-up of heat from both pipes that would occur if they were closer together. By the same principle, continuous operation of the ground tubes over a long period of time would also lead to heat saturation of the ground, therefore running times need to allow for this effect. Unavoidable 90º bends in the ground tube layout are formed from two 45º pipe sections to reduce the air resistance encountered with short radius 90º bends, as long radius bends are unavailable locally.

Periodic cleaning of the ground tubes is catered for by installing the tubes with a fall from start to end of about 1: 60. This allows jetwashing from the intake end of the tubes to the low point at the other end, where a sump enables a temporary pump to remove cleaning fluid.

Ground cooling system integration

Discrete integration of the ground cooling system components into the building, and the method of distributing the available cooled air, requires early consideration as part of the construction strategy and detail design of the building itself. Early decisions on the areas and the form of the building to be cooled are also critical, to ensure the volume of the building to be cooled does not exceed the cooling capacity of a single Coolhouse air-handling unit installation.

There is however no theoretical limit to the number of Coolhouse installations. A double system has been installed in one house to enable the separate zoning of daytime living areas and bedrooms to be under independent control and timing. This volume of space would also exceed the cooling capacity of a single installation. In this case, due to limits on available garden area, a single additional third ground tube has been added, which is common to each air-handling and distribution system.

The thermal performance of the building envelope is also significant, as solar gains through openings and heat transfer through the structure will work to warm the interior and reduce the cooling benefit. There are no rule of thumb figures for cooling capacity or spatial volume as these are influenced by many variables and should be calculated for each case.

Mechanical plant

The mechanical components of the system are limited to a single 170W variable speed air-handling unit and attenuator, which reduces airborne fan noise through the duct into the building. The intake of the air-handling unit is connected to the outlet end of the ground tubes, where it pulls the air through the tubes. This avoids pressurising the ground tubes and risking air leakage through below ground pipe connections. The 315mm diameter cooled air supply duct to the building, also a standard PVCu drainage component, is connected to the outlet from the air-handling unit, which drives the cool supply air into the building.

Plant housings

The minimal space requirements for housing the mechanical plant and ground tube inlets reflect their small size.

The ground tube inlet chamber is located on the shady north side of the building to avoid solar gains and keep the temperature of the outside supply air as low as possible. This chamber is only large enough to house the two 160mm diameter pipes, which are set vertically and drop directly into the ground. Fresh outside air is drawn into the chamber through an appropriately sized louvre, protected by an insect mesh. This louvre is removable to allow for cleaning of the tubes and the chamber.

The air-handling unit chamber accommodates the two incoming 160mm diameter ground tubes at floor level, where they are combined and air sealed within a length of 315mm pipe. The unit itself, size 350 x 400 x 725mm, is wall-mounted vertically with the attenuator below leading directly down into the mouth of the air supply duct to the building. The incoming tubes are connected to the intake at the top of the AHU by a short length of flexible duct. A chamber of about 700 x 1000mm is sufficient for a single AHU installation.

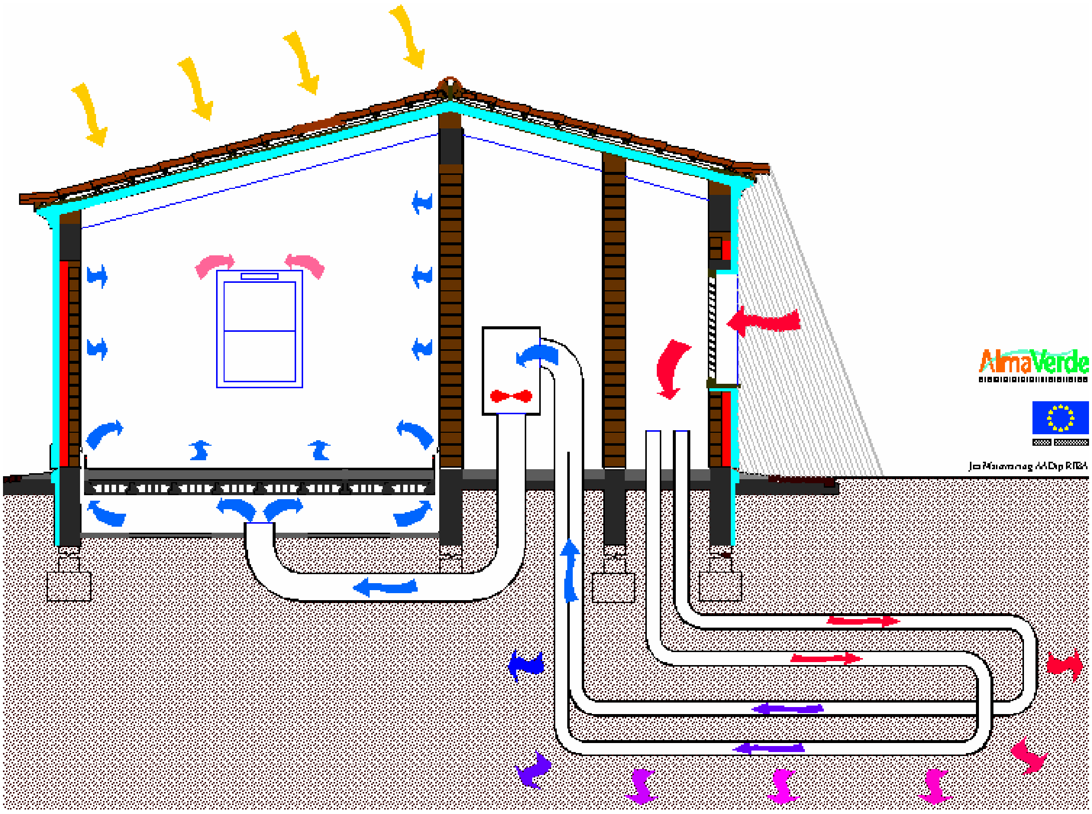
Both chambers are well insulated to keep the air temperature within as cool as possible, and particular attention is paid to sound insulation to inhibit fan noise transmission.

Cooled air distribution

The strategy for distributing the cooled air evenly within the building aims to be simple and effective whilst avoiding the cost and complexity of conventional ductwork. Borrowing the principle of the Roman hypocaust underfloor warm air heating system, cooled air is pumped from the AHU through the single 315mm PVCu diameter supply duct directly into the subfloor void. From the pressurised subfloor void the air exits through discrete slots around the perimeter of the floor slab, discharging directly into the space to be cooled.

Floor slabs are formed from economic conventional precast concrete beam and block construction, bearing on perimeter and intermediate concrete ground beams. Where intermediate ground beams divide the Coolhouse subfloor void, holes are cast through these using 160mm diameter pipe sections as formwork to allow the passage of cooled air throughout the void. Care is taken when casting the concrete topping to the slab to ensure that the perimeter of the Coolhouse void is sealed to be airtight.

Again, there are no rules of thumb to size the outlet slots. These need to be engineered in each case to ensure a balanced and specific distribution of the cooled air from the entire area of the pressurised subfloor void. The cooled air passes behind the skirting and exits through discrete 15mm high vertical slots in the wall surface above the skirting, partially concealed by a plaster detail. The total length of outlet slot to a particular space or room is a function of the volume of the space and variables such as specific solar gains within the space. Typically, a 12m2 room with an average height of 3.2m (the ceiling is sloping) with north facing glazed double doors and a single small south west window, within a well insulated envelope, requires a total of 1.5 linear metres of 15mm wide outlet. In this case this is divided into three evenly distributed lengths of 500mm.



*Schematic of Coolhouse ground cooling system: summer condition- cooling*

## Building envelope

Wall construction in Portugal, in common with many southern European countries, is generally from hollow lightweight terracotta blocks with a painted sand and cement render finish to both surfaces, with minimal insulation. This form of construction has virtually negligible thermal mass with a very limited capacity to store warmth or coolth, and alternative heavy mass building materials are generally not readily available.

The method of construction at Alma Verde has been developed to ensure that both heating and cooling energy is used as effectively as possible. The internal walls and the inner leaf of external walls are built from adobe (sun baked clay) blocks and clay render, which provide thermal mass. These are made on site and are very low in embodied energy. The outer leaf of the external walls is from fired clay Tabicesa hollow system blocks. These have an interlocking profile at vertical joints, which avoids the need for mortar, and therefore allows the adobe blocks the necessary ability to breathe. The fired clay surface provides a good background for adhesion of the 60mm external insulation system, which is finished with a flexible thin coat render system. External insulation also resolves many of the difficulties of construction detail encountered in avoiding thermal bridging, particularly with the concrete structural frame required in seismic areas. The overall u-value of this breathable construction is 0.4 W/m² ºC. Portuguese building regulations currently require a u-value of only 1.4 W/m² ºC.

Roofs are constructed from laminated timber beam rafters with a timber faced sandwich panel deck with 80mm of insulation, and interlocking clay system roof tiles on battens. The u-value of this construction is 0.316 W/m² ºC compared with the 1.1 W/m² ºC required by the regulations.

Windows and fully glazed doors are timber framed with argon filled low emissivity double glazed units, with solar control glazing to inhibit solar gains on facades facing south east round to west. With a u-value of 1.4 W/m² ºC, these greatly exceed the minimum required performance of 4.2 W/m² ºC. Permanent trickle ventilation is fitted to all glazed doors and windows. As well as providing ventilation, these provide an exit route for exhausted warm air as it is displaced by incoming cooled air at floor level.

Floors have a u-value of 0.887 W/m² ºC, and are not insulated below the subfloor plenum. The perimeter ground beams are insulated vertically on the outside to a depth of around 700mm to prevent heat gains from the adjacent ground, and preserve the cool temperature of the structural concrete forming the plenum. The cool thermal mass of the plenum structure and the ground beneath the building contribute to the cooling process.

Adobe has other benefits as a traditional building material as well as its ease of use and thermal storage capacity. Its high density makes it very effective as acoustic insulation, whilst also reducing acoustic reverberation. Its most useful secondary attribute is however its ability to absorb airborne water vapour when Relative Humidity is high, and release it as RH reduces. Monitoring has shown that this attribute in conjunction with Coolhouse ventilation contributes to very significant reductions in RH levels. It is this characteristic that requires that the overall external wall construction retains the ability to transpire.

### Building design considerations

As well as the performance of the building envelope itself, the form of the building also makes contributions to the overall performance of the cooling system.

The control of solar gains remains a balance between achieving some gains from the low winter sun, whilst preventing excessive gains for the remainder of the year. Roof or roof terrace overhangs serve as effective shading devices, and where this is not possible windows with high solar exposure are fitted with timber shutters as well as solar control glass.

The presence of double height spaces is also beneficial, either as entrance halls or within the living areas themselves, perhaps in conjunction with mezzanine decks, as these provide a volume of space at high level to where warm internal air can rise. This happens naturally, but is also promoted by its displacement with incoming cooled air. Opening of windows at high level within these double height spaces allows the warm air to ventilate naturally and prevent heat build-up.

### Integration of systems

A low temperature radiant heated skirting system provides space heating within the Coolhouse villas. This is a 140mm high aluminium section carrying an integral copper pipe wet heating element, with an output of 180W per linear meter. This system allows freedom to place furniture anywhere, and has the advantage over a conventional radiator system in that hot and cold spots are avoided. As well as being a radiant heat source, warm air is distributed evenly throughout the room by a continuous slowly rising convective air current. This is in contrast to the faster moving concentrated convective currents generated by the higher surface temperatures of conventional radiators, and contributes less to the airborne distribution of dust and mites. Importantly, this heat source runs continuously along the foot of the walls where, during the heating season, it works to maintain the temperature of the thermal mass.

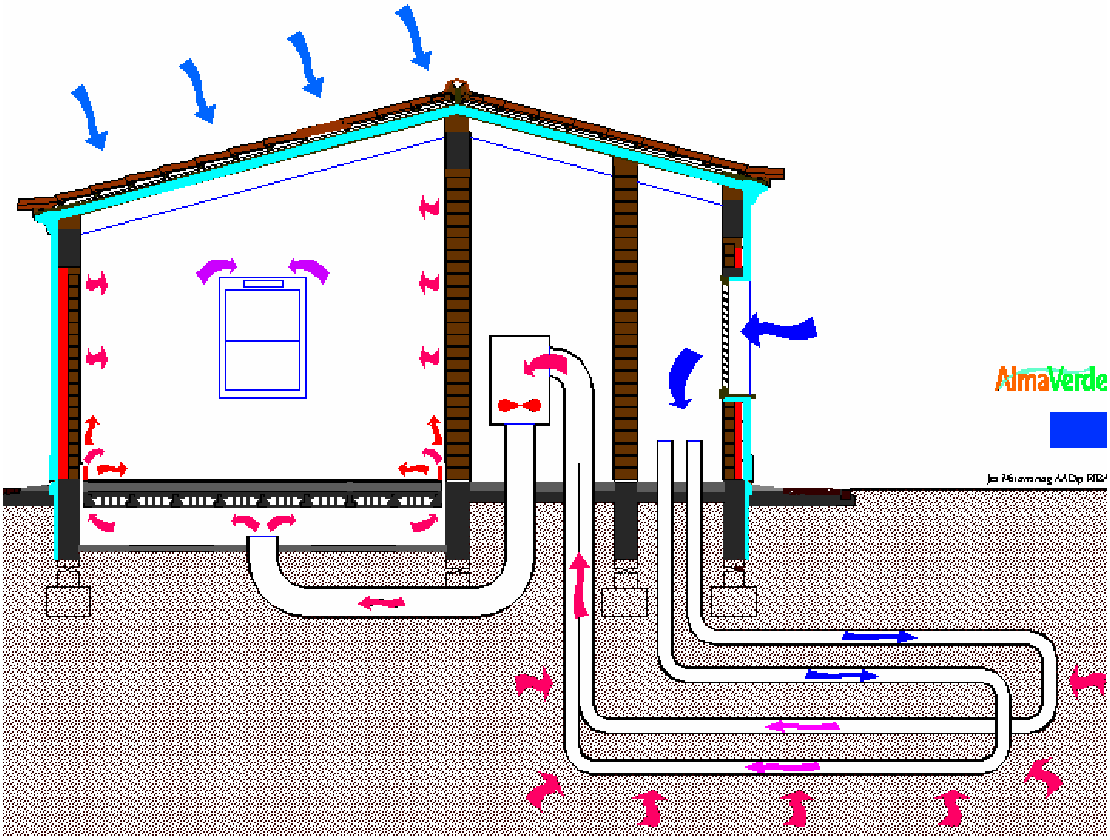
This system is significant for the operation of the Coolhouse system in winter mode. The incoming air passes behind the radiant skirting to the outlet slots in the wall immediately above. The skirting has the structural strength and stability to span the length of the outlet slots. During the heating season, cold outside air drawn through the ground tubes acquires warmth from the ground rather than losing it, thus providing useful low level ventilation preheat. Monitoring indicates that the temperature of incoming cold outside air is being raised to near the below ground soil temperature. This pre-warmed ventilation air then passes across the heated skirting where its temperature is raised further. Operation of the Coolhouse system in winter mode therefore enables fresh ventilation air within the building without the discomfort of cold draughts.

A 97% efficient modulating condensing gas boiler provides hot water for domestic and heating use.

## Controls

The control system for Coolhouse is designed to be as simple and usable as possible. The primary controller is an adjustable timer. This runs the system automatically to the user's pre-set time and duration, and has a manual on/off override.

The second separate controller sets the system to either winter or summer mode, and contains the fan speed controller. In winter mode, when the Coolhouse fan is running and drawing in pre-warmed ventilation air, the skirting heating system is automatically turned on. This overrides any pre-set heating system timings and is to prevent accidental intake of air at cooler than desirable temperatures.



*Schematic of Coolhouse ground cooling system: winter condition- pre-heating*

## 2.8 Description of the performance of the monitoring/measuring system

Three houses were chosen to be monitored, the first house, number 54, was to become the show home of the development. The second, house 56, had been sold and at the start of the monitoring program was being completed i.e. having fixtures and fittings added and being painted internally. The third dwelling, house number 57, had been sold and was occupied by a retired couple who had been living there for a number of months before the start of the monitoring program.

