TEACHERS' DOSSIER: PROJECT-BASED LEARNING

MODULE 3

INTELLECTUAL OUTPUT 2

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Objectives of this module

In the following lines, there are several practical prototypes of useful tools for the farming sector that work with renewable energies. In this sense, the prototypes are made for small scale projects that can be implemented in VET agricultural courses. The classroom can be adapted and include these prototypes to make the students work individually or in group in systems that can be applied in the real world. The different options can be included in one or several subjects, according to the necessity of the VET students.

In order to show how it is possible to include renewable energies in farming, the partners of the Energy for Farming project have created 2 practical prototypes using solar power and 2 experimental prototypes in farming. The reader will find the pedagogical objectives of each prototype but also the concrete construction steps and material that needs to be used during the creation of the models detailed below.

Practical projects prototypes in the classroom

Juan Jorro, Lucía Toledo and José Segarra

Thermosiphon

Description

A thermosiphon is a solar water collector. Usually, the solar water collectors are composed of a surface that captures solar radiation, but also a thermal circuit, frequently made of tubes, through which the water passes. In order to reach a higher temperature, it is necessary to include a transparent cover that allows the creation of a greenhouse effect and an insulated box. In the case of the following prototype, the circulation of the water from the collector to the tank is done by natural circulation[1] taking advantage of the different densities between cold and hot water (thermosiphon).

The thermosiphon effect is when the hot water goes up to the tank because it has less density than the cold water, that descends towards the base of the tank. In order to achieve the thermosiphon effect, it is necessary to place the water tank above the solar collector, as it is described in the following pages.

Pedagogical objectives

- Teaching about water density
- Teaching about the thermosiphon effect
- Calculating lengths
- Understanding solar power
- Applicable usages of solar energy

Required materials

#	MATERIAL	UNITS
1.	Expanded polystyrene[2] box	1 42,5x35x10[3]
2.	Drip irrigation pipe (16 mm)	1 160 cm
3.	Micro drip irrigation tubing (3 mm diameter)	1 640 cm
4.	Drip irrigation barbed connector (4 mm)	40

[1] It is also possible to use a pump for the water circulation (forced circulation).
[2] It can be other material, like wood, but it is needed to line it with an insulating material.
[3] Lenght, Wide, Height

5.	Double barbed elbow [L type]	4 16x16
6.	Water container	1
7.	Threaded PVC wall bushing ½”	2
8.	Reducing coupling connection ½ x 16mm	2
9.	Hose plug	2


Figure 1. Materials

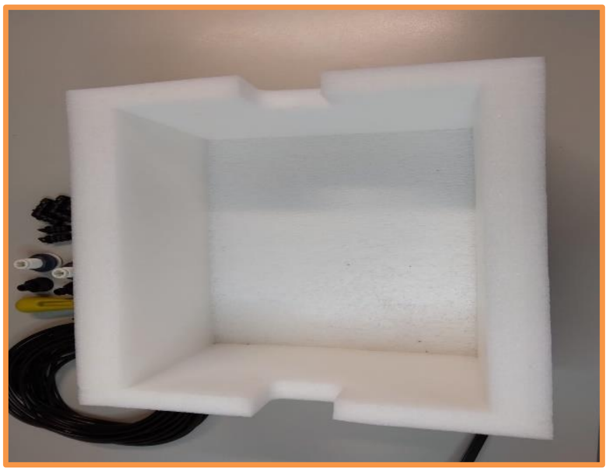


Figure 2. Expanded polystyrene box

Required tools

1. Hole punch with extractor
2. Pliers (optional)
3. Drill
4. Flat-drill for creating a circular hole
5. Scissors
6. Cutter
7. Adhesive[4]

Construction step-by-step (with illustrations)

1. Cut out the base of the expanded polystyrene in case it is too tall[5].

   TIP: The base can be a darker colour to retain more heat.

2. Measure the box, in order to cut the pipe according to this measure.
3. Cut the drip irrigation pipes in two pieces that measure around 5 cm more than the box.
4. Drill a total of four holes in the sides of the box. The holes will be used for passing the drip irrigation pipes.

[4] It can be glue, duct tape, silicon…
[5] It if is too tall, it can create shadows.

5. Insert the two drip irrigation pipes in the holes, this will be the mainline tubing of the thermosiphon.
6. Mark the edges of the pipes, according to the edge of the pipe with the box (the inside part).
7. Measure the distance among the two pipes from side to side.
8. Trim the micro drip irrigation tubes according to the length among the two pipes. In this case, a total of 20 tubes were trimmed.
9. Punch holes in the mainline tubing with the hole punch. A total of 20 holes per pipe.
10. Attach the barbed connectors in the two parts of the micro drip irrigation tubes that have been trimmed. A total of 40 barbed connectors were needed for the 20 micro tubes.

    TIP: Drown the ends of the micro drip irrigation tubes in hot water in order to temporarily soft the tubing and push the barbed connectors easier into them.

11. Insert the barbed connectors attached to the micro tubes in the mainline tubing.

    TIP: use pliers to place the barbed connectors in the holes of the mainline tubing. It will make the process easier.

12. Attach the double elbows in the outside part of the mainline tubbing. A total of four double elbows are needed.
13. Mark the places where the holes will be created in the water container.
14. Drill two circular holes in the water container to place the threaded PVC wall bushings.

    OPTIONAL: in case it is not possible to insert the wall bushings through the container, the upper part of the container can be cut to fit the pieces into their places.

