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Introducing energy saving systems in buildings

A comprehensive summary

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Passive and active systems

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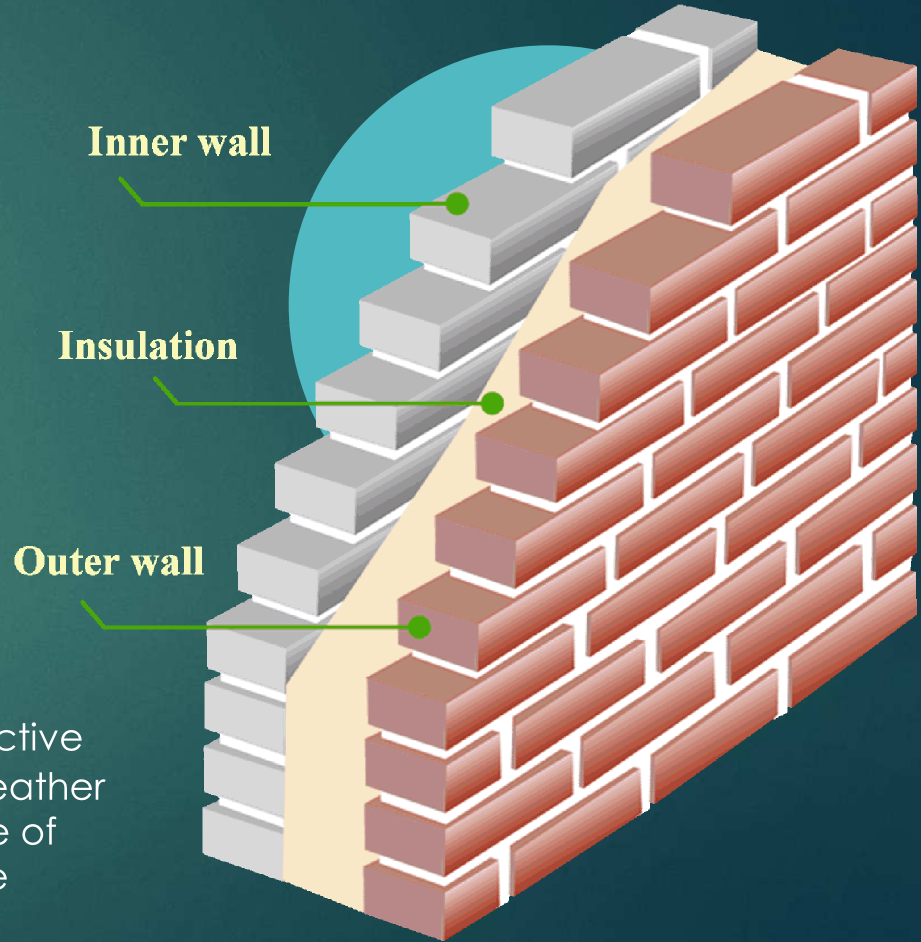
- Renewable Energy Sources (R.E.S.) can be exploited in buildings with the following categories of systems:
- **Passive solar systems:** they are embodied in the buildings' envelope, aiming at the use mainly of the wind and solar energy to minimize the heating and cooling loads.
- **Active systems:** the R.E.S. are captured through specific technologies and converted to useful final forms of energy (e.g. solar collectors for thermal energy, PVs & wind turbines for electricity production).

Passive systems

Outer walls and roofs insulation

The outer walls and roofs appropriate insulation reduces their U-values[1] from values higher than 2W/m²·K to values around 0,5 – 0,7W/m²·K, leading to an analogous reduction of the thermal losses or solar gains through them.

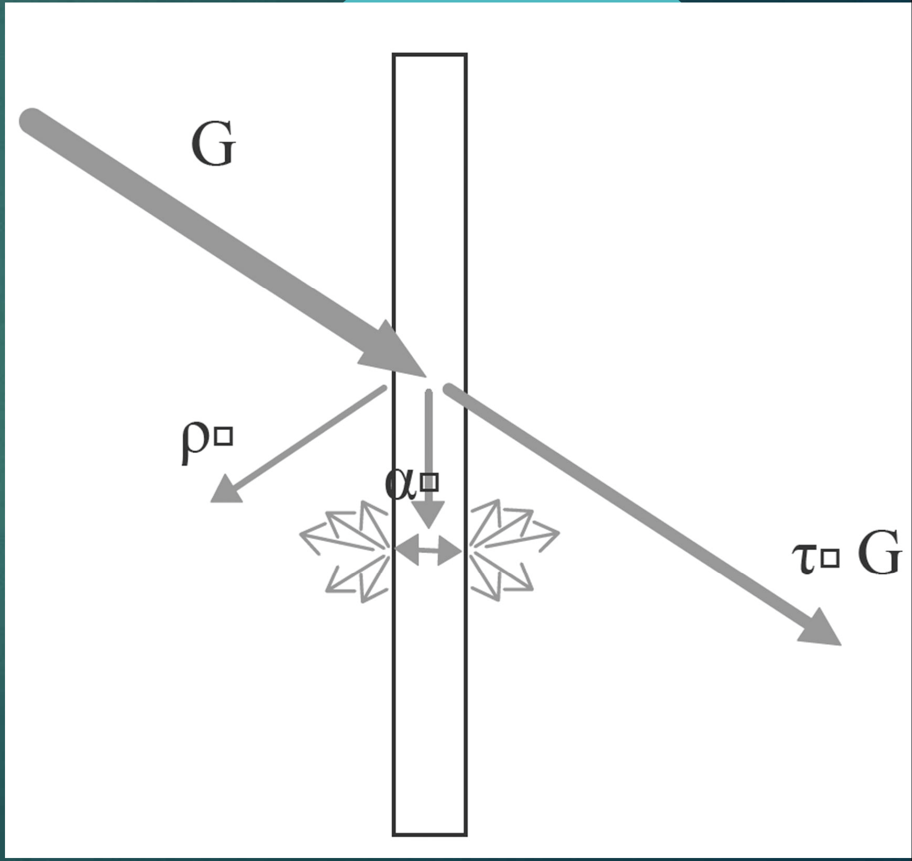


[1] U is the so called "thermal transmittance" of a building's constructive element, configured by its materials' properties and the existing weather conditions. It is measured in W/m²·K in S.I. and it determines the rate of the thermal energy transmittance through the specific constructive element.

Windows

A glass is characterized by three factors:

- **reflection coefficient ρ**: determines the solar radiation reflected from the glass back to the ambient
- **absorption coefficient α**: determines the solar radiation absorbed by the glass and transferred later to the outer and inner space, through conduction, convection and radiation
- **transmission coefficient τ**: determines the solar radiation directly transmitted through the glass to the inner space.



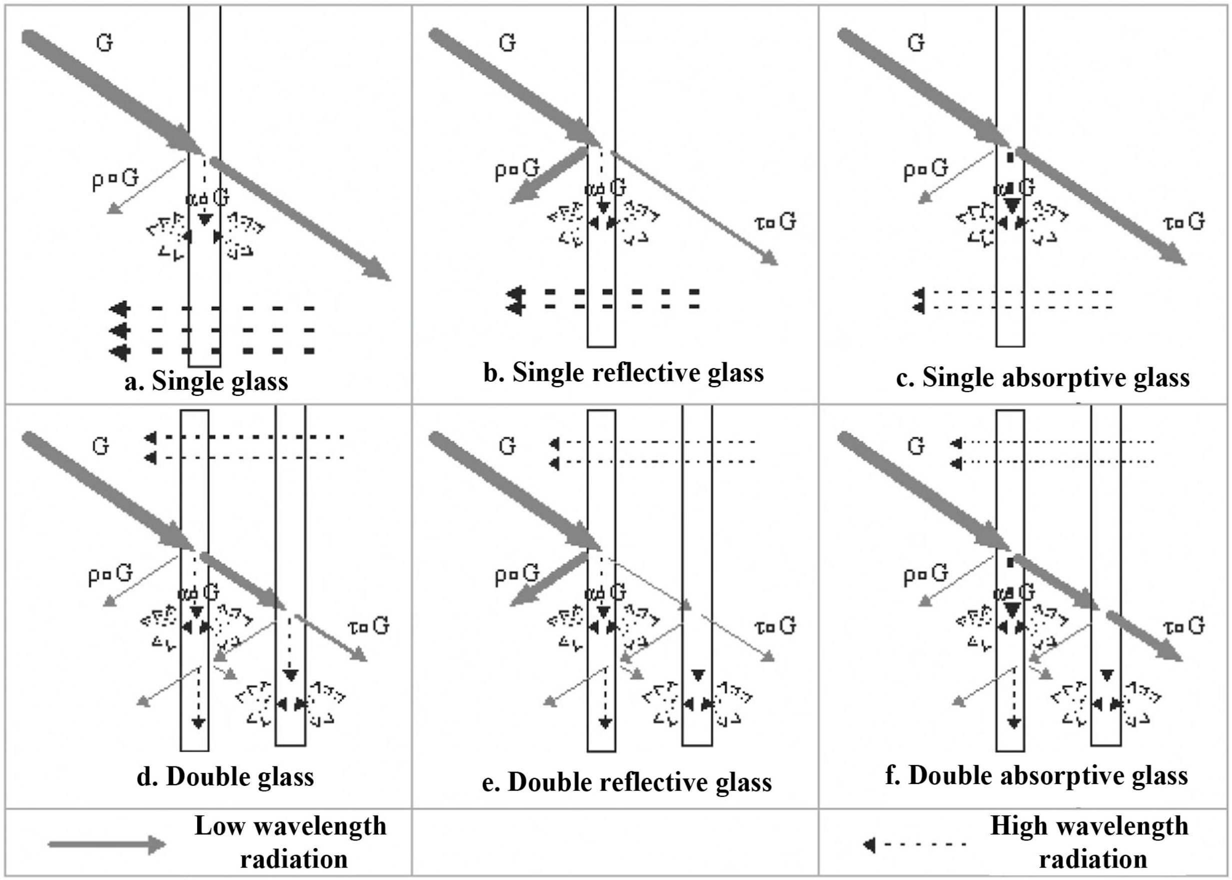
Windows

Depending on the location of the building, the existing weather conditions, and the orientation of the opening, the appropriate type of glass should be installed.

For example:

- in hot climates
  a double reflective glass is a sensible selection
- in cold climates
  a double absorptive glass should be installed.

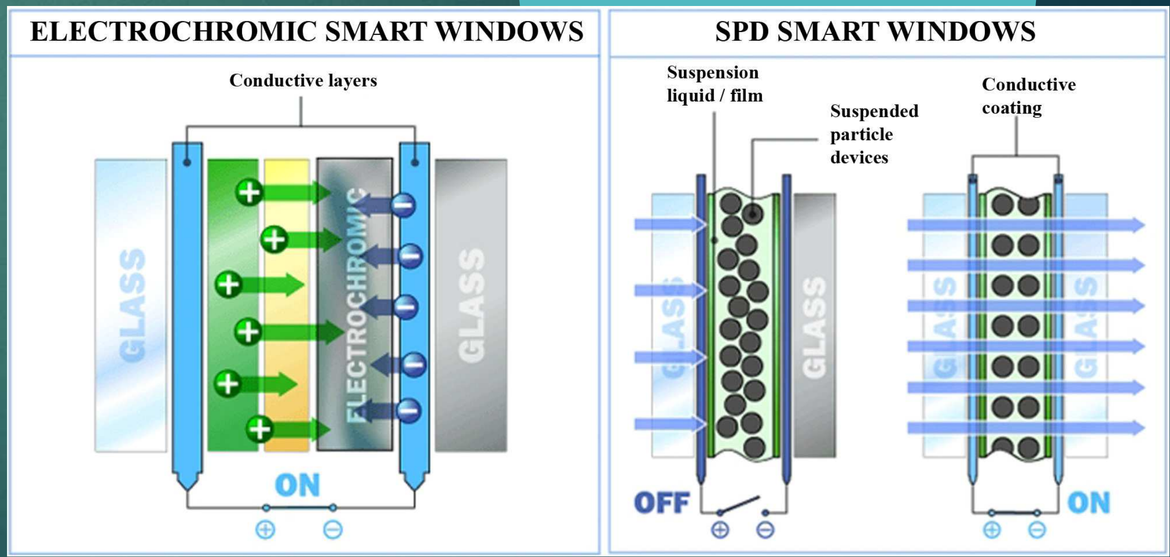
Double glazing aims to reduce the U-value of the window.