Hobo H8 loggers were used to monitor temperatures and humidity in the three dwellings as shown below. An additional Hobo unit was installed on an external wall, sheltered from direct sunlight and weather, of house 54 to monitor outside air temperature and soil temperature. Ground tubes are buried 2 meters underground, monitoring the soil temperature at this depth in the same ‘parcel’ of land as the ground tubes gives an indication of the heat sink characteristics of the soil.

House 54

- One in the master bedroom.
- One in the secondary bedroom.
- One in the main living room.
- One on the air intake.
- One on the air intake after ground treatment.

House 56

- One in the main living room.
- One in the secondary living room (study).
- One in the master bedroom.
- One on the air intake.
- One on the air intake after ground treatment.

House 57

- One in the main living room.
- One in the master bedroom.

External monitoring

- One attached to an external wall, away from the prevailing sun direction to monitor O.A.T. and soil temperature at a depth of 2m.

Tiny Tag Plus Re-ed Count meters used in conjunction with Compact Electrical Unit Consumption Meters were installed in each of the fan rooms to monitor the kWh consumption of the fans and to obtain a load profile of when the Coolhouse system was operating.

The consumption electrical meters were wired into the main power supply for the fans to provide a visual account of the kWh consumption. These units gave an electrical pulse at a calibrated rate whilst the fans were operating which were logged by the Tiny Tag loggers to provide a load profile.

House 54 is unique amongst the present Coolhouse villas in that it has two Coolhouse systems i.e. two sets of fans, two separate ground tubes, two controls etc. These systems supply air to separate areas within the house, one area being the master bedroom and the second bedroom and the other being the main living room, the second living room and the hallway area.

The monitoring program started officially on 14th July 2003, there had been preliminary monitoring during September 2002, however, this mainly concentrated on establishing flow rates and observing the initial construction stage of the houses. In July 2003 the loggers were installed in the positions outlined.

During a week of intensive monitoring various different scenarios were experimented within the dwelling i.e. monitoring with windows and doors opened, with doors closed, with electric radiators on to simulate habitation.

However, the construction method of the buildings i.e. highly insulated with high thermal mass resulted in long lag times between ventilation activity and response.

To achieve long term monitoring, which would take into account the lag times of the building, the temperature/humidity loggers were set up to monitor conditions every half an hour and left in-situ until 15th January 2004.

The Coolhouse system was set to operate at set times as shown below:

House 54 - 14:00 – 23:00 - seven days a week.
Changed later to 18:00 – 06:00

House 56 - 14:00 – 05:00 - seven days a week.

**House 57 -14:00 – 06:00 -seven days a week**

## *Frejus, France*

### 2.9 Aim of the project

“L’Aubier de Cybelle” is a 80 beds care home for elderly people, which has been built in Fréjus, Southern France (Provence Region).

It has been designed to response to high quality standard, in terms of comfort and environmental issues at all levels (inside the building, locally and more globally), and to be the very first “green” nursing home available in the south of France, using in particular bioclimatic and passive cooling design.

Hence, as it will be detailed below, it uses a large number of green building specifications, and, in particular, numerous energy efficiency solutions, for the winter and the summer. Low energy cooling technologies and systems such as vegetal and architectural solar shading, high thermal mass, natural and night time forced ventilation and ground cooling have been installed, and will allow the building to reach summer thermal comfort without using classical active air-conditioning.

### 2.10 Description of the site

- Name : Maison de Retraite avec Section Médicalisée “ L’Aubier de Cybelle ”
- Location : Fréjus (Var Department) – South West Mediterranean zone - France

- Owner : SCA " l'Aubier de Cybèle", representated by Chantal Mérel and Sylvie Demonien (Directors)
- Environmental Management and Energy Efficiency design assistance : Robert Celaire, ingénieur conseil , Concept Energie, Lambesc (France)
- Architects : Yves Guiter et Daniel Tournaire, Villeneuve les Avignon (France)
- Mechanical, HVAC and Electrical Design : BETSO, Montpellier (France)
- Land surface : 13 250 m2
- Building surface : 3950 m2
- Works duration : 2000 – september 2003
- Budget : 4M euros

The building is situated in a suburban area of Fréjus, mainly occupied by private houses, in the area of La Tour de Mare. This area is in an expansion phase and and offers a dynamic commercial zone with all the services elderly people can need : hairdresser, pharmacy, bakery, medical center, post office, etc.

It is situated less than 3kms from the sea, and is only a few Kms far from the A8 motorway.

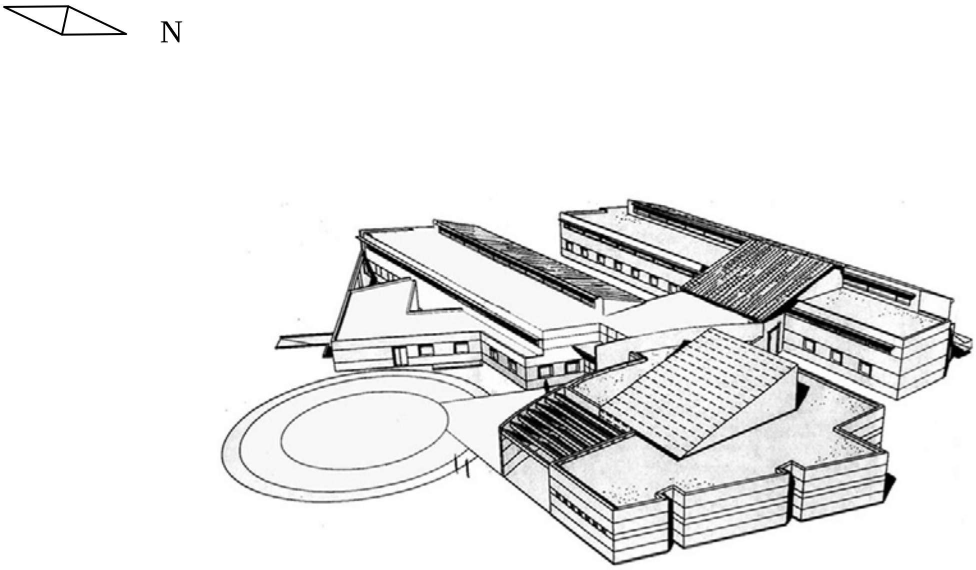
Situated on the Mediterranean eastern coast of France, Fréjus is a touristic town of the French Riviera (latitude 43,26° N – longitude 6.44° E). It shows a typical Mediterranean climate with fairly mild and sunny winters, and hot and dry summers. Both seasons have high daily temperature gradients.

| Frejus Saint Raphaël : climatic data | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Winter | Heat. DD:1425 | | Summer | Av Max :29,1°C | | | | | | | | | |
| | Heat. days : 168 | | | Av min : | | | | | | | | | |
| Heating design T : 0°C | | | | | | | | | | | | | |
| | J | F | M | A | M | J | J | A | S | O | N | D | year |
| | | | | | | | | | | | | | |
| Monthly Average Tmax | 13 | 13,2 | 15 | 17 | 21 | 24 | 27 | 27,2 | 25 | 21 | 15 | 13 | 19,4 |
| Monthly Average Tmin | 2,9 | 3,5 | 5,1 | 7,5 | 11 | 15 | 17 | 16,4 | 14 | 11 | 6,7 | 3,7 | 9,4 |
| Monthly Average T | 7,7 | 8,4 | 10 | 13 | 16 | 19 | 22 | 21,8 | 19 | 16 | 12 | 8,5 | 14,4 |
| | | | | | | | | | | | | | |
| P.P.S | 53 | 55 | 59 | 66 | 68 | 72 | 83 | 78 | 70 | 61 | 51 | 50 | 66 |
| | | | | | | | | | | | | | |
| Deg. Days | 323 | 278 | 250 | 161 | 76 | 14 | 1 | 1 | 13 | 83 | 194 | 291 | 1685 |
| | | | | | | | | | | | | | |
| Av wind speed | 4,5 | 4,8 | 4,6 | 4,4 | 4 | 3,8 | 4 | 3,9 | 4 | 4 | 4,6 | 4,6 | 3,9 |

The site's topography has a gentle south facing slope facilitating bioclimatic design. It is a naturally wooden plot planted with a natural grove of pine trees, most of which have been preserved throughout the construction process .

## 2.11 Description of the installation

Because of the particularly climatic conditions in Fréjus, and the appropriate choice of land, the building has been largely opened towards the south, allowing the best use of natural conditions for passive heating and cooling, and natural light.

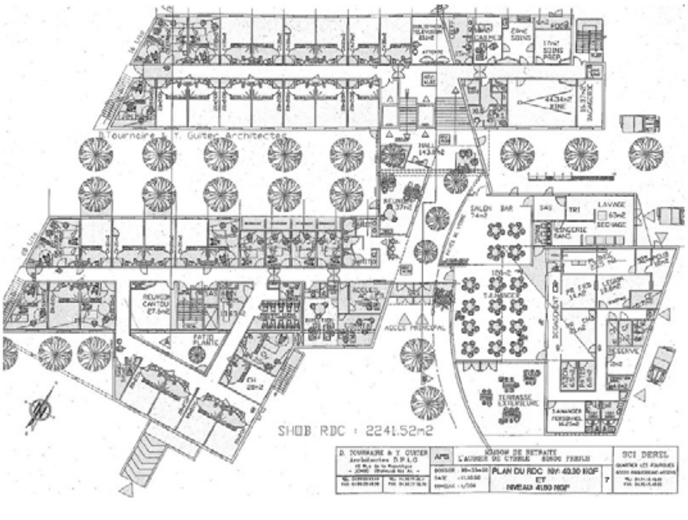


The building, on two levels, covers a total surface of 3950 m2. Four functional units are available :

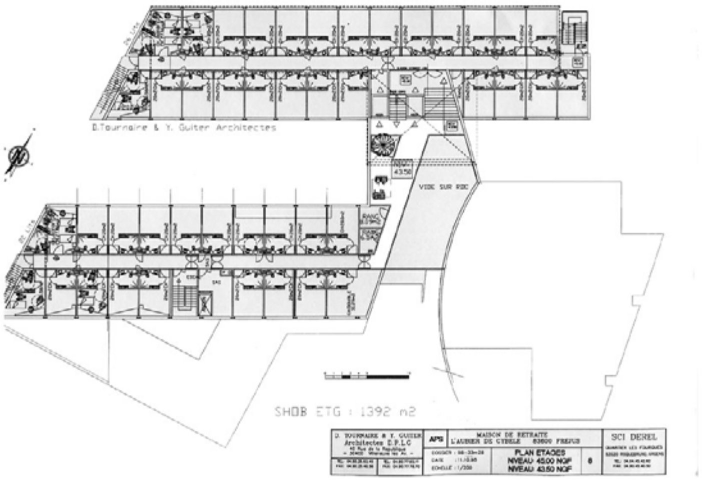
- two 2 level wings spread along an East-West axis with the single rooms for the residents (all equipped with small bathrooms) ;
- one area for the common spaces (entrance hall, dining room, living rooms, activity rooms), the kitchen, and the laundry ;
- one area for the offices and administrative areas.

Technical rooms for storage and HVAC systems, and parking are located in the basement of the building.

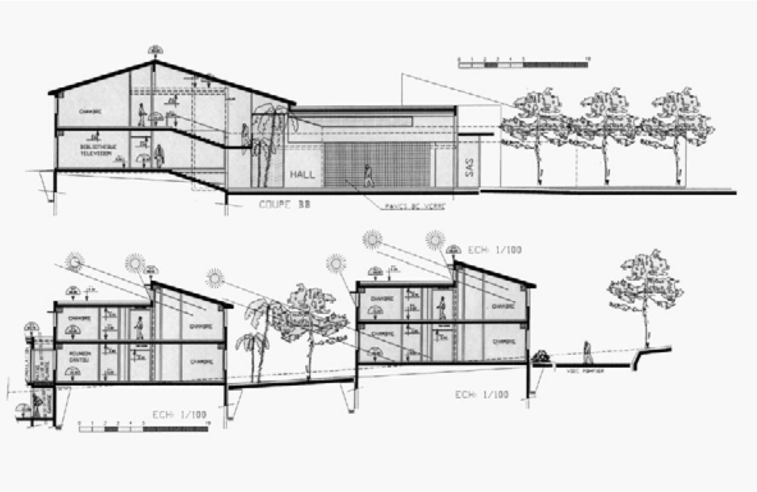
A large garden surrounds the whole building, and patios separate the two wings.



Ground floor



First floor



The building, as a green building, presents as many environmental friendly technical solutions as possible, within a limited budget and within a severe regulation framework related to public buildings in the health sector. Energy efficiency, at the very beginning of the project, throughout all the construction phase, and now during the building's exploitation, has always been a priority, as it is directly related to comfort and health, and economical optimisation including in particular life cycle cost analysis.

Therefore, the energy performance of the whole building, for all energy uses, in summer and in winter, was put forward at every stage and thoroughly studied. The main energy characteristics of the technical solutions applied to the building are detailed below, and expected energy performance is reviewed. A complete list of the technical solutions applied to the building is also attached to the present report (annex I).

In order to reach the best possible energy performance, the occupants behaviour has also been taken into account : special information will be given to the employees, maintenance contracts and processes taking into account energy efficiency will be applied. This work is due to start at the very beginning of 2004.

| **Energy use** | **Main technologies installed** |
|---|---|
| Heating and cooling | • Bioclimatic design : adequate land to use natural energy and climatic resources as possible (sun, wind…) and appropriate landscaping ; best possible orientation of the building (NS axis), with large openings towards the S and minimum opening E and W ; tree planting for solar shade, protection from the wind…; heavy thermal mass ; reinforced thermal isolation regarding regulations ; passive solar gains and appropriate solar shade systems<br>• Ground cooling and preheating system for the dining room<br>• Night forced ventilation during the summer ; minimization of the internal heat gains…<br>• High efficiency gas boilers |
| Hot water | • Solar heater (70 m2 solar panels)<br>• Low water consumption equipments for the kitchen and bathrooms |
| Laundry and kitchen | • High efficient equipment for cooking, washing and drying<br>• Direct use of hot water from the boiler and solar plant |
| Lighting | • Reinforced natural lighting (large S openings, roof windows…)<br>• High efficient equipment |
| Other uses | • High efficient equipment (computers, motors, ventilators, lifts etc…) |

Expected energy consumption

Energy consumptions of the buildings, for the different uses, have been calculated, and will be monitored and compared to these provisional figures for the next two years.

They are here compared to the energy consumptions of a standard care home for elderly people, in the same area (Mediterranean French coast), where gas heating and electrical air-conditioning is usually installed.

| **Energy use** | **Fréjus care home Annual energy consumption in kWh/m$^2$** | **Standard care home Annual energy consumption in kWh/m$^2$** |
|---|---|---|
| Heating | 77<br>(bioclimatic design + gas) | 148<br>(gas) |
| Cooling | 0<br>(bioclimatic and passive cooling design – the ventilators' | 50<br>(centralized air-conditioning |

| | | |
|---|---|---|
| | electricity consumption are included in other uses | |
| Hot water | 18<br>(solar and gas | 52<br>(gas) |
| Cooking | 12<br>(gas) | 15<br>(gas) |
| Lighting | 18<br>(natural lighting + high efficiency equipment) | 30<br>(standard) |
| Other uses | 15 | 27 |
| Total | 140 | 322 |

The total annual energy consumption of the building has been estimated to reach 553 MWh and represents 57% less energy than for a standard similar building. This will represent more than 58 000 euros (VAT included) of financial economy each year.
The ground cooling system will allow the building to avoid centralized air-conditioning and consume 47 MWh less electricity every year (which represent the air conditioning energy needs for a similar building, with the same thermal characteristics of the envelope).

For a standard building, in the region, not using bioclimatic design, the air-conditioning would reach 50 kWh/m2/year, thus 197 MWh a year (which represents 35 % of the energy consumption of the high energy efficient building).