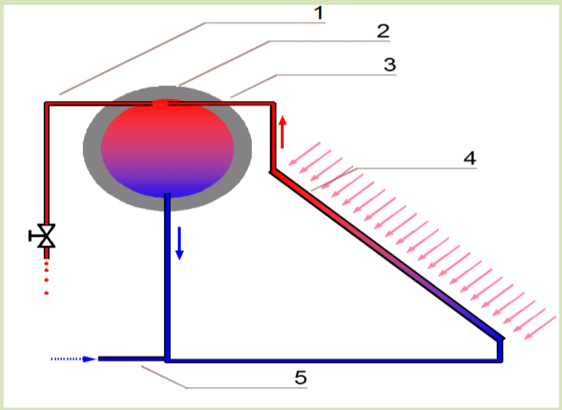
15. Place and screw the wall bushings in the holes of the water container.
16. Screw the female thread in the wall bushings.
17. Place the connectors that will go from the double elbows to the wall bushings' female threads for linking the water container with the box.
18. In order to concentrate the heat in the box, a poly methyl methacrylate glass is used. Place it and attach it on the box.

    OPTIONAL: If the glass is not the size of the box, it will be necessary to custom-made its size to adapt it.

19. In order to have an inclination, it will be necessary to create an extra support base that raises the water container and the solar base.

    TIP: If you had to cut the base, use the remnants of the expanded polystyrene to create the inclination.

IMPORTANT: for making possible the thermosiphon effect and have a natural circulation of water, it is necessary that the upper exit of the solar collector is at a lower level to the entrance of the upper entrance of the water container.



Water heater with thermosiphon (schematic):
1: to the water tap
2: insulated tank
3: hot water inlet
4: flat solar collector
5: fresh water inlet

Figure 3. Thermosiphon effect (CC BY-SA 3.0)[6]

20. Place the thermosiphon, linking the extra support bases and measure the distance from wall bushings' female threads to the elbows and cut the drip irrigation pipes according to this measurement. This will be used for linking the water container and the base.
21. Connect the water container with the expanded polystyrene box with the two custom-made drip irrigation pipes.
22. Glue the extra support in the water container and the box with adhesive.

THERE YOU HAVE YOUR THERMOSIPHON!

[6] https://commons.wikimedia.org/w/index.php?curid=793066

Let's try it out!

In order to test the thermosiphon, place the prototype in a place where the sun rays and let it be for a few hours. You can test the temperature of the water in advance.

After having the thermosiphon in the sun for a few hours, you can measure the temperature of the upper water container and the water in the bottom. If the thermosiphon is working, there will be an important difference in temperature.

How does it work?

In this simple prototype of a thermosyphon solar water heater, the main body of water (water container) is located at the highest point in the system. The water is displaced downward from the water tank in the water tube (which runs out near the base of the tank).

Heated water becomes less dense than cold water, so it rises into the tubes that run back to a point about of the water container. The phenomenon that causes heated liquid to run upward is called natural convection.

Heat, plus a syphoning effect, are the two keys to a free-circulating system.

Meanwhile back at the tank, something called stratification is taking place. Water keeps circulating slowly in the tank too, but gradually colder water settles to the bottom of the tank while the hotter water remains near the top. So, there are several different temperature levels.

Audio-visual material

This material is an extra help for the step-by-step explanation.

Here is the link: https://youtu.be/QcAHHdUoQnY

Temperature and humidity station

Description

This temperature and humidity station has been used in order to obtain information about the soil. In order to transfer the information received by the station, the Arduino system transform it into readable data.

Arduino systems are open-source electronics platforms based on easy-to-use hardware and software. An Arduino board can read inputs and turn it into data (this data can be showed on a LED display, an online platform, etc.).

In this prototype, an Arduino for reading the soil humidity and temperature is built, using a solar panel to obtain the necessary electricity to make it work. The Arduino will display the information in an online platform, for a more comfortable remote controlling. In case it is preferred, a LED display can also be used, but the consumption of the screen will need to be updated in the calculations.

Pedagogical objectives

- Enhance the understanding of the real-world technology
- English competences
- Improve the understanding of renewable energies in farming
- Acquire knowledge by constructing functional equipment
- Basic formulas for obtaining specific data related with solar power

Required materials and tools

DESCRIPTION	UNITS
Temperature and humidity system KeeYess[7]	1
Battery 5V	1
PV panel 10W OR PV panel 18W	1 1
Humidity sensor	1
Temperature sensor	1

[7] It includes a 1.3" large OLED IIC display module, combined with the ESP8266 NodeMCU and BME280 module to obtain weather data.

Calculations

$$Consumption\ (Wh/day) = \frac{(mA) \cdot (V) \cdot (24\text{h})}{1000}$$

CONSUMPTION			
	Consump. (mA)	Voltage (V)	Consump. (Wh/day)
Arduino board	70		
H & T sensors	2,5		
Soil humidity	5		
TOTAL	77,5	3,3	6,138

$$Battery\ Autonomy\ (h) = \frac{Battery\ capacity\ (mAh)}{Consumption\ (mA)}$$

AUTONOMY (without sun)		
Battery capacity (mAh)	Hours (h)	Days (d)
2000	25.81	1.08
5000	64.52	2.69
10000	129.03	5.38
20000	258.06	10.75

The following table shows the PV production for 3 different PV module powers (5, 10 and 18Wp), based on data extracted from PVGIS for the LowCarbon Economy location, and for a PV module tilt of 30º and 0º azimuth.

