Solar decathlon middle east competition house of team twist box

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Abstract:
The Solar House "Twist Box" is a project of the Belgrade University, run by the Faculty of Architecture; School of Electrical Engineering; Faculty of Technology and Metallurgy and Faculty of Mechanical Engineering.
This project has been launched for the purpose of the "Solar Decathlon Middle East" competition and is now in the final stage in which the documentation for carrying out the works is being prepared. Here we will be talking about the HVAC equipment that will be designed for this building, the way they are selected and solutions that are developed in order to reduce heat load. The first problem we encounter is location and climatic conditions. The location where this house will be built in November 2018 is 30km from Dubai UAE. Climatic conditions at this location are very unfavorable from the standpoint of air conditioning because they represent a combination of very high temperatures and intense solar radiation. In order to achieve comfort conditions inside the building, it is necessary to provide the required amount of fresh air of the appropriate temperature. In order to select an adequate system, it was first necessary to calculate the heat load based on climatic influences, thearchitectural and construction model, the number of people envisaged to be in premises, electrical installations and other factors. In addition to the calculated heat flow, a simulation was performed that showed a more realistic picture throughout the year. After calculating the heat load, equipment is selected for covering the total heat load, which ensures the design temperature in the room and provides the required amount of fresh air. The preparation of air-conditioned air is carried out using a heat recovery, and high-static ducted indoor units. The heat recovery serves to cool the fresh outside air at the expense of heating the waste air from the room. The high-static ducted indoor unitsare supplied with the refrigerant from the outdoor unit. Prepared air is supplied to the living space by means of supply air equipment which has been selected so that it fits best into the interior, while ensuring sufficient levels of noise and, more importantly, to provide an adequate air flow inside the space. The second task is the preparation of domestic hot water, which is done by solar energy receiver. Space is allocated on the roof for the solar energy receiver, and it is connected with the hot water boiler inside the house.

Key words: *SDME; HVAC; Solar; Efficiency; Sustainability.*

1. Introduction

The Solar Decathlon Middle East is a competition held in Dubai in November 2018, in which universities around the world compete with the goal of designing and building a solar house. The competition is held every two years and every time it is set in a different location so the challenges are different every time. Teams from colleges

and universities across the globe participate in the Solar Decathlon.The Solar Decathlon encourages students to incorporate energy efficiency and clean energy into their future professional projects and personal lives. Like Olympic athletes, the solar decathletes draw on all their strengths, including design and architecture, engineering and performance, and education and promotion. The teams rely on expertise from many disciplines as they spend months fundraising, planning, designing, analyzing, and finally building and improving their houses. Future engineers work with future architects to create affordable, energy-efficient houses.The competition has now entered its final phase where competitors need to develop final documentation for the house construction and supply materials, machinery and personnel for actually building the house. At this point only 21 universities from across the world have a chance to build their house in November 2018. To get to this point each team has gone through two years of research and development and has successfully completed 5 deliverables of which some included hundreds of pages of drawings and calculations. Team from the university of Belgrade "Twist BOX" is proud to be one of these 21 teams that have a chance of building our vision of the house of tomorrow. Our team is comprised of students and mentors from 4 faculties: Faculty of Architecture; School of Electrical Engineering; Faculty of Technology and Metallurgy and Faculty of Mechanical Engineering. Each faculty contributed to development of the area of the house that it specializes in but teamwork is essential to actually make the house.

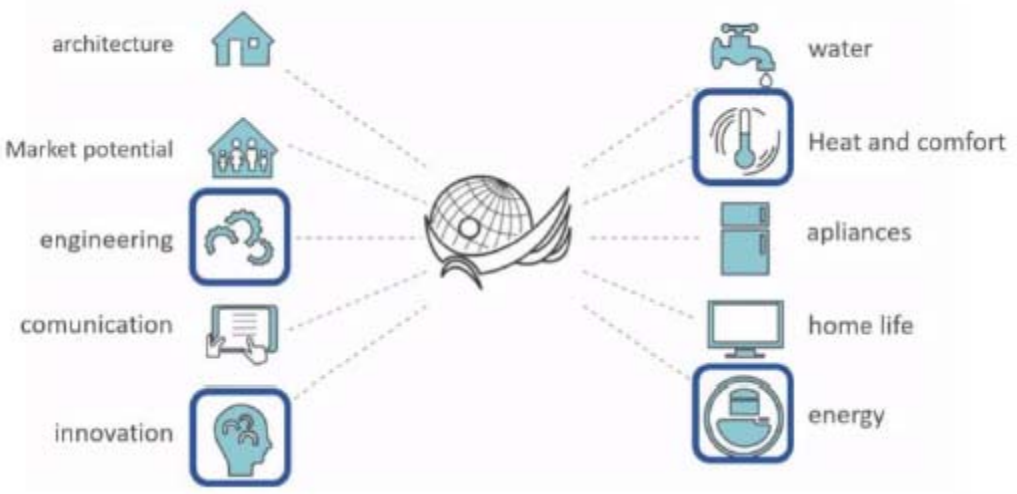

Figure 1: Disciplines of solar decathlon [1]