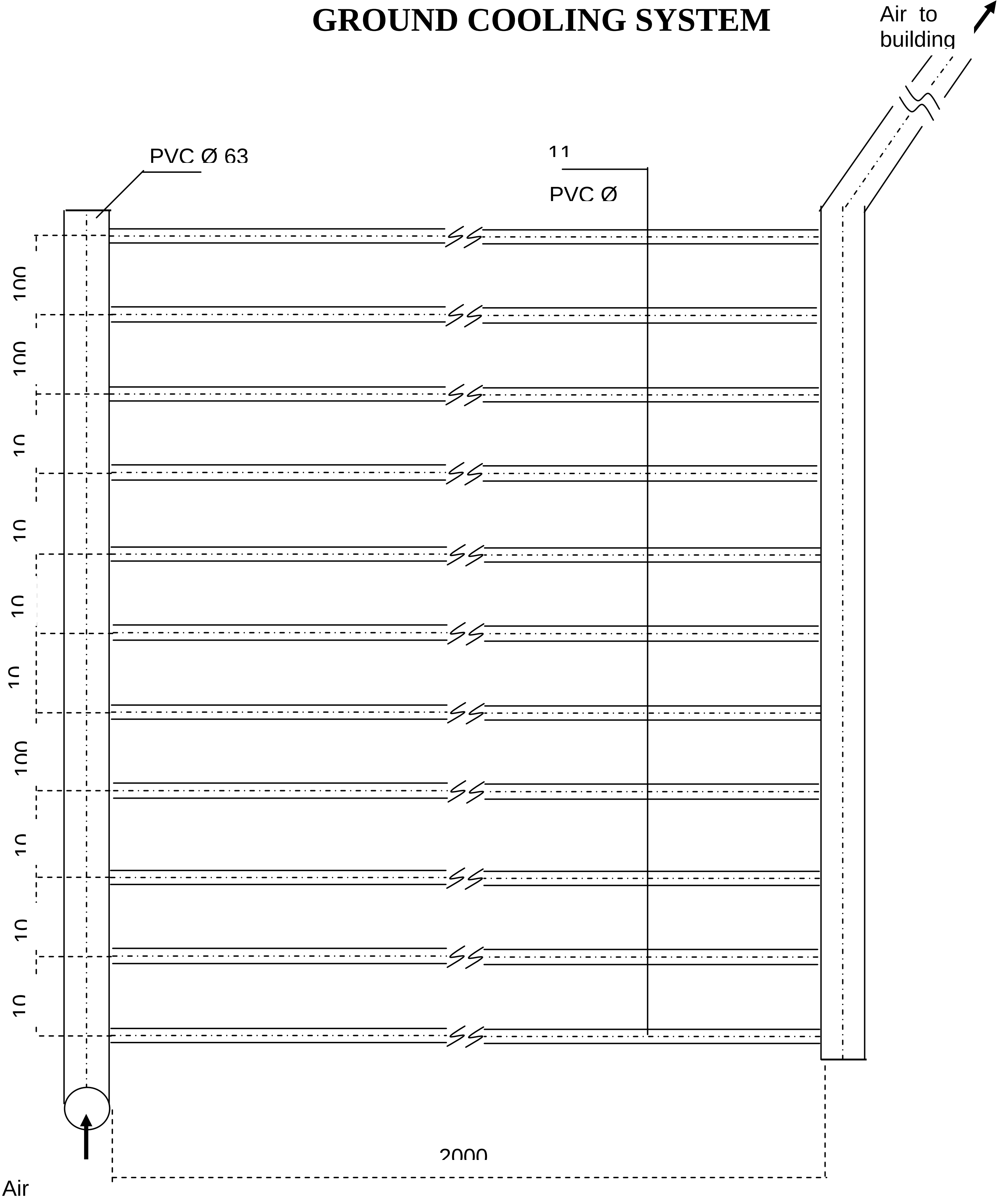
### Passive cooling solutions

As mentioned above, all the technical solutions adopted to reach summer comfort without having to install centralized air-conditioning are described in Annex I. Among these solutions, the most innovative (mainly because very few installations of this type exist in this area) is a ground cooling system for the dining room area (380m2), for which a grid of 11 pipes (0,2m diameter) has been buried 2m under earth (covering 400$m^2$ area outside).

In the summer, the refreshed air from the ground system is forced into the dining room, from an outlet in the ceiling, after passing through a centralised air treatment system (ventilator + filter).

In the winter, preheated air from the ground system is ventilated in the same area.
Associated to all the other passive solutions, this ground cooling system avoids centralized air-conditioning and allows, at the same time, the best use of natural light without over-heating.

# L’Aubier de Cybele
# GROUND COOLING SYSTEM



## 2.12 Description of the performance monitoring and measuring system

Thermal tests were performed on the ground heat storage device. Temperature and relative humidity at the air intake and the air outlet were recorded in 1-minute to 30-minute intervals using autonomous “Testo 175” logger units. All temperature sensors were checked using a hand-held thermocouple thermometer.

Outlet airflow velocities were recorded using a hand-held anemometer at different representative locations.

At 14 points, ground temperatures were measured twice weekly at 1 and 2m depth by resident thermocouples placed in tubes for inspection or replacement.

This monitoring was launched in June 2003, and lasted the two full months of summer 2003 for the air measures, before the measurements had to be stopped to allow the last fittings of the climatic equipments in the building before the opening. A second monitoring campaign started in December, and will continue for the next two years.

The ground temperatures’ measuring also started in June 2003, and is still going on.

## *Aler Pavia, Italy*

## 2.13 Aim of the project

The Pietrasana neighbourhood, Vigevano, Italy, is an area of existing social housing undergoing refurbishment, within a programme of the Ministry for Public Works. The district consists of 220 dwellings located in 10 buildings. The central courtyard area has been completely re-designed and a new community centre built. The centre, which is the “COOLHOUSE” building – named “CircoLab” -, is a multi-functional facility with corporate, conference, recreational, cultural and community functions.

The “CircoLab”, now completed, is going to be managed by a neighbourhood association that covers its running costs.

Therefore, the minimisation of the running and maintenance costs was a relevant point in the “CircoLab” design. A mechanical ventilation system connected to air solar collectors – during the winter season – and to the ground cooling duct – during summer – provides a reduction of the heating/cooling costs, and an improvement in comfort of users.

The general aims of the Aler Pavia project are the same as the general aims of COOLHOUSE, using passive and low energy techniques to provide comfortable conditions for occupants. Ground cooling pipe systems were always seen as an important component of this in all COOLHOUSE projects. The integration of the measures into the CircoLab is different from the other two projects as the building construction and systems are different and rely on mechanical ventilation. Several other measures have also been included.

## 2.14 Description of the site

The original project as identified in the Contract envisaged the construction of two buildings in the community, the Circolab and an Old People’s Home, both of which were to use the COOLHOUSE measures. As the project started there was a policy change by the Municipality and it was decided that the old people's dwellings would be distributed around the site rather than concentrating them in one new block. Thus the Old People's Home was not built. At the same time the size of the CircoLab was increased and it was decided to concentrate the resources of the project on the one building.

The Commission was informed of the proposed changes in the six monthly reporting (approved and resulting in payments) and a meeting with the then project officer, but no formal contract amendment was thought to be necessary as the nature of the project was not changed. (A fuller description is included in our letter of February 2003).

The CircoLab demonstration building is located in the centre of an homogeneous residential area modelled on the garden city, without any particular architectural quality; for this reason the surrounding open spaces, dense with trees, create and idea setting for an architecture in symbiosis with them.

With a rectangular plant, upon only two levels plus and underground space used as warehouse and heating room, it is closed on every side by a green wall, made by a dense cover of parthenocissus tricuspidata, climbing deciduous ("caducifoglio") which gives it a mutant character in accordance with the season.

The work was inspired by the strong knowledge that nature, raw material for the building of the landscape and of gardens, is something alive, ever changing and constantly evolving. It is not only the project of a building - garden, minimal bucolic architectural intervention leaving to the Nature the major role for the outer sides; this apparent simplicity will give to this work the air of experimental laboratory, of ideological test by giving back to gardening a privileged role. It's a garden in a garden.

You can be surprised by the ambiguity between the freedom in the use of Nature and the utmost attention and respect for the "green world", for its growth, its cycles. The result is a building, whose refined luxury lives in the controlled balance of its composing elements.

An architectural programme which becomes an excuse for a new "modern garden"; an enormous green block, almost a sculpture of “topiary art”; a project with a new sensibility, which is architecture, landscaping and sculpture; an architectural garden, surrounded by a smaller garden, in which the public can identify itself easily fully respecting Nature.

Inside the building with a rectangular plant the subdivision are obtained by taking away four patios by inserting two blocks measuring 6.7 x 5.7 meters, the first for the lavatories and the second for the vertical connections.

The purpose was to create an architecture not recognizable at a first glance, whose green facade is a neutral background to the buildings already existing in the area, in a way to multiply the idea of emptiness, of green space, of a garden. This facade is not only the symbol of the merging between Nature and Architecture, but it contains also an ecological idea of climatization of the building.

The main entrance from the South Eastern corner of the building, facing the entrance in the main courtyards for pedestrians, is indicated by an open "atrium" opening on a dehor, the base of a fountain and of the sculptured barbecue.

Inside, the building, at the ground level, has been conceived as an open space deformed by the “opaque volumes" of the lavatories and of the vertical connections and by the "volume" distributing the light of the only patio, among the fours, to get to the ground; together with the entrance, also the space dedicated to the cafeteria opens directly, in a way almost to share with it the nature of interfering space, while the wide multifunction room opens on the artificial nature of the courtyard, sharply filtering the daily reflexes.

On the first floor respecting the plan the division of the spaces are more defined, the courtyards multiplies compensating the absence of views on the outside if not through the courtyards themselves; this follows the idea to create spaces separated from the noise and disturbances of the streets.

Three of these spaces open onto the courtyards are able to access them, on an exclusive basis, by using the external space which continues from the teaching room, so to create favourable situations for concentrating and learning; in the hallway, the floor made by a metal griddle is functional to the natural climatization system.

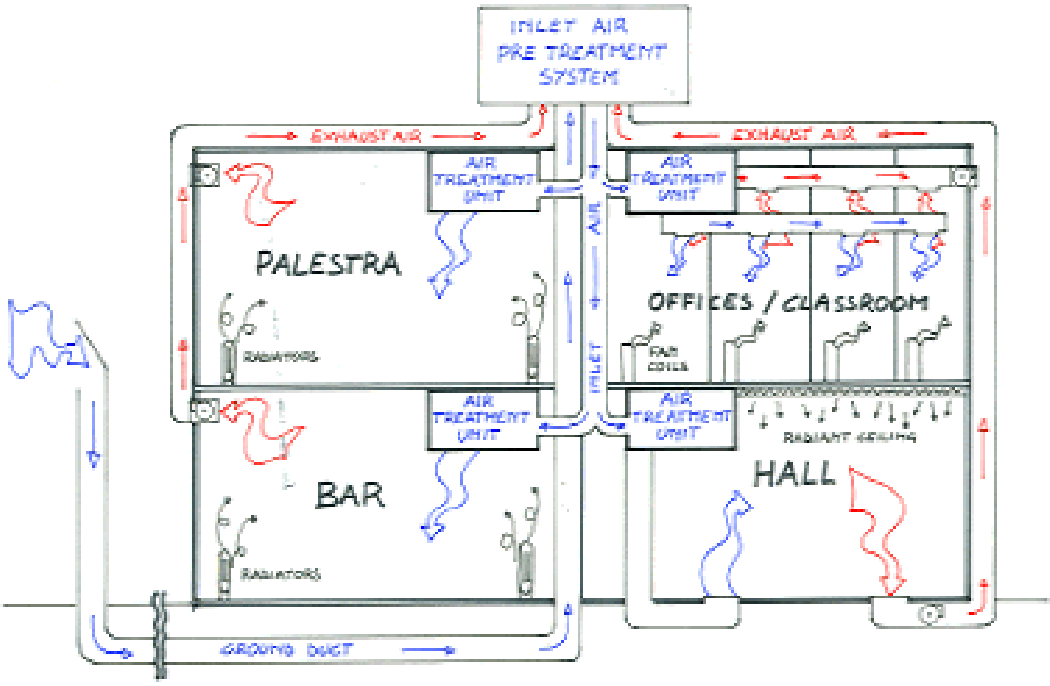
## 2.15 Description of the installation

Building

The building is a concrete box (16 x 24 x 8m), cut by two internal glazed patios along the longest walls, and completely greened by creepers. The visual connection with neighbourhood is given by a large windows on the East side, in front of the central courtyard, while a door on the S/E corner provides the access.

Excluding vertical and horizontal connections, the CircoLAb can be divided in four areas, two for each storey:

- Bar area, opened along all the day (10-23), meeting point of the neighbourhood with rising crowding from morning to evening.
- Multi-functional hall, used mainly during the evening for events (theatre, music, movies, etc.), assemblies and feasts (birthday party, etc.).
- Sport hall, spot opened during all the day (10-22) depending the different courses and activities.
- Offices and meeting room, with an irregular use, mainly in the afternoon and evening.



## Low Energy Technologies

### *Passive Cooling*

The passive cooling of the building is provided connecting the system for the mechanical ventilation with a ground cooling system, which core is made of a PVC pipe - diameter 0,4 m, length 40 m - buried 4 m under the ground level, taking the outdoor air from a shadowed area at the opposite side of the courtyard.

An air-to-air heat exchanger provides the connection between the ground pipe and the ventilation system, avoiding any possible air problem coming.

At night, the building is cooled taking the air directly from the roof, when the outdoor temperature falls below the internal one, giving the ground cooling system time to “re-charge”.

### *Air solar system*

During wintertime, the system for the mechanical ventilation is connected to a set of glazed air solar collectors (about 36 m2), placed on the CircoLab flat roof, which provide the pre-heating of the inlet air. Special shaped metal stands provide the integration of the collectors with the building architecture while give the system an high visibility.

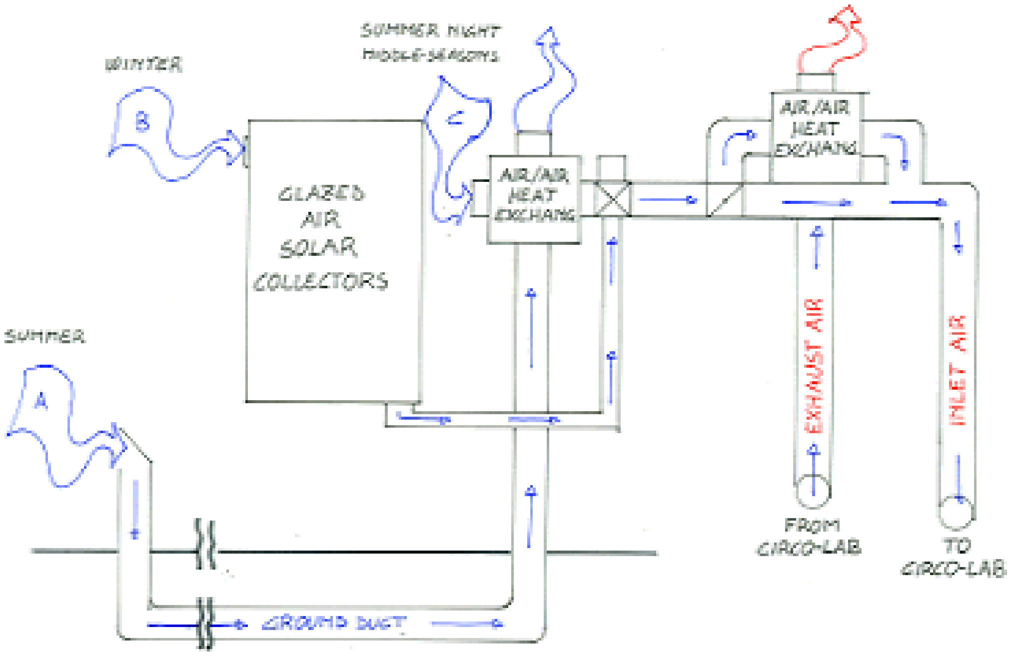
### *Heat recovery*

A mechanical system provides the extraction of the exhaust air from the building and, through an air-to-air heat exchanger, pre-heat the inlet air when the air solar collectors do not work.

### *Radiant system*

A radiant system, placed on the ceiling of the large multi-functions room of the CircoLab, integrates the ground cooling system during the most crowded moment in summertime. The radiant ceiling will be connected to an dedicated heat pump which will start only when the ground cooling system will be unable to provide thermal the comfort in the room.

The radiant ceiling will be connected to the district heating system during wintertime. Its radiant effect will reduce the temperature required to the ventilation air to maintain the comfort within the room.