PRODUCTION							
Fixed irradiation (W/m2)		5 Wp Production (Wh/d)		10 Wp Production (Wh/d)		18 Wp Production (Wh/d)	
		JANUARY	JUNE	JANUARY	JUNE	JANUARY	JUNE
0:00	0	0.00	0.00	0,00	0,00	0,00	0,00
1:00	0	0.00	0.00	0,00	0,00	0,00	0,00
2:00	0	0.00	0.00	0,00	0,00	0,00	0,00
3:00	0	0.00	0.00	0,00	0,00	0,00	0,00
4:00	0	0.00	0.00	0,00	0,00	0,00	0,00
5:00	0	0.00	0.09	0,00	0,19	0,00	0,34
6:00	0	0.00	0.42	0,00	0,84	0,00	1,51
7:00	0	0.00	1.09	0,00	2,19	0,00	3,93
8:00	32,86	0.14	1.82	0,27	3,64	0,49	6,55
9:00	71,57	0.30	2.52	0,59	5,03	1,06	9,06
10:00	543,92	2.24	3.05	4,49	6,10	8,08	10,98
11:00	647,54	2.67	3.36	5,35	6,71	9,62	12,08
12:00	683,57	2.82	3.52	5,64	7,03	10,16	12,66
13:00	656,57	2.71	3.32	5,42	6,64	9,76	11,96
14:00	542,42	2.24	2.94	4,48	5,88	8,06	10,58
15:00	394,19	1.63	2.37	3,25	4,74	5,86	8,54
16:00	36,37	0.15	1.62	0,30	3,25	0,54	5,84
17:00	0,03	0.00	0.89	0,00	1,77	0,00	3,19
18:00	0	0.00	0.26	0,00	0,52	0,00	0,94

19:00	0	0.00	0.03	0,00	0,07	0,00	0,12
20:00	0	0.00	0.00	0,00	0,00	0,00	0,00
21:00	0	0.00	0.00	0,00	0,00	0,00	0,00
22:00	0	0.00	0.00	0,00	0,00	0,00	0,00
23:00	0	0.00	0.00	0,00	0,00	0,00	0,00
TOTAL		14.90	27.30	29,79	54,61	53,63	98,30

As can be seen in the data obtained, the daily photovoltaic production of a 5 Wp photovoltaic module (14.9 Wh/d) would be more than enough to produce the daily energy required by the system (6,138 Wh/d).

Calculations step-by-step (with illustrations)

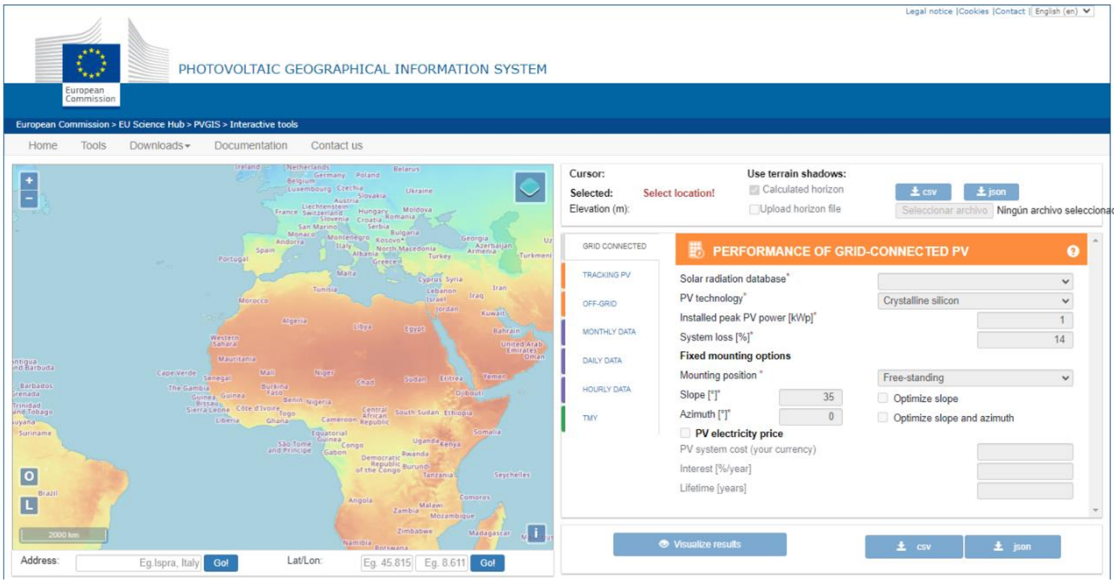
1. First of all, we need to calculate the **consumption**. In order to do this, we calculate the daily energy consumption of the weather station as the sum of the consumption of the individual components.

   For example:

