Project: Design & development of a laboratory building of CRES, with implementation of RES technologies, in Pikermi, Attiki

**Building Volume**

<table>
<thead>
<tr>
<th>Description</th>
<th>m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>1464</td>
</tr>
<tr>
<td>Basement area</td>
<td>483</td>
</tr>
<tr>
<td>Ground floor area</td>
<td>519</td>
</tr>
<tr>
<td>1st floor area</td>
<td>462</td>
</tr>
</tbody>
</table>

**Building Area**

<table>
<thead>
<tr>
<th>Description</th>
<th>m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>1049</td>
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<tr>
<td>Basement area</td>
<td>173</td>
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<tr>
<td>Ground floor area</td>
<td>180</td>
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<tr>
<td>1st floor area</td>
<td>167</td>
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<tr>
<td>Roof</td>
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**Net Headed Building Area**

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</thead>
<tbody>
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<td>Total area</td>
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<tr>
<td>Basement area</td>
<td>127</td>
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<tr>
<td>Ground floor area</td>
<td>154</td>
</tr>
<tr>
<td>1st floor area</td>
<td>147</td>
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</table>

**Windows Surface**

<table>
<thead>
<tr>
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<th>m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>55</td>
</tr>
<tr>
<td>North</td>
<td>14</td>
</tr>
<tr>
<td>South</td>
<td>17</td>
</tr>
<tr>
<td>East</td>
<td>17</td>
</tr>
<tr>
<td>West</td>
<td>14</td>
</tr>
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</table>

**Greenhouse Windows Surface**

<table>
<thead>
<tr>
<th>Description</th>
<th>m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>15</td>
</tr>
<tr>
<td>North</td>
<td>7</td>
</tr>
<tr>
<td>South</td>
<td>7</td>
</tr>
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</table>

**Clerestories Windows**

<table>
<thead>
<tr>
<th>Description</th>
<th>m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>14</td>
</tr>
<tr>
<td>North</td>
<td>8</td>
</tr>
<tr>
<td>South</td>
<td>7</td>
</tr>
</tbody>
</table>

**Greenhouse Area**

<table>
<thead>
<tr>
<th>Description</th>
<th>m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>8.25</td>
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**Solar Wall Surface (thermosyphonic)**

<table>
<thead>
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<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Total area</td>
<td>17</td>
</tr>
<tr>
<td>Right</td>
<td>6</td>
</tr>
<tr>
<td>Left</td>
<td>10</td>
</tr>
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</table>

**Transparent Insulation Surface**

<table>
<thead>
<tr>
<th>Description</th>
<th>m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>8</td>
</tr>
</tbody>
</table>

**Thermal characteristics**

- Roof from reinforced concrete slabs: 0.33 W/m²K
- Reinforced concrete vertical structural elements: 0.65 W/m²K
- Brickwork vertical structural elements: 0.55 W/m²K
- Brickwork vertical structural elements with transparent insulation: 0.53 W/m²K
- Reinforced concrete floor in non-heated areas: 0.58 W/m²K
- Openings: 3.72 W/m²K
- Thermal conductance coefficient of the Transparent Insulation(s): 0.04 W/m²K
- Thermal conductance coefficient of Tektalan (3x): 0.04 W/m²K
- Overall heat transfer coefficient (h): 0.82 W/m²K
- Overall external surface / Volume (F/V): 0.66 m²

**Photovoltaic panels, 600 Wp**

<table>
<thead>
<tr>
<th>Description</th>
<th>m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Users</td>
<td>20</td>
</tr>
</tbody>
</table>

**Site and Climate**

- Longitude: 23° 35' E
- Latitude: 38° 01' N
- Altitude: 153 m
- Average ambient temperature (annual): 18.7 °C
- January: 9.4 °C
- July: 27.8 °C
- Degree Days (base 19 °C): 1218 days
- Global Irradiation on horizontal (annual): 1747 KWh/m²

**Costs (1999 prices)**

- Conventional construction: 352,000 EURO
- Energy systems: 39,780 EURO

**FUNDING:**

- General Secretariat for Research & Technology - Construction Service
  14-18, Messogion Ave. GR-11510, Athens
  Tel:+30 10 77.03.564, fax: +30 10 77.11.071

