Thermodynamics and Heat Transfer LE5 Part 1
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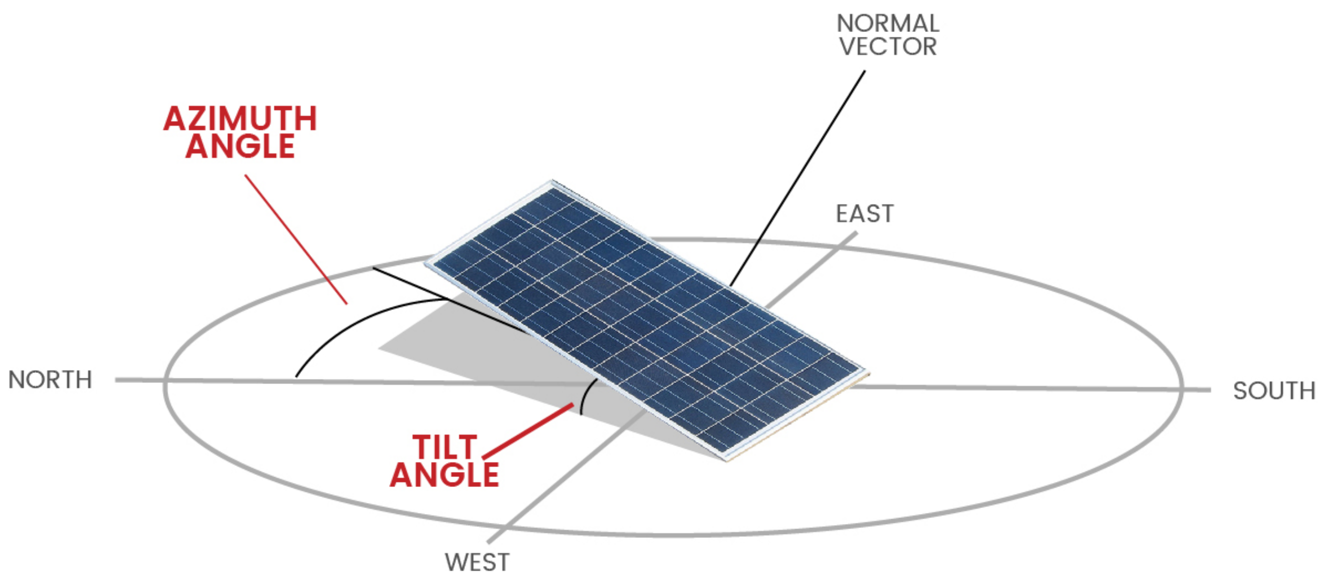
Problem 1 (25 Points):
Design a solar PV system (1 MW) for 5 different locations in Finland:
1. Calculate the best tilt and azimuth angle for each case study.
2. Compare capacity factor and power generation of the PV system for each case study.
3. Compare tracking system with non-tracking system for each case study.
4. The results can be compared with the other Nordic countries and Germany (optional).

1) Calculate the best tilt and azimuth angle for each case study.



The azimuth and tilt angle are illustrated in the figure above. By trial and error from 5 different angles, I pick out the best angle that produces the most power generation by the solar panel in different locations. The five angle pairs I have chosen are:
Tilt angle, azimuth angle = (25°, 180°), (30°, 175°), (35°, 170°), (40°, 165°), (45°, 160°)
By different simulations, I can determine which angle pairs are optimal
The five locations I choose are Helsinki, Turku, Tampere, Jyvaskyla and Rovaniemi

- **Helsinki**

The optimal tilt angle, azimuth angle pair is (35°, 170°)

- **Turku**

The optimal tilt angle, azimuth angle pair is (40°, 165°)

- **Tampere**

The optimal tilt angle, azimuth angle pair is (45°, 160°)

- **Jyvaskyla**

The optimal tilt angle, azimuth angle pair is (40°, 165°)

- **Rovaniemi**

The optimal tilt angle, azimuth angle pair is (40°, 165°)

2) Compare capacity factor and power generation of the PV system for each case study.