Within each of the above categories, certain requirements are set by the organizer. The main task of the team from the Faculty of Mechanical Engineering is to maintain the thermal comfort in the space in the most energy efficient way. The students, together with their faculty advisor are given the task to design the ventilation and air conditioning system as well as the domestic hot water preparation system. Temperature, relative humidity and CO2 concentration inside the house are required to be inside the rangedefinedby the organizer. These requirements coincide with general views on the comfort conditionsinside the room, for example, the temperature is limited in the range of 23 to 25 ° C. For each deviation from the given values, the

number of points achieved is reduced. Diagrams in Figure 1 show how number of points awarded changes in respect to the temperature, relative humidity and CO2 concentration inside the house.

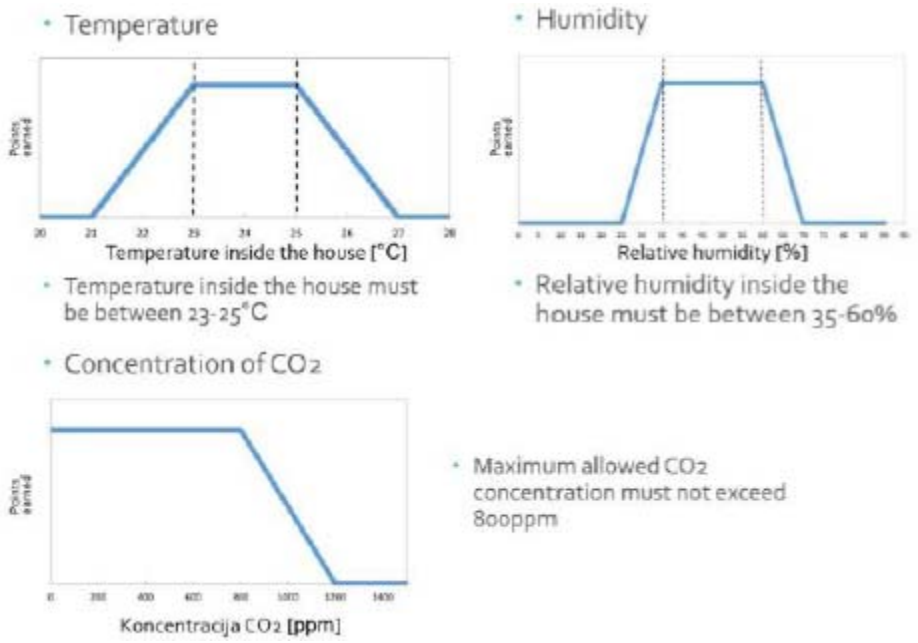

Figure 1: Points earned in relation to task completion [1]

2. Climate conditions

Climate conditions are one of the most important factors affecting the energy consumption of the air conditioning system. The location on which the house will be built is characterized by desert climate.The effects of the climate conditions are mitigated by utilizing smart architectural concepts that will be discussed further in the text.

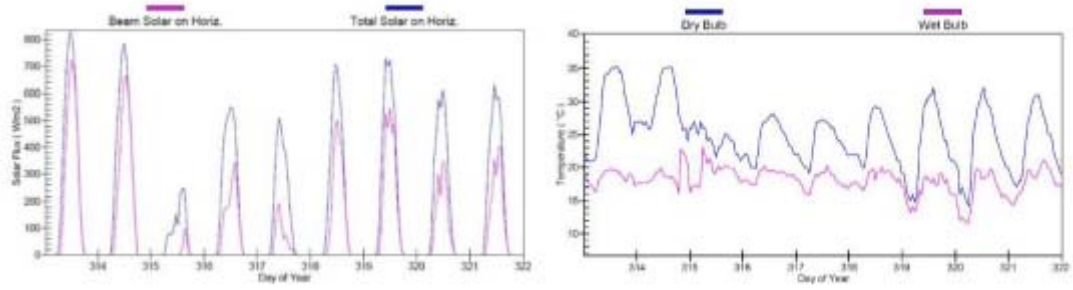

Figure 2: Solar and temperature profiles for dates between 10.11.-18.11. [3]

