

# Solar Decathlon Winner – "Living 2015" Prototype




1st prize in the international "Solar Decathlon 2007" competition to find the most attractive and energy-efficient solar home in 2007 went to Germany. The competition rules require a fully energy-independent building with a floor area limited to 75 m<sup>2</sup>. The prototype is laden with new technologies and concepts: Vacuum insulation (VIP), thermo-active building systems using phase change materials (PCM), solar power generation (PV) integrated into the facade and roof and many other features ensure energy autonomy. The team from the Technical University in Darmstadt, headed by Prof. Manfred Hegger, triumphed in Washington D.C. against 19 other top universities from the USA, Canada and Spain.

This high-tech building will be erected as a project office on the "Lichtwiese" campus at TU Darmstadt, serving as an EnBau model project for detailed testing and optimisation in everyday use.



The prototype – visualisation during the planning stage  
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## Building summary

<b>Project status</b>	 Built / Renovated
<b>Location</b>	64287 Darmstadt, Hessen
<b>Completion</b>	2007
<b>Inauguration</b>	2008
<b>Building owner</b>	TU Darmstadt (+ Betreiber + Nutzer)
<b>Gross floor area</b>	72 m <sup>2</sup>
<b>Heated net floor area</b>	50 m <sup>2</sup>
<b>Gross volume</b>	182 m <sup>3</sup>
<b>Work places</b>	2
<b>Usable floor area (according to EnEV)</b>	58 m <sup>2</sup>
<b>A/V ratio</b>	1.15 m <sup>2</sup> /m <sup>3</sup>
<b>Key aspects</b>	Heat insulation, Facade systems, Glazing + windows, Daylight planning, Ventilation + heat recovery, Active cooling, Regenerative + passive cooling, Thermo-active building element systems, Heat pump, Heat / cold storage, Control technology, operational management, building automation, Solar thermal energy, Photovoltaics, Biomass utilisation, Ecology of building materials

## Project description

20 universities were invited to submit their projects to the international Solar Decathlon 2007 competition and set them up in Washington. All projects were required to capture energy solely from the sun. The extremely compact residential buildings were exhibited in Washington in October. Through this competition with 10 individual disciplines, the US Department of Energy, which hosted the event, wanted to find the most beautiful, most functional and future-oriented house. The houses with integrated solar technology had to generate all necessary energy for everyday life according to (American) standards – including electricity needed to operate an electric car. After eight days the competition was finally awarded to the team from the Technical University Darmstadt.

After the building was returned from the USA, it was initially exhibited at various locations (DEBAU, Essen and Robert Bosch GmbH, Stuttgart). From July 2008, this high-tech building will then be erected as a project office on the "Lichtwiese" campus at TU Darmstadt, serving as a model project for thorough testing and optimisation in everyday use.

## Building concept

The design is based on three basic ideas. Firstly, the principle of layering: The ground plan is sub-divided into various zones which are set like layers of an onion around an inner core. The differently temperature-controlled layers of the building envelope allow a differentiated display of the ground plan depending on the time of year (summer and winter house). Secondly, there is the platform concept for furniture and technology, similar to

automotive construction: A false floor houses the building service components which can be added to the overall system according to the plug-in procedure. An equipment room for the building is no longer necessary. The false floor also serves as storage space for furniture which is crucial for the third topic of design: Thirdly, a quiet room should be created which can be perceived in its pure, actual form. The room can be used flexibly and is, in that sense, also sustainable.

#### **Spatial concept**

The projected floor area was limited to around 75 m<sup>2</sup> according to the competition rules. In the TU Darmstadt's competition entry, a core area comprising all supply and sanitary units separates the 59m<sup>2</sup> of heated internal space into a living and working area to the west and an eating and sleeping area to the east. At the southern end of the building, the eating and living areas are connected via the flexible kitchen.

The core of the building contains the vertical technical installations, the bathroom and the kitchen, as well as further storage space and a wardrobe. In its compacted state, the bathroom is sufficient for basic personal hygiene, the kitchen can only be used as a single kitchen. When the walls or work top are extended, this provides generous space for their respective usages. The bathroom, previously located towards the interior, now becomes a bathroom flooded with daylight and the kitchen becomes a room suitable for shared cooking.