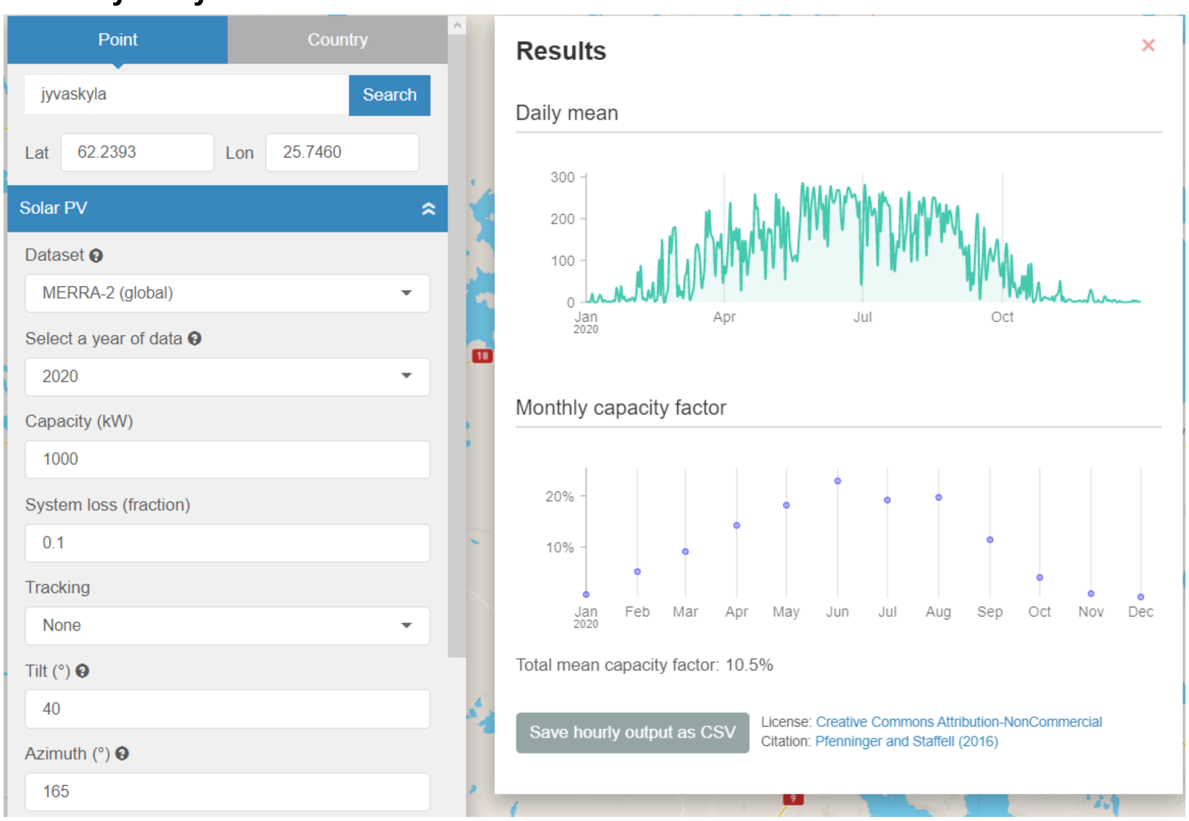
The capacity factor and the power generation of the PV system for each case study are as follows:

- **Helsinki**

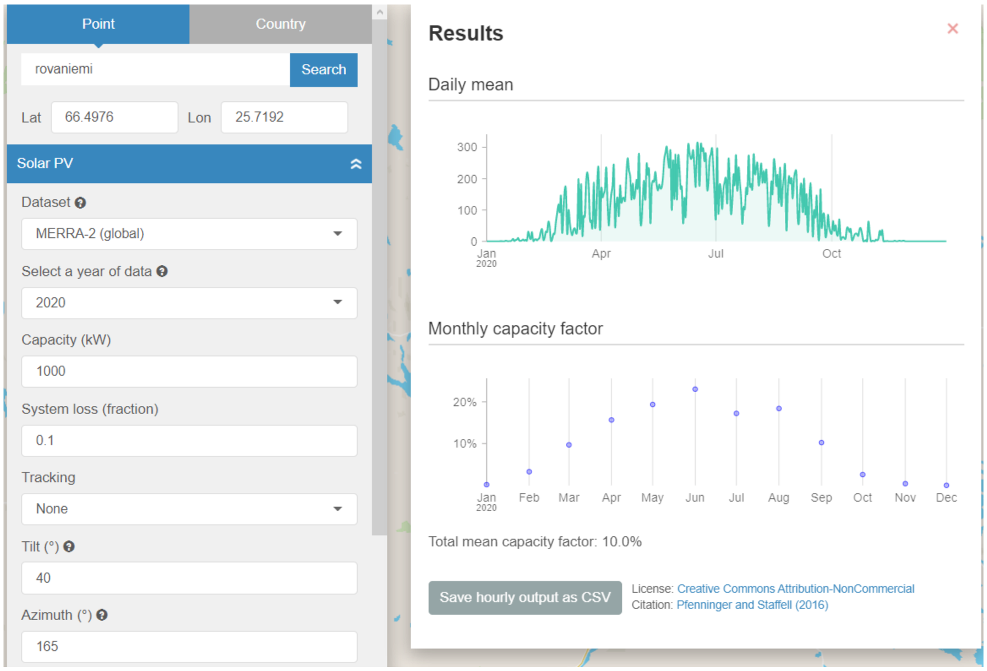
- **Turku**

- **Tampere**

- **Jyvaskyla**

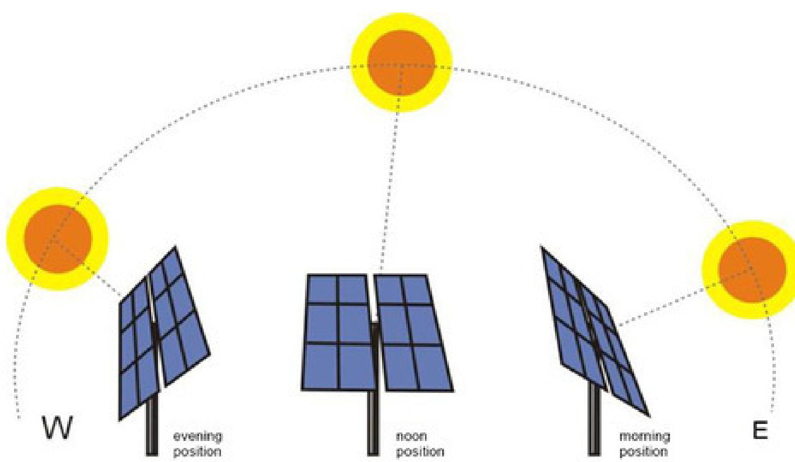


- **Rovaniemi**



=> The more northern the city becomes, the less sunlight hours there are in the whole year. This is why Helsinki has the highest and Rovaniemi has the lowest power generation and monthly capacity factor.

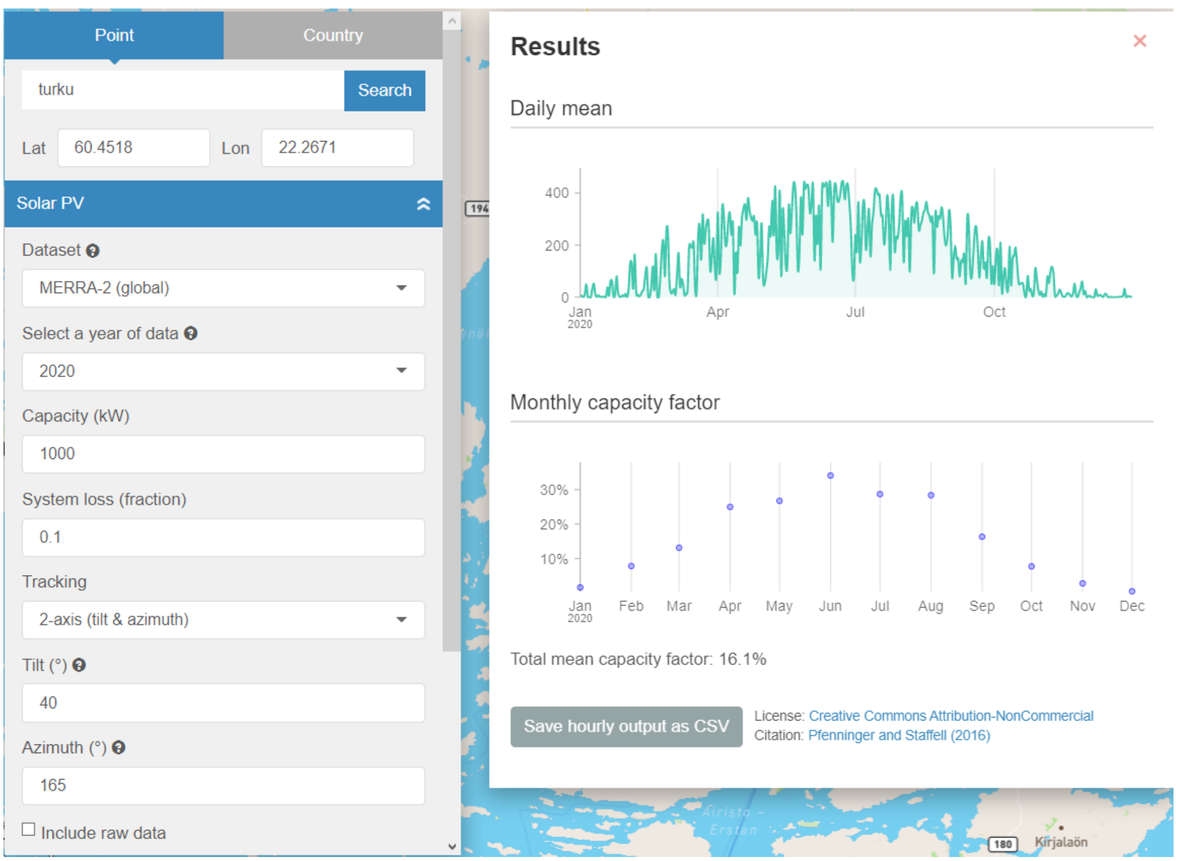
3) Compare tracking system with non-tracking system for each case study.



