Climate control of an outdoor classroom using renewable energy

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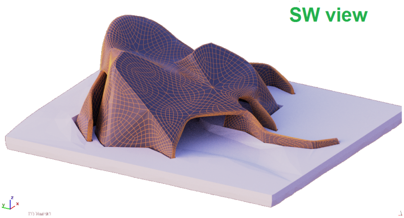
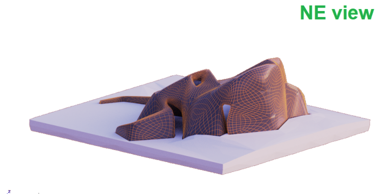
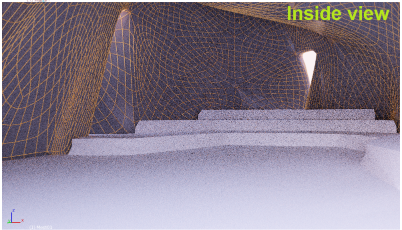
Context

- Project E4 (**E**spacio **E**ducativo **E**xterior **E**ficiente)
- **Objective:** the university wants an outdoor classroom, i.e., a semi-open pavilion integrated into a park located in the main campus
- **Purpose:** the classroom should provide improved environmental conditions compared to the outside (thermal comfort, reduced air speed, adequate lighting, etc.) using passive techniques and renewable active systems (solar in our case)
- **Intended use:** teaching in a different and more natural setting, a place to give press conferences, or a playground for the children of a nearby kindergarten
- **Working group:**
  - Architects: building and environment design
  - Mechanical engineers: thermal analysis, HVAC design, structural analysis
  - Electrical engineers: sensors and AI for system control

Floor area 124 m^2. Three solar collection planes in the ceiling designed to maximize solar insolation while minimizing self-shading. Some openings, the biggest due south. Wind shields. Lightweight construction (concrete mesh + thermal insulation + coverings). Example of **parametric architecture**



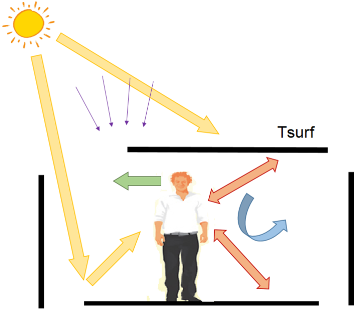




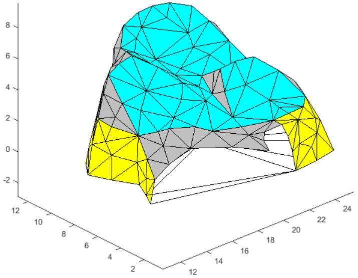
Climate control approach

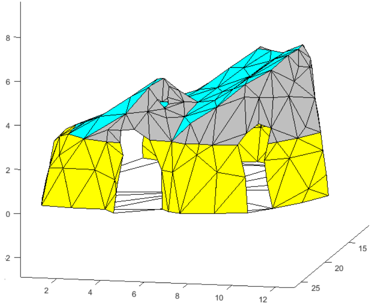
We are dealing with an open thermal zone, so the question is: do we have some control over the indoor conditions?

- Air conditions inside the classroom can not be effectively controlled due to the large infiltrated volumes in the zone
- Inside surface temperatures can be partially controlled using TABS (Thermal Active Building Systems)
- Sun radiation can be selectively blocked using shading devices