#### **Facade**

The facade is simple but, at the same time, adaptable. The lamellae, which have a horizontal structure and are located on all sides of the house, are meant to create a lively and, at the same time, homogeneous external appearance. To the south, this lamella layer is separated from the facade and defines a protected, but unheated cavity as a passage to the outside world.

#### **Construction**

In order to meet the demands on transportation, the house was constructed using a modern timber construction method. The modular construction is a combination of wooden frames with sandwich and cartridge elements. The transport loading condition, supported by steel construction components, was taken into consideration from the outset and aesthetically integrated.

The efficiency and degree of innovation of the wooden materials is shown by using massive wood as a visible construction in combination with modern architectural aesthetics. The appropriate and innovative use of sustainable and/or locally produced construction materials is also the main focus of the interior construction work. Aesthetics, comfort and simplicity of application are criteria for both architecturally integrated and free-standing furnishings.

#### **Innovation**

The building was designed and built by a team of students. In order to meet the high demands on precision, detailed planning and support through the expertise of innovative manufacturers and through master craftsmen were important.

The details of the quadruple-glazing, the vacuum-insulated facade parts to the north and the window panes, suitable for use in passive houses, in the south facade were developed and implemented in conjunction with the manufacturer of the window facades.

The structural integration of photovoltaics into the layer of wooden lamellae surrounding the house represents a new solution, which was realised by students of the TU Darmstadt in cooperation with the TU Munich and a medium-sized facade construction enterprise.

#### **Energy concept**

##### **Building technology – 'Made in Germany'**

The building prototype was intended to demonstrate that extreme energy efficiency can certainly combine aesthetics with living comfort. It was fitted predominantly with materials, components and systems from Germany and built by German manufacturers. With this project, the team wanted to show German procedural methods on the subject of energy efficiency. Their approach in this area was very different to that of the other competitors: The tactic used by most participating US universities was to produce as much energy as possible in order to cool and heat the living areas with the aid of traditional technology. In contrast, the team from Germany placed importance on reducing the energy requirements as much as possible without having to compromise on living comfort.

##### **Heat insulation and temperature control**

Initially, the traditional methods of temperature control were used: The use of solar and internal yields in winter, protection from the summer heat using shade, transverse ventilation, thermal masses as well as a compact and very well insulated shell. The largely transparent north facade allows optimum illumination with daylight.

In addition, high-tech materials were chosen, such as vacuum-insulation panels in the ceilings and walls and high thermal mass in the form of PCM (Phase Changing Materials) in walls and ceilings in order to prevent temperature peaks in the interior rooms.

Right from the beginning, it was decided to integrate the photovoltaic elements and the solar thermal collectors into the flat roof for aesthetical reasons. By placing the elements horizontally, only around 10% of annual yield is lost. In order to obtain enough electricity during the competition in October 2007 with a relatively low-lying sun, the vertical facades to the east, south and west were also fitted with photovoltaics.

#### **Solar power**

Three different types of photovoltaics are used: Highly efficient monocrystalline modules with an output of 8.4 kWp are fitted to the opaque flat roof. Monocrystalline, perforated cells are also used above the veranda; they are embedded in a special glass with an innovative anti-reflective coating. The point-supported modules thus also act as weather and sun protection and create an interesting interplay of light and shade. The wooden lamella facade, the most characteristic element in the house, which provides shade, creates privacy and offers protection against break-ins, is fitted with amorphous silicon modules with an output of around 2 kWp. The lamellae follow the sun automatically and can change their angle to the north or south at the touch of a button. However, the lamella doors to the north and south have to be moved, opened or closed by hand. The electricity obtained from the sun was stored in batteries during the competition. A stand-alone inverter ensured for intelligent control of when electricity could be used directly or stored and taken from the batteries. Once the final installation will be completed in Germany, the solar electricity will be fed into the grid.