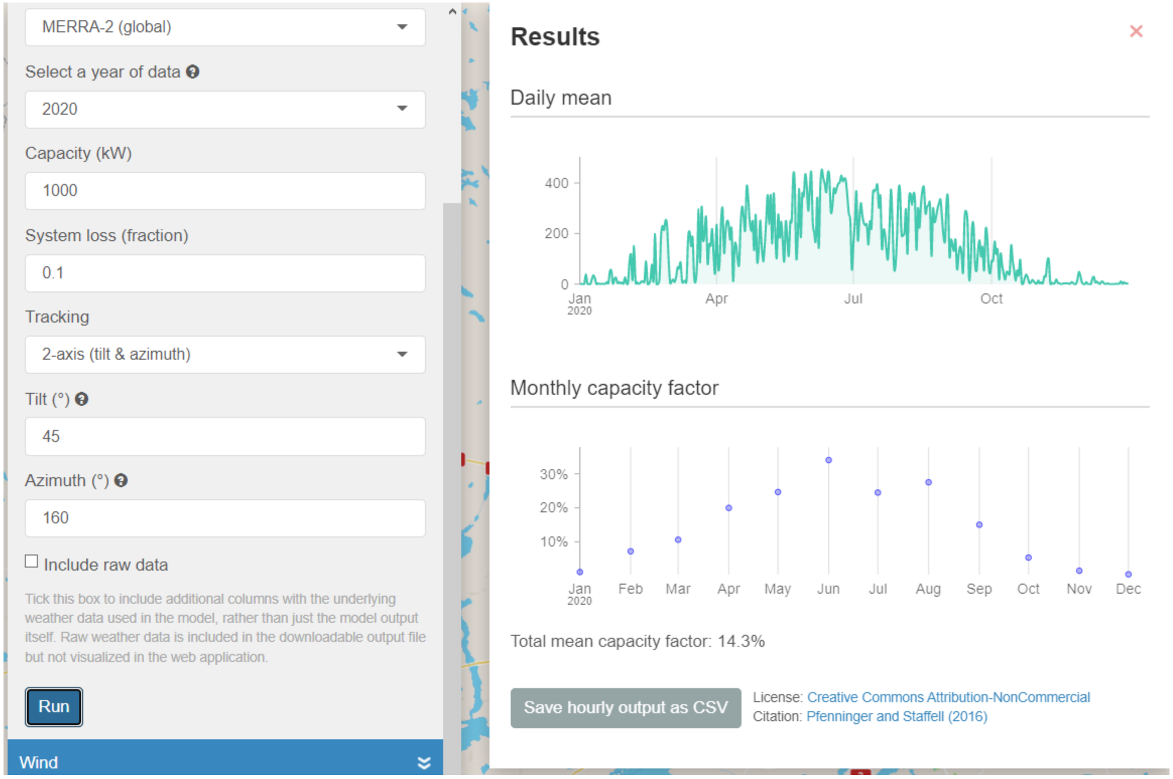
Solar tracker is a system that positions an object at an angle relative to the Sun. The most-common applications for solar trackers are positioning photovoltaic (PV) panels (solar panels) so that they remain perpendicular to the Sun's rays and positioning space telescopes so that they can determine the Sun's direction.
Meanwhile, non-tracking system means the solar panel is fixed without following the sun ray.
=> Solar tracking system will help produces more power than non tracking system solar PV
In part 2, the report is for non tracking solar PV. Below is report for tracking solar PV with 2-axis (tile-azimuth)