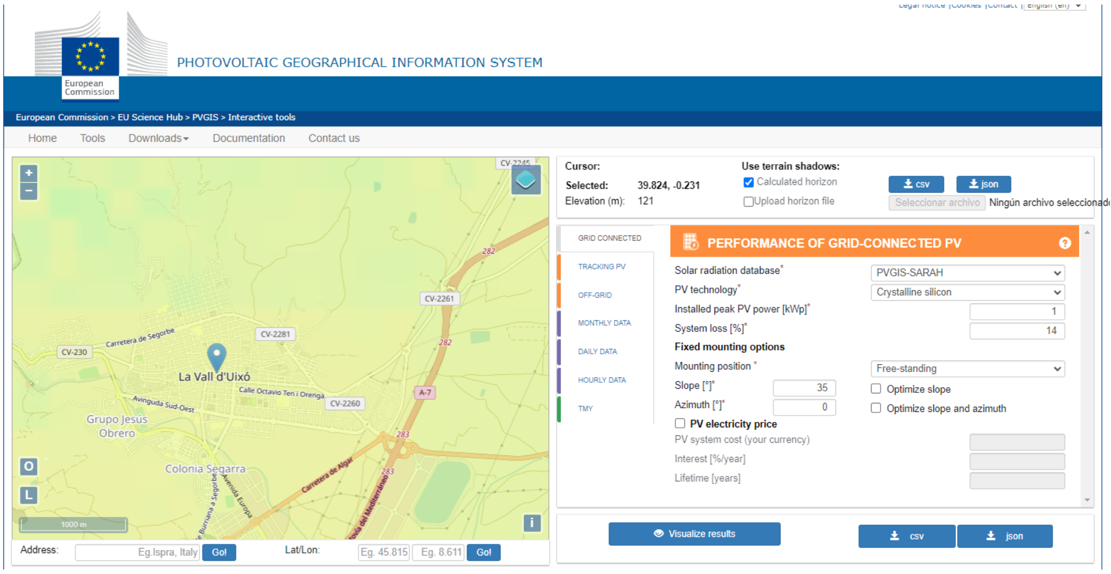
   - NodeMCU (Arduino): 70 mA at 3.3V
   - Temperature and humidity sensor: 2.5 mA at 3.3V
   - Soil moisture sensor: 5 mA at 3,3V

$$Daily\ consumption = \frac{(70 + 2.5 + 5)}{1000}\ A * 3{,}3V * 24h = 6{,}14\ Wh$$

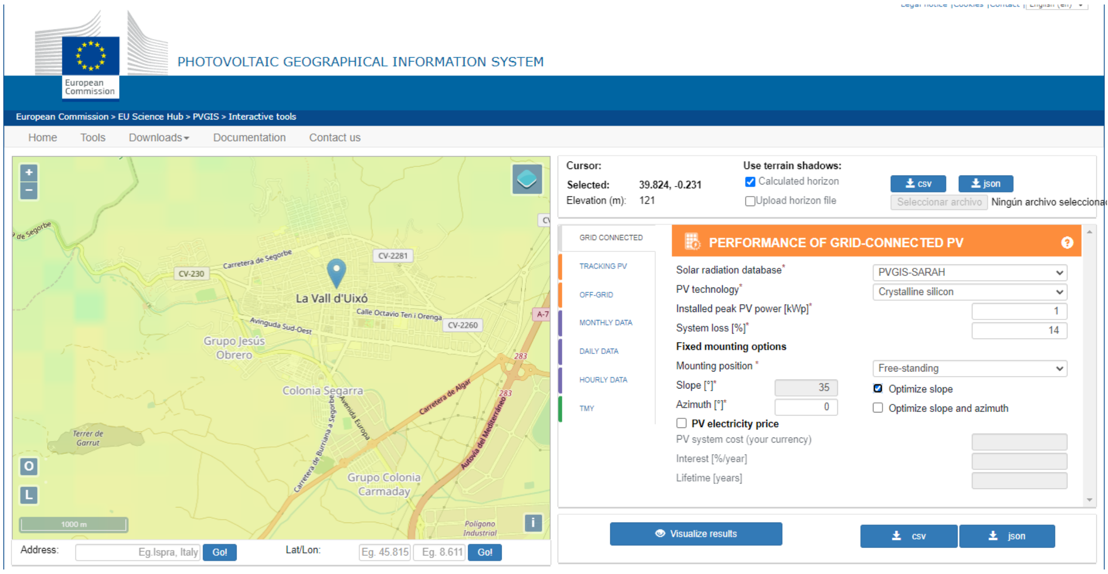
2. Secondly, we continue with the **production, caldulating the peak power of the photovoltaic panel**. For the calculation of the peak power of the PV panel it is necessary to know the solar production that can be obtained at the location of the weather station.
   This information can be obtained with the PGIS website tool:
   https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html
   a. Access to the website