Smart Windows

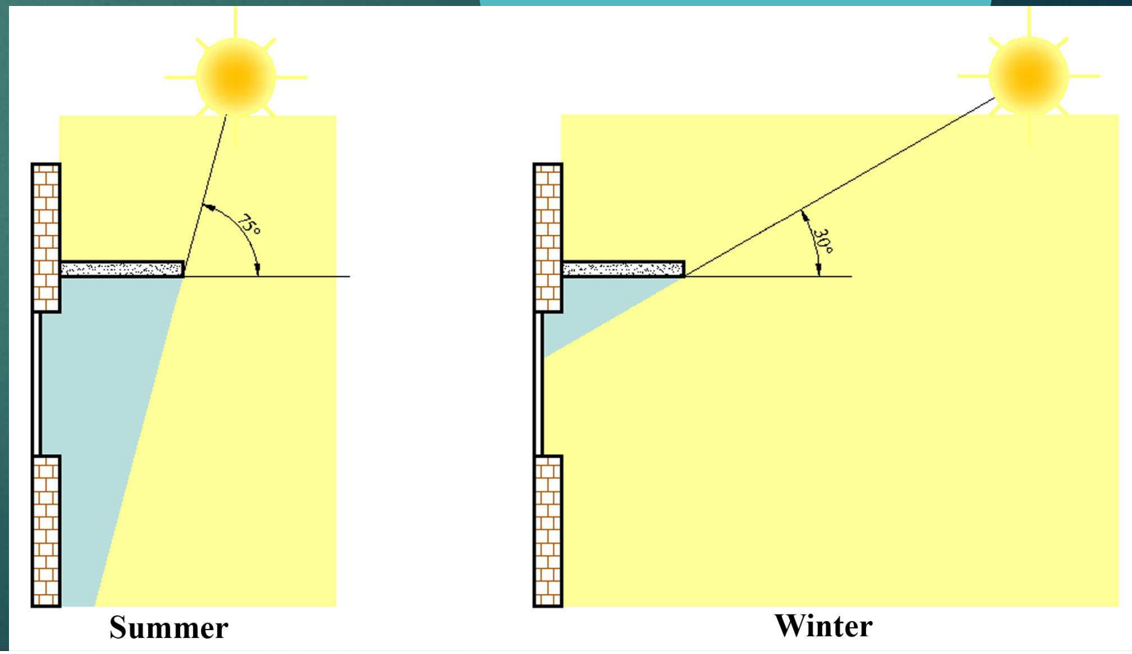
Smart glasses exhibit alternating attitude with the available solar radiation. This is achieved with two different approaches:

- **electrochromic panels**: the clarity of the material changes when voltage is applied, allowing to adjust the amount of transmitted light and heat
- **products with suspended particles (SPD-In)**: thin film panels of the suspended particles in a liquid is placed between two layers of glass or plastic. If no voltage is applied, the particles are randomly oriented and absorb light, causing the glass darkens. If the voltage is applied, the suspended particles align and allow light to pass.



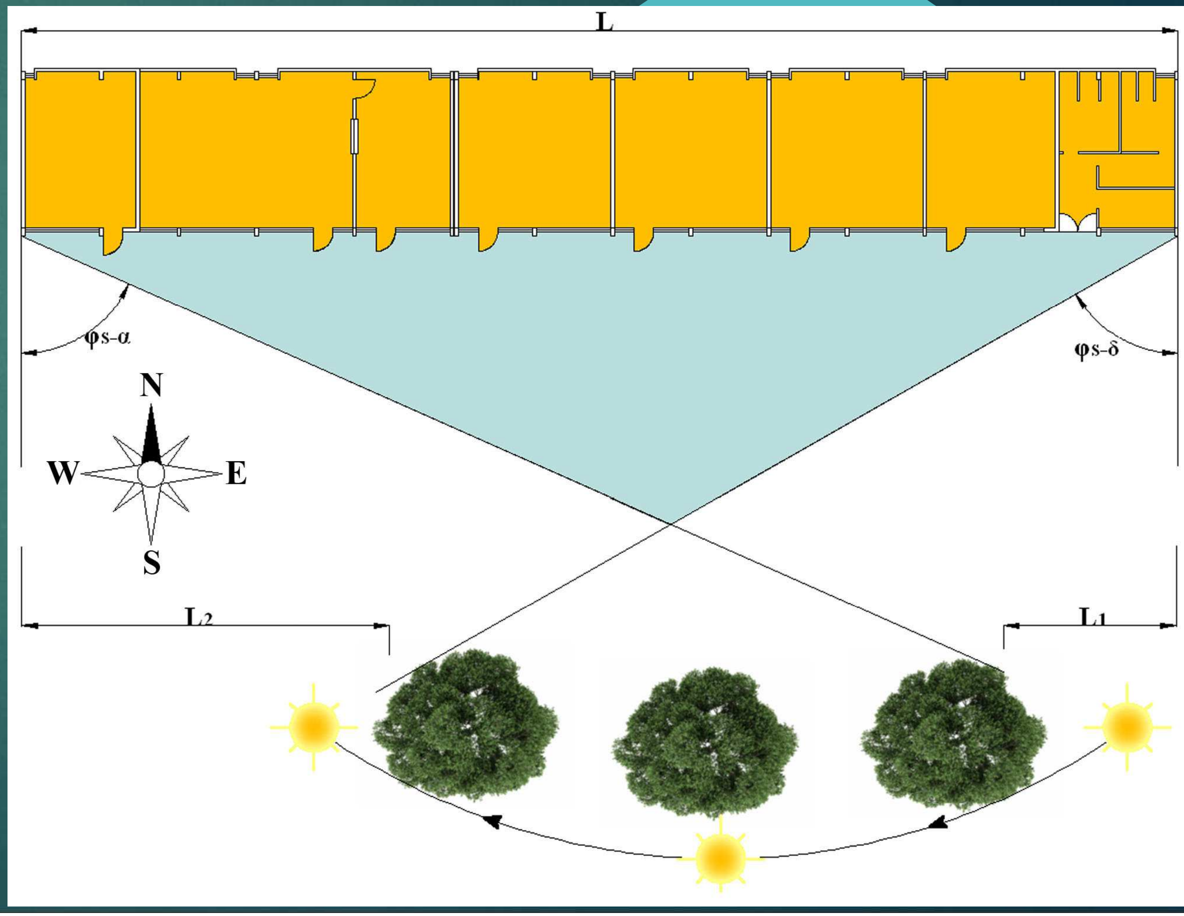
Shading

- The shading of buildings and, especially, windows, is an issue of high importance, since it can contribute to smart exploitation of solar gains during winter and efficient protection against overheating during summer.
- This is achieved with the proper dimensioning and positioning of the shades, given the fundamental principles of solar geometry.
- For example, given the high sun elevation angle during summer and the low sun elevation angle during winter, the appropriate sizing and positioning of an horizontal overhang can provide shading during summer and solar gains exploitation during winter.



Shading

- Efficient shading can be also provided with appropriate planting.
- The appropriate height and positioning of trees outside a building can prevent sun from entering the building during noon, while permitting it to approach the building during morning and evening.
- The use of deciduous trees provide shading during summer, while leaving the sun free to reach the building during winter.



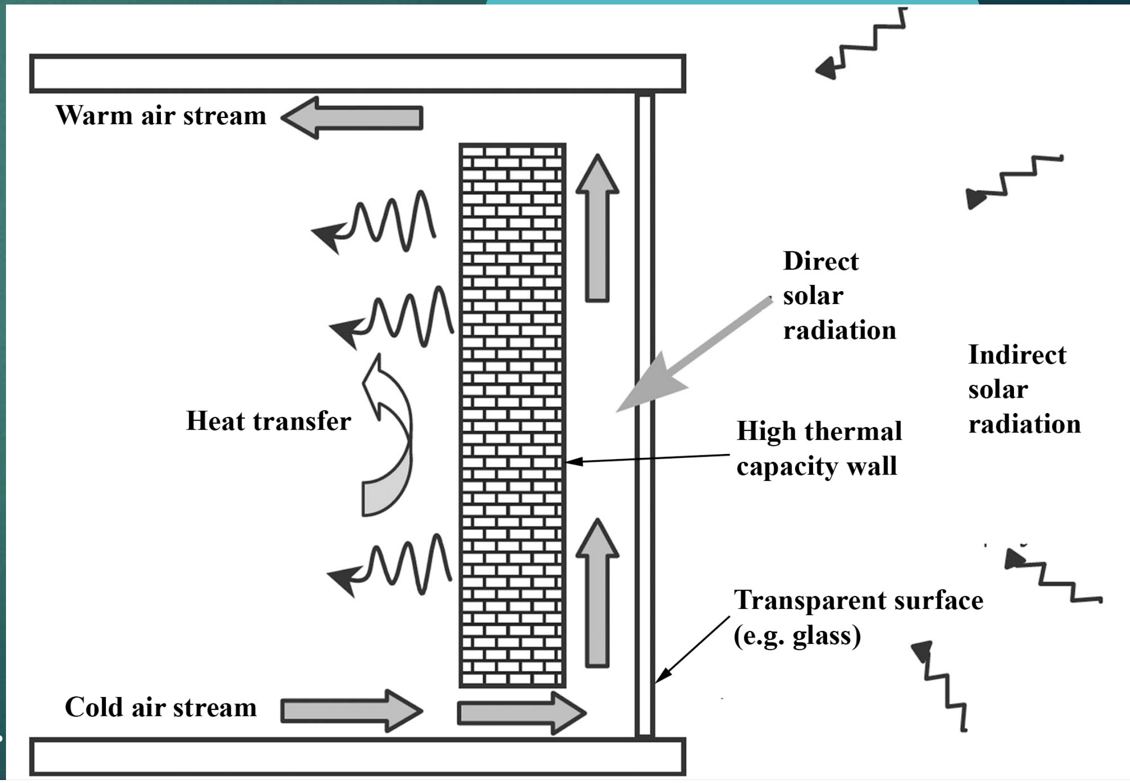
Roofs shading

Roofs shading is also of crucial importance. It can be achieved with several smart ways, such as:

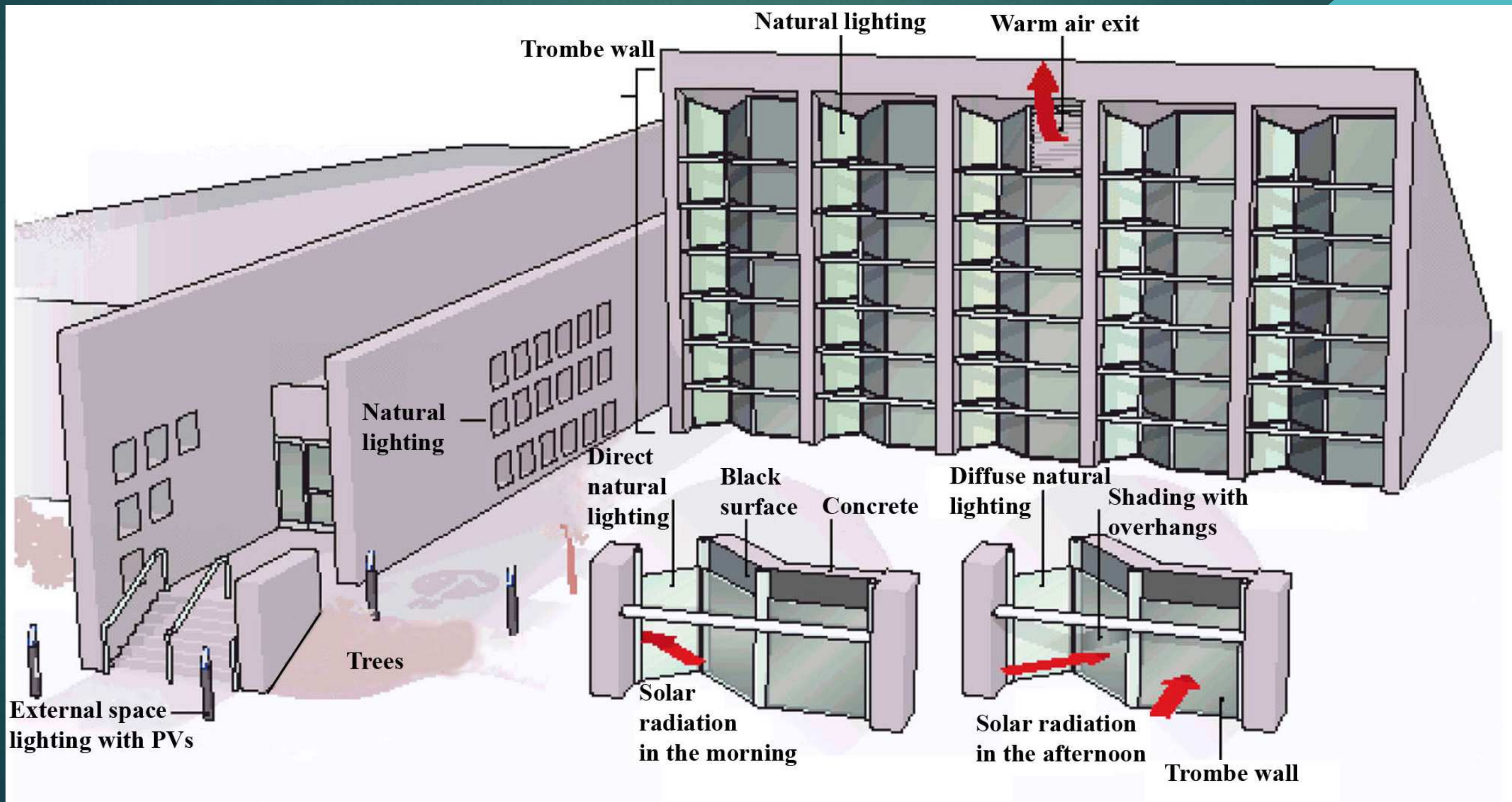
- the construction of green roofs providing at the same time efficient insulation
- the installation of active systems, like PVs or solar collectors
- the integration in the roof of any type of construction that can absorb solar radiation, e.g. swimming pools.

Special passive systems
Trombe – Michel wall

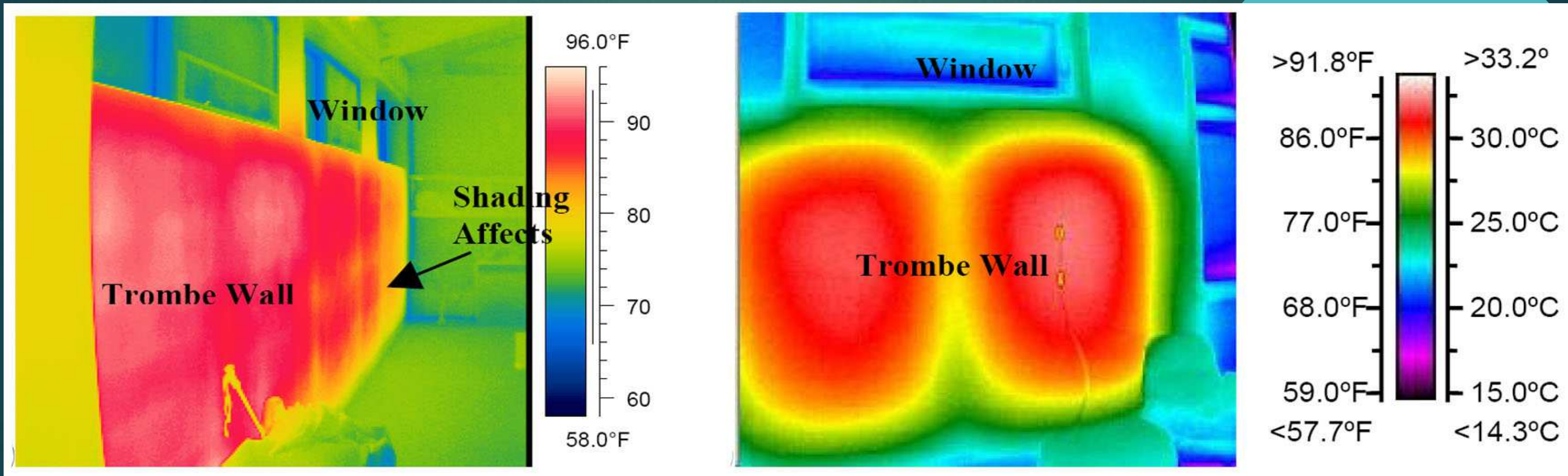
- The Trombe – Michel wall consists of a high thermal capacity wall with a transparent surface (e.g. glass) placed a few cm outside the wall. The wall has openings at its bottom and top.
- The wall stores solar radiation, and gives it back by heating the air between the wall and the glass.
- Due to temperature difference, natural ventilation is created, forcing warm air stream to enter the heated space from the top opening.



Trombe – Michel wall application in N.R.E.L. building (USA)

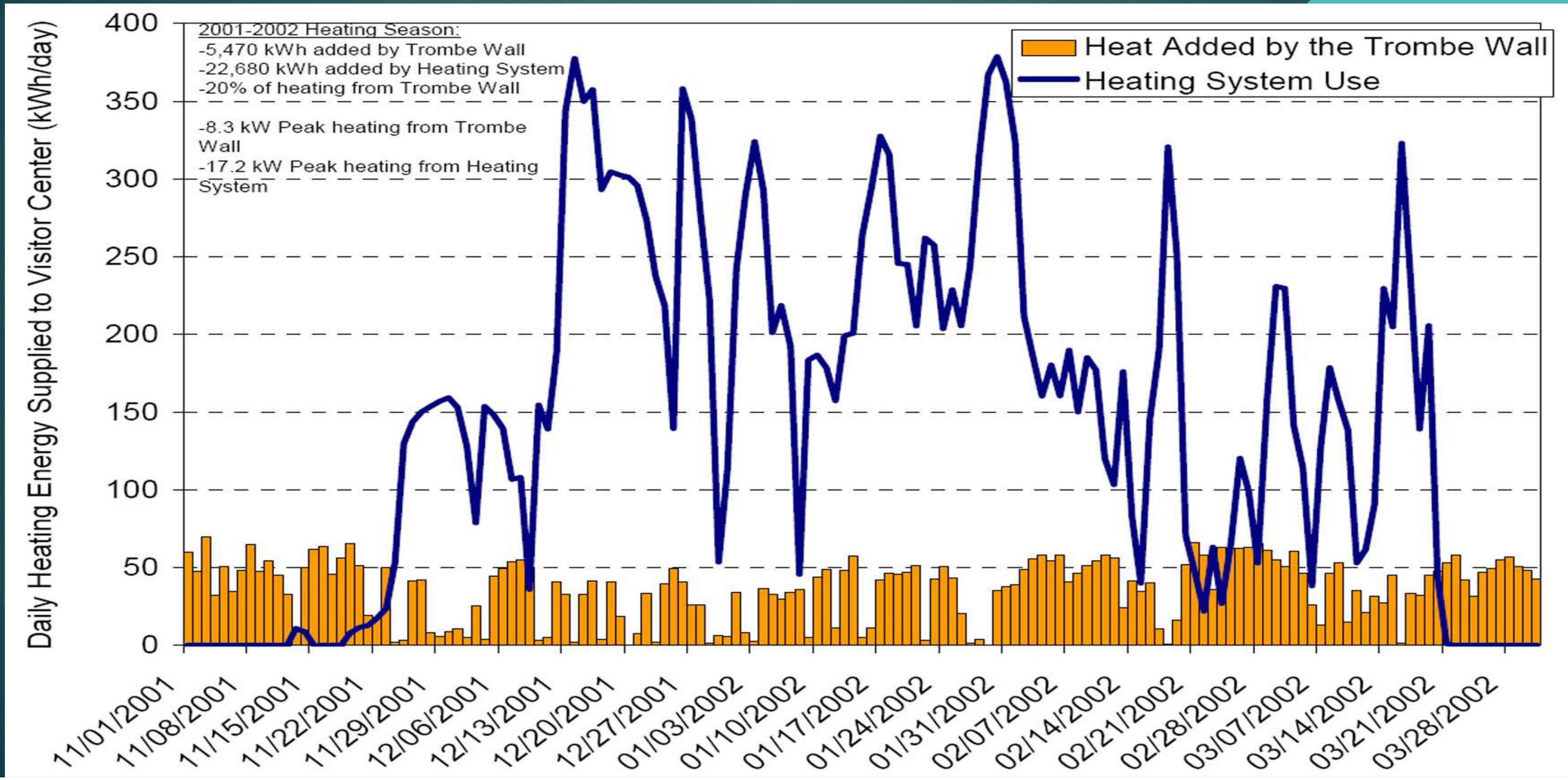


Trombe – Michel wall application in N.R.E.L. building (USA)

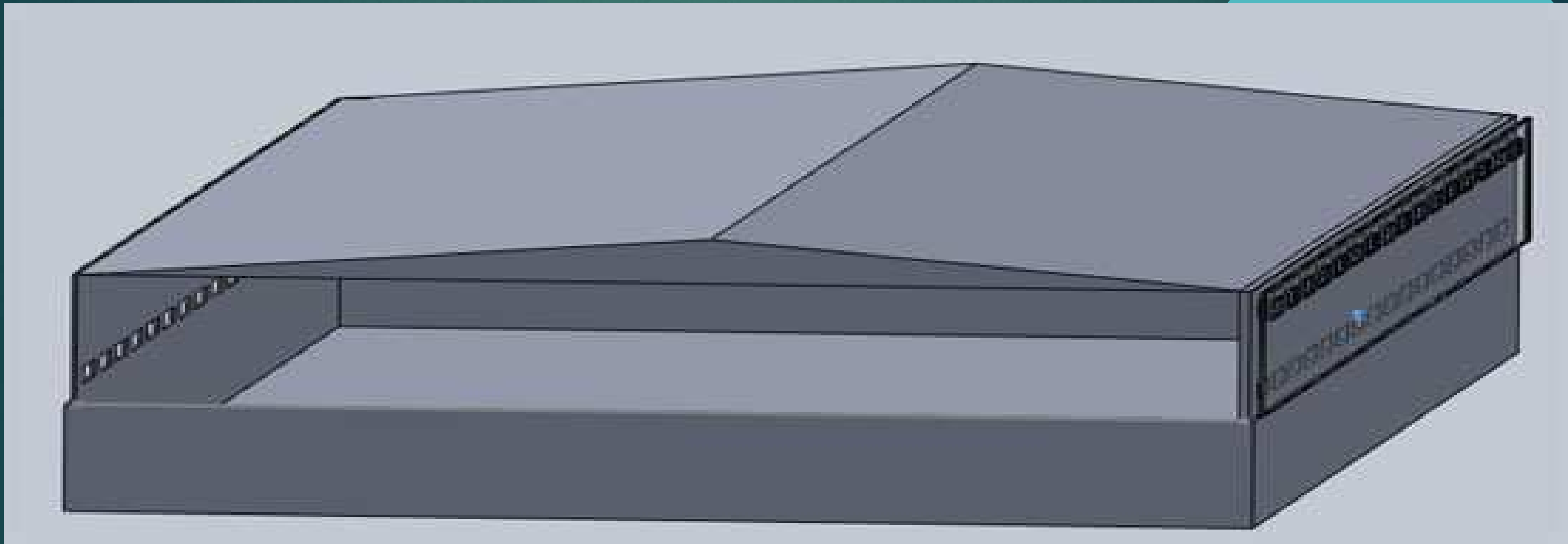


Temperature distribution depictions on the Trombe – Michel wall in the National Renewable Energy Laboratory (N.R.E.L.) building.

