Electric and Photovoltaic chart for the +Hytte

Elisabetta Caharija & Nigar Zeynalova

The purpose of the essay is a data collection for the Electric and Photovoltaic chart for the 3rd SDE delivery.

General description

The roof system enables the uniform distribution of daylight and air. Three skylights are distributed along the linear modules representing the hard-core of the project. Thus the surface area used for PV is reduced to 55 m^2. The inclination of the roof is 10° which was dictated by the limitations of the solar envelope.
The PV panels should have monocrystalline silicon cells in series, a mature technology on the market with higher efficiency and longer lifetime, though more expensive than other technologies.
The photovoltaic systems in the +Hytte consist of photovoltaic arrays (which consist of modules) and grid-connected inverters. The PV array can produce electrical power according to the amount of daylight it receives. The temperature of the PV array and the voltage at which it is loaded are also important factor for an efficient system. Therefore PV are back ventilated to avoid overheating of the modules.

There are two important rules or limitations that need special attention when designing the PV and electrical system of the house:

- Rule 7.3.: the sum of the maximum power of all power conditioning equipment connected to PV generation (DC/DC and/or DC/AC) is limited to 10 kW.
- Rule 51.7.: the connection interface between the house and the Villa Solar electricity grid is limited to 15 kW (equivalent to 63 A - 230 V / 50 Hz) which is limiting also the conventional electricity installation (electrical loads).

Design and specification

PV modules

Ascent Solar

The ZEB centre is promoting and supporting +Hytte in the SDE 2012. Therefore we investigated the possibility of using the product of Ascent solar company which is cooperating with ZEB through Hydro. Ascent Solar is producing light modules that capture and deliver the power of the sun through thin-film PV modules that can be easily integrated into any type of building material or application.

WaveSol Light 5- Meter 96 Voc Specification Sheet CIGS Thin Film Photovoltaic Modules		
Product Class	WSLE-1200-096-ST-06	WSLE-1400-096-ST-06
Electrical Specifications (Measured under Standard Test Conditions)		
Nominal Power (Pmax in Watts)	120	140
Voltage at Pmax (Vmp in Volts)	71.0	77.8
Mechanical Characteristics		
Length	4976 ±5mm	
Width	360 ±5mm	
Weight	3.4 kg	
Thickness	1.2 ± 0.5 mm (excluding junction box)	

Figure 1: WaveSol Light - 5 Meter Data Sheet (www.ascentsolar.com/bipv/)

According to the data from Figure 1 we calculated the energy production for PV surface of 55 m^2. The results were not satisfactory considering our energy goals due to the low production - only 3 kW.

Further investigation was undertaken in order to find an optimal solution for the +Hytte. We started by looking in the Norwegian market and found REC - a leading player in the solar energy industry producing all components for PV systems.

<u>REC (Renewable Energy Corporation)</u>
We chose the modules with monocrystalline silicon solar cells due to their high efficiency.

ELECTRICAL DATA @ STC	REC220PE	REC225PE	REC230PE	REC235PE	REC240PE	REC245PE	REC250PE
Maximum Power - P_{MAX} (Wp)	220	225	230	235	240	245	250
Watt Class Tolerance - P_{TOL} (W)	0/+5	0/+5	0/+5	0/+5	0/+5	0/+5	0/+5
Maximum Power Voltage - V_{MPP} (V)	28.6	28.9	29.2	29.6	29.9	30.2	30.5
Module Efficiency (%)	13.3	13.6	13.9	14.2	14.5	14.8	15.1

MECHANICAL DATA	
Dimensions	1665 x 991 x 38 mm
Area	1.65 m^2
Weight	18kg

Figure2: Rec Peak Energy series – Data Sheet (www.recgroup.com/en/products/modules/recpeakenergyseries)

According to the data from Figure 2 we calculated the energy production for PV surface of 55 m^2 using the module with Peak Power Watts-P_{max}(Wp) of 250W (the highest). For the given surface we are using 24 modules (two stripes of 12 modules each).
We got a better results – the production is two times higher than before (6 kW) but still not reaching 10kW (maximum power according to SDE rules mentioned before).

One solution can be to increase the PV surface by having only one skylight (the central one) instead of three. We need 26,4 m^2 more surface for adding 16 modules to reach the 10 kW of maximum power production (one skylight is 13 m^2). Also adding a shading device with integrated PV can be a solution.

Inclination

In Norway the optimal inclination for the PV modules is 45°. The roof has to be quite steep which is also good for the snow load in winter. In Spain the optimal inclination is lower - 35° because of the sun position. The actual roof inclination of the +Hytte is just 10° which is far from optimal (moreover in September when the competition will take place).

Inclination vs. production

Once we obtained all the necessary data (square meters of the roof, of the skylights, of the PV area, inclination and the time period) we used Ecotect to simulate changes in the main parameters which lead to a range of proposals. The point was to test and compare the results.

1st scenario: full PV (no skylights)

- 100 m^2 of PV area, inclination 10° → total energy production 2364 kWh
- 120 m^2 of PV area, inclination 35° → total energy production 2803 kWh

2nd scenario: three skylights

- 55 m^2 of PV area, inclination 10° → total energy production 1182 kWh
- 60 m^2 of PV area, inclination 35° → total energy production 1402 kWh

3nd scenario: one skylights

- 87 m^2 of PV area, inclination 10° → total energy production 2060 kWh
- 107 m^2 of PV area, inclination 35° → total energy production 2500 kWh

By increasing the inclination of the roof from 10° to 35° the energy production can be significantly improved by 16% in all scenarios.