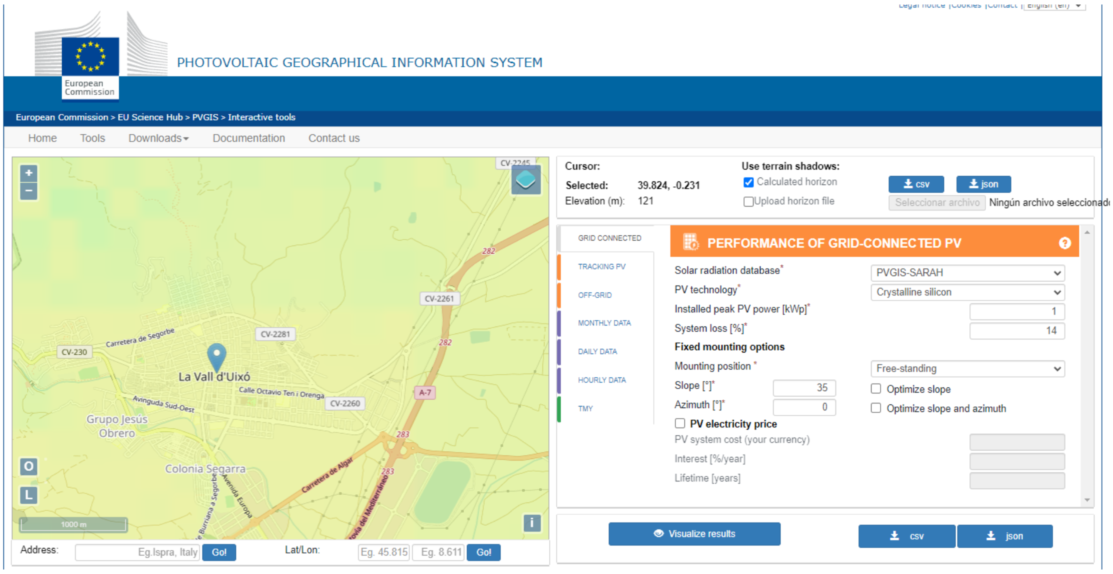
   b. Select the location on the map



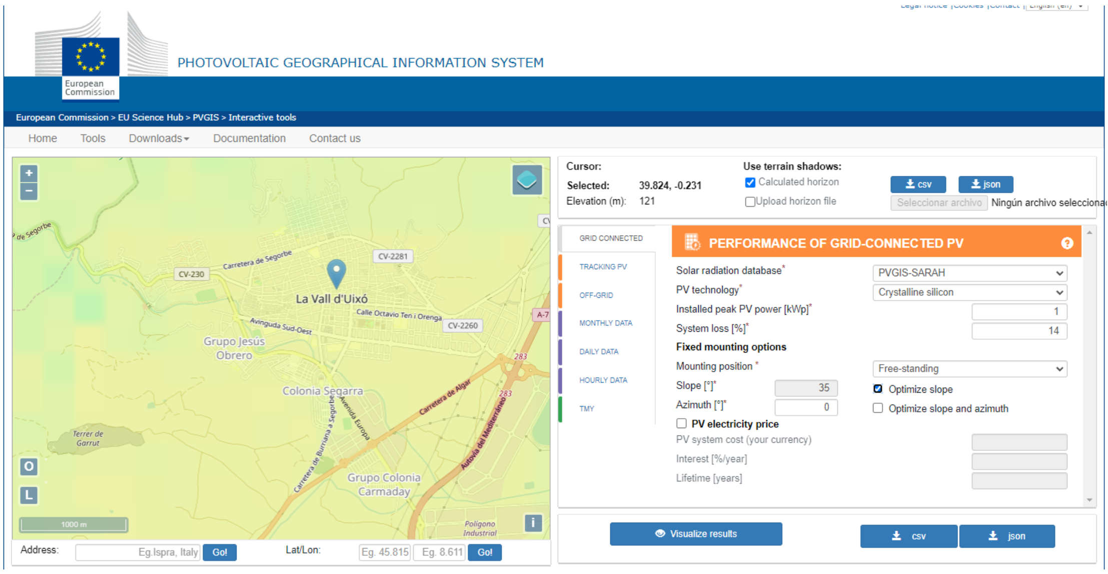
c. In the installed peak PV power [kWp] box, select 1 kWp for the calculation.



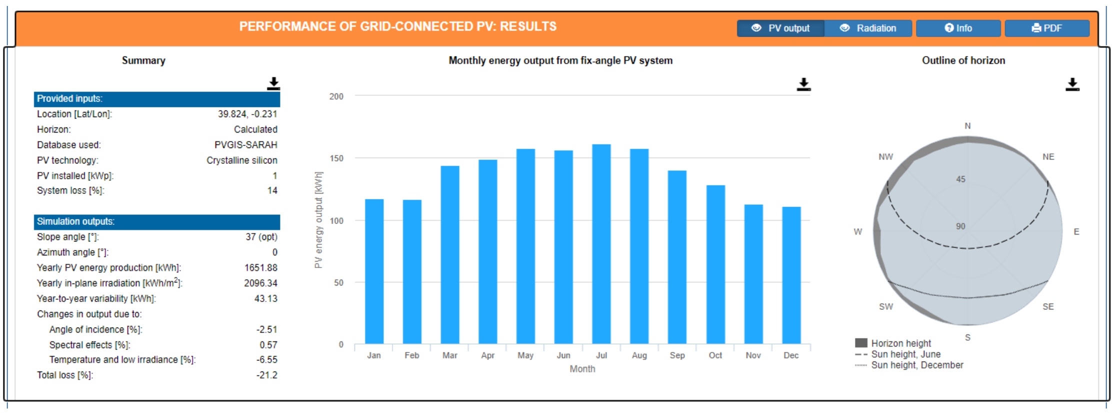
d. Activate the optimise slope checkbox.



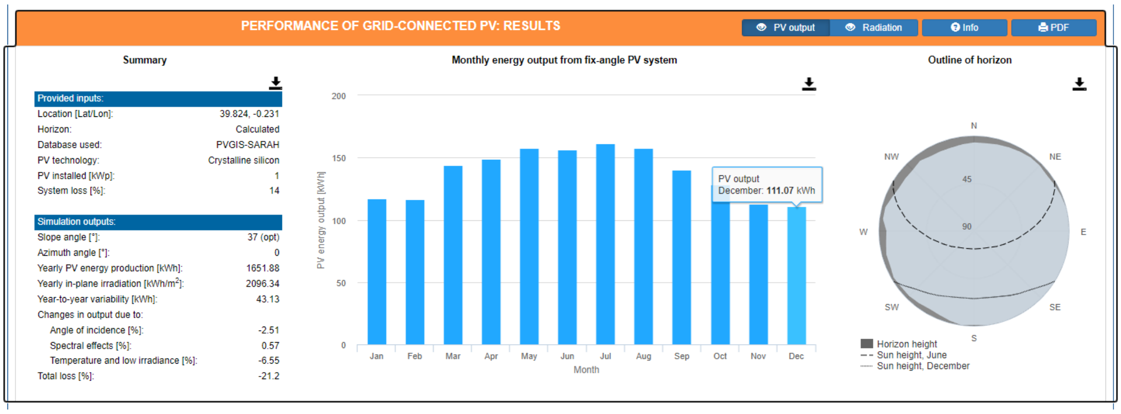
e. Click on the button to visualize results.