Trombe – Michel wall application in N.R.E.L. building (USA)



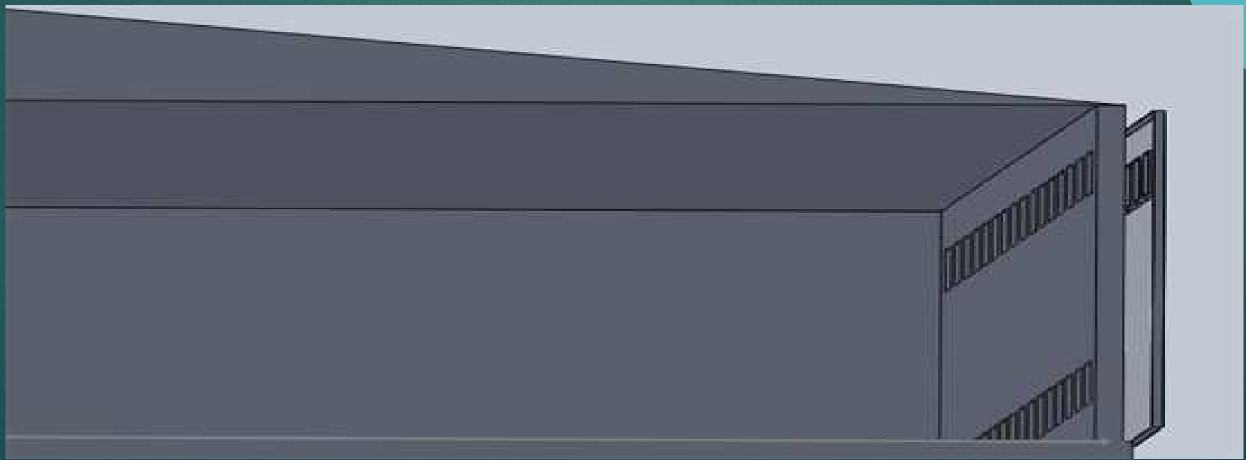
Trombe – Michel wall for all year use
Case study: sports center in Crete



General view of the sports center

Trombe – Michel wall for all year use
Case study: sports center in Crete

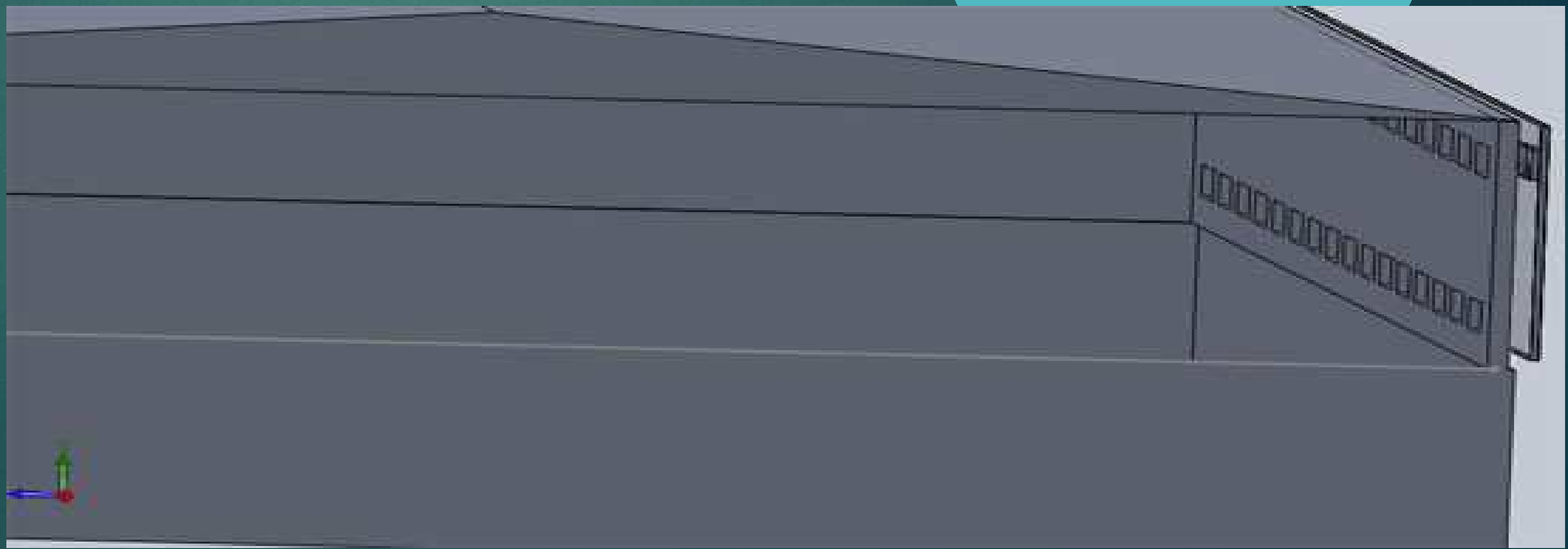
North-eastern (NE) wall



South-western (SW) wall (Trombe – Michel wall)

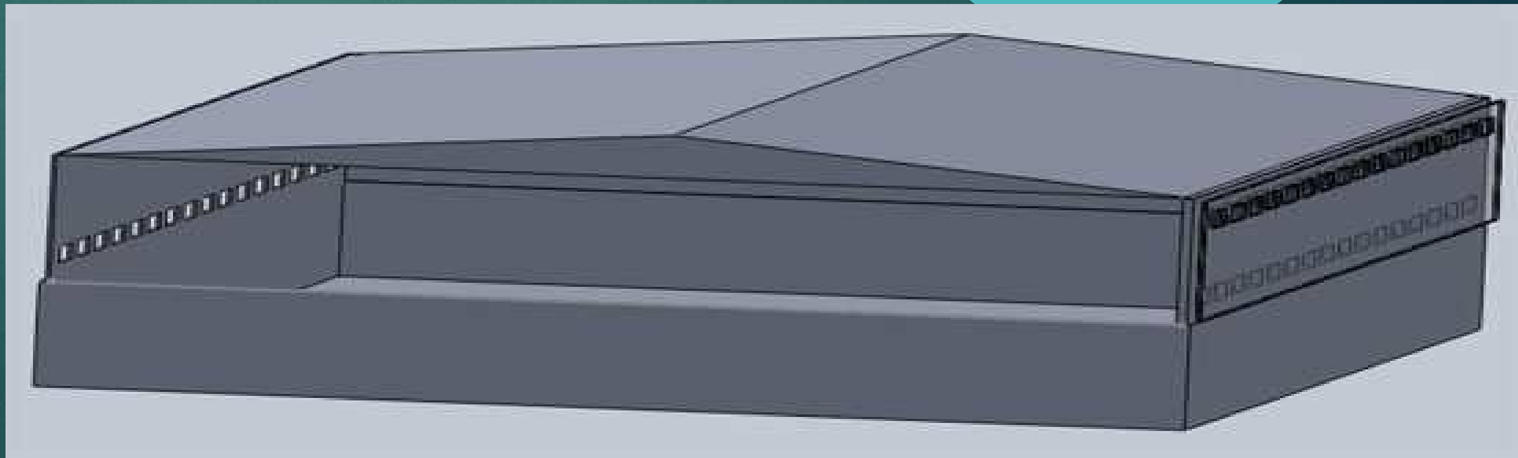
Trombe – Michel wall for all year use
Case study: sports center in Crete

- **During winter**, the openings in NE wall remain closed.
- The Trombe – Michel wall in the SW wall operates normally, adding heat to the inner space of the sports center. In this special construction, there are also openings at the upper part of the glass surface of the Trombe – Michel wall.
  These openings remain closed during winter.



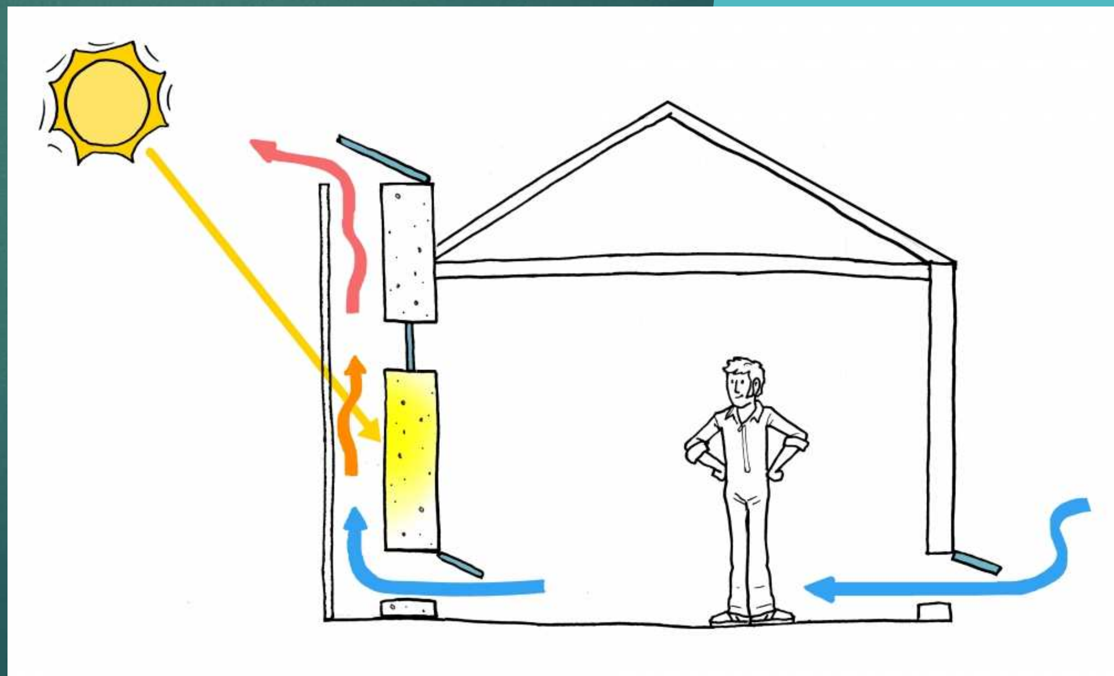
Trombe – Michel wall design for a closed sports center in Crete

- **During summer**, the upper openings of the Trombe-Michel wall at the SW wall remain closed, to prevent warm air to enter the building.
- Both the openings at the NE wall and the lower openings of the Trombe-Michel wall in SW wall remain open.
- The openings at the upper side of the glass surface at SW wall remain open, so the warm air leaves the gap between the wall and the glass, forcing a crosscutting natural ventilation in the building, from the NE to the SW wall.



Special passive systems
Solar chimney

- The incident solar radiation heats the air inside the solar chimney, which is elevated and leaves the building, forcing a natural ventilation inside it.