**Project:**

- OPERATIONAL PROGRAMM FOR RESEARCH & TECHNOLOGY MEASURE 3.1

**Construction:**

- Electromec S.A.
  Catherine Cristide (Civil Engineer)
  Giota Batistatou (mechanical Engineer)
  Ourania Flabouri (electrical Engineer)
  Gregory Economides (Dr. Civil Engineer)
  Evi Tzanakaki (Architect Engineer MSc)
  Michael Karagiorgas (Dr. Mechanical Engineer)
  Spiropoulou (Architect Engineer)

- SOLE S.A.
  Savvas Tsilenis G.S.R.T.
  Alex Kastanis G.S.R.T.
  P. Hatzinicolaou G.S.R.T.
  Gregory Economides C.R.E.S.
  Michael Karagiorgas C.R.E.S.
  Maria Bololia (Technical Mechanical Engineer)

- Christos Dokios
  64, Didaskalou Str.
  GR-156 69 Papagou, Athens
  Tel.: +30 10 65.26.920, fax. +30 10 65.26.920
  e-mail: xdoki@tee.gr

**Monitoring Team:**

- Gregory Economides (Dr. Civil Engineer)
  Michael Karagiorgas (Dr. Mechanical Engineer)
  Maria Bololia (Technical Mechanical Engineer)

**BMS Installation:**

- EB Shop
  Christos Dokios
  64, Didaskalou Str.
  GR-156 69 Papagou, Athens
  Tel.: +30 10 65.26.920, fax. +30 10 65.26.920
  e-mail: xdoki@tee.gr

- Solar Appliances Manufacturer:
  SOLE S.A.
  Lefktron & Laikon Agonon
  18, Tiantsis Str., GR-114 72, Athens
  Tel.: +30 10 23.88.088, fax. +30 10 28.25.690
  e-mail: export@sole.gr
  http://www.sole.gr

**Owner:**

- C.R.E.S.
  Center for Renewable Energy Sources
  19th km Marathonos Ave.
  GR-190 09 Pikermi
  Tel: +30 10 66.03.300, fax. +30 10 66.03.305
  e-mail: groiko@cres.gr
  www.cres.gr

**Bioclimatic and Low Energy Office Building**
Passive and Hybrid Solar Systems

The building design specified the incorporation of passive solar systems (P.S.S.), the aim of which is to use solar energy for heating:

- Direct gain systems (openings on the south face with a total area of 17 m²) for collecting solar radiation for passive heating during the winter.
- Greenhouse with an area of 8.25 m² added to the south face of the building, with openings of 12 m² where solar radiation is collected as heat and is distributed through openings in the building.
- Solar air collectors: air panels with a total area of 17 m² incorporated into the south face of the building which collect solar radiation and give off heat either through openings (direct) or when preheated air to a heat pump on the roof (indirect).
- Solar atrium (glazed part of the roof of the building with an area of 14 m²) to collect solar radiation and produce thermal energy to heat the central internal part of the building.
- Transparent insulation with a total area of 8 m² to reinforce solar gains on the south facing parts of the building.

Daylighting

Parallel to and in conjunction with the passive solar systems, daylighting systems were studied in order to provide the building with natural light for the greatest possible part of the day resulting in a reduction of electricity required for lighting. For this purpose, the following were designed:

- Roof lighting system partially glazed roof to let in natural light for the central part of the building.
- Atrium onto which internal doors open to allow daylighting to enter the innermost parts of the building.

Use of Renewable Energy Sources in the HVAC System

- Geothermal water to water heat pump
  During the winter period, water from the well comes through the evaporator of the geothermal water to water heat pump and provides heat to the chilling cycle (the design temperatures for the circulation of the stored water are 18/2°C). At the same time, the heat pump condenser heats the separate circulation of the water in the fan coil network on the ground floor and provides heat for it, thus raising the temperature which was reduced by the heat loss load of the building, the temperatures specified for the fan coil units are 45/40°C. The system works the same way during the summer period. The unit uses the stored water of the existing well which is 80 m deep, located 10 m north of the building. The temperature of the well water was measured in May at 21°C and the well provides water at a rate of 1.2 m³/h. The heat pump has a refrigeration power of 16 Kw and a heating power of 17.5 Kw. It is R22 technology with a reciprocating compressor and set step at 0-100. The COP factor of the heat pump for the above temperatures is 4.2 and the water heat exchanger is a concentric type.