f. On the left side, it indicates the slope angle for the chosen location.



g. In the graph, we place the cursor on the month with the lowest production, in order to calculate the worst-case scenario.
   In the example, the month of December has a monthly production of 111.07 kWh/month per 1 kWp installed.



h. Calculate the **daily production** by dividing the above figure by the number of days in that month.

$$Daily\ production = \frac{Monthly\ production}{\#\ days\ per\ month}$$

In the example:

$$Daily\ production = \frac{111{,}07 \frac{kWh}{month \cdot kWp}}{31\ days/months} = 3{,}58 \frac{kWh}{day \cdot kWp} = 3{,}58 \frac{Wh}{day \cdot Wp}$$

i. It will be necessary for the energy produced by the system to be greater than the energy consumed, therefore:

$$Daily\ production \geq Daily\ consumption$$

The peak power of the panel is calculated using the following formula:

$$Peak\ power\ (Wp) \geq \frac{Daily\ consumption\ (Wh/day)}{Daily\ production\ (\frac{Wh}{Wp \cdot day})}$$

In the example:

$$Peak\ power\ (Wp) \geq \frac{6{,}14\ (Wh/day)}{3{,}58\ (\frac{Wh}{Wp \cdot day})}$$

$$Peak\ power\ (Wp) \geq 1{,}72\ Wp$$

The peak power of the PV panel to be selected for the example project shall be at least 1.72 Wp.

3. Now, it is time to calculate the **battery capacity**.

a. The capacity of the battery will depend on the autonomy of the system and its consumption.

$$Battery\ capacity\ (Wh) \geq Daily\ consumption\ (Wh) \cdot Autonomy\ (días)$$

$$Battery\ capacity\ (mAh) \geq Battery\ capacity\frac{(Wh)}{(V)}Battery\ consumption\ (V) \cdot 1000$$

Following the example and for an autonomy of 5 days, the required battery capacity would be:

$$Capacidad\ bateria\ (Wh) \geq 6{,}14\ Wh \cdot 5\ días \geq 30{,}7\ Wh$$

$$Capacidad\ bateria\ (mAh) \geq \frac{30{,}7\ Wh}{3{,}7\ V} \cdot 1000 \geq 8.297\ mAh$$

In the example for an autonomy of 5 days the battery capacity will have to be greater than 30.7 Wh (8,297mAh at 3.7 V).

4. After having all the calculations, it is possible to know which solar panel we need to power up the humidity and temperature station, following the construction instructions of the selected station.
5. In order to extract the data from the station to a remote equipment, it is possible to do so if the station has wifi connection, and it can be sent to the following tool: Ubidots at https://ubidots.com/

Audio-visual material

This material is an extra help for the step-by-step explanation of our selected temperature and humidity station.

Here is the link: https://youtu.be/XRxYTHoQ9j8

Experimental prototypes

László Lakatos, Tamás Misik and Csaba Patkós (EKCU)

Greenhouses and film tents are one of the easiest ways to use solar energy

Operation of greenhouses and film tents

In greenhouses or film tents, the covering material largely transmits sunlight, i.e., short-wave radiation, but retains a significant part of the long-wave, so-called heat radiation. Due to this, the temperature inside the greenhouses and foil tents can be up to several degrees higher. As a result of the higher temperature, the evaporation of the plant or soil surface will also be more intense in the interior, i.e., not only higher temperatures but also higher humidity can be experienced in greenhouses and film tents.

Why do we use greenhouses?

Through the use of greenhouses, we have the opportunity to grow before and after the growing season. That is, by using it, we can extend the length of the growing season and also protect our crops from the effects of adverse weather conditions (frost, ice, windstorm).

Materials for greenhouses, foil tents

Greenhouses can be made of single or insulated glass or polycarbonate sheet. The material of the foil tents is a UV-stable transparent foil, which transmits short-wave radiation well, but retains the long-wave radiation in the space of the foil tent (Fig. 1).

Figure 1 UV filter EVA film tent

EVA films consist of three layers: the outer layer traps UV rays that are harmful to plants, the other prevents high-wavelength heat rays from escaping the system, and the third layer ensures the strength of the film. On the side facing the inside of the film housing, EVA films are often treated with a dehumidifying additive to prevent condensation.

Types and forms of greenhouses and film tents

There are two basic types of greenhouses: attached to a building or free-standing. The greenhouses connected to the building usually have a much smaller floor area, mainly for growing seedlings or as a conservatory. The building to which it is attached also provides protection and heating for the greenhouse or foil house. The connection to the building can be made not only through the ground but even through the window (Figure 2).

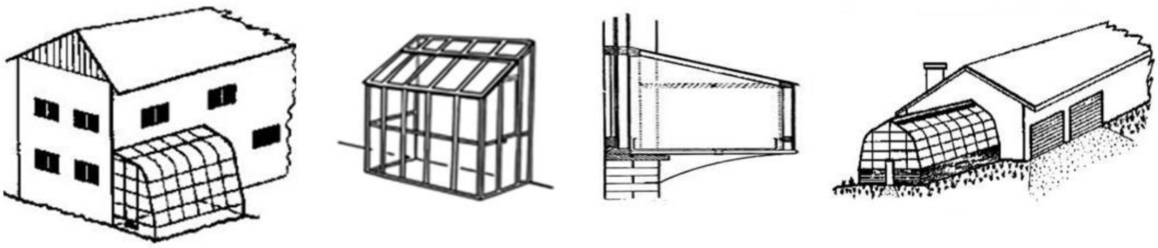


Figure 2 Design forms of greenhouses connected to a building

Freestanding greenhouses usually have a symmetrical design, but there are also asymmetrical greenhouses. Their design varies from country to country (Figure 3). The main purpose of the design is to provide continuous radiation to the plants in it during the day and to provide adequate protection against the effects of adverse weather conditions, such as hail or frost.

