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HOCHSCHULE FÜR TECHNIK (HFT) STUTTGART'S PROJECT HOME$^+$ FOR THE SOLAR DECATHLON EUROPE 2010 IN MADRID, KEY INNOVATIONS

PROJEKT DOMU NA KONKURS „SOLAR DECATHLON EUROPE 2010" W MADRYCIE ZESPOŁU HOCHSCHULE FÜR TECHNIK (HFT) ZE SZTUTGARTU – GŁÓWNE INNOWACJE

Abstract

The Solar Decathlon Europe [1] is an international competition for universities from all over the world to design and build a self-sufficient home, grid-connected, using solar energy as the only energy source and equipped with technologies that permit maximum energy efficiency [5]. At the hightest architectural design level. An interdisciplinary team of architects, interior designers, structural engineers and building physicians at the Hochschule für Technik Stuttgart (HFT) accepted the challenge and has been working on the design of the building since October 2008. The basic idea of our design 'home$^+$' is to use traditional means of dealing with the climate in hot and arid zones and to combine them with new technolgies. The competition took place in June 2010 in Madrid and our project home$^+$ finally ranked 3rd with only 4.5 of 1000 possible points distance to the the winner. However, it received first awards in the desciplines "engineering and construction" and "innovations" and second awards in "Solar Systems" and "Appliances and Functioning" and a third prize in "Sustainability". The design and energy concept of home$^+$ has previously been described and published in [2-4] and others.

Keywords: *Solar Decathlon Europe 2010*, *Innovative PVT collectors*, *multi-colour PV modules*, *PCM-ceilings cooling glass tower*, *low energy systems*

Streszczenie

Solar Decathlon Europe jest konkursem międzynarodowym dla uniwersytetów z całego świata na zaprojektowanie i budowę domu samowystarczalnego, podłączonego do sieci energetycznej wykorzystującego energię słoneczną jako jedyne źródło energii i wyposażonego w technologie, które zapewniają maksymalną efektywność energetyczną. Interdyscyplinarny zespół architektów, projektantów wnętrz, konstruktorów i fizyków budowli z Hochschule für Technik w Stuttgarcie pomógł wyraźnie i pracował nad budynkiem od października 2008 r. Podstawową ideą budynku home było zastosowanie tradycyjnych środków wykorzystywanych w gorącym suchym klimacie połączonych z nowymi technologiami. Projekt home+ zajął trzecie miejsce w konkursie, który odbył się w Madrycie w 2010 r. Uzyskał pierwsze nagrody w dyscyplinach „inżynieria i konstrukcja" oraz „innowacyjność", drugie w „systemy solarne" i „urządzenie i funkcjonowanie" oraz trzecie w kategorii „budownictwo zrównoważone".

Słowa kluczowe: *Solar decathlon Europe 2010*, *innowacyjne kolektory PVT*, *kolorowe moduły fotowoltaiczne*, *sufity PCM*, *chlodzące wieże szklane*, *systemy niskoenergetyczne*

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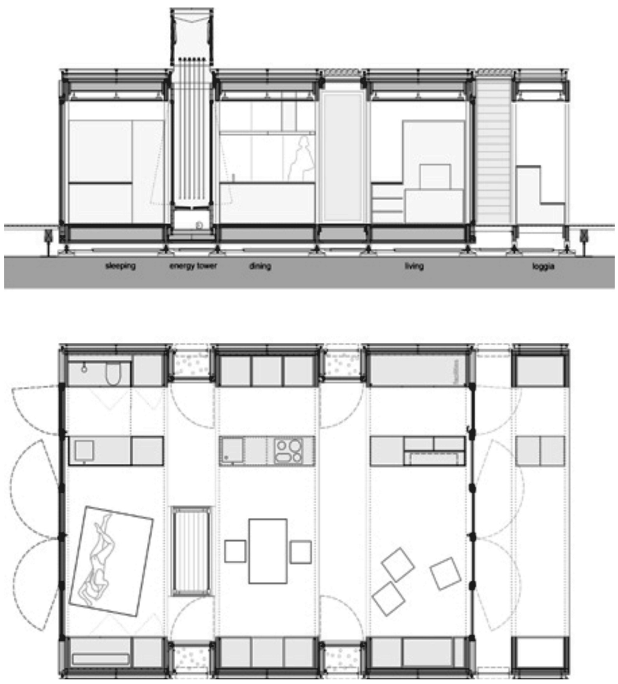
1. Design Concept

The design is based on architectural and energetic considerations. The starting point is a compact and highly insulated volume, with a small surface to volume ratio. The volume is segmented into four modules, which are positioned with interspaces between them (Ill. 1).

