Energy generation and distribution: Can photovoltaics power our department?

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Photovoltaics panels have been gaining popularity as the demand for clean and sustainable energy resources increases. Turkey has a great potential when it comes to the photovoltaic energy generation capacity thanks to its location as can be seen in Fig. 1.

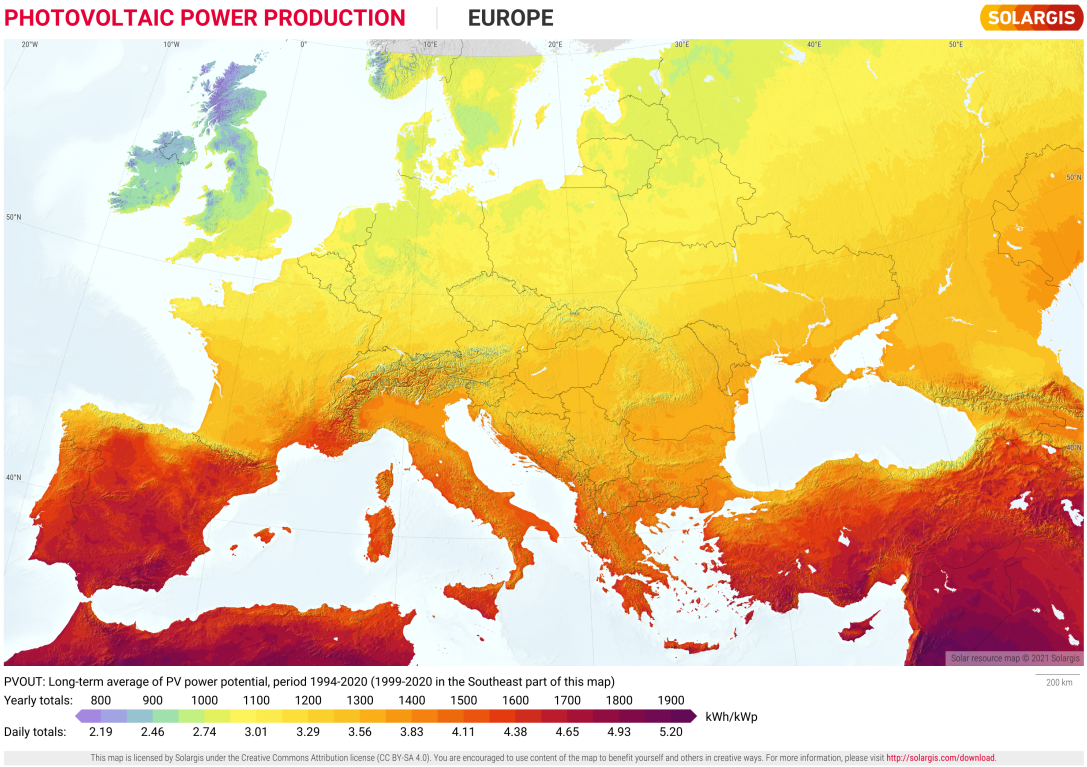

Figure 1: Solar irradiation map of continental Europe [1].

We have photovoltaic panels that are placed on top of Ayaslı Research Center and Electrical Machinery Laboratory at our department. You can see the photo of panels on Ayaslı Research Center in Fig. 2. In this project, you are going to investigate the electrical

energy generation of one of the panels. The electrical power generation data of the one of the panels for two different days (one in summer and one in winter) is shared on ODTUCLASS.

Figure 2: Photovoltaic panels on Ayaslı Research Center.

1. Using the data shared with you, plot the power generation vs the time of day graph as shown in the Fig. 3. You need to plot the power generation graph for winter and summer on the same figure. X-axis should read time of the day in hours and y-axis should read power in Watts (P_{mpp}).