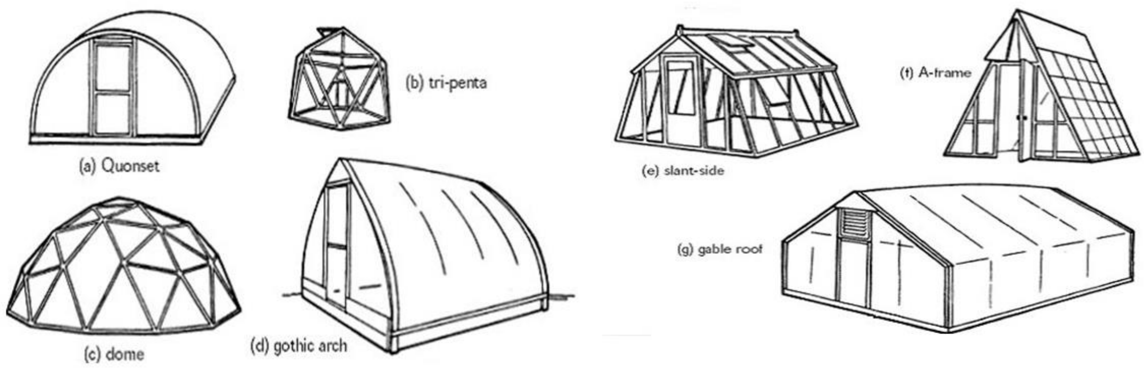


Figure 3 Types of free-standing greenhouses

Their area allows for large-scale cultivation, but they are also suitable for hobby gardening in small gardens. Foil tents and greenhouses can only be used in winter, in countries with colder climates, with heating.

Chinese type foil tent

The use of a foil tent is very common in China. Over the centuries, a special foil tent shape has been developed that allows efficient vegetable production even in winter (Figure 4).

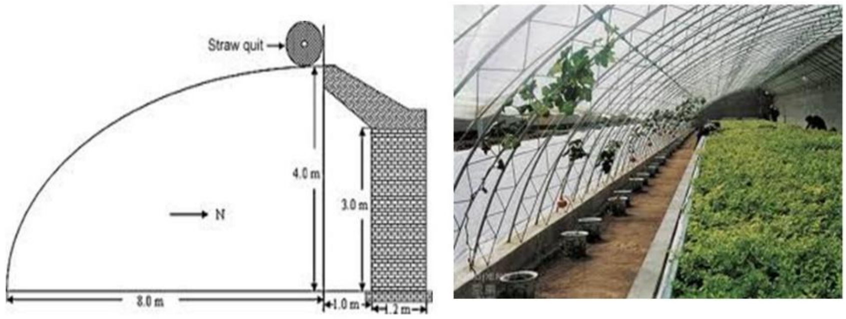


Figure 4 Cross-sectional profile and interior of a Chinese-type film tent

The efficiency of the operation is the 1 m thick back wall and the mat that can be covered with foil. During the daytime, not only the interior of the foil but also the thick back wall heats up. It transfers heat to the air at night. The radiation is significantly reduced by the mat covered on the foil, which leaves more heat in the interior at night than in the case of a simple foil tent. In the case of larger film tents, the night covering of the mat is provided by electric motors (Figure 5). Its southern orientation is of paramount importance because it is the only way to make proper use of the energy of the solar radiation.

Figure 5 The mat is rolled up at the top of the foil tent

In these specially designed Chinese foil tents, not only vegetables but also fruits can be grown using suitable dwarf subjects (Fig. 6).

Figure 6 Orchard in Chinese type foil tent

Foil bedding

Foil beddings are facilities 2-3 m wide, 70-90 cm high and 10-15 m long. Their frame structure is made of a hard PVC pipe with a pressure rating of P3 with a diameter of 2 cm and a wall thickness of 2 mm (Figure 7). The pipes are placed 1 m apart, bent in an arc. Their two ends are inserted so deep into the ground that the ridge height of beds with a basic width of 3 m is 90 cm and that of beds with a width of 2 m is 70 cm. The stopped arcs are connected along the ridge line with a 2 cm diameter plastic tube to prevent the machine from moving in the longitudinal direction. 0.1-0.15 mm thick PE film is used for covering. In addition to the ribs, a groove 25-30 cm deep is made on the outside on both sides of the bed, and the foil spread on the frame is grounded here so that it is strongly tensioned on the ribs.

Due to their low ridge height, foil beds are not suitable for working in a standing position. They are suitable for cold shedding of cold-tolerant vegetable species.