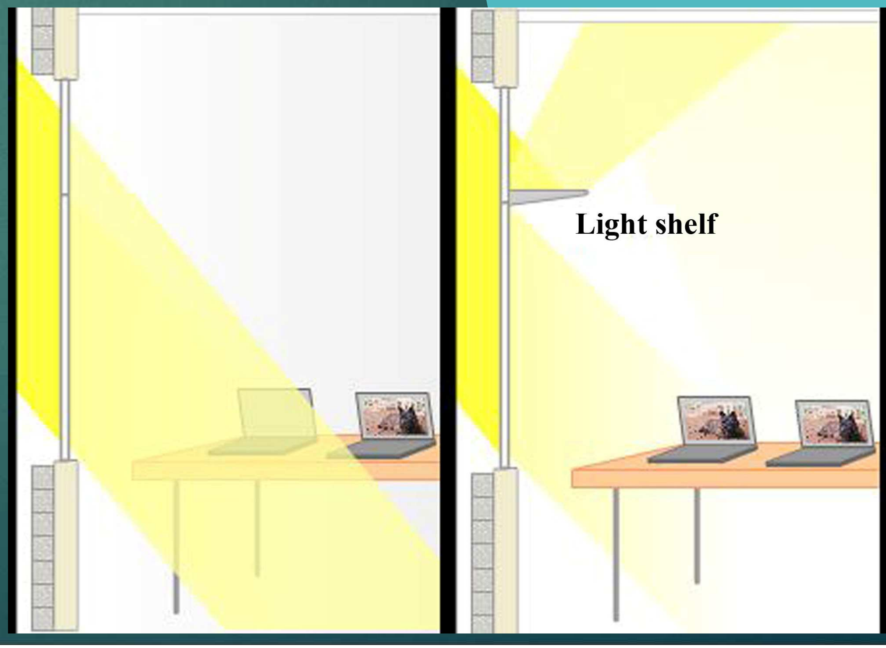


Evaporation cooling

- The integration of water free surfaces in spaces outside buildings creates the prerequisites for natural cooling with the evaporation of water.
- Solar radiation is converted into latent heat,
through the evaporation of water,
instead of sensible heat,
avoiding thus the temperature increase
at the buildings' surroundings and offering
natural cooling.

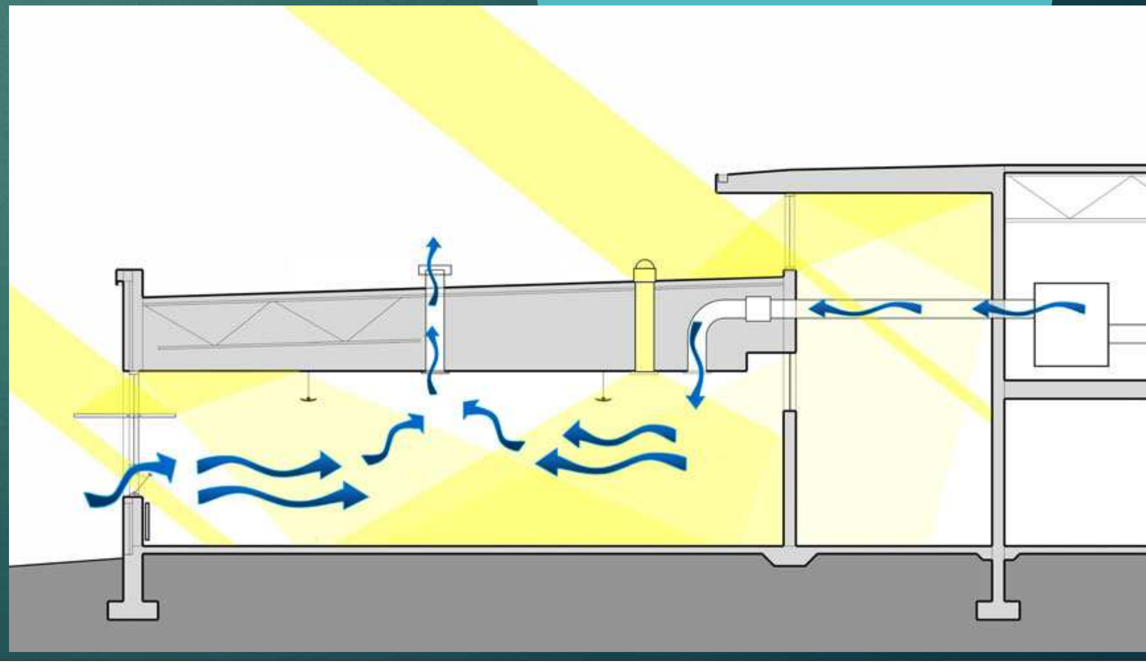
Natural lighting

- Natural lighting of buildings is essential for both energy saving and good mood and health.
- Direct natural lighting must be avoided, since it creates conditions of intensive lighting differences and optical dazzling.



Natural lighting

- Instead of direct lighting, diffuse lighting should be approached.
  This can be achieved with several configurations in the building's openings as well as the installation of sky tubes in the building's roof.



Passive systems - Epilogue

- Passive systems should be introduced in buildings with considerable attention, taking into account the existing weather conditions in the area of installation, the building orientation, the use of the building and several other parameters that can potentially affect the building's energy efficiency.
- Passive systems are not "plug-and-play" solutions. Their application should come after thorough studies with specialized software applications, which aim to justify their contribution to the buildings' energy efficiency with their appropriate dimensioning and positioning.
- Inappropriate integration of passive systems in buildings may lead to the undesirable results, such as the building's overheating from a Trombe wall during summer.

Active systems

Thermal energy production
Solar collectors

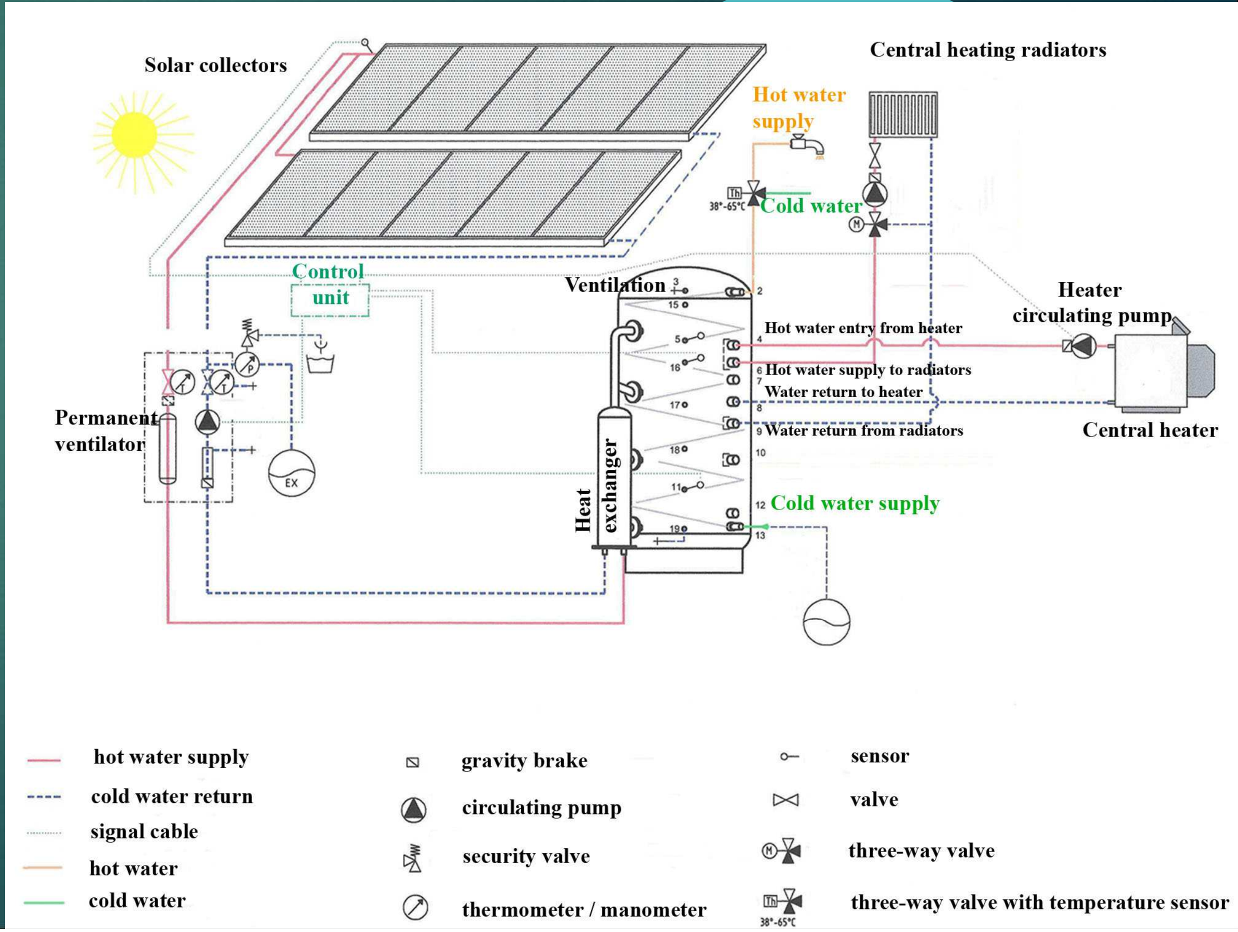
Solar collectors can be introduced for:

- **hot water production**
- **space heating**, co-operating with a conventional heater, as back-up unit and thermal storage, usually water tanks
- **swimming pools heating**, co-operating with a conventional heater, as back-up unit and thermal storage, usually water tanks.

The integrated operation of solar collectors, conventional heaters and thermal energy storage is known as “solar combi-systems”, or “thermal hybrid power plants”.

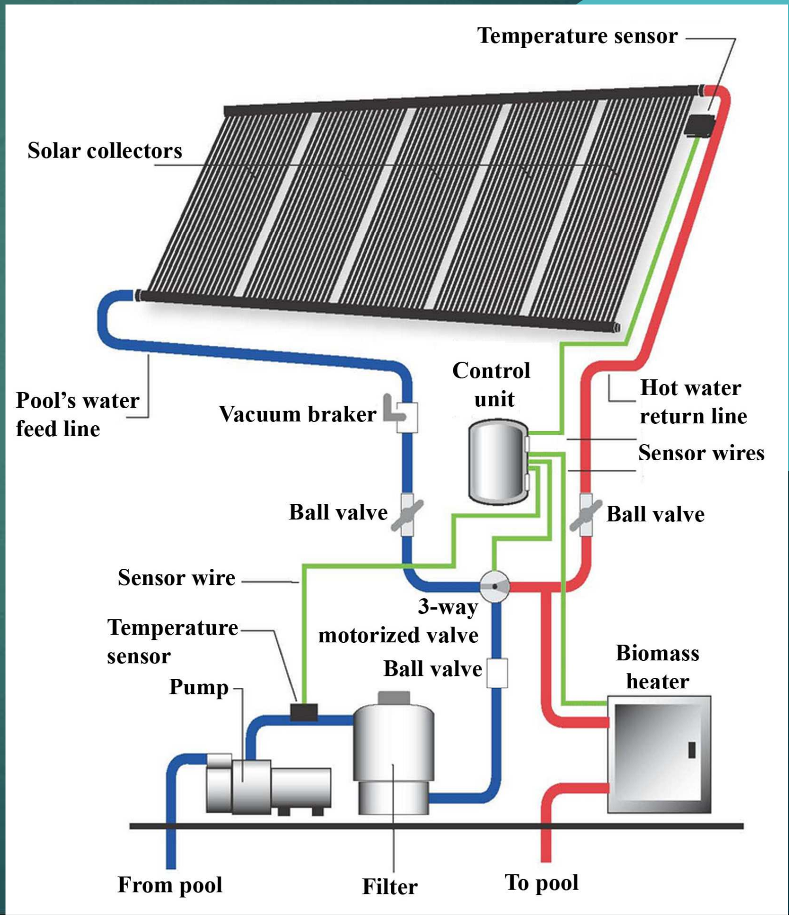
Thermal energy production
Solar collectors