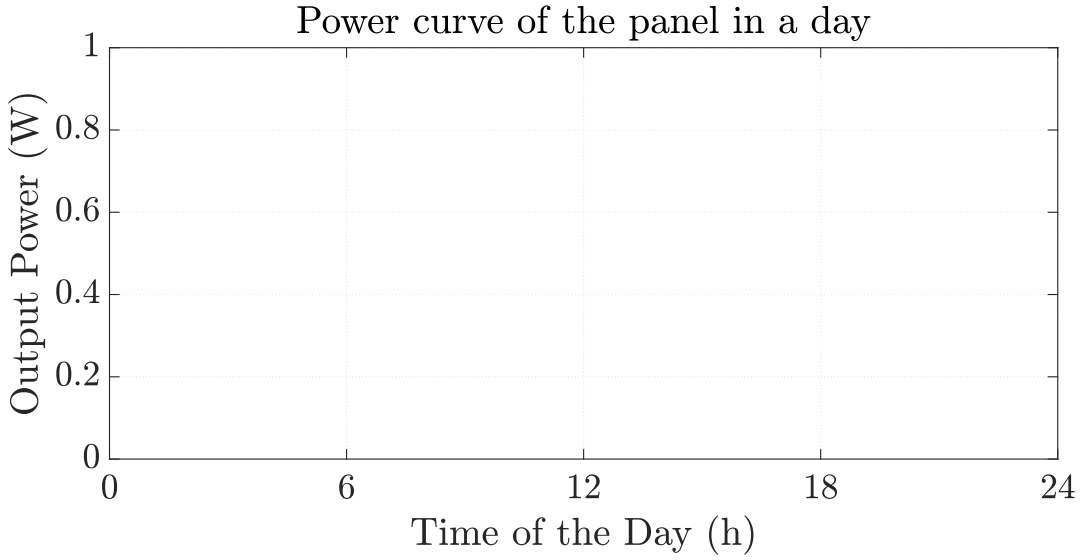

Figure 3: Template for the power generation vs time of the day graph.

2. Calculate the total energy generation (in $kW.h$) of the panel in a day for summer and winter.

Hint: You can use numeric integration function $trapz()$ of Matlab.

3. Given that the panel's surface area is 1.64 m^2, calculate the efficiency at peak power values in summer and winter.

Hint: You can use the I_{tilted} which is the solar irradiance (W/m^2) to calculate the efficiency of the panel.

4. Choose three different time instants in summer and winter where temperature of the panels are close to one another, but with different irradiance values. Fill the Table 1 by calculating the efficiency of the panel for these three instants and comment on the effect of solar irradiance on panel's efficiency. What would happen if the irradiance is increased while the temperature is kept constant?

Table 1: Table template of three time instants with similar temperatures.

Instants	Panel Temperature ($°C$)	Irradiance (W/m^2)	Output Power (W)	Efficiency
First				
Second				
Third				

5. Choose three different time instants in summer and winter where solar irradiance of the panels are close to one another, but with different panel temperatures. Fill the Table 2 by calculating the efficiency of the panel for these three instants and comment on the effect of temperature on panel's efficiency. What would happen if the temperature of the panel is increased while the irradiance is kept constant?

Table 2: Table template of three time instants with similar irradiance.

Instants	Panel Temperature ($°C$)	Irradiance (W/m^2)	Output Power (W)	Efficiency
First				
Second				
Third				

6. In which month in a year would the efficiency be the highest? Similarly, in which month in a year would the energy generation capacity be the highest? Comment using the previous calculations and data. You can give your answers in a format like in Table 3.

Table 3: Table template for the highest efficiency and power generated months.

Parameter	Month	Reasoning
Highest efficiency		
Highest energy generation		

7. Assume that all of the roofs of our department buildings are covered with the same panels and panels are not shaded. Calculate the maximum power generation capacity of the photovoltaic panels on top of the roofs by using the previously given data. You can estimate the area of the roofs using **Google Maps**.

8. Assume that our department has a constant power demand of 450 kW throughout the day. How would the power demand curve look like if we covered the roof with photovoltaic panels as you have calculated in part 7? Plot the power demand vs time of day graphs for both winter and summer conditions by assuming that all panels generate electricity with the curves in part 1. Between what hours does the department supply electricity back to the grid?

References

[1] "Solar resource maps of europe." [Online]. Available: https://solargis.com/maps-and-gis-data/download/europe

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