Photovoltaics - solution

1) A given type of solar cell module delivers 2 kW/m^2 at an efficiency of 20% and an irradiance at that moment of 950 W/m^2. How is this possible ?

With an efficiency of 20% at 950 W/m^2, a normal solar cell module delivers 190 W/m^2. If this particular cell delivers 2 kW/m^2, or 10.5 times more, it can only be a concentrating solar cell (with a concentration factor of 10.5).

2) At the MPP (maximum power tracking point) of a solar cell at 30°C, we measure 0.55 V, while at 0 V (short circuit) we measure a current of 36 mA/cm^2. What maximum power can this cell deliver and what is its fill factor ?

The thermal voltage at 30°C (303 K) $V_T = kT/e_0$ = 1,38.10^{-23} * 303 / 1,6.10^{-19} = 0.02613 Volt.

From

$$V_{max} = V_{OCV} + V_T \ln\left(\frac{V_T}{V_{max}}\right)$$

and V_{max} = 0.55 V, we get V_{OCV} = 0.63 V.

From

$$i_{max} = i_{cc}\left(1 - \frac{V_T}{V_{OCV}}\right)$$

and i_{cc} = 0.036 A/cm^2, we find i_{max} = 0.0345 A/cm^2.

Therefore, max power = 0.55 V * 0.0345 A/cm^2 = 19 mW/cm^2.

The fill factor is then 19 mW/cm^2 / (0.63 V * 0.036 A/cm^2) = 19/22.7 = 83.8%, which is a particularly good characteristic.

3) Consider average annual solar irradiance in Switzerland, 1250 kWh/yr.m^2, on a horizontal surface.

We have photovoltaic cells on the roof (20 m^2, total chain efficiency 18%). The roof tilt improves the captured irradiation on an annual basis by 10%. How does the generated electricity compare to annual needs of 5000 kWh$_{el}$ (for a family)?

We have thermal absorbers as well (6 m^2, annual efficiency 30%). How does the collected heat compare to total annual heat needs of 20'000 kWh (for a family) which split up as ≈5/6 for space heating and ≈1/6 hot water heating ?

The 20 m^2 P.V. module, when on a horizontal plane (i.e. if the roof were flat), recovers 1250 (horizontal surface) x 1.1 (tilted roof) x 0.18 (efficiency) x 20 (m^2) = 4950 kWh_{el} and so provides in theory ≈100% of the yearly electricity consumption of the house (obviously with excess in summer and lack in winter). Households electricity needs account for ≈25% of the total electricity consumption in the country.

The 6 m^2 solar thermal module would capture 1250 (horizontal surface) x 1.1 (tilted roof) x 0.3 (efficiency) x 6 (m^2) = 2475 kWh and so provide only 12% of the heating needs. With ≈5/6 (16'700 kWh) for low temperature space heating, and ≈1/6 (3300 kWh) for sanitary hot water preparation, which in fact is the best and most adapted application of solar thermal absorbers, the 6 m^2 thermal solar panel would then cover 2475/3300 = 75% of the annual hot water needs. Households consume 2/3 of the space heating + hot water heating for the whole country, so the total contribution to heating needs would be 75% x 66% = 50% of all sanitary hot water.