SOLAR DECATHLON EUROPE 2010 - CONCEPTS FOR PLUS ENERGY HOMES

Prof. Dr. Harald Krause[1], Dipl.-Ing.(FH) Johannes Donaubauer[1], Dipl.-Ing.(FH) Eric Boucher[1] , Johannes Bayer[1] and Dipl.-Ing.(FH) Johannes Maderspacher[2]

[1]University of Applied Sciences Rosenheim, Rosenheim (Germany)

[2]Lucerne University of Applied Sciences and Arts, Lucerne (Switzerland)

1. Solar Decathlon Europe 2010 (SDE 2010)

In 2010 the European version of the Solar Decathlon took place in Madrid for the first time. Solar Decathlon Europe is organized by the Secretary of State for Housing and Urban Development at the Spanish Ministry of Public Works with the collaboration of Universidad Politécnica de Madrid and the support of the US Department of Energy. Four editions of the US DOE Solar Decathlon were presented to date, on 2002, 2005, 2007, and 2009. All of them took place in Washington DC. The 2011 edition will start in September [1]. For 2013 the first Solar Decathlon China is announced.

“Solar Decathlon Europe aims to:

- Communicate our need to diminish our energy consumption by changing our habits and using technologies that reduce energy demand without affecting our lifestyle and comfort.
- Prove that the demands of lighting, heating, and refrigeration can be met with technologies in more efficient ways.
- Show how the energy required can be generated using renewable energy sources such as solar radiation.
- Finally, integrate these changes in ways that are affordable in conjunction with solid architecture practices. As European cities are often dense and have a long history, we try to develop ideas that can be transferred to other kinds of buildings as flats or help to refurbish existing ones.” [1]

17 university teams were qualified for the final competition in June 2010 at the Villa Solar near the royal palace in Madrid. The 4 German teams came from Berlin, Wuppertal, Stuttgart and Rosenheim. [2]

During the project duration of some 2 years the student teams had to design their buildings, particularly with regard to the ten contests of the competition. Finally, for ten days the solar houses were presented to different juries and to the public. Some contests were evaluated by a panel of expert judges, e.g. architecture, innovation and sustainability, as well as the communication strategy. Other contests are based on measured values, for example energy production and consumption and comfort conditions.

2. The Rosenheim “Ikaros Bavaria” Team

In the Ikaros team 50 students from different faculties and almost all study courses were working on the project for up to 2 years. As the Solar Decathlon is mainly a student project, student teams were also responsible for the project management with support of the faculty staff and Professors. Fortunately, a lot of our students passed a professional education before their studies e.g. as carpenter. Therefore, the building was not just designed but also manufactured by our students.

3. The Rosenheim House

The Rosenheim house was designed according to passivehouse guidelines for different climates. The most important design criteria were to minimize all kind of energy consumption through passive measures. Depending on the estimated climate the focus had to be put on heating or cooling. In the concept studies the climate conditions of Rosenheim, Madrid and Kuala Lumpur were taken into account. As the final location of the house is near Rosenheim [3], the house was accordingly built for that climate. The main goal was to create a plus energy balance building. At all three locations the Rosenheim house produces more energy than is used for heating, cooling and all technical services.

Thermal Envelope and Modules

The Rosenheim house was constructed in a modular structure. Each of the four modules was completely assembled in Rosenheim, including the interior finish and all domestic appliances. Using special fittings, the house can be assembled and disassembled several times.