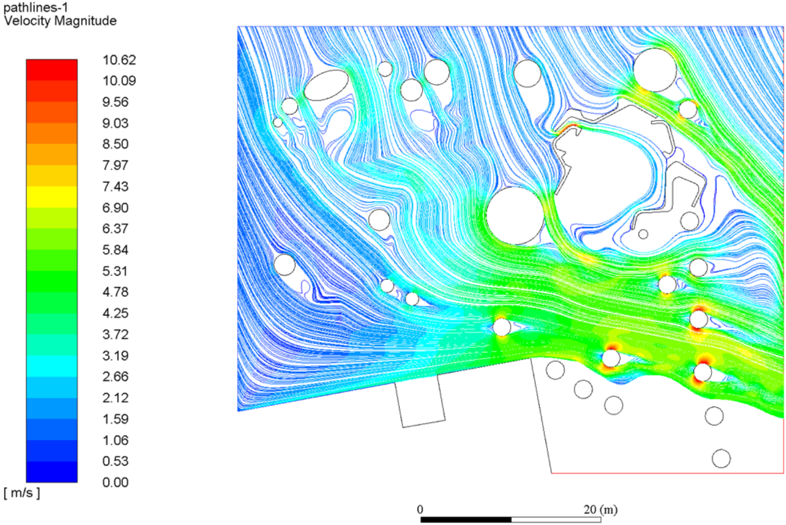
Proposed solution



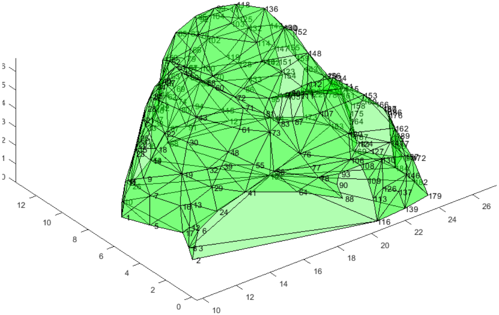


- Blue: solar collection plane (PV in our case)
- Yellow: thermally active surface (controlled T inside face)
- Gray: passive surface

Help to locate the wind shields, estimate internal wind speed, estimate Nusselt numbers

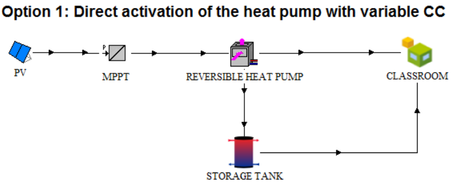


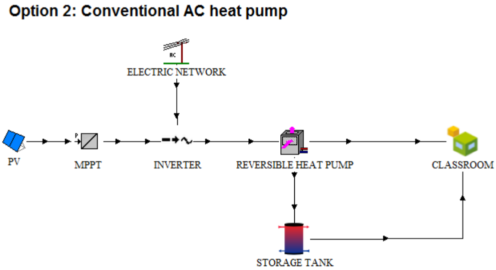
Non-standard shape ⇒ a tailored model has been developed in MATLAB and Fortran. The external surface has been meshed as showed in the figure



The incident solar radiation has been calculated for each mesh element (includes shading mask to account for obstacles). Elemental view factors between mesh elements have been calculated and latter aggregated. Thermal balances on the surfaces were formulated and written as a system of DAEs (Differential Algebraic Equations) The solution of this system of equations giveste the temperature of each surface and the thermal demand of the classroom

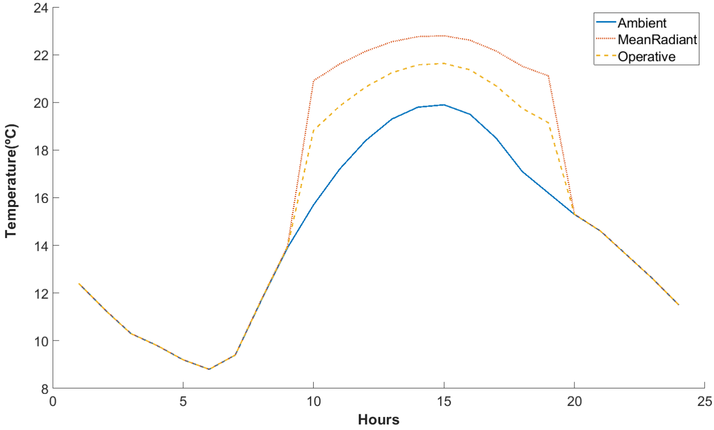
Mechanical plant



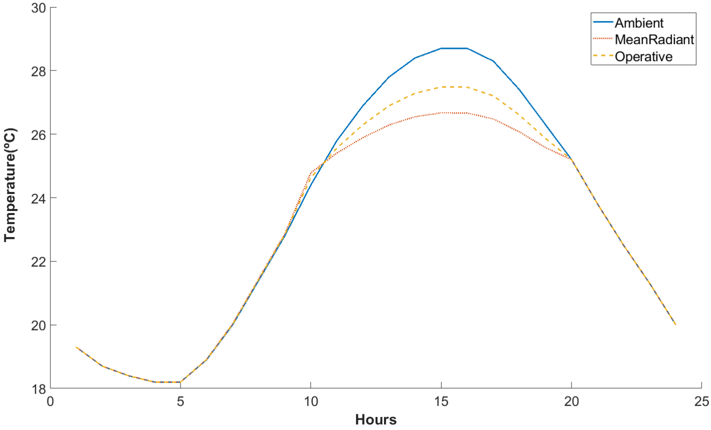


Installed PV = 14 kWp; Peak thermal power delivered to zone = 40,8kWp

Temperature evolution: winter day



Temperature evolution: spring day



Concluding remarks

- Unusual building geometry difficult to model with conventional building simulation programs (E+, Trnsys Type56, ...)
- Operative temperature improvement between 2 and 10 K
- Severe limits to cooling capacity in humid days (high dew point)
- Few if any CC activated heat pumps in the Spanish market
- More research needed on thermal comfort in semi-open spaces