- Solar assisted water-air heat pump
  The cooling and heating load of the first floor is covered by a solar assisted 18 Kw air-water heat pump. During the winter, the air, pre-warmed by the solar air collectors with a total area of 17 m² and with a specified supply rate of 1700 m³/h, is drawn into the evaporator of the solar assisted air-water heat pump, aided by centrifugal fans and supplies heat to the refrigeration cycle (the temperatures specified for the circulation of the prewarmed fresh air is 18/3°C).
  The distribution network of the first floor heat pump is similar to that of the ground floor heat pump.

- Solar assisted water-air heat pump
  The heat pump has a chiller power of 16.5 Kw and heating at 18 Kw.
CRES is located 20 kilometres from the center of Athens in the Mesogeia area on Marathon Avenue in the village of Pikermi, an agricultural area with olive groves and vineyards, which has been rapidly built up over the last 20 years.

The location is quite favourable with minimal noise and air pollution. The vegetation around the building does not have an impact as it leaves the south face open to direct sunlight. The buildings adjacent to the north face and the small trees to the west provide partial protection from cold north winds. The average ambient air temperature in January is 9.4°C and 28.7°C in July.

The building is heated from mid-October to the end of April and the degree days for heating are 1217.5 (19°C base).

The building was constructed according to its design specifications and Greek building regulations. The building envelope was constructed using reinforced concrete C20/25 with S500 steel. The walls are double brick and the insulation was placed on the outside to avoid creating thermal bridges.

The internal walls are made of drywall (gypsum board), internally insulated with fiberglass. The external surfaces were constructed of 3 coats of cement plaster.
Artificial Lighting System

Artificial light is supplied through the general lighting installation of the building which is automatically controlled by the BEMS. The luminates used have low energy consumption fluorescent pipes or compact PLC type lamps. Ceiling light fixtures have high frequency electronic ballasts, metal lengthwise parabolic blinds and double parabolic elements or ceiling spots with shiny reflectors.

Building Energy Management System (BEMS)

The reason for installing a BEMS was the monitoring and/or automatic control of the building's electrical and mechanical installations so that it will be possible to have immediate access, uninterrupted operation, settings adjustment and data analysis for all the building and system functions from a single control station. In certain rooms, the operation of an air cooled heat pump.

The central control unit and the first floor control board

- Greenhouse
- Solar atrium
- Walls with transparent insulation
- Lighting system
- Cooling systems
- Air quality
- Building electricity consumption monitoring

The control system consists of a Central Control and Monitoring Station, the EB system sensors, EB command execution devices and connecting cables. The programming and operation of the system is easily carried out through the central control station. In certain rooms, the operation and selection of different modes is carried out with local controls which have mode options.

The system is composed of independent structural elements which have been selected and connected to each other so as to allow control and monitoring of the building from a central point by computer. The Control Station is connected by a 65235 interface.

The latest digital technology EB has been used. The guiding commands are transferred through a pair of twisted reinforced cables from the central unit to the decoders. The system is supplied with low voltage power (up to 24 V).

In the basement of the building (the library), two air to air heat pumps of semi-central type have been installed.

Photovoltaic Panels

On the sloping part of the roof which covers the solar atrium, 12 photovoltaic panels (dimensions 152 cm x 64 cm x 5 cm) were installed with a total power output of 600 W (amorphous silicon), directly connected to the building's electricity supply through an inverter. The inclination of the photovoltaic panels is 20° for architectural and aesthetic reasons, although for maximum yearly output it should be 40°. Also, a solar collector for producing hot water (60 °C) was installed to cover the building's limited needs for hot water.

Economic Analysis

The energy technologies and systems installed in the building cost 1990 prices, 11% (30,710€) of the total cost of the building. Based on the results of the first 126 days of energy measurements in the building and on the calculated energy saving (35165 Kwh/ year) compared with similar "conventional" buildings, there is a simple payback period of 14.5 years. The payback period would have been much smaller, but because the building was a demonstration project, systems were installed which increased the cost of energy technologies (three air conditioning systems, double number of sensors and actuators for the BEMS, etc.) and therefore, the payback period.

User Behaviour problems which were Encountered

Due to the many different systems which were installed for demonstration, the building requires systematic monitoring by an energy manager. In particular, maintenance problems were encountered with the automatic controls and controlled devices (relays, filters, etc.) of the well pump. There were also complaints from building occupants who work in rooms facing a site orientation associated with adverse thermal loads because it was not possible to control effectively the room air temperature (range of 3.5 °C by the system thermostat). Additionally, BEMS computer breakdowns often created malfunctions in the various controlled systems, especially the air conditioning one.