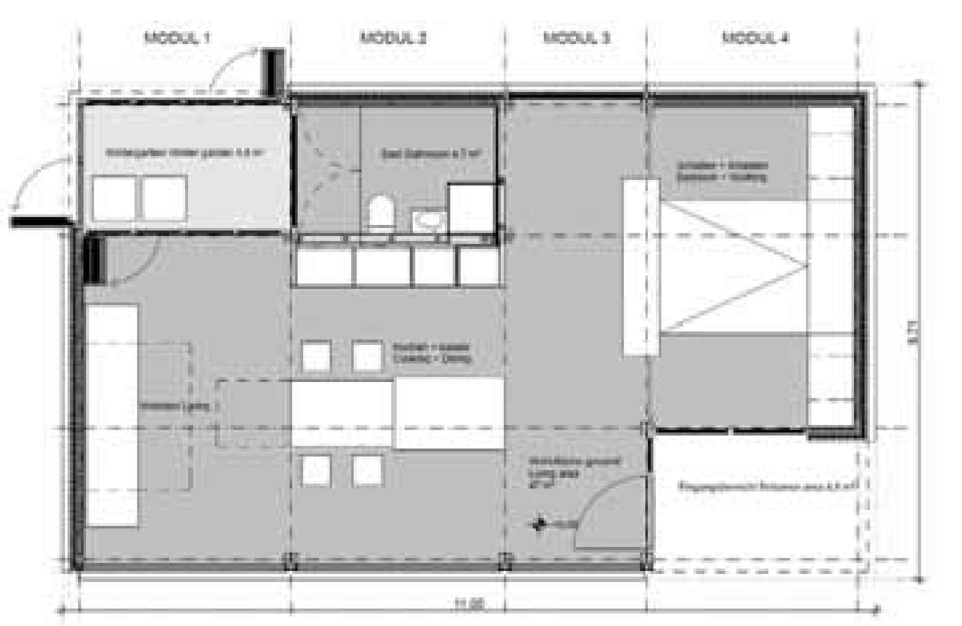

Fig. 1: Floor plan and module structure

Fig. 2: Picture of the Rosenheim house in Madrid

The building was designed for a two person household. Because of the small dimensions, it was necessary to use relatively slim wall constructions. To reduce the dimensions of a conventional timber frame construction, vacuum insulation panels were used.

Tab. 1: General data of the Rosenheim house optimized

	description	data
Thermal envelope	Area, envelope/volume ratio	255 m^2 / 1,54
TFA	Treated floor area incl. winter garden	65 m^2
Window area	Percentage of window area	22 %
External wall	Timber frame construction with VIP	U = 0,098 W $m^{-2}K^{-1}$
Roof	Timber frame construction with VIP	U = 0,095 W $m^{-2}K^{-1}$
Windows	Fix frame, triple glazing with sun protection coating, Krypton	U_g = 0,5 W $m^{-2}K^{-1}$ g = 0,35
Entrance door	Certified passivehouse door	U_d = 0,7 W $m^{-2}K^{-1}$
Sun shading	In-house development: „Zig-Zag-Facade“	Fc = 0,1 to 0,03

Design Tools and Results

The basic energetic design was performed with the PHPP 2007 [4]. These results were also used as first estimations for the heating and cooling loads. Due to the special requirements during the competition in Madrid, e.g. the public visit times, and the very narrow temperature band for the comfort conditions between 23°C und 25°C, dynamical simulations with IDA ICE were necessary [5]. Figure 3 shows the positive energy balance for Madrid. The yearly energy demand for heating and cooling calculated with the PHPP and IDA ICE were quiet similar. The PHPP results therefore seem also to be valid for very small buildings. The cooling load peaks cannot be determined with the PHPP method, because the peak loads were needed to guarantee the comfort conditions, which were measured in an interval of some minutes. Assuming standard living conditions of a two person household, the daily mean values for heating and cooling loads with both methods fit rather well.