Solar combi-system
for space heating



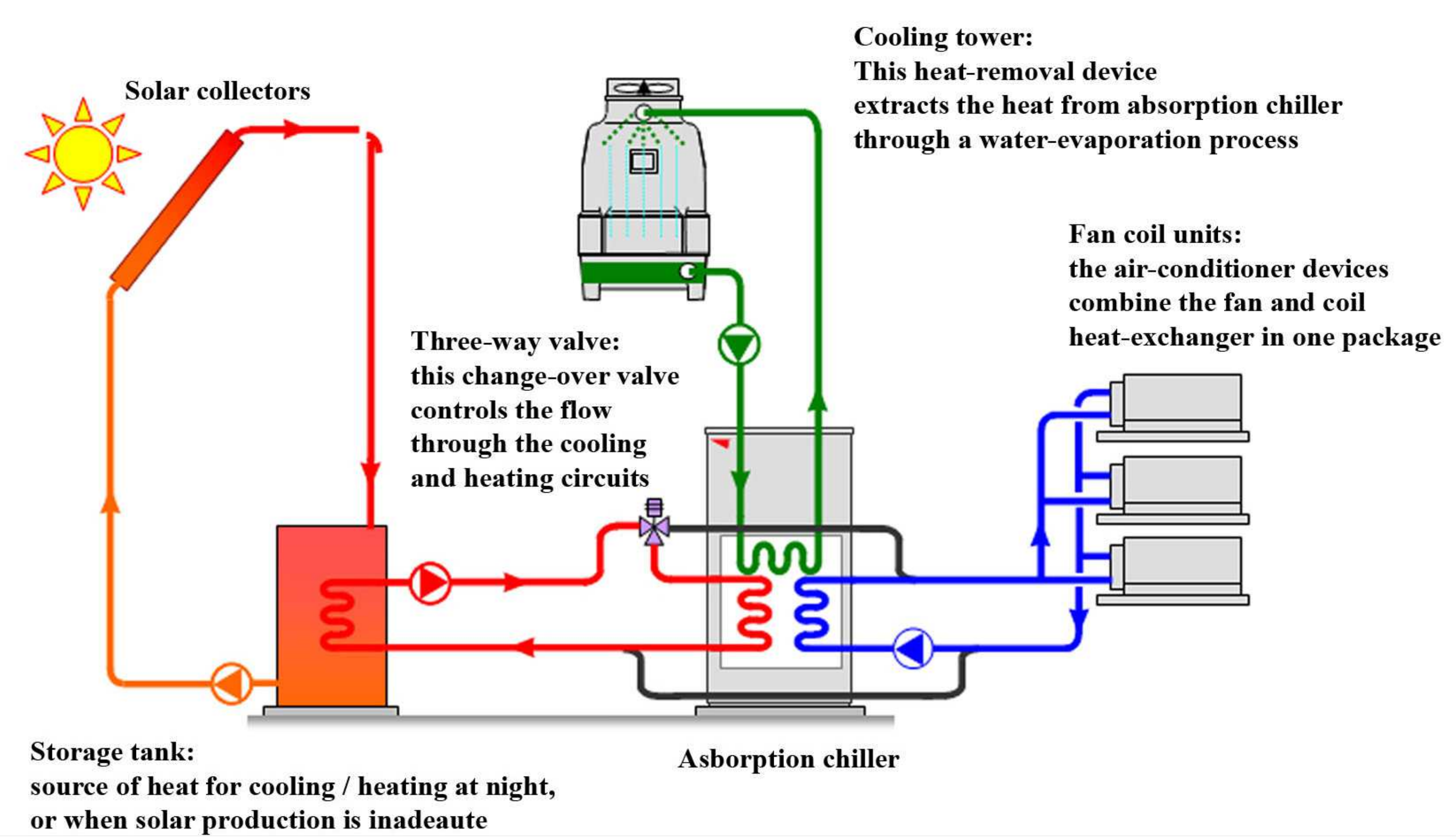
Thermal energy production Solar collectors

Solar combi-system
for swimming pools heating



Solar cooling

- Solar collectors can be used as the thermal energy source required for the implementation of the cooling absorption cycle.
- This process is known as “solar cooling”.
- With solar cooling electricity is consumed only by the pumps or circulators of the hydraulic networks.



Heating and cooling production Geothermal heat exchangers

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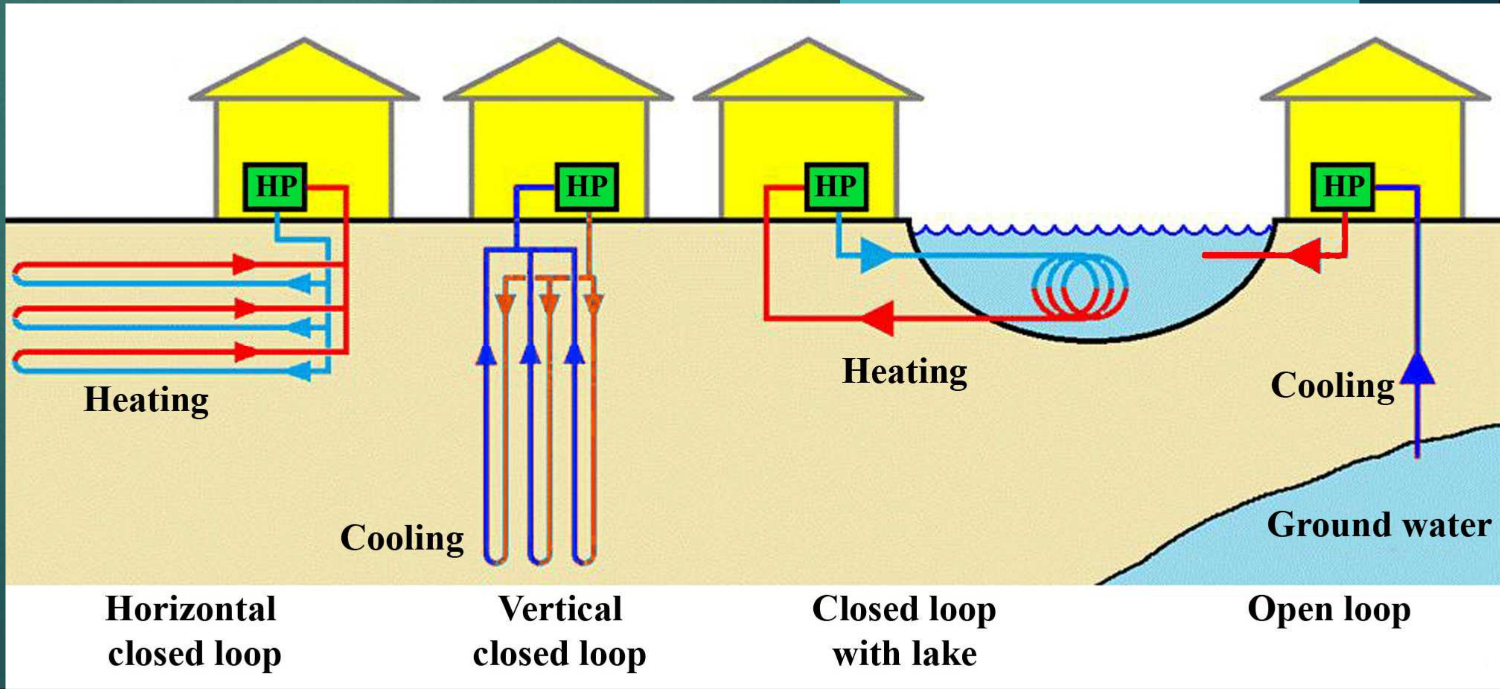
- Geothermal Heat Exchangers (GHE) are used for:
  - the disposal to the ground of the heat removed from a space during cooling process
  - retrieving from the ground the heat offered to inner spaces during heating process.
- Since water temperature inside the GHE (determined by the ground's one) is considerably lower or higher than the ambient one during summer or winter respectively, the efficiency of the cooling / heating process is strongly improved, comparing to the efficiency of air-to-air heat pumps.
- With GHE, annual electricity saving at the range of 30-40% is achieved, compared with the one of a conventional air-to-air chiller.

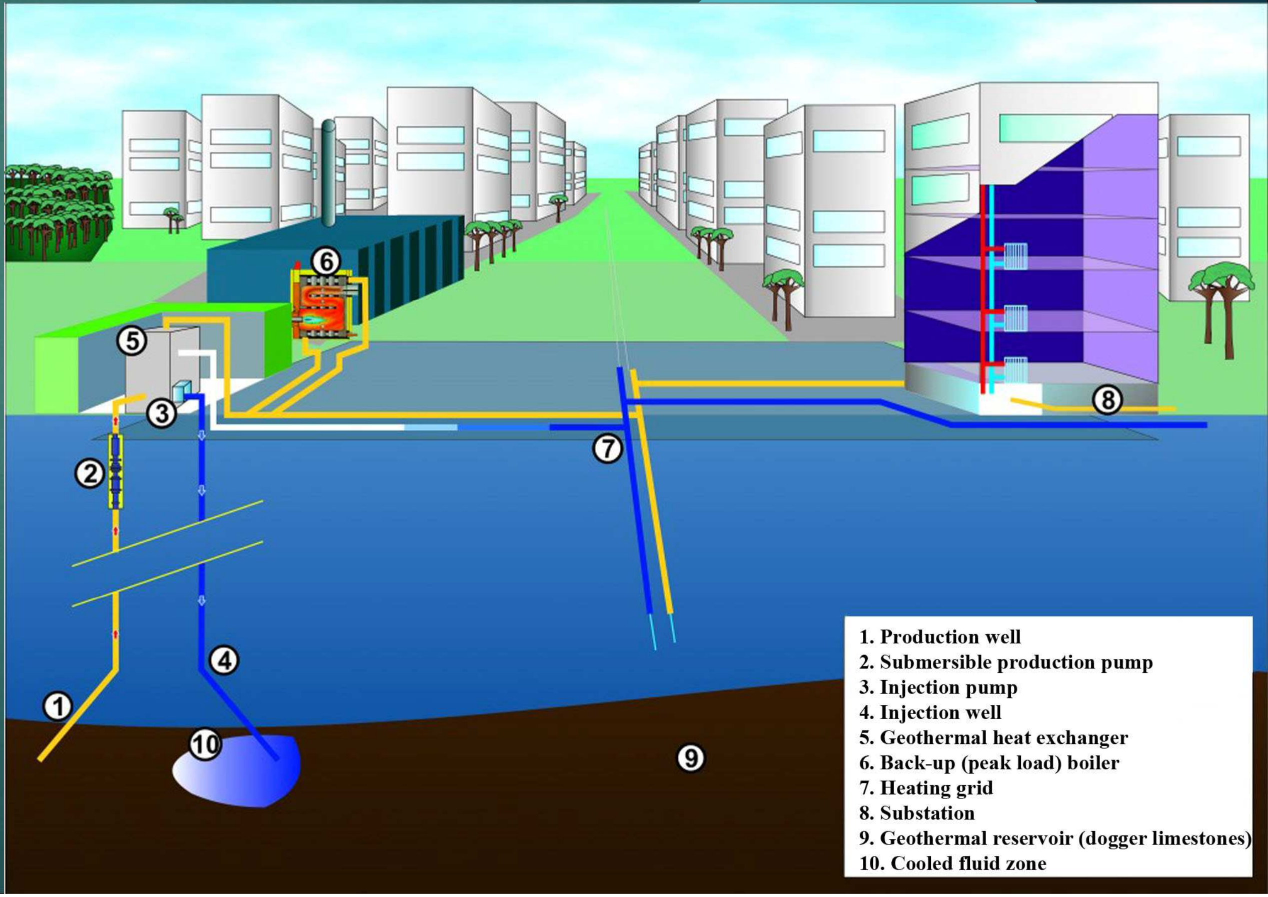
Heating and cooling production
Geothermal heat exchangers

- Geothermal Heat Exchangers (GHE) can be of:
  - closed loop, horizontal or vertical configuration
  - open loop.