These gaps are used for lighting, ventilation, pre-heating in winter and passive cooling in summer. One of these gaps is higher than the others, containing the “energy tower”. Based on traditional principles of climate control, the energy tower is a key element for the energy concept as well as for the outer appearance of the building and the interior space. The modules and the gaps are bound together by the building envelope, which is covered in large areas with photovoltaic elements. The interior shows a clear zoning. In north-south direction the terrace, the living area and the dining area are marked by the gaps, but can be used as one big space also. This is especially important for the two dinners we had to invite our neighbours in the solar village to in June 2010. The more private working and sleeping area is separated by the volume of the energy tower. In east-west direction each area is accompanied by a serving zone (kitchen, entrance and facilities, bath). The modular design of the building does not only facilitate the transport to and the assembly in Madrid, but also allows thinking about a modular building system for different requirements. Using the same basic modules it is possible to create living and working space for singles, couples, families or apartment-sharing communities in detached and semi-detached as well as in multi-family houses.

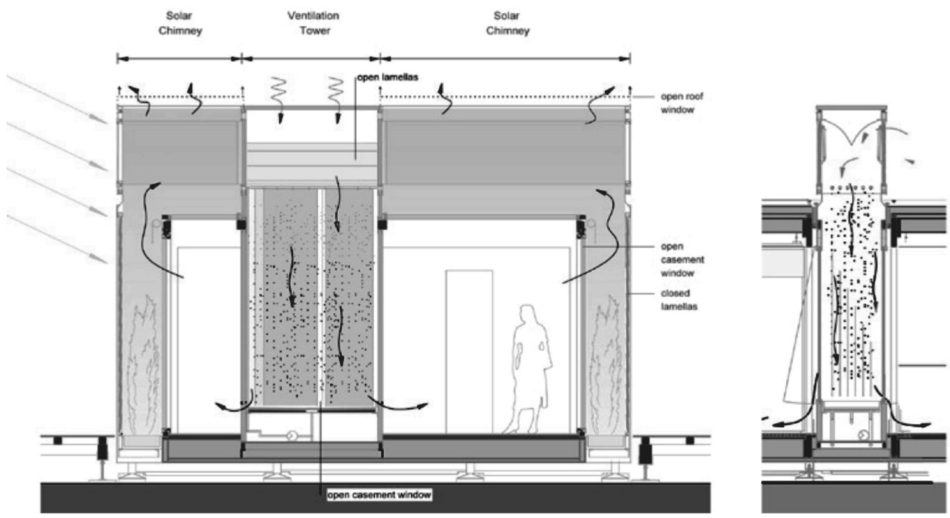


Ill. 1. Floor plan and section

Il. 1. Rzut i przekrój budynku

2. Energy Concept

The basic idea of our design is to use traditional means of dealing with the climate in hot and arid zones and to combine them with new technologies. Thermal mass, sun shading and evaporative cooling will help to achieve a comfortable indoor climate with passive means. The key element of our passive cooling concept is a new building component that we call "energy tower" (Ill. 2), which is also an important feature of the interior design. In addition night cooling via sky radiation and evaporation is used to discharge Phase-Change-Material (PCM). Active cooling is supplied by a reversible heat pump powered by photovoltaics.



Ill. 2. Energy Tower (Sections)

Il. 2. Wieża energetyczna (przekroje)

Since the competition occured in June in a Southern Europe country, the most challenging part has been to satisfy the comfort level in cooling mode, which will be the focus of this study.