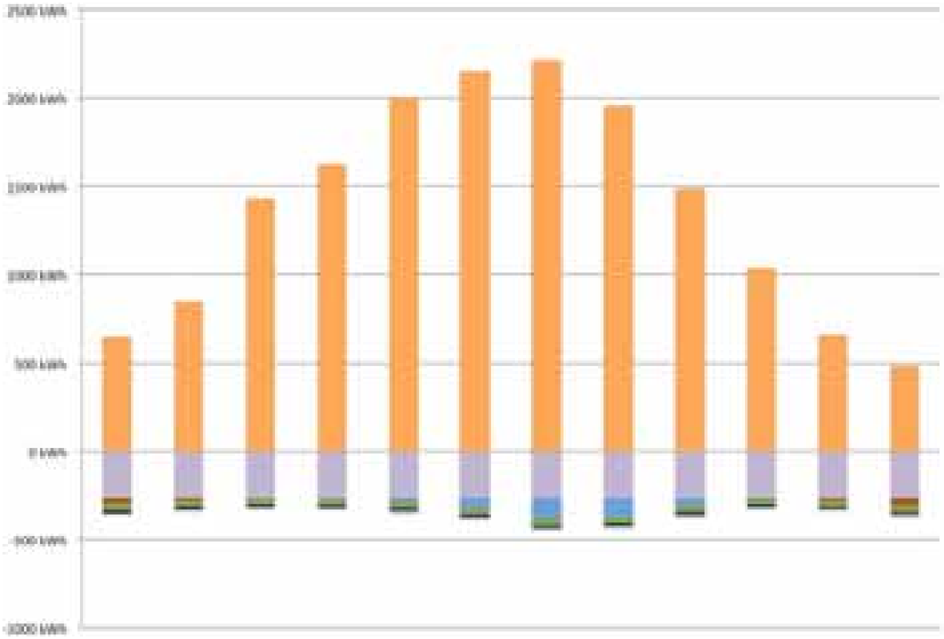

Fig. 3: Overall energy consumption (negative scale) and production (positive) for Madrid from Jan to Dec.

Passive House Standard for Different Climates

Due to the definition of Feist [6] a "A Passive House is a building in which thermal comfort [ISO 7730] can be ensured by only heating or cooling the fresh air volume that is needed for sufficient air quality – without using additional circulating air." This is a purely functional definition and is therefore applicable to every climate. Furthermore this definition leads to extremely low energy demand for heating and cooling. The maximum heating power is limited by the air flow rate and a maximum reliable supply air temperature to approximately 10 W m^{-2}. This heat load leads to a typical annual heat demand for central Europe of some 15 kWh $m^{-2}a^{-1}$.

In our design studies we tried to optimize our house for different climates, which are described in Table 2. Kuala Lumpur was chosen, because of a new master study course for energy efficient buildings, which is a cooporation project of the University of Kuala Lumpur and the University of Applied Sciences Rosenheim [7].

Tab. 2: Different Climates for Passivhouse Design Studies

		Madrid	**Rosenheim**	**Kuala Lumpur**
Max. monthly mean temp.	°C	25,4	15,8	28,5
Min. monthly mean temp.	°C	6,0	-3,0	27,1
Min. monthly ground temp.	°C	11,6	6,3	27,9
Max. monthly ground temp.	°C	22,8	16,0	28,6
Temperature difference day/night in cooling period	°C	13,0	10,1	7,5
Min. monthly dew point temperature	°C	2,1	-4,8	22,7
Max. monthly dew point temperature	°C	10,7	11,7	24,2
Annual Solar radiation January	kWh m^{-2}	66	39	134
Annual Solar radiation July	kWh m^{-2}	230	168	140

The climate data obviously lead to the following main design criteria:

- Madrid: moderate cold winter, hot but low humidity summer, cold nights even in summer: heating and probably active cooling will be necessary
- Rosenheim: cold winter, moderate summer, cold nights in summer: heating, almost no cooling
- Kuala Lumpur: high outside temperatures and high humidity over the whole year: cooling and dehumidification will be necessary

The house was designed for a minimum room temperature of 20°C and a maximum of 25°C. The humidity was limited to 12 g/kg. The supply air flow rate was designed for two occupants with 60 m^3 h^{-1}. All calculation were performed with the PHPP [4].

In Madrid and Kuala Lumpur heating and cooling can be provided by using the supply air. In Rosenheim the heat load is too high for supply air heating. This is due to the very small treated floor area. In all location very high insulating and air tight constructions are necessary. For example: if one uses a standard roof construction with an U-value 1,0 W $m^{-2}K^{-1}$ the cooling load increases some 70%. In Kuala Lumpur smaller windows and a ventilation system with humidity recovery is recommended. The building in Kuala Lumpur leads to the highest energy demand, because of cooling and dehumidifying. On the other hand solar gains with a PV-system will be more than sufficient to cover this demand.

Similar Calculation were presented by Rongen and Schnieders recently. As their calculations were performed for somewhat bigger houses, the results are not identical [8].

In conclusion it was shown, that using the passivehouse standard in combination PV-system it will be possible to achieve a net plus energy building including domestic appliances for nearly all climates.

Tab. 3: Suggestions for optimized passivehouse design in different climates.