Heating and cooling production Geothermal heat exchangers

- Open loop GHE can be used for **district heating / cooling**.
- This option is ideal for coastal settlements.



Electricity production Photovoltaic stations (PVs)

- P/V stations can be placed on roofs, in yards etc, producing 1.500 – 1.700kWh annually per kW of installed rated power, for typical Mediterranean climates.
- Photovoltaic stations of larger size can be used for the electrification of small settlements.



Electricity production
Small Wind Turbines (SWTs)

- Small wind turbines of horizontal or vertical axis can be placed on roofs and in yards of buildings. The annual electricity production depends on the available wind potential. Generally it is expected higher than the annual production of a PV station with the same rated power.

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Electricity production
Hybrid power plants

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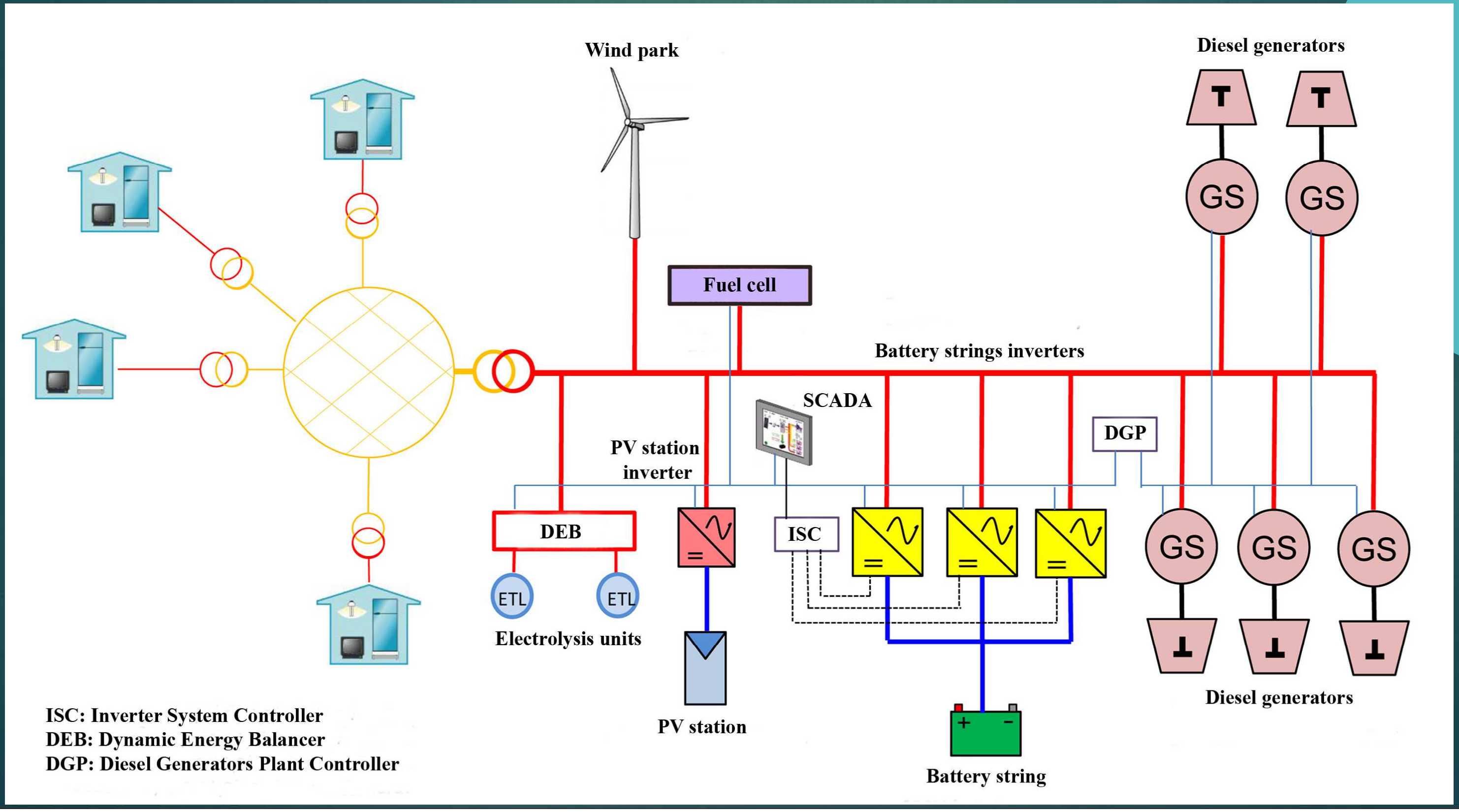
- A hybrid power plant aims to cover without interruptions and according to the pre-defined qualitative requirements a specific power demand, based on non-guaranteed power production plants (wind turbines or PVs).
- To achieve this aim, it is necessary to support the non-guaranteed power plant with a storage plant (or more than one).
- In any occasion, to guarantee secure energy production, the hybrid power plant is integrated with a guaranteed power production unit, as a back-up unit.

Electricity production
Hybrid power plants

- In an electricity production hybrid power plant the R.E.S. units can usually be:
  - wind parks or small wind turbines
  - photovoltaic stations.
- In an electricity production hybrid power plant, the storage units can be:
  - electrochemical batteries of several types, depending on the size of the hybrid power plant (lead acid, redox flow batteries etc)
  - fuel cells co-operating with hydrogen production electrolysis units
  - pumped hydro storage systems
  - compressed air energy storage systems.

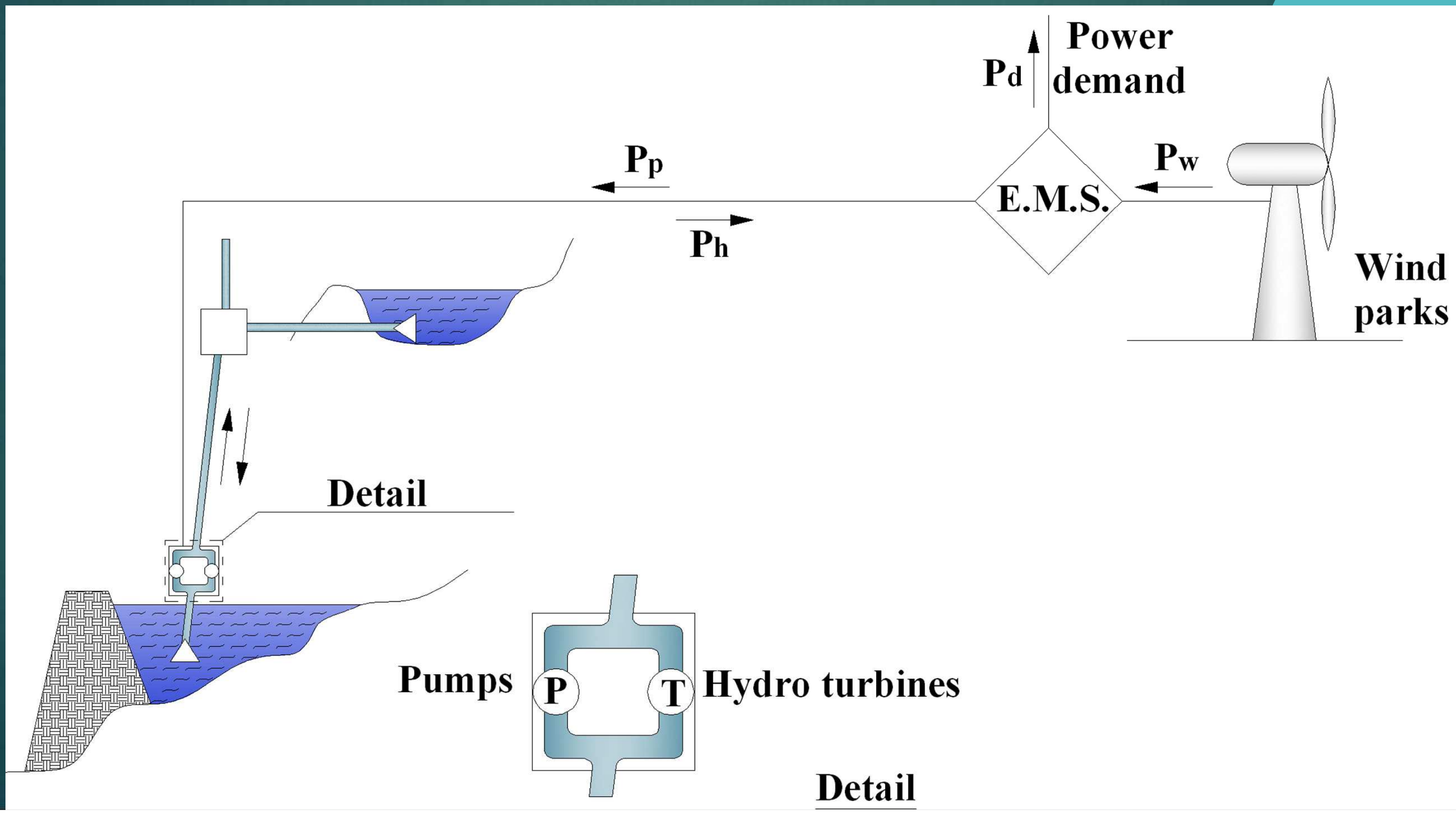
Electricity production
Hybrid power plants

Small size – Storage in electrochemical batteries



Electricity production
Hybrid power plants

Large / medium size – Storage in pumped hydro storage systems



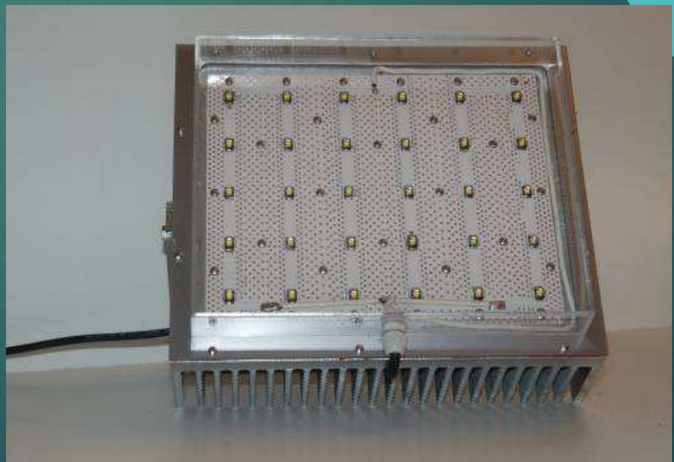
Electricity saving - Lighting

Energy lighting saving can be achieved with the following actions:

- the substitution of high nominal electric power lamps with energy saving lamps of equal luminous flux
- with the automatic monitoring and control of both the lamps' operational time period and operational power regulation, for street lighting.