2.1. Innovative PV Modules

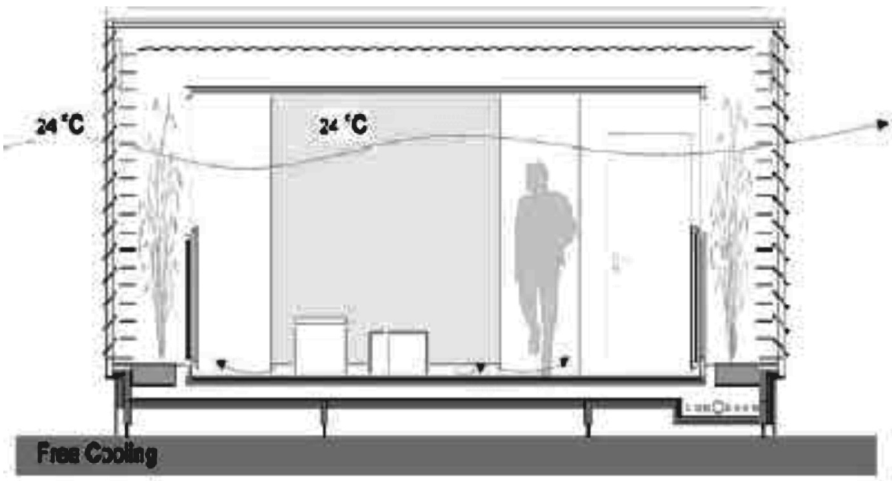
With regard to a unique design we have different façade and roof PV modules. The roof should provide a maximum of electricity output. Roof and façades are visually connected using differently coloured cells in a unique 'pixel design' (Ill. 3). The cell colours are gold and bronze on the roof edge and façade while the roof is covered with monocrystalline black cells. The overall installed power is in the range of 12.5 kWp.

2.2. Passive cooling systems

The energy tower supplies passively part of the ventilation and cooling needs by evaporative cooling when the ambient conditions are not extreme (not too hot, not too humid). Free cooling operates in moderate climate conditions and/or at night by letting the air flow through the openings in the gaps (Ill. 4).

Ill. 3. PV cell modules (in real multi-colour) on the east and west façade (source: J. Cremers)

Il. 3. Moduły fotowoltaiczne (w rzeczywistości kolorowe) na wschodniej i zachodniej elewacji (źródło: J. Cremers)

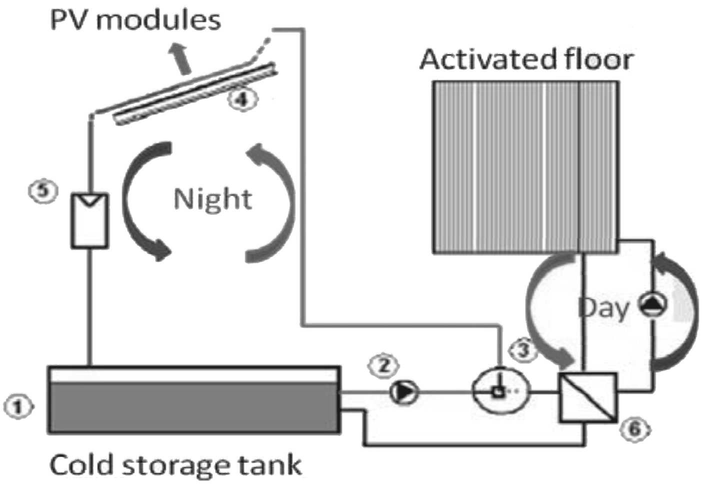


Ill. 4. Free Cooling

Il. 4. Chłodzenie aeracyjne

2.3. Low energy night cooling systems

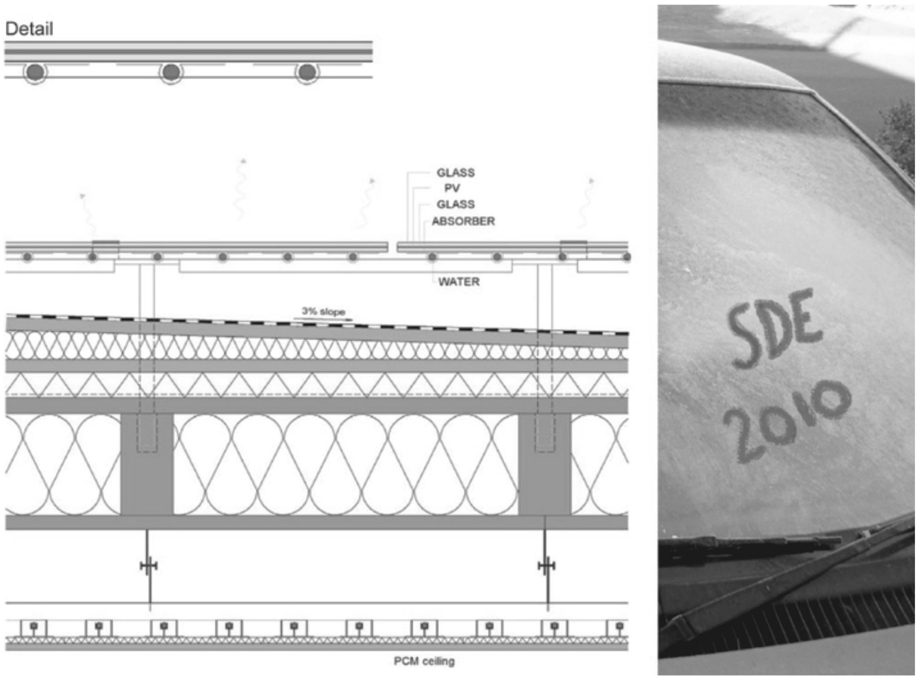
During the day, the PCM ceiling uses the latent heat of the PCM to store the heat and maintain the room temperature around the melting temperature (21–23°C). During the night, the PCM ceiling is actively regenerated using cold water from the night radiative cooling system on the roof (Ill. 6). The main innovation is a photovoltaic/thermal (PVT) collector, which is not designed for maximum heat production, but for most efficient night cooling and a maximum PV power output during the day. The cold water produced at night is stored in a cold storage and used during the day to activate the radiant floor (Ill. 5).