- **Helsinki**

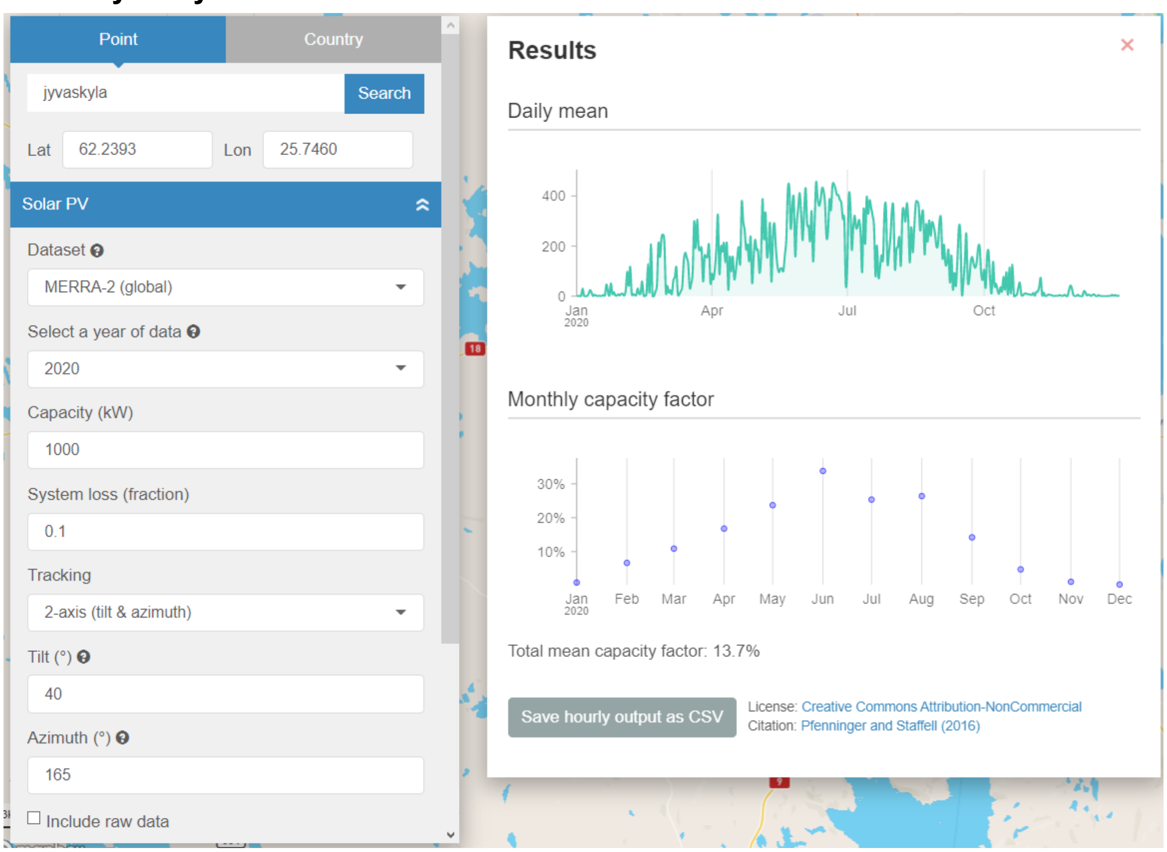
- **Turku**



- **Tampere**



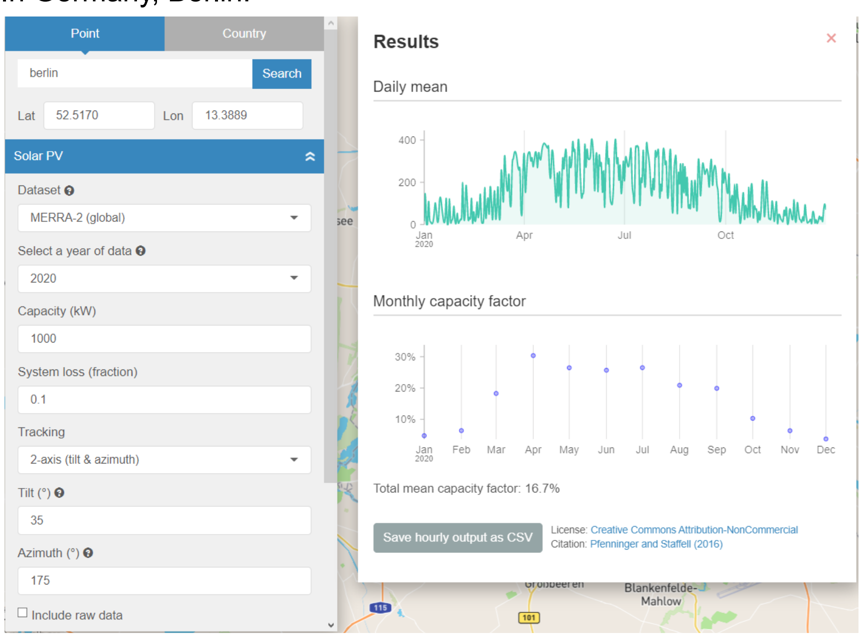
- **Jyvaskyla**



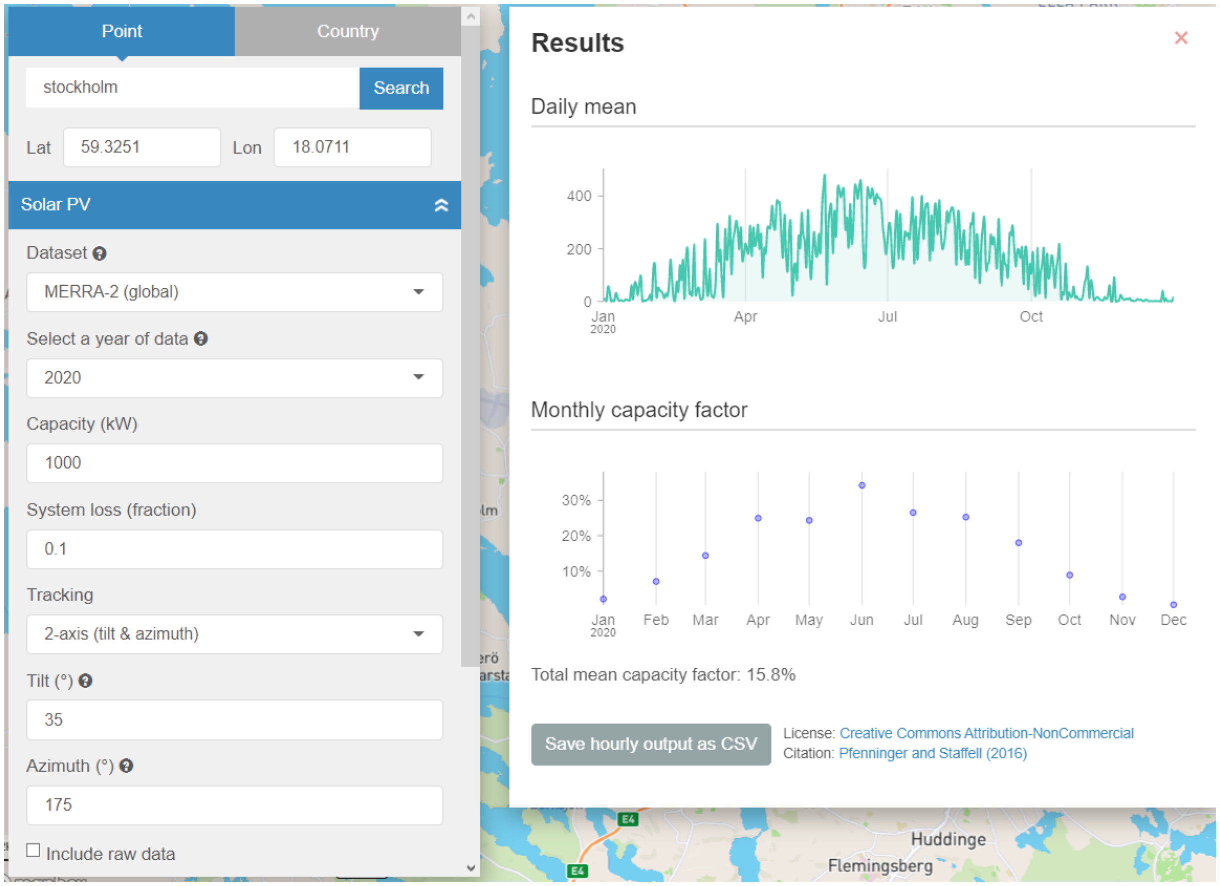
- **Rovaniemi**

=> tracking system solar PV consistently generates more power as well as having higher capacity factor than non-tracking system solar PV for all locations in Finland. However, there are studies stating that this increase in power generation is not worth the cost of installing the tracking device and thus, the non-tracking system is still financially preferable.

4. The results can be compared with the other Nordic countries and Germany (optional).
In Germany, Berlin:



In Stockholm, Sweden:



Power generation in Sweden and Germany of tracking solar PV are not significantly different from Finland, suggesting that the number of sunlight hours in the three countries are quite similar.

Problem 2 (25 Points):

Design a wind farm (1 MW, 5 types of wind turbine) for 5 different locations in Finland:

1. Compare capacity factor and power generation of each wind turbine for each case study.

2. The results can be compared with the other Nordic countries (optional)

1) Compare capacity factor and power generation of each wind turbine for each case study.