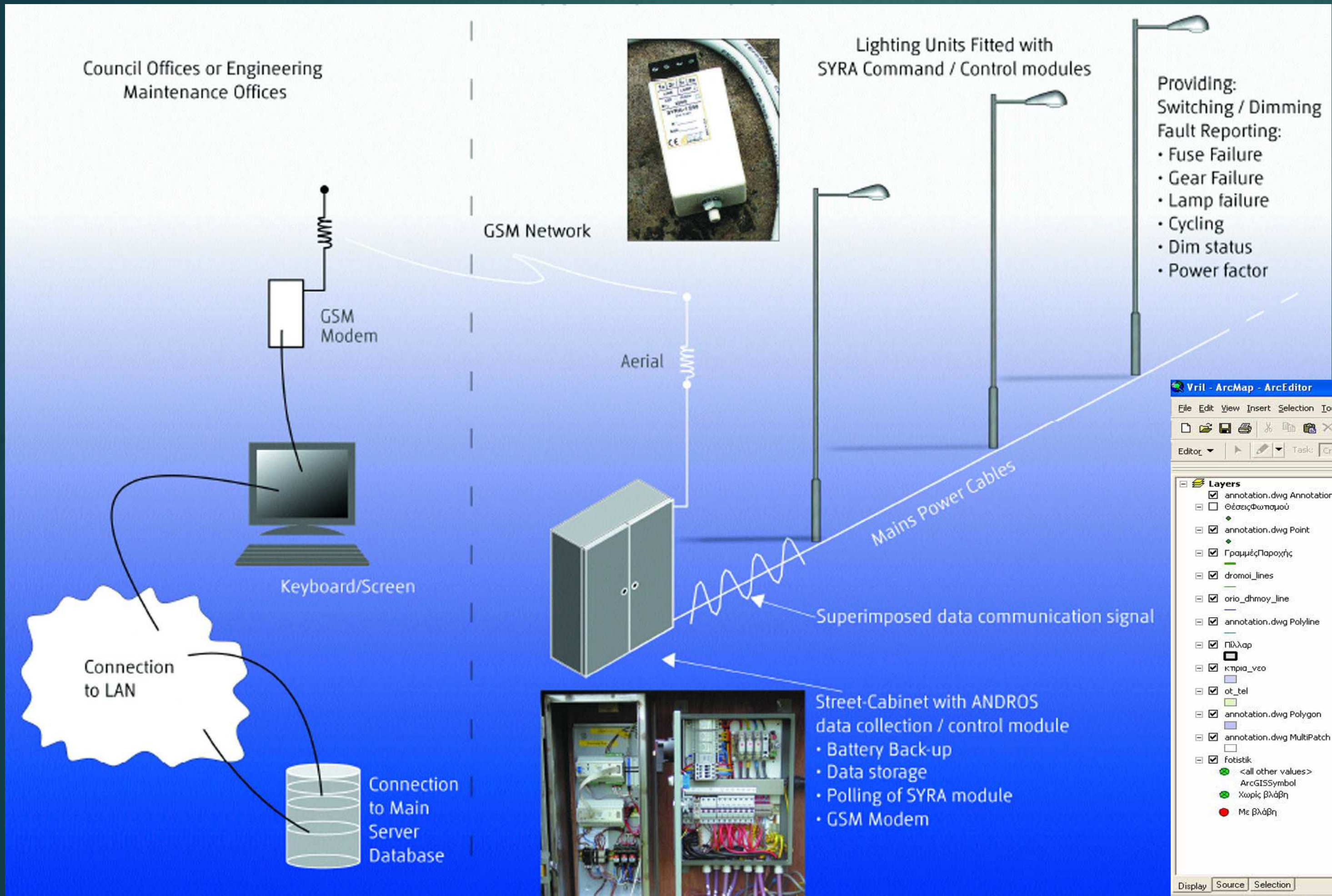
MFB mercury lamp

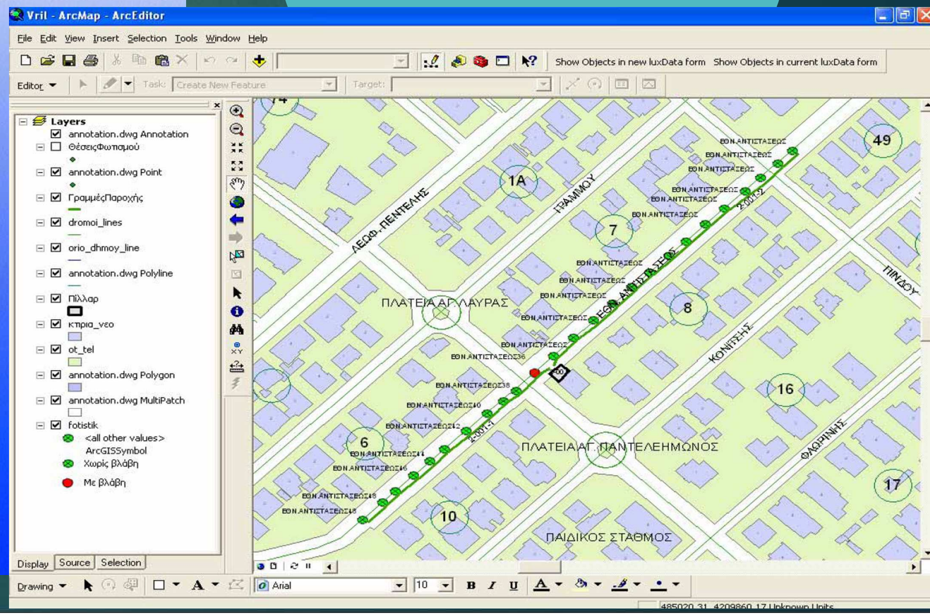
HPS lamp



LED lamp

Electricity saving - Lighting

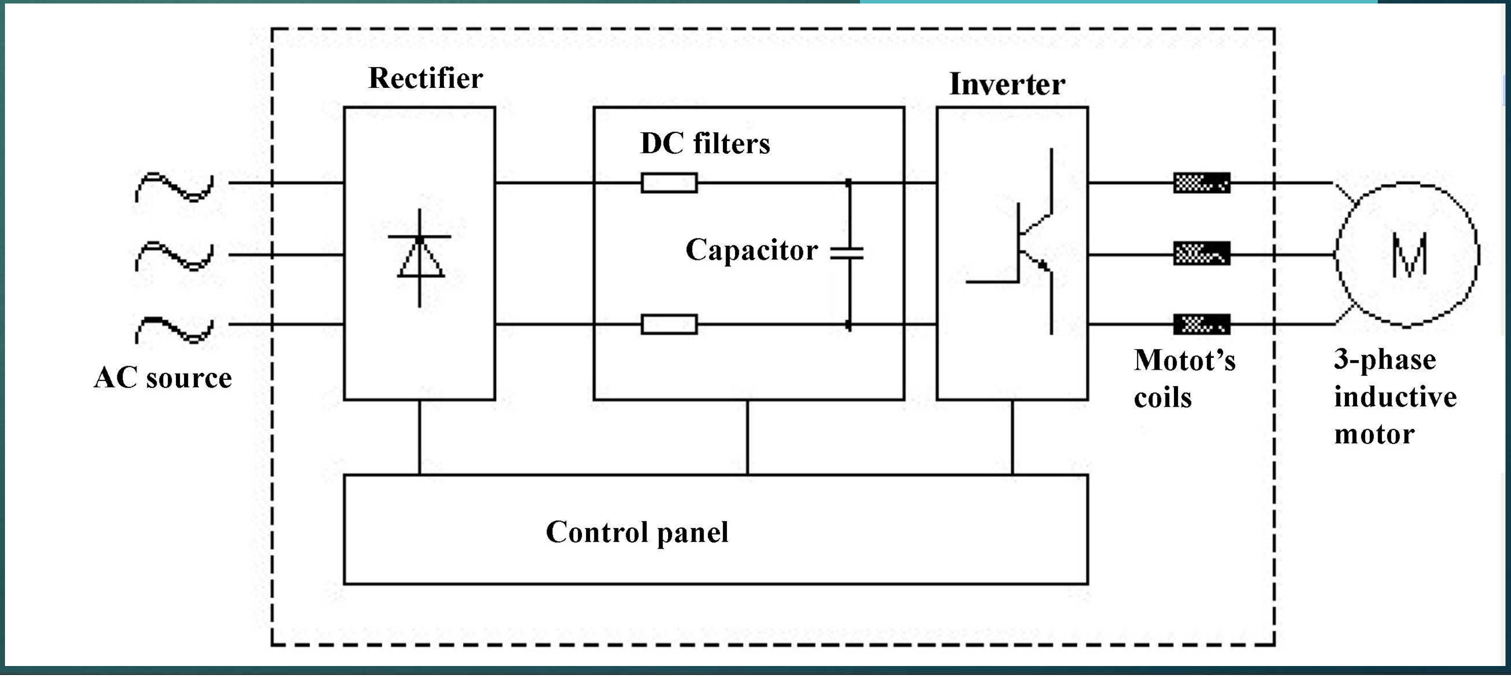




Other energy saving applications of active systems

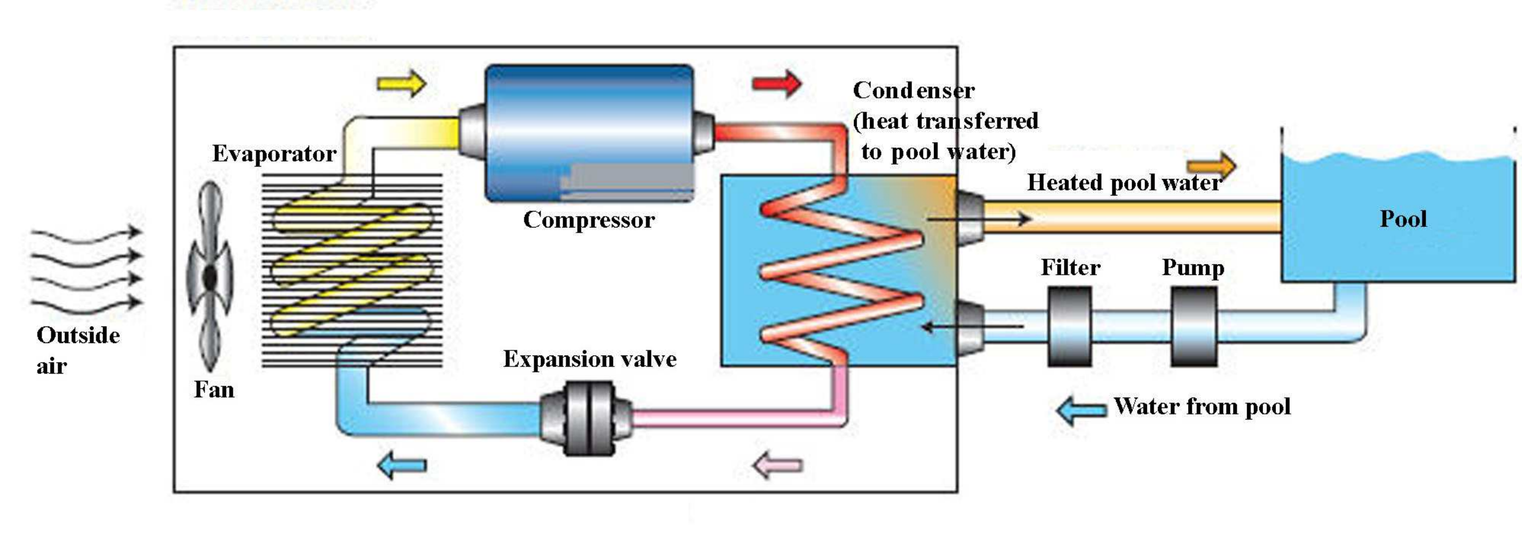
Energy saving in electrical motors (pumps, elevators etc) can be accomplished by applying the following measures:

- installing inverters to control the flow of the pumps according to the demand, essentially to adjust the pumps to work at lower rotational speed than rated one
- installing equipment to correct the power factor of the motors (reactive power compensation).



Heat recovery from cooling devices

- The exploitation of the disposed heat from cooling devices (cooling towers, condensers of refrigerators etc) to heat up a space, a swimming pool, etc, is called "heat recovery".
- Heat recovery is a clever and cheap procedure, which exploits an amount of heat that, normally, is going to be disposed.
- The only required equipment is a heat exchanger and the necessary hydraulic network (tubes, pump, filter).



Epilogue

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Epilogue

- Saving energy is saving of planet's natural resources.
- Even if there are still places on earth with abundant and cheap non-renewable energy resources, it is mathematically sure that there will come a time that they will not be.
- The more non-renewable energy sources we save now, the longer they will be available in the future, providing the possibilities for the productive countries to negotiate higher selling prices.

Thank you for your attention

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