The strategy of the indoor climate control (heating, cooling and ventilation) is driven by the following conditions:

- high variability in use and crowding of the different rooms during all the opening time of b the CircoLab
- outdoor continental climate (warm summer and cold winter) very humid (river and rice fields in the neighbourhood)
- passive ventilation prevented by architectural and technical problems (greened facades, mosquitoes, safety from intrusions, etc.)

<u>General features of the installation</u>

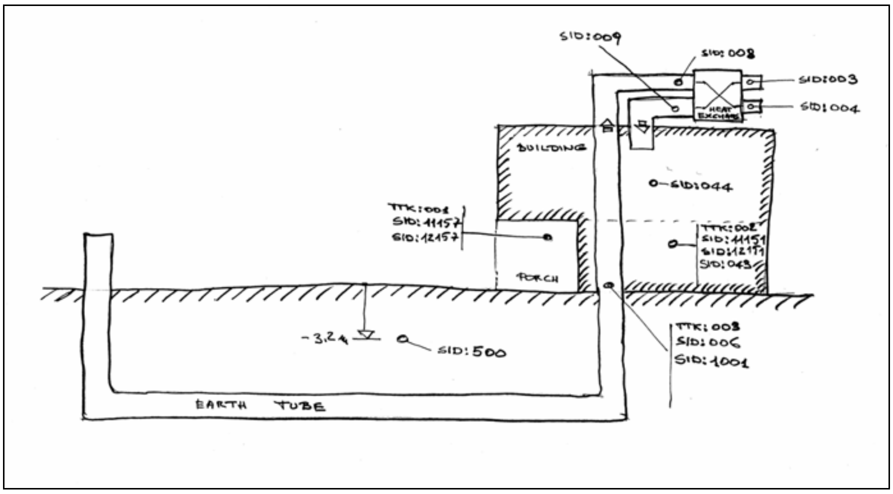
Main indoor climate control through four air treatment units, one for each of the functional areas of the building

1. central duct distributing the fresh air – cooled or preheated – to the units
2. winter pre-heating of the outdoor air through:
    a) a set of air glazed solar collectors (36 m2)
    b) the heat recovered by the exhaust air of the building
3. ground passive air cooling in summertime
4. use of an air-to-air heat exchanger in order to provide cool transfer from the ground duct, preventing contamination to the fresh air
5. mechanical cooling of the building during night time, excluding the ground duct and taking the air from the building roof
6. possible installation of a refrigerating unit, connected to one or more air treatment units, to integrate the passive cooling system if overloaded
7. mechanical extraction of the exhaust air
8. room climate control through:
    a) local electronic control of the air treatment units

b) thermostatic valves on heating devices

## 2.16 Description of the performance of the monitoring/measuring system

The following picture shows a schematic diagram of the building and earth tube cooling system. This diagram is a very simplified draw, just to show a schematic map of most important sensors.



Lightweight monitoring by TINYTALK

When 220V mains power supply was not yet reliably available, a lightweight monitoring of the main performance of the earth tube was done by using 3 TINYTALKS for:

1. External Air Temperature
2. Indoor Air Temperature
3. Output Air of the Earth Tube

High resolution monitoring by wired instrumentation, high accuracy sensors and data acquisition

For high accuracy monitoring the following intruments were installed and wired in the building and HVAC system:

- 2 DataTakers DT500 with 10 PT100 (4 wires) channels each or 30 voltage channels each.
- 12 PT100 (4 wires) Temperature sensors according to the specified measurement point list specified above. All PT100 are 1/3 DIN accuracy and have been individually calibrated against each other to achieve 0.1 °C accuracy for temperature difference.
- 1 Rotronic RH sensor for earth tube air relative humidity measurement with 2% nominal accuracy.
- 2 Honewell RH sensors for external and indoor relative humidity measurement with 2% nominal accuracy.
- 1 semiconductor based solarimeter for horizontal solar radiation.
- 1 TESTOVENT 4000 vane anemometer.

## *Ecological ElGreco Community, Crete, Greece*

### 2.17 Aims of the project

The project concerns the construction of 10 innovative, low energy, high quality and environmentally friendly residential buildings within a new prototype ecological village that is developed in the island of Crete, in Greece.

Primary aim of the research is the utilization of natural, passive or hybrid cooling techniques in order to reduce or even eliminate the cooling energy required by the residential buildings during summer. In addition to that, the research aims at reducing all domestic energy use by means of optimizing the buildings' shell, optimizing the natural daylight levels and the buildings' ability for natural ventilation, reducing all cooling and heating loads and making optimum use of landscaping.

### 2.18 Description of the site

The residences are located within a site with a total area of 1300 hectares, in which an environmentally friendly community will be developed, constructed and managed by private investors offering high quality accommodations. The Community will be constructed utilizing the latest innovations in building materials, emission control, recycling of waste products and energy conservation and will be independent and self supporting. The site is located 3 km from the northern coast of the island and overlooks the only freshwater lake on the island. It has a 700 m frontage on the southern side of the lake, rising at a south-southwest direction to an elevation of 1400 m over the sea level. The Community will have a population of over 2200 residents, a hotel, a conference center, a clinic, a commercial area, golf courses, swimming pools, tennis courts, a health farm, a school etc. All buildings together will use only 2 % of the project site. The area of the villas concerned covers only 2,5 % of the total living area.

### 2.19 Descriptions of the installations,

Each of the 10 innovative designed villas has two storeys –ground and first floor- with an area of approximately 100 m² each. The buildings have the shape of a square with one side missing and include an open atrium at the centre of the square. Figures 1 to 4 show the four different elevations of the residences. The atrium has south orientation and a covered arcade is constructed at its entrance in order to protect the atrium and the adjacent surfaces from solar gains during summer. In addition, all glazed openings of the building are also protected by direct solar gains. The role of the atrium is very important as it enhances both natural ventilation and daylighting. The construction of the building will be of high quality while the surrounding landscape will be treated through plantation and use of water in order to improve the microclimatic conditions around the buildings during cooling season.

Within the framework of this research, the cooling and heating loads of each one of the ten buildings were evaluated for the following bioclimatic and sustainable measures.

<u>Insulation</u>

The installation of 5 cm additional extruded polystyrene insulation both on the external vertical walls and on the clay roof. The additional insulation will result at a decrease of the thermal losses of the vertical walls and the roof.

Glazing

The installation of double glazed windows with clear 5 mm thick glass panes and 12 mm gap at all windows, which will decrease the thermal losses from the transparent elements. Also the installation of Low E glazing with or without Argon filling.

Shading

The construction of east and west overhangs and side fins and of a covered arcade in the southern entrance of the atrium which will efficiently shade the building and reduce the entrance of direct radiation.

Buried pipes

The installation of an advanced ground cooling system consisting of a number of 5 underground pipes with a length of 30 m each, running in parallel at different depths up to 3 m below surface. Air will be circulated through the pumps using an inverter driven central fan. As the ground is cooler than the ambient air, the outgoing air is much cooler than the incoming air and cool enough to be used for covering the cooling requirements of the building. A special designed control system will be installed in order to manage the operation of the system according the environmental conditions and the building requirements. Cool air will be distributed within the building through a distribution network. The efficiency of the system depends mainly on the climatic conditions of the site, on the thermal mass of the building and on the control strategy. In addition, the system can be used for the application of night ventilation strategies, utilizing in this way the high thermal mass of the building.

The above mentioned system can also be used in order to increase the ambient air during the winter period.

Ceiling fans

The installation of ceiling fans which will increase the summer cooling set point from 26 ºC to 28 ºC.

Lighting

The installation of an expert artificial lighting system, which will include occupancy sensors and low consumption lamps.

## 2.20 Project did not proceed beyond the design stage.

As the Contractor did not proceed to construct the project for unknown reasons, there is nothing further to report. The design report is included in the Appendices.

# 3. Construction, installation and commissioning

## *Overall COOLHOUSE project*

The first stage of the COOLHOUSE project was the design and modelling phase - design of the buildings; investigation and design of the cooling systems; modelling of the performance; and integration of systems into the construction. This included local weather analysis, ground conditions investigations, local materials investigation and mechanical plant options, as well as the usual liaison with clients and other technical designers and financiers. Copies of the four design reports are included in the Appendices. When all agreements were reached, the building construction had to be put out to tender, construction companies appointed and eventually the buildings were constructed with integration of the cooling systems and the buried pipes at the same time.

Some particular difficulties were experienced and these are described in the individual sections below. Water penetration into the Alma Verde house in an unusually wet autumn was a bad example, causing some damage (repairable) to the adobe walls.

### 3.1 Suppliers of equipment and services

Names and addresses of suppliers of all major items of expenditure given in each site section. They are different for each site.

### 3.2 Project management

Particulars of companies/individuals responsible for project management indicating to which phases or areas their work related, given in individual site sections. They are different for each site.

### 3.3 Problems, solutions, successes

Building construction in all cases caused several headaches, though it is fair to say not really with the ground cooling systems or energy saving measures but more with the general building construction and inevitable delays (described below in 3.5). These are common on construction sites and the programme for construction can never be set to accord with rigid timetables drawn up years in advance.

The general successes in design and construction was that mainstream easily available products, such as plastic drain pipes, were used for the ground cooling systems and that no problems in installation arose.

Commissioning of the systems was not really a significant operation in Frejus and Alma Verde as there is little to do other than decide when to switch on the fan. More commissioning was necessary in Aler Pavia where the ground cooling was integrated fully into the mechanical ventilation systems of the community centre.

### 3.4 Modifications and over-runs during construction

Several modifications were necessary throughout the project and these were discussed at the six monthly meetings and included in interim reports. The first stage of the project was the design phase when different options were tested out before the final design was appropriate for construction. The modifications at each site are described in the site sections below. The modifications did not change the principles of COOLHOUSE, to integrate passive cooling techniques into sustainable buildings, but varied some of the detailed ideas originally included. All these modifications were necessary to produce viable operating systems and demonstrate the practical application of the technologies in the buildings.

### 3.5 Time schedule

The original timetable given in Annex 1 of the contract was highly optimistic, a fact that became clear as the project evolved. The initial delay in the contractors receiving the signed contract from the Commission formed a delay of more than three and a half months. Subsequent delays were caused by design delays where different options were explored, complications in the tendering and financing packages, inclement or unusual weather condition, bankruptcy of subcontractors involved in the construction, unfamiliarity with the construction system and materials, and a number of minor site specific issues. These are described in each site section.

| **COOLHOUSE original and revised Work programme** | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Workpackage** | **Project** | **Duration** | | | | | | | | | | | | | | | |
| | | 1st year 2000 | | | | 2nd year 2001 | | | | 3rd year 2002 | | | | 4th year 2003 | | | |
| 1.Planning/design | 1. U Furnas | ▨ | ▨ | x | x | x | x | x | | | | | | | | | |
| | 2. Aler P | ▨ | ▨ | x | x | x | x | x | | | | | | | | | |
| | 3. L'Aubier | ▨ | ▨ | x | x | x | x | x | x | | | | | | | | |
| 2. Construction | 1. U Furnas | | | ▨ | ▨ | ▨ | ▨ | ▨ | x | x | x | x | x | x | | | |
| | 2. Aler P | | | ▨ | ▨ | ▨ | ▨ | ▨ | | | x | x | x | x | x | x | |
| | 3. L'Aubier | | | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | | x | x | x | x | x | |
| 3. Commission | 1. U Furnas | | | | | | | | ▨ | | | | x | x | | | |
| | 2. Aler P | | | | | | | ▨ | | | | | | | x | x | |
| | 3. L'Aubier | | | | | | | | ▨ | | | | | | x | x | |
| 4. Monitoring | 1. U Furnas | | | | | | | | | ▨ | ▨ | ▨ | x | | | x | x |
| | 2. Aler P | | | | | | | ▨ | ▨ | ▨ | ▨ | ▨ | | | | x | x |
| | 3. L'Aubier | | | | | | | | ▨ | ▨ | ▨ | ▨ | | | | x | x |
| 5. Reporting | 1. U Furnas | | | | | x | | x | | x | | x | ▨ | x | | | x |
| | 2. Aler P | | | | ▨ | ▨ x | | x | | x | | ▨ x | ▨ | x | | | x |
| | 3. L'Aubier | | | ▨ | | ▨ x | | ▨ x | | ▨ x | | x | ▨ | x | | | x |
| 6.Publicity/diss | 1. U Furnas | | | | | | | x | ▨ | | | | ▨ | ▨ | ▨ x | ▨ x | ▨ x |
| | 2. Aler P | | | | | | | | | | | ▨ | ▨ | | | x | x |
| | 3. L'Aubier | | | ▨ | | | | | ▨ | | x | | ▨ | | x | x | x |

▨ Indicates original contract programme

x Indicates final programme.

### 3.6 Costs

No breakdown of costs was given in the contract Annex 1, the only cost data are in the CPF. No breakdown of the costs of each phase have been kept during the project A request is made to vire up to 20% between some cost heads to reflect the reality of the project.

## *Alma Verde, Portugal*

### 3.7 Suppliers of equipment and services

- Architecture and development: Alma Verde Village and Spa
- Energy and Environmental Consultants: Faber Maunsell SDG
- Services Engineers: Hurley Palmer Flatt, Beech House, 840 Brighton House, Purley, Surrey, UK
- External insulation and thin-coat render system: STO AG, Ehrenbachstraße 1,D-79780 Stühlingen, Germany
- Insulation installer: ConforSinergia Lda, Estrada Municipal 535, Barao de S. Miguel, PT-8650, Vila do Bispo, Portugal
- Timber windows and glazed doors: Bieber, 67430 Waldhambach, France
- Solar control and low-E glazing:St. Gobain, France
- Terracotta Termoarcilla system blocks: Tabicesa SA, Carretera Nacional 430, Km.120, Spain
- Timber insulated sandwich roof panels: Onduline and others, Portugal
- Adobe blocks and renders: Construdobe, on-site, AlmaVerde
- Celsius 25 condensing gas boiler: Keston Boilers, 34 West Common Road, Hayes, Bromley, Kent, BR2 7BX, UK
- Radiant skirting: Chatsworth Heating Products Ltd Riversmeet, Mill Lane, Shiplake Oxfordshire, RG9 3LY, UK
- Coolhouse air handling unit, attenuator, controls:The Nuaire Group, Western Industrial Estate, Caerphilly, CF83 1NA, UK

### 3.8 Project management

All project management was carried out by Alma Verde staff.

### 3.9 Problems, solutions, successes

No significant technical difficulties have been encountered during construction and operation of the Coolhouse ground cooling system, since it has been designed down to the simplest installation possible with space requirements and component demands minimised.

The low energy specification of the building envelope introduced new materials and technologies to the building contractor. These led to some minor difficulties, due in part to a lack of familiarity with these methods of construction. These problems were very much a matter of the builder’s own experience, involving issues such as inaccurate setting out and building to suitable tolerances. Any such difficulties were simply and rapidly remedied, and the systems and materials themselves presented no inherent problems. The lessons learned in the first phase of villa construction using this system ensure that the construction of later phases to the same specification are presenting no more difficulties than would be encountered on any building project.

### 3.10 Modifications and over-runs during construction

In terms of the building construction techniques and Coolhouse system there were no modifications during the project phase. Minor modifications to construction details to accommodate the risk of adobe damage due to heavy rain during construction have been introduced for later phases.

## 3.11 Suppliers of equipment and services

Concerning passive cooling solutions, all directly related to the whole building design, several teams were involved :

- the overall environmental quality of the building supervisor, Robert Celaire,
- the energy design engineers bureau BETSO,
- the architects Tournaire and Guitter,
- several construction firms, mainly for the envelop construction, the excavation work related to the ground cooling system, the installation of the grid of pipes, the connexion to the air treatment system (JAVEL CLEMESSY)

## 3.12 Project management

The whole building project was supervised by the owners, represented by Mrs Chantal Merel, assisted by Robert Celaire, concerning the environmental issues and the Coolhouse project, and by Michel Landry, concerning the works' progress.

The team of architects Tournaire and Guitter coordinated directly the conception and construction works.

## 3.13 Problems, solutions, successes

Throughout the construction phase, the main difficulties which occurred were related to financial aspects and heavy and difficult negotiations with the constructors, in order to come to an agreement on the estimated over costs of their tenders, and bring down the prices – which were at first 15% above the target costs of the project. These negotiations lasted a year, and slowed down the original schedule of the project. By the end of July 2001, an agreement on the prices was found, and did not affect the building's performance and technical design (and especially energy wise), but the project was then one full year and a half late according to original schedule.

