# Solution Series 4

**Exercise 1: PV installations**

We want to design a PV system for a house with a suitable roof area of ca. 5 m times 6 m. We use modules X22-360-COM whose data is provided on Moodle (datasheet Sunpower).

a) What is the maximum number of modules you can install on the available surface and what is the nominal power of such a system?

***Solution:***

Datasheet 1 (eff=22.2%)
N° modules $\approx 5 \times 3 = 15$
The modules can be arranged with frame supports.
15*360 Wp = 5.4 kWp

b) On a sunny day in winter, reflection from surrounding snow compensates for the low position of the sun in the sky. Thus you can have irradiance of $1000\,\mathrm{W\,m^{-2}}$ at a module temperature +5 °C. How much power does the system generate under such conditions?

***Solution:***

Max V = 15*360(1-0.0029*(-20))=5.71 kWp

c) How would you accommodate the limitation of the maximum system voltage?

***Solution:***

The maximum voltage the system can reach is the number of modules times the open-circuit voltage of a module, which would happen if all the modules are connected in series and the system is disconnected from the inverted/grid during the day due to, for instance, a maintenance or malfunction. If this voltage exceeds the maximum allowed system voltage, the cells should be stringed in a way to lower the voltage.

In our case, the system voltage can reach up to 69.5 x 15 V = 1042.5V, which is above the limit of the system. To lower the voltage, two strings of 8 + 7 modules or three strings of 5 and an inverter with multiple string input can be used.

(Bonus, probably not discussed in the course: if the inverter accepts only symmetric strings, you would have to reduce to 2 times 5 = 10 modules or 3 times 4 = 12 modules, or create an ugly patch of 2 times 5 plus two more that are rotated by 90°, or you have to use power optimizers.)

**Exercise 2: Cell processing improvements**

State 3 major improvements that made possible to reduce silicon usage/EPBT over the last few decades.

***Solution:***

The silicon usage has improved from 17 g/W to 3.5 g/W in the last twenty years. The energy payback time of PV is now reduced to 6 months - 1 year. The major improvements in the solar cell production chain that have made this reduction possible are:

- The Siemens silicon recrystallization process: it lowered the energy consumption related to Si production from 200 kWh/kg to 45 kWh/kg;
- The introduction of diamond wire in the wafer sawing process: it reduces the material losses form 200 $\mu$m to about 60 $\mu$m;
- The fast improvement in the module efficiency, which is growing by 0.3-0.4 % every year.

These topics will be treated more in depth in dedicated lectures in the course.