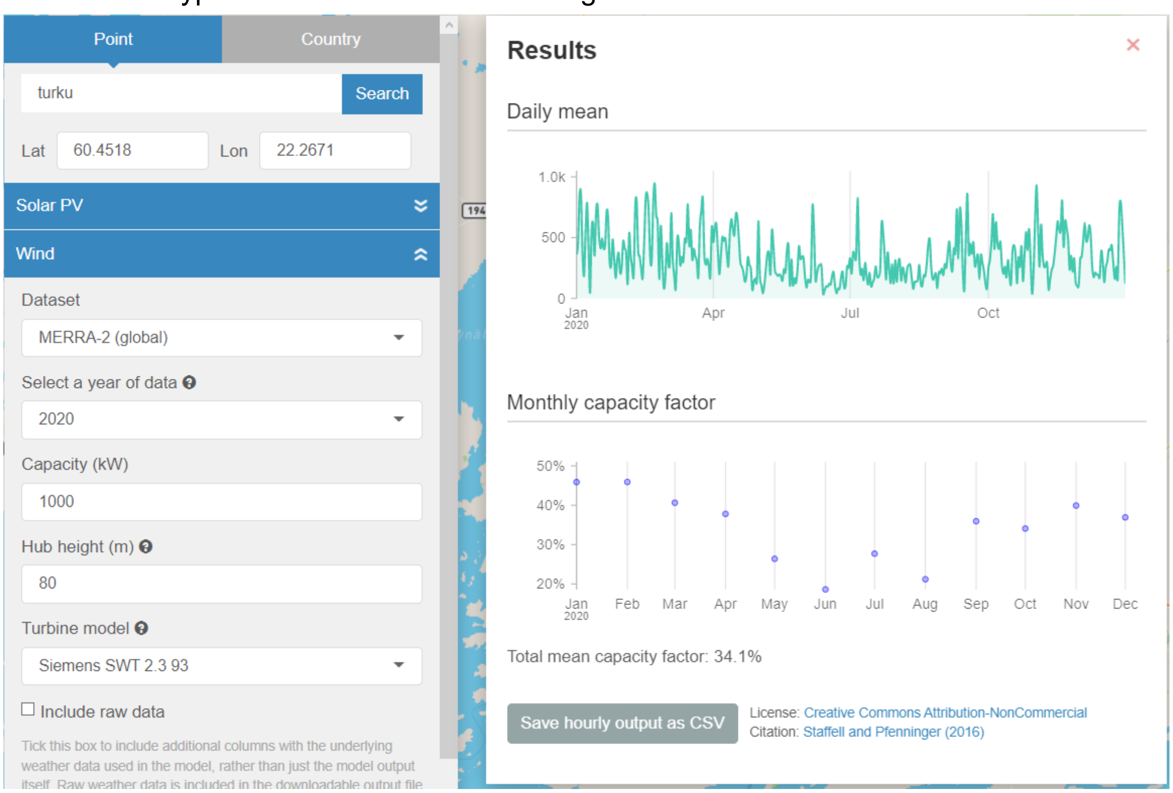
The five locations I chose are like above: Helsinki, Turku, Tampere, Jyvaskyla and Rovaniemi. The capacity and power generation of each wind turbine are as follows:

- **Helsinki**

Wind turbine type: Vestas V90 2000. Height: 80m

- **Turku**

Wind turbine type: Siemens SWT 2.3 93. Height: 80m

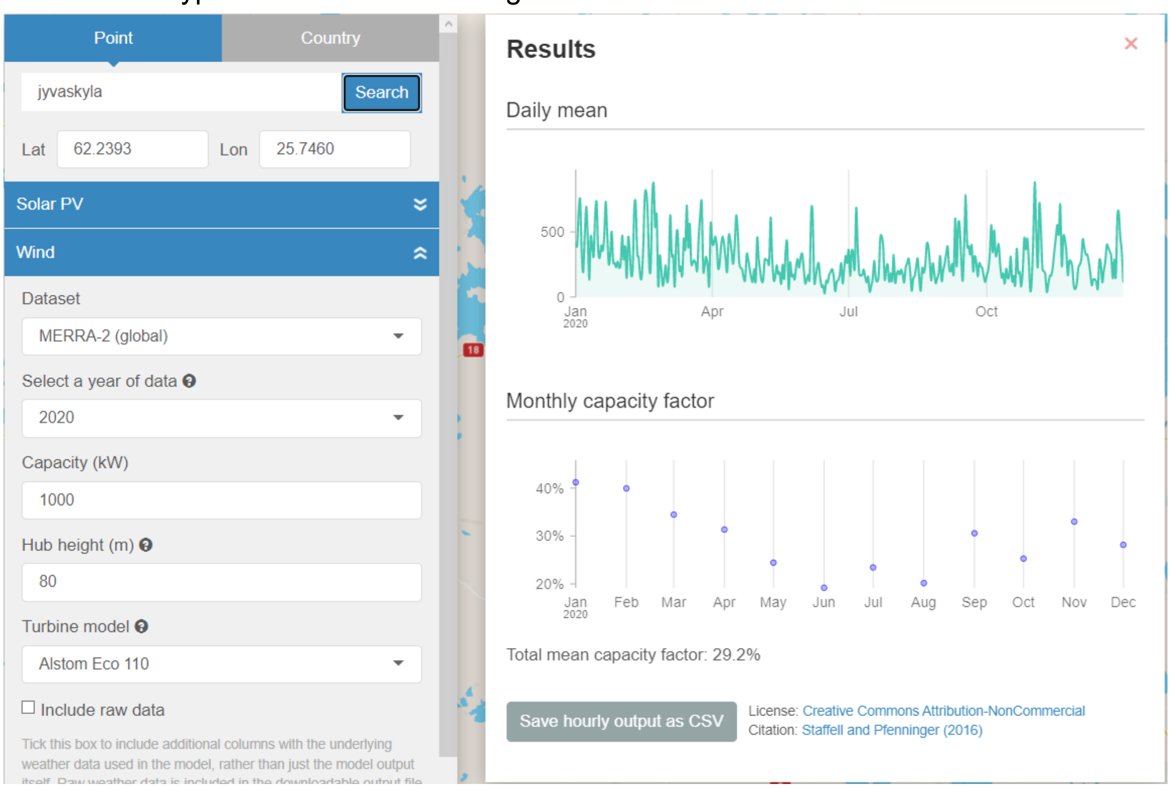


- **Tampere**

Wind turbine type: Enercon E82 2000. Height: 80m

- **Jyvaskyla**

Wind turbine type: Alstom Eco 110. Height: 80m



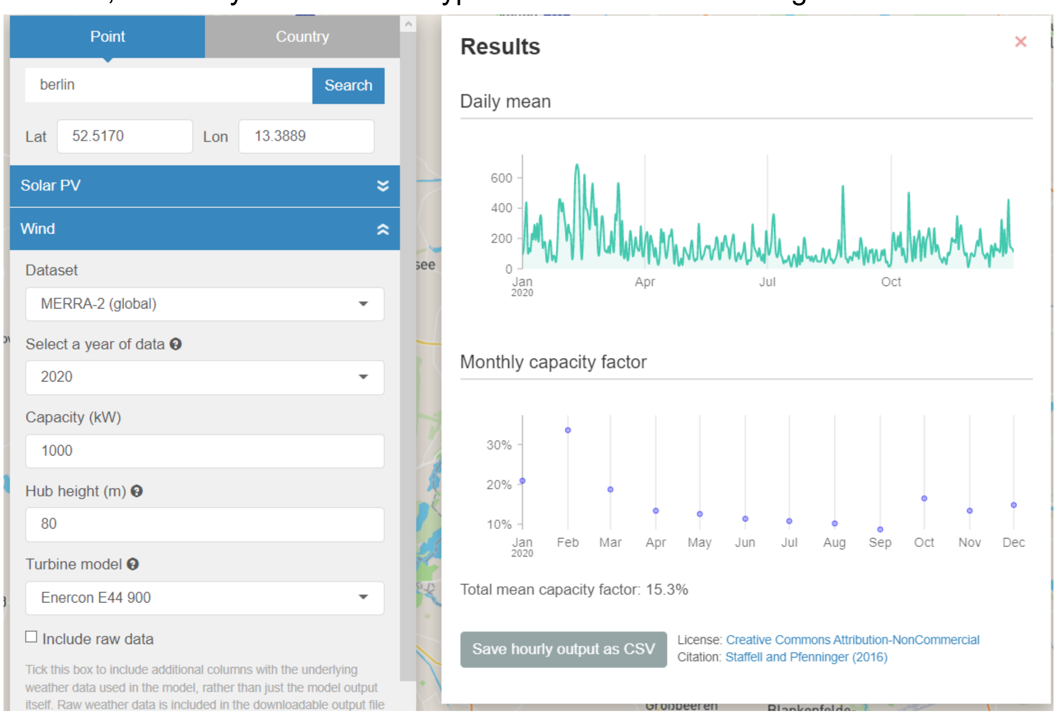
- **Rovaniemi**

Wind turbine type: Dewind D6 1000. Height: 80m

Comparison: It appears that the power harnessed and the capacity factor depends a lot on the wind turbine model. However, the difference could be due to the terrain and the weather as it appears the further north the location is, the less power generated.

2) The results can be compared with the other Nordic countries (optional)

In Berlin, Germany: Wind turbine type: Enercon E44 900. Height: 80m



In Stockholm, Sweden: Wind turbine type: Gamesa G90 2000. Height: 80m

There is a significant difference between the capacity factor between Sweden and Finland, but not so much for Germany. This is mostly due to the wind turbine model.