#### **Solar heating**

Two flat plate collectors are mounted above the core area between the PV modules on the roof. They generate the hot water in combination with an innovative compact ventilation device. The compact ventilation device can ventilate, heat, cool and even generate hot water, and takes up minimal space with its reversely operable compression heat pump in combination with heat recovery.

#### **Light**

At the Solar Decathlon competition, 'light' was a discipline in its own right. It dealt with light as an energy factor and also as a visual comfort and an aesthetic element. Continuous measurements of lighting intensity were taken at various points in the building throughout the competition and the daylight and artificial light situation was subjectively assessed by a jury.

The jury's assessment criteria here were: Consistency of the lighting concept with various lighting situations (light to see, perceive and look at), architectural integration, colour rendering, innovation, design of the lights, energy consumption and flexibility, difference between interior and exterior spaces, sensible use of a light control system, lighting atmosphere, artificial light. In addition, the layout of the lighting system had to be directly determined by the 'energy balance' discipline, as the house had to be completely lit up in the evening.

In the Darmstadt house, all the lights are integrated into the architecture – except the desk lamp. Shelves made of Plexiglas are turned into lighting objects through a combination with LEDs. Both aesthetics and suitability were considered in choosing the lighting. The result is a combination of LEDs, halogen and compact fluorescent lamps. A BUS system allows various lighting scenarios to be programmed and daylight and artificial light to be controlled intelligently.

The transparent northern facade made it possible to reach the minimum light intensity prescribed in the work area: 50ftc - 538 lx had to be achieved for four days between 9 am and 5 pm - while the southern facade, depending on the level of sunshine, could be wholly or partly in the shade. The lighting concept in the exterior space was also assessed: Here, LEDs were mounted as orientation lights behind polycarbonate cladding, giving the surrounding deck a floating character. The house itself glows from the inside out through fine slits in the lamella facade and, as a result, becomes a lighting object itself.

#### **Simulation and modelling**

The layout and interplay of the systems were calculated using various static and dynamic balance models. In the competition, these simulations were also crucial for deciding on a strategy to optimally deploy the available energy in order to adhere to as many of the competition criteria as possible.

#### **Performance**

The Solar Decathlon competition was won, not least, due to the building's high level of efficiency and the systems used. This becomes clear when comparing the discipline, energy balance (which 5 other teams also won in addition to the team from Germany) with the disciplines, household devices, light and comfort. As well as the fact that the batteries used by the Darmstadt team never fell below their original levels during the whole week, some of the other 'energy balance winners' were only able to achieve this result by turning off the building services, household devices and lighting.

In this regard, the 'light' category is also worth mentioning, which the Darmstadt team also won overall, having been awarded 2<sup>nd</sup> place in the sub-assessment of their daylight and artificial light concept by the jury, due to the good quality daylight in the workplace and the use of efficient and suitable lamps (energy consumption!).

Detailed information on this subject will become available as the project continues.

### Optimisation measures and possibilities

The energy concept is based on the optimum interplay between passive measures and energy-efficient, active systems. The monitoring is intended to optimise the systems in terms of energy consumption and comfort for continuous operation. In addition, the advance calculations can also be calibrated.

Another aspect of optimisation will be the lamella facade. Here, it is a question of checking whether the energy gained from tracking justifies the associated complexity.

Detailed information on this subject will become available as the project continues.

### Construction costs and economic viability

The investment totalled around 550,000 euros. The costs were financed by industrial sponsoring, by material donations and research subsidy grants. The comparatively high costs of 10,000 €/m<sup>2</sup> of heated footprint are due to various factors: the prototype development, an extremely small area, the use of new kinds of systems and materials, the complex technology for monitoring and controlling the building, the grid-independent solar system and, not least, the high quality fittings – both requirements of the competition.

Detailed information on this subject will become available as the project continues.

### Key energy data

Energy indices according to German regulation EnEV (in kWh/m <sup>2</sup> a)	
Heating energy demand	12.00

 **Projektinfo by BINE Information Service**

 **The winners-website of the TU Darmstadt**

 **Website of the department of architecture - Energy Efficient Building Design, TU Darmstadt**

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