Inverter

The inverter is used to invert the DC produced from PV panels to AC for appliances and the gird.
One of the possible supplier can be a Norwegian company - Mascot As but the AC output is only 1500 W.
A good alternative can be SMA Solar Technology. The model Sunny Boy 5000TL seems to be the most efficient with output 5000 W and designed for the maximum production from 10 to 20 kW. They are optimally suitable for use in small and mid-range systems. They are highly efficient, reliable, flexible and ensure optimum solar yield.
Two inverters are required for the +Hytte.

	Sunny Boy 3000TL	**Sunny Boy 4000TL**	**Sunny Boy 5000TL**
Input (DC)			
Max. DC power (@ cos φ=1)	3200 W	4200 W	5300 W
Max. input voltage	550 V	550 V	550 V
Output (AC)			
Rated output power (@ 230 V, 50 Hz)	3000 W	4000 W	4600 W
Max. apparent AC power	3000 VA	4000 VA	5000 VA
Efficiency			
Max. efficiency / European efficiency	97 % / 96.3 %	97 % / 96.4 %	97 % / 96.5 %

Figure 3: Sunny Boy 3000TL / 4000TL / 5000TL Data Sheet (www.sma.de/en/products/solar-inverters/sunny-boy.html)

Battery

Since in Madrid the organizers provide the village with an electric power grid (AC power) maybe there is no necessity to have a battery to store the energy, but if the +Hytte will be used as a cabin in Norway without the connection to the grid (stand alone system) there will be necessary to have a battery as a system component.

Appliances

AC power became the standard of all appliances, so nowadays is the most common solution even though it has more losses due to distribution. The DC appliances are becoming more available, they have less losses but are more expensive. If the +Hytte will have DC appliances the part of the DC loads in the Electric and Photovoltaic chart has to be filled in.

Cables, protections and electricity

Once we have decided the supplier of our PV modules, choose the optimal product and the inverter we will know which type of cable and the values of the two types of protection (magnetothermic and differential protection). And when we know the production of each model, efficiencies and losses we will have all the data necessary to calculate the monthly and annual generation of electricity in Madrid.

Possible Innovative solutions

Solar Hybrid PVT

PVT solar system combines solar electrical generation (PV) with solar thermal (T) hot water. There are many ways to combine different PV and Solar thermal technologies to a PVT collector. So far, most developments have been done on the following technologies : PVT liquid system PVT air heating (air collectors, ventilated PV with heat recovery).

PVT liquid system – Power Volt Panel (Hybrid PV and solar thermal panel produced by Eco Merchant – UK)
The combination increases the performance of the PV panel by running a liquid glycol behind the PV unit reducing the panel temperature which allows the panel to work at maximum efficiency whereas conventional PV panels reduce in performance as the temperature increases. The panel is also capable of producing a reasonable amount of heat production in the summer. The peak outputs of this panel are 175/460 W electrical/thermal respectively.

PVT air system – Hybrid Air Collector (Grammer Solar – Germany)
The sun energy penetrating is transformed within a photovoltaic module only by 25 % into electric energy. The major part of the radiant energy becomes heat which reduces the efficiency of the cell with the production of current. Therefore a good heat removal must be assured, usually by rear ventilation of the modules. With the hybrid collectors the modules are cooled actively by means of a ventilator, the heated air can be used if required.

After analyzing different technologies we came to the conclusion that PVT systems produce only 25% of electricity while generating 75% of thermal energy. As +Hytte will be highly insulated to minimize summer heat gain and preventing heat island effect, the average heat demand will therefore drop as less heat is wasted, this implies a shift of the electrical power/heat ratio towards a predominance of electricity demand. Furthermore the energy consumption will increase due to the household appliances and other sophisticated electronic devices integrated in the +Hytte, thus the technology maybe is not a suitable solution for the +Hytte.

Solutions proposed by Velux - Denmark

As a manufacturer of roof windows and skylight systems, the company's goal is to enhance and encourage the role of daylight in architecture and analyze the impact of daylight and windows on the environment and well-being. At the same time they are also working on an efficient energy concept for the projects by applying traditional solar technology, such as solar thermal collectors and PV system. If the +Hytte wants to design and install innovative photovoltaic solutions with high efficiency, Velux's technologies may not be the best source to explore further.

BIPV skylights by Onyx Solar – Spain

The skylight provides a multifunctional solution where not only energy is being generated in-situ, but also natural illumination is being provided implementing solar control by filtering effect, avoiding infrared and UV irradiation to the interior and at the same time enhancing thermal comfort. The peak power of monocrystalline photovoltaic glass used for the skylights is 120-180 W/m^2.
It can be an optimal solution since the three skylights aim at providing a homogeneous distribution of lighting and thus play an important role in the energy concept of the +Hytte.

References:

SDE, the official website of the Solar Decathlon Europe competition www.sdeurope.org, 2011.
NTNU, Transitioning towards high-quality low-impact housing. +Hytte; designing for change, 2011.
www.ascentsolar.com
www.recgroup.com
www.macslab.com/optsolar
www.sma.de
Gevorkian, P., *Solar power in building design.* The *engineer's complete design resource*, The McGraw-Hill, pp. 2-4, 2008.
Haase, M., *Available Technologies for Renewable Energy Supply to Buildings*, NTNU, Department of Architectural Design, History and Technology, 2010.
www.ecomerchant.co.uk
www.grammer-solar.com
www.velux.com
www.onyxsolar.com