As from then, the construction works went ahead and, at completion by end September, almost met the new schedule target of early summer 2003, with 2,5 months delays, even though summer 2003 was particularly difficult in this geographical area due to very hot climatic conditions and important forest fires around.

This new delay, and the fact that the first occupants could only arrive by end of October was due to :

- delays in delivery of metal frames for the windows of the dining room (all the other works having been finished by September) ;
- delays due to administrative processes in order to obtain the final authorization to open the home.

Concerning the constructive works, no major difficulties occurred, despite the fact that several technical solutions (or at least the fact that they were all put together in a same project) were innovative and required, therefore, specific effort to inform and follow up constantly the working teams. By the end of this project, the firm mainly involved in the installation of the ground cooling system had developed knowledge which will be used on other similar projects.

## 3.14 Modifications and over-runs

Relating to building design, and especially energy efficiency solutions, no major changes have occurred since the very beginning of the project.

The completed and occupied building is similar to the original project, except for a few non -major options which finally were not taken up, mainly for economical or regulatory reasons.

## 3.15 Time schedule

| Period | Works and results |
|---|---|
| July – December 2000 | Global energy efficiency design of building<br>Envelope and technologies design leading to optimal use of solar energy<br>Passive cooling and low energy cooling technologies design<br>Ground cooling system pre-designed and pre-sized |
| January – December 2001 | Energy design finalisation (including all passive cooling and low energy technologies)<br>Construction tendering and contracting negociations |
| January 2002 – June 2003 | Building construction<br>Finalised design and installation of the grid of pipes for the ground cooling system |
| June 2003 – September 2003 | Building construction finalization<br>Monitoring of the ground cooling system<br>Agreement commission |
| October 2003 | Arrival of the first occupants |

## 3.16 Costs

The whole cost of the building (including the land) has reached 4 M Euros.

Concerning the energy efficiency of the building, and in particular, the innovative cooling solutions, the costs ot the works (not including the studies and the coordination work) are shown in the table hereafter.

| **Item** | **COST (€)** |
|---|---|
| High thermal inertia : Reinforced thermal insultation : the building is 20% beyond the insulation standards required | 698 910 |
| Natural daylighting, contributing to minimize the cooling loads | 30 617 |
| Shading devices protecting for solar radiation during the summer | 45 927 |
| Cooling solutions | 231 418 |

| | |
|---|---:|
| Efficient heating equipment | 186 134 |
| Land | 567 792 |
| Vegetation | 53 105 |
| **TOTAL** | **1 813 903** |

## *Aler Pavia, Italy*

### 3.17 Suppliers of equipment and services.

Project Manager – Pasqualine Venezia Technical director of Aler Pavia
Energy designer – Softech Energia
Builder – EDIL TRE ELLE s.r.l.
Architectural designer – Andrea Borlini, Marina Dallera,
Luciano Giorgi
Equipment designers – Studio Termotecnico Rossi

### 3.18 Project management.

The project was managed by Aler Pavia, who employed all the participants and contractors.

### 3.19 Problems, solutions, successes

Problems

- hygiene/sanitary requirements (inlet air quality all year round)
- maintenance of interior temperatures at comfort levels during summer.
- Low noise levels when the system is opetaing
- Air quality output of the underground piping and indoor air quality
- Technical and economical requirements

Solutions

The system is particularly coherent for widespread replication. It used current components commonly used in the building market and when a centralised ventilation and heating plant is already installed or it is included in the project request, the cost of the system can be reduced to the underground part (excavation and tube) and the integration to the central unit.

Successes

- Increasing indoor air quality all year round
- Realised simplicity
- Limited system costs
- Limited installation cost
- Reduced management cost
- Integration with other energy saving to reduce the global payback time of the installation.

### 3.20 Modifications and overruns during construction

The project has been delayed compared with the original programme. This delay was caused by the whole planning of the district retrofit. In fact the CircoLab is part of an urban pilot project involving 220 dwellings belonging to the social housing authority of Lombardy region (Aler Pavia)

The whole renovation of the district is still on-going while Aler Pavia has given priority to the CircoLab to respect the contractual obligations with EC.

The original COOLHOUSE scheme was to include the CircoLab 545 m2 and Homes for the Aged, renovation of an existing building. During the project development , all cooling and renewable energy technologies were concentrated on a newly designed and expanded CircoLab building which is now 626 m2 with a volume of 2550m3.

Monitoring started in August 2003 and provided results in the monitoring report. During winter 2003/4 the energy performance of both the building and solar collectors were monitored and assessed.

In addition the monitoring activity will continue during the summer of 2004.

### 3.21 Time schedule

Design started January 2000
Construction started March 2002
Finished December 2003
Monitoring equipment installed June 2003, started August 2003.

### 3.22 Costs

Project costs are as follows.

| | | Total cost (euro) |
|---|---|---:|
| 1 | Planning and Design | 125 305 |
| 2 | Extra costs of construction | 219 823 |
| 3 | Commissioning and testing | 61 766 |
| 4 | Monitoring | 102 576 |
| 5 | Reporting and Dissemination | 40 904 |
| | **Total** | **550 372** |

# 4. Operation and results

## *Overall COOLHOUSE project*

### 4.1 Operating History

The COOLHOUSE buildings at the three sites came into occupation and use at different times during 2003. The ground cooling systems were all operating in the summer of 2003. As all the buildings were built to house people and accommodate permanent activities, all are still operating and monitoring is ongoing after the end of the COOLHOUSE Contract. Each site is described below.

### 4.2 Performance

The individual monitoring reports attached in the appendices give the full results of the measured performance of the ground cooling system and the related buildings. Where full monitoring of the completed and occupied buildings was not possible within the timescale of the project, modelling and calculations have been used to demonstrate the effects of the cooling systems on the cooling of the building. The most important aspect of the project and the most innovative, is the performance of the buried pipes in providing cooling in summer and this has been proved to be very effective in two of the sites, less effective at Aler Pavia. This cooling is provided with zero external energy use and thus zero $CO_2$ emissions, as the cooling comes directly from the ground. The use of fans in the system is to draw this cool air into the buildings and circulate it around as required, as with any air cooling (or heating) system. Summaries of the three site monitoring results are given below.

1. Alma Verde Portugal

| | | | |
|---|---|---|---|
| Energy Savings | Space cooling demand (Kwh/m$^2$)<br>Quantity of energy saved (Kwh)<br>Cost of energy saved (€/ Kwh) | 81 kWh.m2/yr<br>33 468 kWh<br>0.10 €/kWh | Electricity demand of conventional cooling system, for whole house<br>Demand, less the fan energy used |
| Renewables | KW installed (KW)<br>RES contribution (%)<br>RES costs (€/m$^2$) | 4.8 kW min<br>94.6%<br>51.7 €/m2 | Ground cooling system. Rating increases with increase in inlet air temperature. Total system cost estimated at 7500€, typical house internal area 145m2 |
| Investment costs | Extra investment costs (€/m$^2$)<br>Extra running costs (€/m$^2$)<br>Payback period (years) | 51.7 €/m2<br>0<br>6.7years | |

2. l'Aubier de Cybele, France

| | | | |
|---|---|---|---|
| Energy Savings | Space cooling demand (Kwh/m$^2$<br>Quantity of energy saved (Kwh)<br>Cost of energy saved (€/ Kwh) | 52.6 kWh/m2<br>387 000kWh<br>0.15 €/kWh | For whole building. For ground cooled dining area only 20,000kWh. |
| Renewables | KW installed (KW)<br>RES contribution (%)<br>RES costs (€/m$^2$) | 5kW minimum<br>11%<br>145€/m2 | Ground cooling system. Rating increases with increase in inlet air temperature. From ground cooling pipes. GC system only |
| Investment costs | Extra investment costs (€/m$^2$)<br>Extra running costs (€/m$^2$)<br>Payback period (years) | 109€/m2<br>0<br>7.5 years | For all measures in whole building (3950m2)<br>For whole building. For ground cooling dining area 18.3 years |

### 4.3 Success of the project

The project has been a large success. The areas of success are:-

- the buried pipes in providing cool air in summer, with zero $CO_2$ emissions
- the passive design of the buildings
- the use of adobe for internal walls
- the buried pipes for providing heating in winter
- the demonstration that ground pipe systems are cheap and easy to construct
- the reduced relative humidity from using ground pipes
- the absence of any problems from the ground pipes such as smells, dampness etc.

Across all three sites the ground cooling pipes have been a great success, providing cool air at several degrees below external air throughout the summer. Although the ground heats up in summer by up to $10^0$C from the winter low, as a result of the heating effects of the buried pipes and the sun on the ground surface, cool air still was provided for the buildings. The details of all the site buildings were very different but all used passive building techniques to reduce the heat gains in summer and thus enable the ground cooling systems to maintain comfortable temperatures. The combination of low energy and passive building components and construction systems, is demonstrated to be the best starting place for ground cooling systems which by their nature provide coolth slowly compared with active cooling systems. Buildings designed using shading or coated glazing against solar gain (in summer) and thermal mass to even out peaks in heat gains and to store coolth, require much less input of cool ventilation air to provide adequate summer comfort. The houses at Alma Verde demonstrate this very well. We believe that the use of adobe for the internal walls, with external insulation, provides a large amount of accessible thermal mass which moderates temperatures ideally. It also seems to have a great effect on evening out variations in humidity but being vapour permeable (in conjunction with other layers of the walls).

Other successes of the systems are that relative humidity levels are reduced by the ground cooling. This may be important in Portugal where humidity is very high and houses frequently suffer from mould growth.

Although COOLHOUSE was originally envisaged mainly as a project to avoid active air-conditioning, it has also demonstrated the benefits of buried pipes in providing ventilation air in winter which is much warmer then external air. In practice it seems that more energy may be saved in winter due to the pre-heated air than is saved in summer by avoiding active cooling, though this depends on climatic conditions

### 4.4 Operating costs

Passive and low energy building construction has virtually no additional maintenance costs associated with it. The ground cooling systems have not received any maintenance during the project. It is likely that at some times in their life it will be beneficial to clean out the buried pipes using high pressure water or pull through cleaners. This is not likely to incur any great cost. The low powered fans used to draw the air into and around the buildings require minimal maintenance. Compared with air-conditioning systems and chiller units, ground cooling appears a much lower maintenance approach.

### 4.5 Future of the installation

All the buildings on the sites are permanent buildings and are likely to continue in use with their ground cooling and other systems operating for the foreseeable future. Each site address this aspect below.

### 4.6 Economic viability

For each site the calculations are different as the installations vary. In summary the payback times vary between 7.5years and 10 years, depending on what areas and components are considered The ground systems have a indefinite life as do the passive measures in the buildings.

### 4.7 Environmental impact

The avoidance of air conditioning equipment and associated chillers using electricity as the power source reduces the emission of $CO_2$ from the generation of this power. By using the cool air from the ground all $CO_2$ emissions are avoided. The use of passive building methods reduces the emissions of CO2 from both heating and cooling of the buildings. The buildings at Alma Verde in Portugal and the Old people's home at Frejus in France are built on environmental principles as described in the separate sections below.

## *Alma Verde, Portugal*

### 4.8 Operating History

The control system for Coolhouse is designed to be as simple and usable as possible. The primary controller is an adjustable timer. This runs the system automatically to the user's pre-set time and duration, and has a manual on/off override.

The second separate controller sets the system to either winter or summer mode, and contains the fan speed controller. In winter mode, when the Coolhouse fan is running and drawing in pre-warmed ventilation air, the skirting heating system is automatically turned on. This overrides any pre-set heating system timings and is to prevent accidental intake of air at cooler than desirable temperatures.

Monitoring has taken place during the entire cooling season, when the system has been set to run for a fixed number of hours per day and has generally not been varied. Within this context, different time settings have been programmed in different houses to establish what the actual effects on internal temperature might be. This is to examine the effects of different cooling strategies, for instance using the system primarily for night purging.

### 4.9 Performance

The Alma Verde houses were monitored to demonstrate the effects of the passive design and the buried pipes on internal conditions in the houses, and to understand the heat transfer results within the buried pipes. In terms of energy use, the cooling is passive but a fan is required to move the air through the pipes and into and around the houses. Thus the electricity use of the fans was also monitored. Full details nare given in the monitoring report attached as an appendix.

Temperatures in the houses

In the main living area of house 54 (the show house), the temperature of the room is related to the Outdoor Air Temperature (O.A.T.) in that it raises and falls through out the year in conjunction with the seasons. However, the thermal mass, provided by the adobe bricks and low solar glazing creates a thermal buffer that prevents the peak outside air temperature from raising the internal temperatures to unpleasant levels.

For example on the 1st August when O.A.T were peaking at around 37°C (in the shade) but internal temperatures were around 25°C i.e. temperature difference (DT) was 12°C. This thermal mass can be seen to work in the opposite direction during the heating season with O.A.T. temperatures going as low as 5°C around the 23rd of December but with internal temperatures never dropping below 14.4°C.

During the cooling season the Coolhouse ground tube system then provides a supply of coolth that helps to regulate the internal temperature and prevent breakaway temperature escalation that would be shown by increasing internal temperatures.

From a comparison between this house with ground cooling used in the bedroom (No 54) and one with no bedroom cooling (No 57), the results show that the ground tubes do make a substantial impact on reducing this temperature. Indeed during the questionnaire that was completed during the monitoring program the residents of house 57 replied to the question 'Any other comments' they stated that

'*They would like the Coolhouse system to work in the master bedroom, at present they cannot have the window open during the night because insects come into the room, they have a fly screen on order for the last two years but it has still not arrived! They feel that a Coolhouse vent in the bedroom would allow them to have fresh air during the night as well as keeping them cool.'*

The results from house 56 (unoccupied) show a very similar picture.

In house 57 (occupied) the temperature graphs show the consistency of the internal temperatures achieved throughout the year even with human interaction.

Throughout the monitoring period the DT for the internal temperatures is 12°C in the main living area and 11°C in the bedroom, when these are compared to the outside DT of 35°C for the same period the thermal stability of the building is highlighted.

As with house 56 the figures for the internal temperatures in the bedroom seem to fluctuate less than the figures for the living area. These fluctuations are probably due to the way in which the living area is used i.e the large doors leading to the garden being opened during summer days, the use of appliances i.e. cooker, television etc that provide heat during the evening, the occupiers spending the majority of their time in this area (a retired couple lived in the house) whereas there were no heat sources in the bedroom (except the heat given off by them whilst sleeping).

However, even with these heat sources the closeness of the two DT figures shows the level of coolth provided by the Ground tubes and show how affective they are at dragging internal temperatures down within the treated areas which otherwise could increase uncontrollably due to the level of insulation within the building.

Ground pipe temperatures.

The monitoring shows how effective the ground is at removing the peaks and troughs of the external air during hot weather and adding heat to the incoming air during cooler weather.

- throughout the monitoring period for house 54 the maximum +DT i.e. heat removed from the incoming air was 11°C and the maximum -DT was 8°C i.e. heat added to cold external air (during winter months or during the evening).

- throughout the monitoring period for house 56 the maximum +DT was 12°C and the maximum -DT was 8°C.

This addition and subtraction of heat energy shows how effective the ground tubes are and helps to explain the consistency and stability of the internal temperature of the Coolhouse villas.

The temperature of the air leaving the ground pipes varied from 26$^0$C in August to 15$^0$C in winter, only one or two degrees different to the temperature of the ground itself.

The graph that shows the relationship between the soil temperature and the O.A.T is interesting as it shows how rapidly the soil temperature reacts to a rise or fall in O.A.T. Research at the beginning of this project stated that the baseline temperature for the soil will be the same as the average external temperature throughout the year, in this area of Portugal this is 14°C

The relationship between the two is important as it is expected that when the incoming air is losing heat to the soil heat sink, i.e. from an area of greater heat energy to less heat energy, this heat will be stored and then used when the energy relationship is reversed, i.e. heating air that is less than the baseline. Normally this reversal would expect to be done within every diurnal cycle to provide a constant input temperature over 24 hours. However, during the summer when even the night temperatures are greater than the baseline figure the heat removed builds up within the ground heat sink causing a reduction in efficiency of the system for the next day i.e. night time purging of the heat sink is not occurring.