		Madrid	**Rosenheim**	**Kuala Lumpur**
U-values / solar absorptance	$W\ m^{-2}K^{-1}$			
Walls		0,15 / -	0,12 / -	0,15 / 0,2
Roof		0,15/ 0,2	0,11 / -	0,12 / 0,2
floor		0,20	0,15 / -	0,20
Windows U-value/g-value	$W\ m^{-2}K^{-1}$	0,7 / 0,40	0,7 / 0,60	1,2 / 0,25
Total window area	m^2	34	27	20
Shading, F_c-value	-	0,15	0,30	0,15
Air tightness n_{50}-value	1/h	0,60	0,3	0,6
Ventilation				
Heat Recovery	-	0,8	0,9	0,8
Humidity Recovery	-	-	-	0,8
Night Ventilation through windows		yes	yes	no
Heat Load (daily mean value)	$W\ m^{-2}$	13	20	0
Cooling Load (daily mean value)	$W\ m^{-2}$	13	4	8
Annual Heat demand	$kWh\ m^{-2}$	3	12	0
Annual Cooling demand	$kWh\ m^{-2}$	10	0	50
Annual total electrical energy consumption	kWh	2650	2900	3400
Necessary size of PV-system to obtain zero energy balance	kWp	≅ 2	≅ 3	≅ 2

Building Services

The heating and cooling in the Rosenheim house is performed in a combination of active and passive components. A schematic drawing is shown in Figure 4. The system seems to be very complicated in relation to the small energy amount of the building. Indeed, a lot of systems were combined, which are in some cases redundant. As there was the opportunity to use a combination of systems, we decided to learn much about different possibilities for heating and cooling and not to use a prefabricated standard system (even if this had been much simpler and cheaper). The energy source is a 13 kWp photovoltaic system positioned on the nearly flat roof. As all houses were connected to the electrical grid, no batteries were necessary for buffering. The central heating and cooling unit is a heat pump, which is connected to a cold and a hot water tank. The simulations showed, that the waste heat during cooling time is sufficient to provide all domestic hot water needed for showers, washing and the dish washer. Thus, a thermal solar system was not necessary for the competition, although it would be generally helpful.

In addition, a radiation cooling system in combination 2000l non-pressure water tank is used to provide cold water for stationary cooling during day time (see also Figure 4). Both active and passive systems are connected to a ceiling cooling (heating) system, which covers most of the whole ceiling area. A ventilation system with heat recovery and optional humidity recovery is also connected to the system.

The ceiling cooling system was not able to cover the peak loads after the public visits during the competition. Figure 5 shows a box, which is fitted to the house below the floor, and filled with PCM panels. With this system, a maximum cooling power of 2,5 kW is possible.

Table 4 summarizes the mechanical systems.