3. Architecture-Building model

The house is mainly constructed from lightweight prefabricated materials that are easierto set up and transport. The weight aspect is very important because the house needs to be shipped from Serbia to Dubai so the lighter the material the lower the cost of shipping will be. Low weight materials also have the property of low thermal accumulation, so when the house is constructed in Dubai, and the air

conditioning system is turned on for the first time, it will not require that much energy to cool the walls down to room temperature. Walls are also equipped with insulation layers that greatly reduce transmission heat gains. In Dubai, the biggest challenge for achieving the comfort conditions inside the house is solar radiation. In order to minimize this effect, a brisesoleil system is created (Figure 4). This system has the role of blocking most of the direct solar radiation that would fall on the outside walls of the house and penetrate through the glass surfaces. Brise soleil are rotated throughout the day so as to completely block the Sun's radiation at the places where it is needed and provide an unobstructed view at places where there is no direct sun radiation. By installing the brise soleil, it is possible to place larger windows, without compromising the concept of the thermal efficiency of the house. Although brise soleil block a large part of the solarradiation, it is necessary that large glass surfaces have good thermal characteristics because direct solar radiation is not the only way to get heat into the room. In order to reduce the transmission load, windows with dual or even triple glass with inert gases between the glass layers are used to minimize transmission gains. The south facade of this building is covered with windows so it is necessary that these windows have the best thermal properties. Due to the weight, a compromise was made, so the windows with double glass with a heat transfer coefficient of 1,2 [W / m^2K] were selected instead of the windows with triple glass.

Figure 3: House model

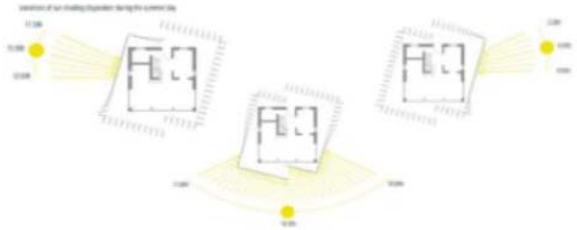

Figure 4. Functioning of brise soleil

4. Air conditioning system

In order to achieve comfort conditions in the climate conditions that are in Dubai, it is necessary that the air in the room is cooled and a certain amount of fresh air is continuously supplied. Supply air is prepared separately for each zone and distributed to all the rooms through insulated duct system. Each zone has its own high-

static ducted indoor unit that cools the air to designated temperature. Fresh air is first prepared inside

the heat recoveryand then distributed to all duct units. The ducted indoor unitsare part of the multi splitVRF (Variable Refrigerant Flow) heat pump system. The advantage of a variable refrigerant flow system is that it has much better control of heat load and the heat pump much more rarely enters the on/off mode. The variable refrigerant flow is enabled by the inverter compressor. The inverter compressor is a compressor drive technology that ensures the control of refrigerant flow in order to maintain the air temperature in a very narrow range close to the set temperature. The COP of the selected device is 5,34 [2]. This COP is obtained from the manufacturer and it is defined on the basis of the design temperature of the outside air (in this case, this temperature is 41.1 ° C) and the design air temperature in the room (in this case temperature is 25 ºC). The heat pump selected has temperature and pressure control so it can further optimize it's work to best fit the conditions inside and outside the house.

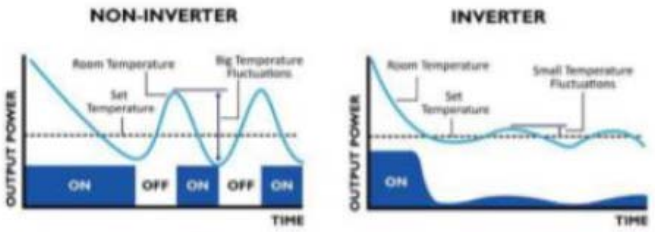

Figure 5: Difference between inverter and non-inverter heat pump

4.1. Heat recovery system

Heat recovery systemsenable using of waste heat, which significantly reduces the required energy for heating or cooling. In the summer, the outside air is warmer than the exhaust air. When they pass through the heat exchanger, heat is transferred from the outside air to the exhaust air and by doing so the outside air is cooled. In this way ventilation heat load is reduced, so the cooling system consumption is lower.

In the winter mode, the heat recovery works on the same principle, only now the return air, which is at a higher temperature than the outside air, transfers the heat to the outside air.If the device operates in summer mode, and the outside temperature is lower than the temperature inside the house, the return air will be directed so that it does not pass through the heat exchanger. By doing this unnecessary heating of the outside air is avoided and energy is conserved.