Within this monitoring project this lack of purging seems to be occurring for 34% of the time as the heat sink was increasing in temperature however, this was only at the start of the project, it was during the summer months and the heat sink started from a very hot start. As the external temperatures started to decrease the soil temperature also decreased until the temperature of 14°C that was originally predicted was achieved.

Due to the size of the soil heat sink it cannot be determined if the temperature will increase again next summer to the levels seen during this monitoring program or whether now that baseline has been achieved and there will be no further external interference in the structure of the heat sink whether the system will now become self sustaining on a diurnal/season cycle.

Fan electricity use.

The appendix shows the excel table that outlines the activity of the fans for houses 54, 56 and 57. This data shows the load profile of the fans and also produces information regarding the kWh consumption of the fans. This consumption is shown in the table below.

| House number | kWh consumed during monitoring period | kgs $CO_2$ produced during monitoring period | Cost - € |
|---|---|---|---|
| | | | |
| 54 – Living area | 505 | 217 | 51 |
| 54 – Bedroom area | 505 | 217 | 51 |
| 56 | 627 | 270 | 63 |
| 57 | 245 | 105 | 25 |
| | | | |
| **Total** | **1,882** | **809** | **190** |

Assuming:

1 A factor of 0.43 for kWh to kgs $CO_2$ – standard factor in UK but this is dependent upon a countries electricity production breakdown.

2 A cost of €0.10 per unit of kWh – based on standard UK cost of £0.07 per unit of kWh electricity.

Within the ‘conventional’ air conditioning industry there is a standard method used that takes into account floor area, percentage glazing, North/South alignment etc to produce a kW figure required for split unit air conditioning. This has been used to produce the following table.

**Split Unit Electricity Consumption**

| House number | kW rating of required split unit. | kWh consumed during monitoring period | kgs CO2 produced during monitoring period | Cost - € |
|---|---|---|---|---|
| | | | | |
| 54 – Living Area | 15.1 | 10,948 | 4707 | 1,095 |
| 54 – Bedroom area | 4.5 | 1,634 | 702 | 163 |
| 56 | 13 | 10,816 | 4,651 | 1,082 |
| 57 | 9 | 11,952 | 5,139 | 1,195 |
| | | | | |
| **Total** | **41.6** | **35,350** | **15,199** | **3,535** |

It must be highlighted that unlike the Coolhouse system that is a passive system split units outputs are thermostatically controlled. This means that whereas the Coolhouse fans would operate for the entire period of hours that they have been programmed i.e. ten hours to provide a constant supply of coolth. A split unit would operate until it achieved its setpoint, at which point it would either switch off until required again or reduce its output to maintain its environment as closely to the setpoint as required. Therefore, using knowledge based on experience an assumption has to be made regarding the kWh consumed by a split unit to produce the same environmental conditions as those experienced by the Coolhouse system. These assumptions are included in the table above and are as follows.

| House Number | Number of hours Coolhouse operates daily. | Number of hours a split unit would operate. | Number of hours Coolhouse operated over the monitoring period. | Number of hours a split unit would have operated over the monitoring period. |
|---|---|---|---|---|
| | | | | |
| 54 – Living Area | 10.5 | 4 | 1,904 | 725 |
| 54 – Bedroom area | 10.5 | 2 | 1,904 | 363 |
| 56 | 15 | 5 | 2,495 | 832 |
| 57 | 16 | 5 | 4,248 | 1,328 |

Therefore, based on the four separate areas (i.e. three houses but one with two systems) it can be determined that the Coolhouse system is capable of making the following savings per year if installed in houses in hot climates where otherwise conventional air conditioning system would be used. This assumes that the system is also used for heating in winter and approximates the contribution to the heating load.

| | **kWh** | **kgs $CO_2$** | **Cost €** |
|---|---|---|---|
| **With Coolhouse** | 1,882 | 809 | 190 |
| **With Conventional Air Conditioning** | 35,350 | 15,199 | 3,535 |
| | | | |
| **Savings for monitoring period.** | **33,468** | **14,390** | **3,345** |

## 4.10 Success of the project

The mechanical components incorporated into the Alma Verde Coolhouse system are essentially very simple and from tried and tested technologies, and are performing well and are likely to continue to do so.

The system is successful in providing low-cost low-energy temperature reductions generally sufficient for homes and residential buildings as an alternative to air conditioning. To do this, the construction of the building needs to achieve a good thermal performance whilst guarding against solar gains, and carry high levels of thermal mass to optimise the coolth available from the Coolhouse system.

Subject to the availability of adequate external area for ground tube installations, there is no limit to the number of zones within a building that can be individually cooled by the addition of further air handling units. The system achieves the equivalent cooling of fresh ventilation air at a 95% reduction in energy and $CO_2$ emissions compared with air conditioning. This it achieves with negligible impact on the architecture of the building, beyond the provision of a small fresh air intake chamber, and minimal housing for the air handling unit(s) and attenuator.

Useful ventilation pre-heat gains are available in winter mode. The Coolhouse air distribution strategy needs to integrate with the heating system to exploit these gains.

An unexpected benefit from the Alma Verde Coolhouse system when combined with the use of adobe blockwork and vapour permeable external wall construction, is that it is very effective in making significant reductions in internal Relative Humidity compared to external conditions. Monitoring shows these reductions to frequently reach 25%RH and occasionally up to 30% reductions have been recorded.

The simplicity of the system and general availability of its components makes the system easy to replicate anywhere.

Few technical difficulties have been encountered during construction and operation, since the system has been designed down to the simplest installation possible with space requirements and component demands minimised.

A minor problem arose with the use of flexible ductwork for connection of the ground tubes to the air handling unit. The walls of this duct are designed for blowing rather than suction, and proved unable to withstand the suction pressure and partially collapsed inwards, reducing the available section area and air volume transfer rate. This had to be substituted with 315mm PVCu rigid pipe for the 1.5m straight length of the vertical run to the top intake of the AHU. The final radiused connection to the AHU has worked satisfactorily in flexible duct as the curved profile lends additional structural strength to the duct walls.

## 4.11 Operating costs

The very limited amount of plant and equipment comprising the Alma Verde Coolhouse installation reduces repair and maintenance costs to a minimum.

The fan unit requires standard maintenance procedures as recommended by the manufacturer, and the attenuator filter similarly. Airborne dust is likely to be the only consideration regarding the filter, although after a year of use in a relatively dusty construction site environment there is no evidence of dust making its way to the outlet end of the ground tubes or fan unit.

The ground tubes themselves can be cleaned with a normal drainage pressure jet periodically, and are designed to facilitate this.

### 4.12 Future of the installation

The readily available components of the system and its simplicity make it a relatively low cost means of procuring effective comfort cooling, whose low energy benefits will become increasingly relevant as energy costs increase. For this reason, the Coolhouse system is now installed as standard in all houses at Alma Verde, unless specifically omitted by purchasers, and could be simply replicated virtually anywhere.

### 4.13 Economic viability

The additional capital cost of providing the “COOLHOUSE installation in a house is estimated at 7 500euro. The annualised cost of future maintenance is thought to be very low and so has not been included. The calculation of the annual performance of the system above extrapolates the savings for use in cooling and heating over a one year period. This gives a saving per house of around 2000euro. If this figure is taken, it produces a payback period of less than 4 years. However this seems a large annual saving and an alternative calculation simulating more likely contributions gives a saving of under 1000euro, giving a more realistic payback of under 10 years (TO BE CHECKED)

### 4.14 Environmental impact

The principal environmental benefit of the Coolhouse system as applied at Alma Verde is the savings in $CO_2$ emissions by reduced energy use from the avoidance of active cooling in summer and in reduced heating demand in winter. This is estimated as up to 10 000kg of $CO_2$ per house per year.

The other environmental benefit is in the use of adobe bricks for the internal walls of the houses, which have very low embodied energy and little environmental impact in quarrying.

The Alma Verde development in general respects the environment by providing vegetation and planting……….

## *Frejus, France*

### 4.15 Performance

The ground cooling system was monitored during the summer season, as described above.

According to the results, the device is functional. In first tests in June, it delivered an initial cooling power of 14 kW at $2m^3/s$ air flow-rate and of 9.5kW at $1m^3/s$ air flow-rate which corresponds to expectations in terms of wall-to-air heat transfer coefficients. In tests in July and August, cooling power values of typically 5 kW were observed after one to three days of uninterrupted use.

The measured cooling power values are probably lower than values under operational conditions: the soil was filled into the storage volume in summer conditions (high temperature, low humidity), just before the monitoring could start – this lowers the cooling power.

Ground temperatures were measured over 6 months and shown to rise by typically 1 to 2°C per month until the end of August when decline sets in. In a depth of 2m, earth temperatures evolve between 13 and 28°C.

Based on these results, a one-dimensional finite element simulation calculation predicts annual yields of 2.2 MWh for cooling, 6.7 MWh for heating and a forced ventilation COP of 16.

Full details of the performance are described the Monitoring Report included in the Annexes

## 4.16 Success of the project

Despite the difficulties detailed above, and mainly thanks to the energy and will of Mrs Merel and Demonein, the building, as it was designed at first, is now open, and occupied up to 70% of it capacities in only a couple of months. A first survey on the occupants comfort in winter will soon be carried out, but one can already guess that this survey will be most satisfying : visitors, pensioners, and employees regularly express the fact that the building is a pleasant place to live or work in. A second survey, next summer, will also be carried out .

Passive cooling technologies used in the building will find a good echo in the zone (from Nice to Montpellier), now that one of the leading HVAC installation firms working in the area (JAVEL CLEMESSY) has worked on its first ground cooling system, and has gained knowledge and practice of the technology. In a time when very hot and dry climatic summer conditions might occur regularly (similar to what happened in summer 2003), and when summer comfort for the most fragile group of the population (elderly people) is a vital issue, passive cooling success stories will help offering comfort without massively installing centralised air-conditioning, and thus avoiding other possible difficulties (increase in electricity consumption and power installation needs ; health and comfort problems related to mechanical air-conditioning).
The Fréjus installation will therefore play a key role in showing how passive technologies may be a good response to such issues.

## 4.17 Operating costs

These costs will be evaluated during the two first years the building is in operation. Main costs which will be studied concern not only the energy consumptions of the building, especially related to the passive cooling technical options (and in particular the ground system cooling), but also the maintenance costs.

## 4.18 Future of the installation

This building is the very first one of its type in the South of France. Not only because it concentrates many “green” solutions and management, but also because its does not belong to the public sector – where innovative projects are usually carried out. It is therefore a very good illustration of what can be done and reached by private firms, particularly in the health sector.

72 pensioners and 30 employees are already living and working in the building since last autumn. The building will be full by the end of June (80 elderly people and 40 employees), and is due to stay occupied and busy for many years. In a very close future, next summer, the building's natural cooling performances will be appreciated and evaluated, whereas the first winter period is being evaluated at the moment.

Technical management and maintenance contracts are being negotiated, and all include specific terms related to the performance of the building (ie comfort and energy expenses).

After a first three months operating period, the building shows no major technical dysfunction, nor does the ground cooling system which has been operating for almost six months.

## 4.19 Economic viability

The total building over costs related to the greening of the building represent approximately 23% compared to a standard care home‘s building costs in the same area.

The over costs related to the summer cooling (and partly to the heating and over all electricity efficiency) of the building have reached approximately 430 000 €.

Air conditioning of a standard building, in the same health sector, and the same geographical area, reaches approx 50 kWh/m2/year (source PACA Region – 2003), thus 197,5 MWh/year, and 30 000 €/year. Which is therefore the total avoided energy consumption and expenses evaluated, for this building, which has no air conditioning system.

The payback period of all the solutions installed to avoid centralized air-conditioning and to reach thermal comfort during the summer is of 14,2 years.

Focusing on the sole ground cooling system, and the related cooled area (380m2 ), the annually avoided energy consumption will therefore reach 20 MWh, and represent an economy of 3000 €/year, compared to the over cost of 55 000 € for the installation. A simple payback analysis shows that the system has a payback period of 18,3 years.

## 4.20 Environmental impact

Looking at the environmental impact of the Fréjus building is the best way to put forward its qualities and performance, as the whole project was carried out with two main objectives :

- reducing the impact of the building on the environment, throughout its total life-time (including the construction phase)
- offering high quality comfort, and healthy living conditions, to the occupants.

The project focuses on several major issues concerning environmental impacts :

- adequate landscaping and siting, and preservation of the original flora (as many trees as possible were preserved during the construction phase ; excavation was strictly limited ; earth was re-used on site as much as possible) ;
- high energy performance, meaning less conventional energy consumptions (gas and electricity) and more renewable energy (passive solar design and active thermal solar system for the hot water) ;

- minimization of water consumption for the building and the gardens.

Other environmental impacts were also deeply studied, and many other technical solutions were decided so as to reduce these impacts : noise treatment , waste management , indoor air quality … The building has been assessed in the HQE system, Haute Qualite Environmentale.

The building will limit its $CO_2$ emission up to 1193 tons/year instead of 2445 tons/year, compared to an equivalent standard building. The passive cooling will contribute to this avoiding 59 tons of $CO_2$/year and will also contribute to a reduction of the peak demand load in the summer, as no electrical air-conditioning will be used. This is of particular importance in the South East area of France, where a specific DSM programme has been launched recently.

## *Aler Pavia, Italy*

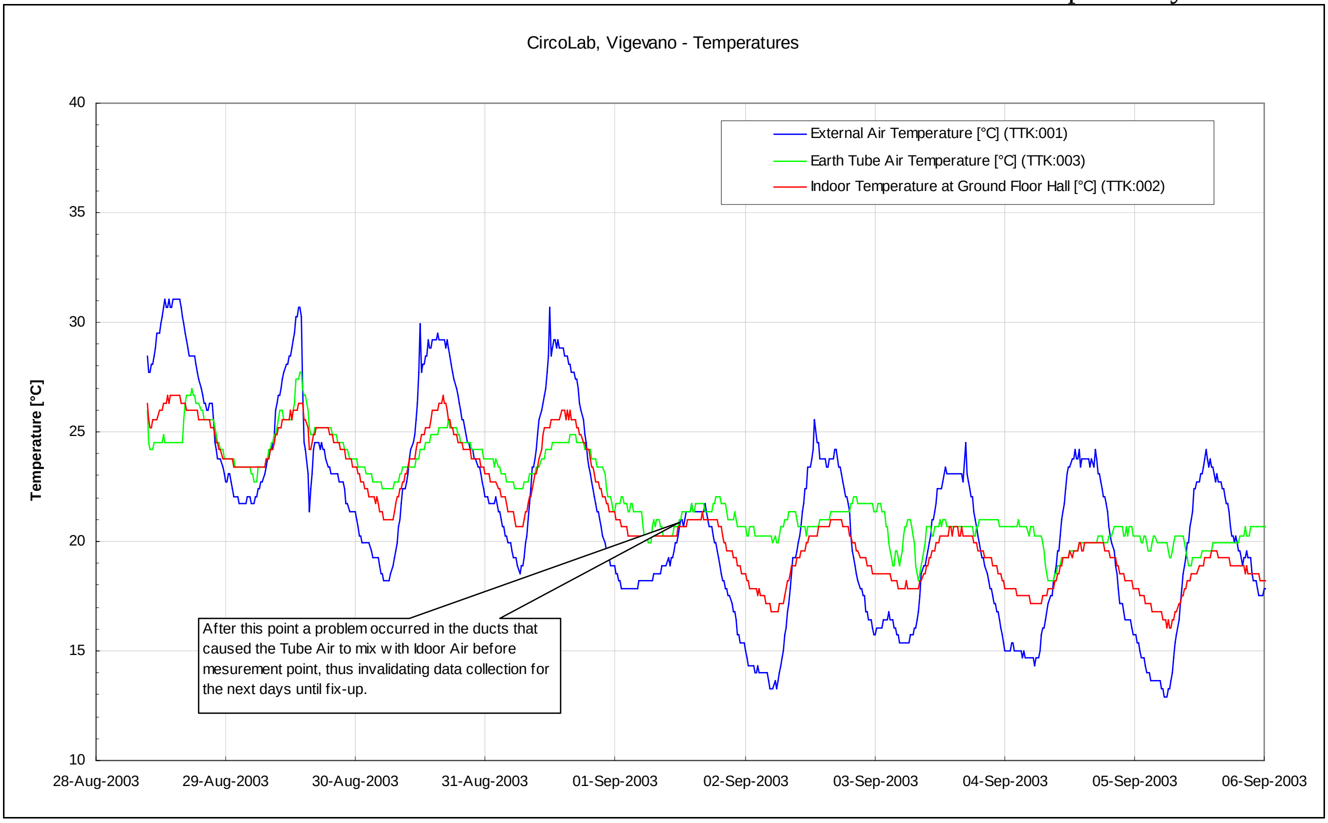
### 4.21 Operating History

The start up of system operation and monitoring was August 2003. Monitoring on the ground pipe system was started immediately although the building itself was not completed due to construction delays. It was felt that the most important monitoring was of the supply of cool air from the buried pipe system. The building came into full use as a community center at the start of 2004.