Ill. 5. Night sky radiation cooling system

Il. 5. System nocnego chłodzenia radiacyjnego

The conventional ventilation system (active) is equipped with a heat recovery system between the return air and the supply air for winter and summer. Additionally an indirect evaporative cooling device enhances the cooling capacity through ventilation in summer.

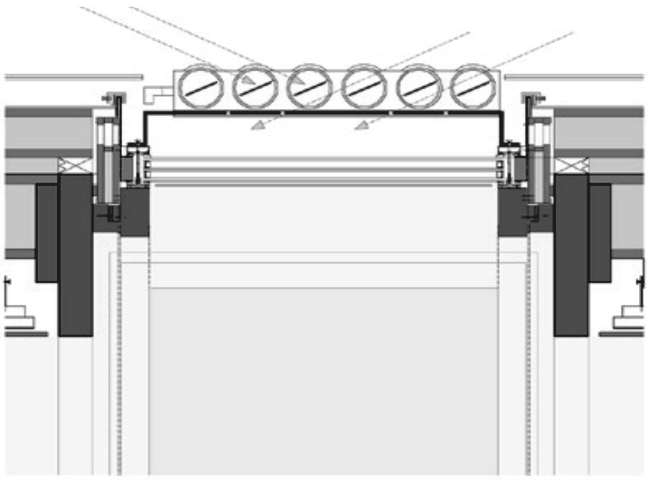


Ill. 6. Principle of PVT collectors on the roof and PCM ceiling

Il. 6. System kolektorów fotowoltaicznych na dachu i sufit PCM

2.4. Back-up cooling system

When the passive or the low energy cooling systems can not cover the demand, the reversible heat pump removes heat from the radiant activated floor to cool down the house. The choice of an electrical solution for the back-up is due mainly to the lack of thermally driven chillers in the range of small power and the lack of space available for the equipments (solar collectors, heat rejection devices, etc.). Therefore, the façades and the roof are covered with PV modules in order to provide the electricity needs of the house and inject the rest into the grid. A classic solar thermal system will provide the domestic hot water needs of the building. It is based on vacuum tube collectors located over the glazed roof lights of the gaps. Here, they act as the key shading system at the same time (Ill. 7).



Ill. 7. Vacuum tube collectors with two functions: production of DHW and solar shading system

Il. 7. Kolektory próżniowe dwufunkcyjne: produkcja ciepłej wody użytkowej a osłona przeciwsłoneczna

2.5. Control strategy

Once we know all the components able to meet part of the cooling demand of the house, one needs to define the order of use of these elements in order to meet the required cooling demand. The passive technologies will be used with the highest priority and then the technologies that require low parasitical energy will have the priority. Ill. 8 shows the priority given for each subsystem in the control strategy.

Priority	Subsystems
1	PCM ceiling
2	Energy tower (if possible)
3	Free cooling
4	Night cooling/activated floor
5	Indirect evaporative cooling
6	Reversible heat pump

Ill. 8. Control strategy of the energy concept

Il. 8. Strategia sterowania w koncepcji energetycznej

Ill. 9–14. Photographs of home^{+} (sources: J. Cremers)

Il. 9–14. Fotografie domu (home^{+}) (źródło: J. Cremers)

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