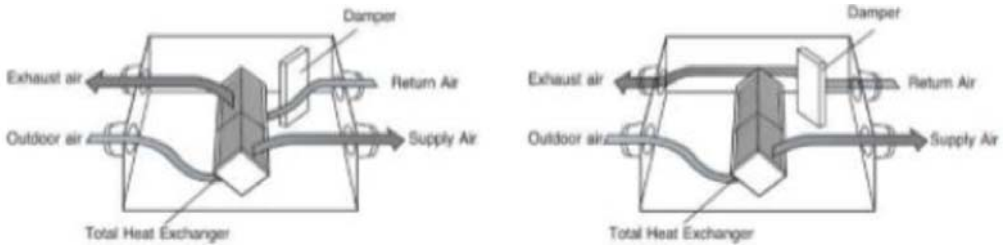

Figure 6: Heat recovery system in heat exchange mode (left image) and in by-pass mode (right image) [2]

4.2. Heat pump

The heat pump is selected based on the maximum heat load that occurs during the year. The heat load was calculated in the "Hourly Analysis Program"(HAP). The program performs a calculation of heat load and energy simulation for every hour of the year (8760 hours per year). This program works on the transfer function method, which is one of the most accurate methods for calculating heat load. The maximum load occurs in September at 15h and it is 8,8[kW] [3]. The duct unitsare supplied with fresh air which isprecooled in the heat recovery. This is also done to ensure the proper operation of the heat pump because the temperature of air that is entering the evaporator is limited (in this case 30 ºC). The prepared air is suppliedto the rooms using slot diffusers. Slot diffusers are chosen because they are the most suitable for mitigating heat loads at large glass surfaces and provide the best flow inside the living space. Using thisequipment, it is possible to achieve sufficient ventilation and temperature in all parts of the living space, assuring that there are no dead zones. Air is distributed to the diffusers using lightweightpre-insulated ducts.

Duct size is determined so that the pressure drop in them does not exceed the capabilities of the fans inside duct units. Air is drawn out of the rooms using the exhaust air grilles and is then sent to duct units and to the heat recovery. Kitchen and bathroom are under vacuum pressure so that contaminated air does not leak into surrounding spaces.

5. Domestic hot water preparation

Domestic hot water preparation is a significant energy consumer in households. Considering that solar energy is very abundant resource in Dubai it was rational to use this form of energy to prepare domestic hot water. The system chosen for this purpose consists of solar energy absorber, a tank where water is heated and stored and all the necessary equipment to insure stable operation.

5.1. Solar collectors

The main parts of the flat plate solar collector are: absorber, transparent cover and insulated casing. The absorber is usually a layer of highly conductive metal with integrated or added channels or tubes. The surface of the absorber is colored or coated in black to maximize the absorption of solar radiation. The transparent cover lets the Sun's radiation pass through to the absorber, but also isolates the space above the absorber from cold air entering into the enclosure. The insulated casing is a support for a complete plate collector assembly and reduces heat losses from the back or side.

The main element of the full plate solar collector is the absorber plate. The absorber plate covers the complete base of the collector and fulfills 3 functions: it absorbs the maximum possible amount of solar radiation, transfers the heat collected to the heat transfer fluid, and reduces heat losses to a minimum.

The solar radiation passes through the transparent cover and is absorbed directly into the absorber. The surface of the absorber is coated with materials that absorb short wavelength radiation and low emission of long wavelength radiation.

The second role of the absorber plate is to transfer the collected heat to the fluid flowing through the pipe. The heat transfer fluid can be water or water mixed with antifreeze.

Since the temperature of the surface of the absorber is higher than the ambient air temperature, a part of the heat is lost to the environment. By carefully selecting the material from which the absorber is made and the coating of the absorber, heat loss can be reduced. The absorber is usually covered with one or more transparent covers in order to reduce heat losses. The cover ensures that the air above the absorber is stagnant which reduces convection heat losses.

Each additional cover increases the efficiency of the collector in operation at high temperatures as it reduces heat losses but reduces efficiency at lower temperatures. Solar collector that was chosen for this house has selective coating that prevents the solar collector from overheating when the heat load is small but the Solar radiation is high. This improves efficiency of the Solar collector drastically. Total surface area of solar collector is around 4,15 m^2[4] and the volume of the collection tank is 250 liters.

Figure 7: Flat plate Solar collector

References:

[1] Solar decathlon Middle east, Rules and building code.
[2] LG Electronics, Total HVAC solution provider engineering product data book 2017.
[3] Hourly Analysis Program Carrier, Report [4] Viessman, Engineering product data boo