The following chart summarises the behavior of the earth tube during summer 2003.
During these measurements the fan for air flow in the earth tube was ON (full air flow in the earth tube. After few days, a problem occurred in the ducts. They started to mix ambient air and earth tube air before the measurement point, thus invalidating data collection for the next few days. Once discovered, the problem was fixed.

The chart shows that some reduction of the inlet air temperature from the earth tube (green) is provided, while outdoor temperature levels (blue) are 3 to 5 C° higher.

The Cool-House Monitoring Report extensively describes the system operation. (see annex)



CircoLab, Vigevano - Temperatures

After this point a problem occurred in the ducts that caused the Tube Air to mix w ith Idoor Air before mesurement point, thus invalidating data collection for the next days until fix-up.

## 4.22 Performance

Some conclusions can be drawn from the observation of the trends of the data collected.
Some cooling potential can be extracted from the underground by means of the earth tube, but it seems limited to exploiting day-night dynamics.
The earth cools the air during the day and the air cools the earth during the night.
Only short term damping effect of the underground thermal mass on external air temperature seems exploitable, and not the seasonal damping. This may be due to the fact that the thermal resistance of the ground does not allow a fast enough dissipation of the thermal flow towards the cold sink at average annual temperature represented by the deep underground.
The measured cooling potential of the air flow of this earth tube is summarised in the following table.

| DESCRIPTION | VALUE | UNITS |
|---|---|---|
| **Peak Cooling power,** defined as the top 3% performance over the whole integration period, at peak temperature difference. | 3.2 | kW |
| **Peak temperature difference,** defined as the peak temperature difference between external air and air coming out of the tubes, average of the 3% highest temperature differences. | 5.0 | $^0$C |
| **Average Cooling Power**<br>defined as the daily average dissipating power and measured as the total energy dissipated by the earth tube when the air temperature at the output of the earth tube is below the external air temperature divided by the total time. | 0.8 | kW |
| **Average Electric Power for Air Movement**<br>defined as the daily average electric power needed to move the air across the earth tube, heat exchanger and all ducts by an electric | 0.3 | kW |

| | | |
|---|---|---|
| fan, both for dissipating heat during the day and for cooling the ground around the tube during the night. | | |
| **Average Air Speed**<br>in the earth tube. | 4.0 | m/s |
| **Volumic Flow Rate**<br>of the air across the earth tube. | 1800 | $m^3/h$ |
| **Mass Flow Rate**<br>of the air across the earth tube @ 25 °C 1 atm | 645 | g/s |
| **Average DT below External Air Temperature**<br>defined as the daily average temperature drop when the earth tube works as a dissipator of the energy of the air flow across the earth tube (typically from 10AM to 20PM local solar time during summer). | 2.9 | °C |
| **Average Daily Fraction**<br>during which the earth tube works as a dissipator. | 0.44 | adim |
| **Specific Thermal Flow**<br>moved by the air across the earth tube @ 25 °C 1 atm in both directions (it cools the earth tube output flow during the day and heats it during the night). | 641 | W/°C |
| **Average cooling power per dissipating area of earth tube** | 8.11 | $W/m^2$ |

The winter monitoring has shown the amount of heating energy generated by the solar panels and the overall building performance. Details are given in the monitoring report. In summary the solar panels gave 15% of the heating supply, more that 12 000kWh per year.

## 4.23 Success of the project

- The temperature of the air flowing out of the earth tube stays quite stable near the th ground temperature taken at -3.2m. This may suggest that the cooling engine (the earth tube) somehow works.

- The ground temperature taken at -3.2m during summer is higher than theoretically expected. This may be due to seasonal accumulation effects in the ground near the tube because of the heat exchange with the air flowing in the tube. This fact may limit the cooling potential to the average temperature reached during some previous days, instead of exploiting the lower average temperature of one full year.

- Cooling power seems too small to overcome solar heating of the duct and heat exchanger located on the roof. In future applications, cooled air should not be brought outside the building for heat exchange in order to keep all cooling potential inside the building.

- Relative humidity of cooled air grows quite high. Additional dehumidification of cooled air carried into the interior of the building may be necessary in addition to basic earth tube cooling.

- The day-night temperature difference of the air flowing out of the earth tube (behaviour detected during the hottest days), and the fact that the temperature of the ground around the tube settle to the average temperature of the external air of some previous days, suggest that only the air at a temperature below daily average should be used to cool building interior. However, based on the observed data in our projectand with the limitation of a short monitoring period, in our system air should be allowed to flow inside the tube also during the night, when the air temperature is lower than the average underground temperature and than the air temperature flowing out the tube. During the summer period, this helps keeping the ground temperature around the tube at weekly average.

- Keeping the same size (20cm diameter) and length (40m) of tubes higher distances between pipes could have improved the cooling effects.
- No much greater cooling potential could have been achieved by longer tubes or lower air flow, since the outlet air temperature was already near the daily average, which is the lowest limit of the ground sink.
- The general conclusion is that the earth tube system in Vigevano was optimally planned for the specific location and use.
- The relatively smooth oscillation of the temperature inside the building seems mainly due to the thermal mass of the building.

## 4.24 Operating costs

| | | | |
|---|---|---|---|
| Energy Savings | - Space heating demand (Kwh/m$^{2)}$<br>- Quantity of energy saved (Kwh)<br>- Cost of energy saved (€/ Kwh) | 132.3 kWh/m2<br>15863.4 kwh<br>0.41 euro/kwh | Thermal space heating<br>Heating a<br>nd cooling |
| Renewables | - KW installed (KW)<br>- RES contribution (%)<br>- RES costs (€/m$^2$) | 3.6 kW<br>15%<br>54.3 euro/m2 | Ground cooling and solar collectors<br>For solar collectors<br>Net cost of renewables |
| Investment costs | - Extra investment costs (€/m$^2$)<br>- Extra running costs (€/m$^2$)<br>- Payback period (years) | 258.4 euro/m2<br>0<br>14.3 years | Ground cooling and solar collectors |

## 4.25 Future of the installation

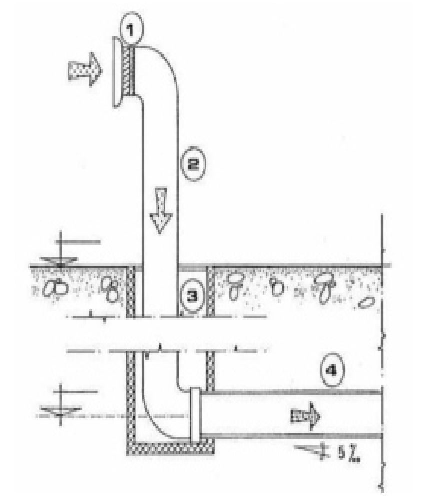
The building is going to be inhabited during 2004 with agreement between Aler Pavia and the Municipality of Vigevano. The building is showing good use.

SUITABILITY:
Domestic use ●●●
Non-domestic use ●●

New build ●●●

## 4.26 Economic viability

Several design parameters influence the cooling capacity of the ground cooling system. The length and diameter of the pipes is critical, as they must be long enough to induce the required amount of cooling at the appropriate air change rate within the constraint of site area. It is worth locating the pipes under soil that is shaded for a significant part of the day, as this will provide more effective cooling. Pipe bends sharper than 90° are not recommended due to the resultant air pressure loss and to facilitate cleaning. The material of the



ground cooling pipes must maintain a good balance of durability and ease of cleaning. The ground cooling system could be used for night cooling during the summer months. A drainage system will have to be designed into the ground cooling pipe arrangement to dispose of any excess water that may collect in the pipes. The thermal capacity of the surrounding soil type is important, as is the careful selection of backfill for the pipes to maximise their cooling capacity. The air inlet should be constructed in an unobstructed area to maximise the positive wind pressure, reducing the need for fan power.

Application

The system can be used in any residential or commercial type building. The earth tube is especially suited to climates where the hot season is matched with low-umidity levels.

Key benefits

- Provision of summer ventilation and improved comfort
- Reduction of summer thermal load (cooling)
- Reduction of summer peak temperatures
- Reduction in energy use (avoided air conditioning)

Recommendations

Cleaning and maintenance of the ground cooling system should be carried out regularly. A vacuum-type cleaner may be effective for pipe maintenance. Mesh grills could be used to remove airborne grit at the air inlet, but these would have to be cleaned regularly and may cause a slight drop in incoming air pressure. The relative humidity of the building location must be taken into account, as there can be a risk of condensation if the soil (and therefore pipe wall) temperature is significantly lower than the ambient temperature

SUITABILITY

| | |
|---|---|
| ● | Unsuitable in this situation |
| ●● | Possibly suitable but not ideal |
| ●●● | Ideal Solution |

AVAILABILITY

| | |
|---|---|
| ● | Specialised competence required |
| ●● | Competence required, but not specialised |
| ●●● | Easy no competence required |

RENTABILITY

| | |
|---|---|
| ● | Payback over 15 Years |
| ●● | Pauback between 8-15 years |
| ●●● | Payback between 3-8 years |

ARCHITECTURAL INTEGRATION

| | |
|---|---|
| ● | Consistent extra design activity required |
| ●● | Limited extra design activity required |
| ●●● | No extra design activity required |

# 5. Publicity, commercialisation and other developments

## *Overall COOLHOUSE project*

### 5.1 Publicity and publications

Much publicity has surrounded the developments because this is necessary for all the sites. Alma Verde needs to sell its houses, L'Aubier de Cybele needs to attract its elderly residents and the Circolab is being built in the middle of an old housing development to serve as the community centre. The environmental aspects of the buildings have been an important part of the publicity. Also all the technical consultants involved use the developments as examples of their work, and the COOLHOUSE buildings are very good examples to use. Below is a list of publicity activities, publications and awards.

- A paper was written and presentation made by Simon Burton at the 22nd AIVC conference in Bath, UK in September 2001
- Jes Mainwaring (Urbanizaçao das Furnas) and John Doggart (FaberMaunsell) attended the 2002 Building Services Awards held in London on the 1st July. The AlmaVerde project was chosen out of around 160 entries for the "International Achievement" category. The AlmaVerde project did not win, but was one of the runners up. An article about the Awards and the Coolhouse project appeared in FaberMaunsell's newsletter which is circulated to all divisions within the company and some clients.
- One of the Alma Verde houses, L53, received the Mercedes Benz Portuguese Property of the Year Award (this is an international award). This was substantially due to the enthusiasm by the judging panel for the integrated design approach driven by Coolhouse. This bodes very well for acceptance and replication by the broader property world in the future when the monitoring verifies performance.
- The Coolhouse website is up and running and improvements are in progress. Alma Verde (Urbanisacao Furnas) web site also features the Coolhouse project.
- In Italy a four pages full colour brochure was prepared in February 2003 for distribution during ALER Pavia institutional events (conferences and meetings with the other Italian Public Housing Companies and public administrations at local and national level) and at specific events related to passive systems and architecture, RE in buildings, etc. Publicity of the COOLHOUSE project to magazines and newspapers at local level (local news) and regional/national level (energy, environment, architecture, social housing) will take place in February and September 03.
- A full page colour article about the L'Aubier de Cybele appeared in the Feb 2002 edition of "Le Courier de l'age d'or" focussing on the Batiments Haute Qualite Environnementale (copies of pages attached).
- A new version of the CoolHouse web-site, upgraded in graphics and updated in contents was released in May 2003. The new web-site address is http://www.softech-team.it/coolweb/cool-index.htm
- A new Alma Verde brochure has been produced.
- The Alma Verde house were entered for the UK RIBA environmental awards in May 2003. They did not win a prize in this instance.
- Contact has been made with the Portuguese OPET network to publicise the buildings.
- Two articles on the CircoLab in two of the most popular local magazines.
- An A4, four pages full colour leaflet is been printed by ALER Pavia on the Circolab project. The leaflet shortly describes the EC funded CoolHouse Project, the CircoLab concept, the energy saving and substitution technologies, the functioning of the system during the cooling and heating seasons and gives detail on the participant. The leaflet, printed in 300 copies, is and will be distributed to the ALER Pavia institutional events (conferences and meeting with other Italian Public Housing Companies and public administrations at local and national level) and to specific events related to passive systems and architecture.

- On 19th of June a press conference with journalist of the local newspapers was organized in the CircoLab, in connection to the visit of the Coolhouse meeting held in Torino. Mr. LUISANI, Deputy Mayor to Social and Welfare Programs of the City of Vigevano, and Mr. ROSSETTI, President of ALER Pavia, were attending to the conference and interviewed by journalists.
- An abstract for presentation of COOLHOUSE at the 2004 AIVC conference in Prague has been submitted
- The COOLHOUSE web site is being reworked to include final results.
- Alma Verde won the Gold medal 2004 for “The Most Environmentally Aware Development” in “Homes Overseas” magazine sponsored by British Airways and the Daily Telegraph and Moneycorp.

The interest in the project and the three sites has been very positive. All three developments are architecturally interesting and have been seen and are used by many people. All are seen as sustainable constructions and there is growing interest in this aspect. In terms of results, alma Verde houses are selling well and the development growing fast. The Frejus nursing home is nearly full of residents and the Circolab is proving a great success with local community.

## 5.2 Patent activity

No patent activity has been taken relating to this project.

### 5.3 Outlook

No outstanding problems have been identified with the technologies demonstrated in COOLHOUSE. No doubt small improvements could be made in the details but these will be related to specific conditions and situations in different developments. There may be future maintenance difficulties related to cleaning or water collection in the tubes but these may not become apparent for many years. Paybacks for fully commercial replication are estimated by the sites to be less than 10 years with a very long lifetime and low maintenance compared with active chilling systems

What is the wider replication potential? Ground cooling and passive design has been used in the past to achieve comfort in summer before the availability of active chillers and associated systems, and more recently in relation to commercial non-domestic developments (we know of many in Germany). Current domestic type construction in hot countries is normally designed without considering the use of insulation, thermal mass and shading, to reduce summer overheating. Occupants expect more and more to have lower temperatures in summer and the solution adopted is to have active cooling using chillers, frequently simple through the wall split systems. Energy is still relatively cheap and chillers can be turned on and off to provide blasts of cold air when required. Studies of energy consumption in southern European countries show an alarming increase in summer electricity demand resulting principally from air conditioning.

Ground cooling and passive cooling design could be used right across Europe in all new developments, both residential and commercial, giving this project tremendous replication potential. One of the main factors to be considered is not just payback but also up front cost, as this is what the developer pays (not the fuel bills) and what the individual purchaser must add to his purchase price. Compared with individual through-the-wall chiller units costing less than 500euros, ground cooling is expensive. Whilst life time costings may show the benefits of passive cooling systems over active chillers, it is unlikely to appeal to the majority of developers without financial support or regulatory pressure.

### 5.4 Commercialisation

COOLHOUSE is a demonstration project and all results are made public. As with most building components and systems, replication can be carried out by anyone. Alma Verde is replicating the system on the future developments of the site, as long as purchasers wish it. The Frejus contractor is unlikely to build many similar developments being a personal organisation. "Commercialisation" or rather replication of the passive building measures and ground cooling systems, will also be undertaken by the other design, and construction partners, particularly FaberMaunsell, Softech, University of Athens, Concept Energie, and the building contractors at Frejus.

## *Alma Verde, Portugal*

### 5.5 Publicity and Publications

The Alma Verde Coolhouse villas, have received a number of awards to date. These awards are:

- Chartered Institute of Building Services Engineers, Building Services Awards 2002 (UK)-
- Finalist in International Achievement of the Year Category. Awarded for the Coolhouse system.
- Mercedes Benz International Property Awards, 2002 (UK)- Best Portuguese Property
- Overseas Homes Awards, 2004 (UK)- Gold Award, Most Environmentally Aware Development. This award covers Spain, Portugal, France, Florida and Cyprus.