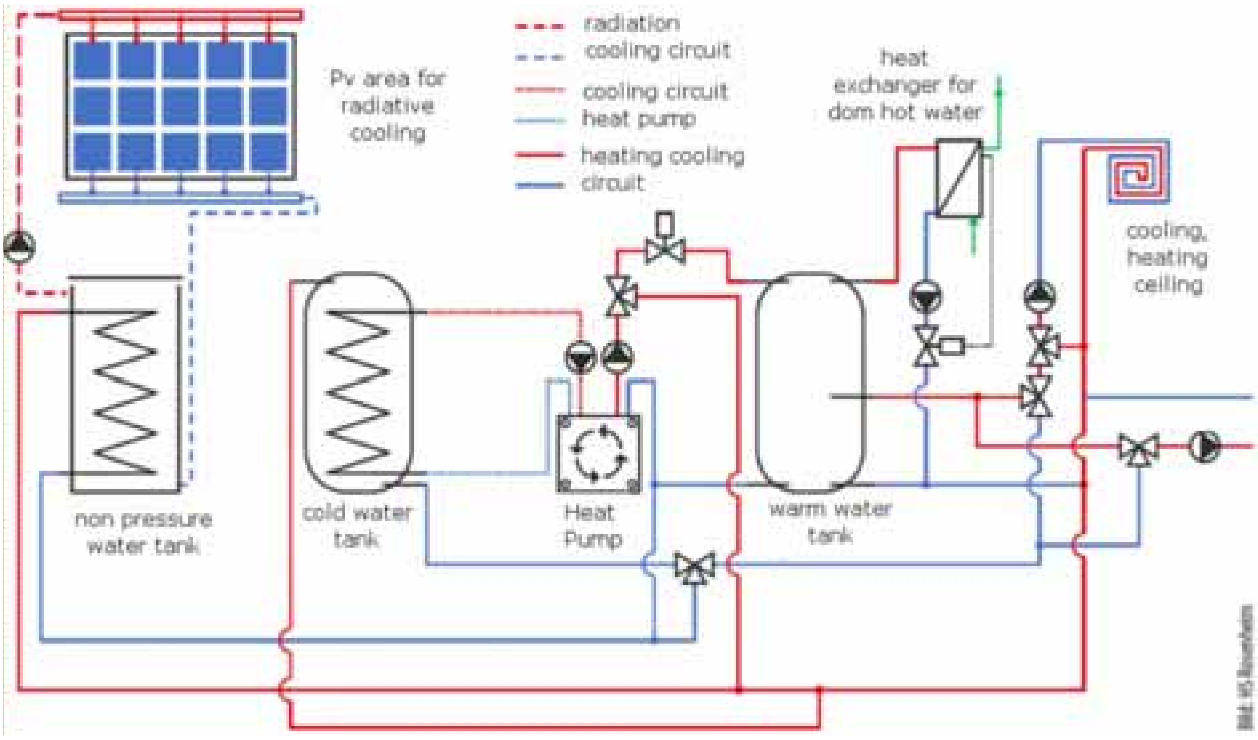

Fig. 4: Schematic drawing of the mechanical services for heating, cooling and domestic hot water

Tab. 4: General data of the heating and cooling systems in the Rosenheim house

PV- system	13 kWp, 40 Module 315 WTH – Sun Power, Inverter – SMA – Sunny Mini Central 4600A, Sunny Boy 3300
Heat pump	EnTitan SW 5,5 kW heating power, COP 5
Warm, cold tank	300 litres
Cooling ceiling	Incotec WEGO, net area 53 m^2, cooling power at ΔT=10 K: 54 W m^{-2}
ventilation	Zehnder Comfoair 350, ca. 120 $m^3\,h^{-1}$
PCM channel	2,6 m x 1,1 m x 0,4 m PCM Dörken: Delta Cool 24 Latent heat: approx. 14kWh Cooling power: at 600$m^3\,h^{-1}$, ΔT=10°C: approx. 2,5 kW

Fig. 5: Passive radiation cooling on the roof using the PV panels and the PCM channel.

4. Results

The Rosenheim house finally won the second price at the SDE 2010. First places were obtained in the following competitions:

- Energy balance
- Comfort conditions
- Appliances
- Lighting

Students of all teams (and Professors too) learned much about the designing, running and monitoring of energy efficient buildings. The Rosenheim house was presented at the Landesgartenschau in Rosenheim (open air exhibition) and the BAU 2011 in Munich to a large audience. Every visitor left the house with the same impression, that passive houses are beautiful, comfortable and produce almost no costs for energy.

5. Acknowledgements

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For further information see: http://solar-decathlon.fh-rosenheim.de/

[1] according to http://en.sdeurope.org/?page_id=2

[2] Solar Architektur: Die deutschen Beiträge zum Solar Decathlon Europe 2010 von Bergische Universität Wuppertal, Hochschule Rosenheim, Hochschule für Technik Stuttgart und Hochschule für Technik und Wirtschaft Berlin von Ins. F. Int. Architektur, detail Verlag 2011

[3] www.eneff-stadt.info/en/pilot-projects/project/details/engl-eine-militaerbrache-auf-dem-weg-zur-nullenergiestadt

[4] PHPP 2007: W. Feist, R. Pfluger, B. Kaufmann, J. Schnieders, O. Kah, 2010. Passivhaus Institut.

[5] IDA ICE, Ver. 4, Equa Simulation AB

[6] B. Krick, J. Schnieders, W. Feist, Proceedings Passivehouse Conference Innsbruck 2011

[7] www.unikl.edu.my/images/pdf/programmes/programmesOffered/MICET/master%20of%20engineering%20technology%20in%20green%20buildings.pdf

[8] L. Rongen, J. Schnieders; Proceedings Passivehouse Conference Innsbruck 2011