Alma Verde has been publicised extensively to prospective purchasers and the COOLHOUSE aspects are a part, all be it small, of these efforts. Full details and an analysis of the marketing potential of environmental design are included in Common Task 3, the "Marketability of Passively Cooled Housing". This describes the brochures produced, the web site etc.

### 5.6 Outlook

There are no outstanding problems or improvements that could be made to the system that we are aware of at the present time, and all of the technology is commercially produced and readily available.

The availability of the components of the system and its simplicity make it a relatively low cost means of procuring effective comfort cooling, whose low energy benefits will become increasingly relevant as energy costs increase. For this reason, the Coolhouse system is now installed as standard in all houses at Alma Verde, unless specifically omitted by purchasers, and could be simply replicated virtually anywhere.

### 5.7 Commercialisation

Commercialisation of the Alma Verde ground cooling system is limited to its installation as standard in all houses at Alma Verde, unless specifically omitted by purchasers. There are currently a further eleven houses with the Coolhouse system under construction at Alma Verde, with two more due to commence in the immediate future.

## *Frejus, France*

## 5.8 Publicity and publications

Being the very first green building in this activity, and especially showing many interesting technical choices concerning summer comfort, l'Aubier de Cybelle is of first interest to public and private builders, in this region of France, where the population is growing constantly and building programs are frequent. Climatic conditions of last summer, and its dramatic issue (mainly concerning elderly people) have also largely contributed to interest even more builders, and public authorities, in passive cooling of care homes.

Several articles have already been published in professional journals and the local newspaper. Two recent conferences for architects, taking place in Marseille, and in Moustiers Ste Marie, included a presentation of the building . Visits are being regularly organized for professionals, and builders (for instance, the Conseil Général du Var, who builds all the public secondary schools and care homes of the department).

Dissemination actions will be carried out all through 2004, and beyond, when monitoring results of a full year's exploitation will be available.

Dissemination strategy

Four main targets have been identified for the dissemination strategy, which main objective is to show how to reach the targets of a "green building", and in particular what bioclimatic global design and its different energy efficient alternative solutions can be applied to the tertiary sector, with comfort and high global quality guarantee :

- main public contracting authorities, concerned by the construction of buildings in the tertiary sector (health, education…) : local authorities such as the Conseil Régional (Region board), the Conseil Général (Department board), Towns …;
- main private contracting firms involved in tertiary sector construction (mainly in care homes and office buildings) ;
- architects and future architects (schools and universities) ;
- engineering offices, working in the field of energy in buildings.

All these professionals will be reached through different dissemination actions and documents, as from beginning of 2004 :

- articles to be published in professional magazines in the field of architecture, energy efficiency, green buildings, the health sector and the specalized sector of care to elderly people (two articles have already been published and others are expected early 2004 ) ;
- presentations at meetings and conferences (3 presentations have already been performed – others are expected) ;
- detailed presentation of the building for training sessions dedicated to architects and other professionals (2 sessions have already been performed )
- visits of the building (three visits have already been organized ) ;
- presentation of the building to be published in reports and publications on Mediterranean bioclimatic architecture ( a report is actually been prepared – see annex 1) ;
- information and experience sharing and discussion with the EnviroBat Association (professional organisation on green buildings in the Mediterranean zone in France).

For this purpose, a press file of the building is being prepared.

Besides, several non technical actions are taking place and will be carried all through 2004 and beyond :

- non technical articles to be published in local newspapers (an article has already been published ) and in magazines dedicated to elderly people ;
- technical and non technical leaflets to be handled to visitors ;
- visits for schools.

They should allow local residents and the young public to discover the reality of environmental friendly buildings, and energy efficient and renewable energy technologies

List of publications

| | |
|---|---|
| Le Moniteur du BTP – 07/03/2003 | Une maison de retraite qui respecte les principes de l'éco-construction |
| Terre d'Architecture – septembre 2003 | Energie capitalisée, isolation répartie |
| Var Matin – 3/02/04 | Fréjus : une maison d'avenir pour les anciens |
| Association Envirobat – 2004 | Répertoire des constructions bioclimatiques de la region |
| Atouts Solaires – Enerplan - 2004 | Technical leaflet on the building, to be distributed to more than 4000 professionals and owners through France |

List of presentations

| | |
|---|---|
| Séminaire EnviroBat – 9/03/04 | 50 members of EnviroBat association |
| La demarche environnementale et la maîtrise de l'énergie : exemple de la maison de retraite de Fréjus – Moustiers Ste Marie – 18/2/04 | 25 architects |
| Séminaire Haute Qualité Environnementale – Marseille – 23/01/2004 | 70 people, mainly architects and public authorities |
| Formation au Parc Naturel Régional du Luberon – 18/01/2004 | Staff of this Natural Park : architects, environmental engineers, energy agents… |
| Formation et sensibilisation des architectes à la demarche HQE – Association HQE – November 2003 | 20 architects |

List of visitors

- CONSEIL GENERAL DU DEPARTEMENT DU VAR : DIRECTION DU PATRIMOINE (Var Departement authorities in charge of the building sector)
- AGENCE DE L'ENVIRONNEMENT ET DE LA MAITRISE DE L'ÉNERGIE (SOPHIA ANTIPOLIS) (French Environnement and Energy Efficiency Agency )
- ENERPLAN (Society of professionals working in the field of renewables energies)
- ACCENT ENVIRONNEMENT (Environment Engineer)

### 5.9 Outlook

The main outlook referring to this project is related to the technical feasibility, economical viability of energy efficient solutions to reach high summer comfort, for elderly people (a population whose health and capabilities to fight physiologically against hot conditions), in a region which is particularly exposed to hot and dry summers, and after a dramatic 2003 summer.

The success of the project will participate in developing such technical choices in all south Mediterranean region of France, where, since last hot summer and its dramatic issue, indoor comfort during the summer in hospital and care homes has become a key societal and environmental issue. Alternative solutions to centralized air-conditioning are of even greater importance in this very part of France, where an important demand-side management program for electricity was launched a year ago, in order to avoid the development of a new high voltage grid through the Verdon area (natural protected park).

The Frejus project is one of the very first concrete realization in the area aiming towards less electricity consumption, and power need in the building sector.

## *Aler Pavia, Italy*

### 5.10 Publicity and publications

- A new version of the CoolHouse web-site, upgraded in graphics and updated in contents was released in May 2003. The new web-site address is http://www.softech-team.it/coolweb/cool-index.htm
- Two articles on the CircoLab in two of the most popular local magazines.
- An A4, four pages full colour leaflet is been printed by ALER Pavia on the Circolab project. The leaflet shortly describes the EC funded CoolHouse Project, the CircoLab concept, the energy saving and substitution technologies, the functioning of the system during the cooling and heating seasons and gives detail on the participant. The leaflet, printed in 300 copies, is and will be distributed to the ALER Pavia institutional events (conferences and meeting with other Italian Public Housing Companies and public administrations at local and national level) and to specific events related to passive systems and architecture.
- On 19th of June a press conference with journalist of the local newspapers was organized in the CircoLab, in connection to the visit of the Coolhouse meeting held in Torino. Mr. LUISANI, Deputy Mayor to Social and Welfare Programs of the City of Vigevano, and Mr. ROSSETTI, President of ALER Pavia, were attending to the conference and interviewed by journalists.

### 5.11 Outlook

The outlook for use of the CircoLab is very positive and the building is operating well.
The cooling performance of the buried pipe system is disappointing but in other respects the project is a great success.

# 6. Lessons learned/conclusions

An overall summary is given in section 6.4.

## *6.1 Alma Verde, Portugal*

- The Alma Verde Coolhouse system is successful in providing low cost low energy temperature reductions generally sufficient for homes and residential buildings as an alternative to air conditioning. Subject to the availability of adequate external area for ground tube installations, there is no limit to the number of zones within a building that can be individually cooled by the addition of further air handling units.
- The system achieves the equivalent cooling of fresh ventilation air at a 95% reduction in energy cost and $CO_2$ emissions compared with air conditioning.
- There is negligible impact on the architecture of the building, beyond the provision of a small fresh air intake chamber, and minimal housing for the air handling unit(s) and attenuator. These could be housed in an annexe building in close proximity such as a garage.
- The construction of the building needs to achieve a good thermal performance whilst guarding against solar gains, and carry high levels of thermal mass to optimise the coolth available from the Coolhouse system. This is true of any building that aims to be energy efficient whether considering heating or cooling energy.
- Integration of the system into the building needs to be accommodated at design stage.
- The maximum capacity of the system to cool a building volume is largely a function of the thermal performance of the envelope and the balanced distribution of cooled air. These require mechanical engineering design in each case.
- Useful ventilation pre-heat gains are available in winter mode. The Coolhouse air distribution strategy needs to integrate with the heating system to exploit these gains.
- The Alma Verde Coolhouse system combined with the use of adobe blockwork and vapour permeable external wall construction is very effective in making significant reductions in internal Relative Humidity compared to external conditions.
- ·The simplicity of the system and general availability of its components makes the system easy to replicate anywhere.

In terms of design development of the technology, installation and operation of the system, the process has progressed satisfactorily. It has presented no more difficulties beyond those one would normally expect to encounter in such a design and installation exercise, where parameters are established, options considered and optimal solutions developed. We would be unlikely to proceed in a different way if the project were to be repeated.

Further research into the thermal behaviour of different types of subsoil and the effect of varying moisture contents would enable this work to become more precise in terms of predicting cooling potential and therefore refining design limits.

## *6.2 Frejus, France*

This very ambitious project has managed to reach successful completion, even though having to go through many difficulties, and thus without any major changes compared to the very first original project. Human energy and will were the two major factors that allowed the building to grow and stick to its initial plans, mainly thanks to Mrs Merel and Demonein who were present during all the works.

The main lessons learned throughout this project are :

- the importance of preliminary work which has to be carried out, during the conception phase, and before the construction works, with all the actors involved (engineers, architects, construction firms) in order to make sure that the global environmental issue of the building has been well understood, that each actor is aware of his responsibility and work field ;
- the difficulty in heading straight forward according to a initial schedule in such innovative projects, where financial terms have to be discussed and overcosts strongly discussed, using a global costs approach at every stage of the project ;
- the necessary training of technical teams on alternative solutions to centralized air-conditioning, to avoid difficulties and unnecessary over-costs – especially concerning the ground cooling system which does not present major technical difficulties but can be cause of time and money waste for non-trained workers.

After the very hot summer of 2003, and the dramatic issue in France, French Government has just published an official request, addressed to local authorities, in order to make sure that a common space, in all care home for elderly people, is properly cooled in the summer. L'Aubier de Cybelle, with its passive cooling numerous solutions, and its innovative ground cooling system, is already beyond French authorities' recommendations and will, with no doubt, play a major demonstrative role in a very close future for all new buildings in the same sector.

## *6.3 Aler Pavia, Italy*

- The temperature of the air flowing out of the earth tube stays quite stable near the th ground temperature taken at -3.2m. This may suggest that the cooling engine (the earth tube) somehow works.

- The ground temperature taken at -3.2m during summer is higher than theoretically expected. This may be due to seasonal accumulation effects in the ground near the tube because of the heat exchange with the air flowing in the tube. This fact may limit the cooling potential to the average temperature reached during some previous days, instead of exploiting the lower average temperature of one full year.

- Cooling power seems too small to overcome solar heating of the duct and heat exchanger located on the roof. In future applications, cooled air should not be brought outside the building for heat exchange in order to keep all cooling potential inside the building.

- Relative humidity of cooled air grows quite high. Additional dehumidification of cooled air carried into the interior of the building may be necessary in addition to basic earth tube cooling.

- The day-night temperature difference of the air flowing out of the earth tube (behaviour detected during the hottest days), and the fact that the temperature of the ground around the tube settle to the average temperature of the external air of some previous days, suggest that only the air at a temperature below daily average should be used to cool building interior. However, based on the observed data in our projectand with the limitation of a short monitoring period, in our system air should be allowed to flow inside the tube also during the night, when the air temperature is lower than the average underground temperature and than the air temperature flowing out the tube. During the summer period, this helps keeping the ground temperature around the tube at weekly average.

- Keeping the same size (20cm diameter) and length (40m) of tubes higher distances between pipes could have improved the cooling effects.

- No much greater cooling potential could have been achieved by longer tubes or lower air flow, since the outlet air temperature was already near the daily average, which is the lowest limit of the ground sink.

- The general conclusion is that the earth tube system in Vigevano was optimally planned for the specific location and use.

The relatively smooth oscillation of the temperature inside the building seems mainly due to the thermal mass of the building.

## *6.4 COOLHOUSE overall conclusions*

COOLHOUSE confirms that several straightforward construction measures are important in providing summer comfort, including solar shading, thermal mass, insulation etc. and that ground cooling pipes can also contribute. The report on Common Task No 1 shows that a whole range of measures and systems are possible. Ground cooling pipes work best if they are used in a simple way e.g. air pulled slowly through and used directly as cooled ventilation air. Then they can deliver air at, at least $10^0$C below outside air temperatures at peak times. At night if the air is cold it can be drawn through to help cool the ground ready for the next day. The pipes can be used only for peak times of the day or for longer periods and also for preheated ventilation air in winter. They can make active air conditioning unnecessary but cannot supply the same blasts of cold air, they work in a slower way and will work best if there is a pre-planned strategy for their use. Ground cooling pipes supply coolth over long periods of time but at a low rate, which is almost the opposite of active chillers. This is very important in understanding and designing a good ground cooling system.

The experience in the community centre in Italy is more difficult, as the ground pipe cool air passes through a heat exchanger first and is integrated mechanically into the heating and ventilating system of the building. The benefits of ground cooling are more difficult to identify and it seems that the particular use strategy was not best suited to the pipe system installed.

We conclude that ground pipe systems work best where the building itself is passively designed to minimise the need for cooling and then a ground cooling system will lop off the peaks of temperature. This generally gives a very comfortable internal environment.

The costs of ground cooling obviously vary with the size but are not expensive, a price per house of about 7500euro was quoted at Alma Verde and a rough estimated payback was 10 years, due to avoided electricity running cost of chillers. From an environmental point of view the energy savings are large at around 5000 tonnes of $CO_2$ per year per house. This is a very significant conclusion for European energy consumption.

The study on Regional Suitability of the technologies (Common Task No 5) concludes that all technologies are widely applicable across southern Europe where cooling is needed, and could become useful in more northern areas as global warming spreads its effects.

Design of passive cooling measures, including ground pipe systems is not difficult and methods are described in the report on Calculation Methods Used (Common Task No 4). Computer modelling and calculation methods are available and are tried and tested. The integration of the passive measures into the architecture of a building are not likely to cause any major difficulties, is the conclusion of the Architecture and Passive Design report (Common task No 2), but they must be carefully considered from the start of the design process.

Overall it is concluded that occupants like the passive systems but there remains the question as to whether individuals will actually buy in. The Marketability of Passively Cooled Housing report (Common Task No 3) concludes that although passive cooling is low on the list of priorities of prospective purchasers it does have some marketing benefits and has been used as such at Alma Verde (the only private development for sale in COOLHOUSE). The report also indicates that a significant number of purchasers will opt for the optional “COOLHOUSE” system, if offered to them at the current price.

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# 8. Photographs

Photographs of each of the three active sites are provided.

# Annexes (separate)

## Design reports

1. Alma Verde, Portugal
2. Frejus, France
3. Aler Pavia, Italy
4. Ecological ElGreco Community Developments, Crete, Greece

## Common Task Reports.

1. Report on technologies used, description, cost, advantages and potential difficulties
2. Report on the architecture and effects of passive cooling design and lessons for other countries
3. Report on the marketability of the passively cooled housing
4. Study of Calculation Methods used and design techniques used, including modelling
5. Analysis of regional suitability of project technologies in different countries.
6. Summary report of monitored performance, savings and payback in each country
7. Dissemination report

## Monitoring Reports.

1. Alma Verde, Portugal
2. Frejus, France
3. Aler Pavia, Italy

## Other attachments.

1. L'Aubier de Cybele, Batiment de Haute Qualite Environnmentale, HQE Assessment.
2. Dissemination and publicity materials.