Figure 7 Lettuce cultivation in foil bedding

Climate hall

Climate change is a huge challenge for future agricultural production. There are currently a number of climate and plant simulation models that are being used to try to produce how crop size will evolve in the future. Both climate and plant models have some flaws. As the errors in each system add up, our modelled agricultural vision is rather inaccurate. A further problem with plant simulation models is that they are ill-suited to predict plant quality indices, although for many plants today, content indices (protein, sugar, acid, vitamins, anthocyanins) are more important than the yield itself. The use of climate chambers and phytotrons is very common in biological and agricultural research. In these, some plants can be placed in culture pots or medium. In these plants, they develop under artificial lighting and controlled temperature and humidity. As these devices do not represent real field conditions, they are less suitable for conducting cultivation experiments. Data from small-plot field or small-plot greenhouse experiments already provide useful data for the introduction and testing of new plant varieties. However, with this traditionally used research method, we cannot adequately control either temperature, humidity, or carbon dioxide concentration. The solution to this problem is the climate hall. The climate hall is a specially designed greenhouse with almost uninterrupted access to solar radiation and precision control of environmental conditions (soil, air). Its size can vary widely, from a few cubic meters of interior space to hundreds or thousands of cubic meters of air volume. Smaller indoor units are not usually equipped with air conditioning, so they function as a specially designed greenhouse (Figure 8).

Figure 8 Geodetic dome greenhouse
(Source: Guangzhou Hengnuo Tent Technology Co., China)

The biggest advantage of the special dome-shaped greenhouse is that it makes excellent use of the radiant energy, and taller plants and fruit trees can be placed in the middle and the growth and various parameters of the crop can be examined (Fig. 9).

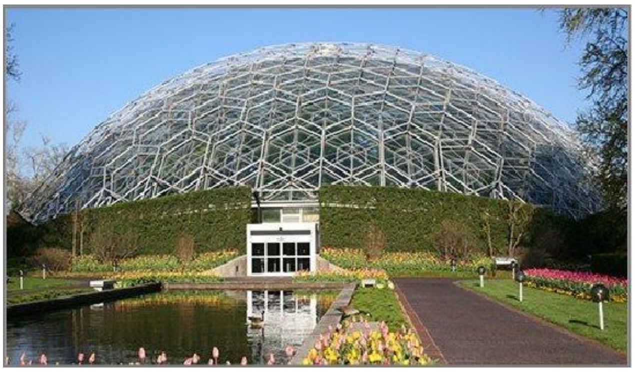


Figure 9 Dome-shaped climate hall
(Source: Pilarska et al., 2018)

The Crops for the Future Research Center (CFFRC) was established on the Malaysian Campus of the University of Nottingham (Figure 10). The goal of the research center is to study different cultivated plant species under controlled climatic conditions to see how plant content indices develop at higher temperatures and carbon dioxide levels (CFFRC, 2011).

Figure 10 Crops for the Future Research Center
(Source: https://www.linkedin.com/company/crops-for-the-future-research-centre)

In many countries, a botanical garden is placed in the dome-shaped climate hall, as a particularly high temperature, humidity and a wide range of carbon dioxide concentrations can be maintained inside. The image below shows a botanical garden built in Vietnam in 2018 (Figure 11).

Figure 11 Glass and metal dome building of the Botanical Garden in Vietnam, in the city of Nha Trang

Benefits of using it

The risk of future cultivation of our agricultural crops will be more accurate than the results of the current model. It can play a very important role in basic agricultural research, whether in testing the cultivability of currently grown or new varieties. It can function not only as a research laboratory but also as an agricultural exhibition. Through visitors, all ages can more accurately see and learn about and experience future changes in agricultural production.

“Energy for farming” experimental film tents

The purpose of the construction of the experimental foil tents was to find out what design of the foil tents provide greater protection for early-grown vegetables. In terms of practical solar energy utilization, we have developed experimental foil tents in which we can grow different vegetables on 2 indoor levels on a floor space of almost 1 m2 and compare how much the plant develops faster in foil tents of different designs than in the natural environment. The construction of the three foil tents can also provide useful information for gardeners on which type of foil tent to provide greater safety for the early development of plants in colder climates at the end of the winter. The efficiency of solar energy utilization depends on the design of the film tents. There are single and double walled film tents. Single-walled film tents are the most common, they have the cheapest design, and they can be made the fastest. There is air between the double foil, which provides better insulation for the foil tent than the single-layer foil tent (Fig. 12).

Figure 12 Double-walled foil tent

Due to the low heat capacity of the air, double-walled systems cannot store significant heat energy either. As a result, the temperature in their interiors also decreases more significantly during the night. Of the natural media, water is one of the substances with the highest heat capacity. Therefore, foil tents with a water wall not only protect the plants from radiant heat loss, but also radiate energy into the interior of the foil tent during the night due to their slower cooling. Thus, the air in the foil tent can be significantly higher in the morning than the outside air temperature. In our case, the water wall was constructed by placing water-filled balloons in front of the back wall of the foil tent (Fig. 13).

Figure 13 Foil tent with heat storage medium and water balloons

Thus, during the day, the water in the tanks heats up under the influence of direct sunlight and transfers this heat energy stored in the water to the air inside the foil tent during the night. The three differently designed foil tents also provide an opportunity to try out which is the most suitable for growing plants in a given place. Our test plants are lettuce and tomatoes. Lettuce can be sown in zen foil tents as early as winter, when night frosts still occur. The efficiency and frost protection of the foil tents of different designs can be tested separately. Tomatoes are a heat-intensive plant, but can be sown in film tents in early spring. In this case, too, we can test the efficiency of film tents of different designs. With the help of the three differently designed foil tents, we can compare how the daily course of temperature develops in a so-called heat storage foil tent equipped with a double-walled one and with water balloons. We can analyze which of the three differently designed tents in which our cultivated plants develop most optimally (Figure 14).

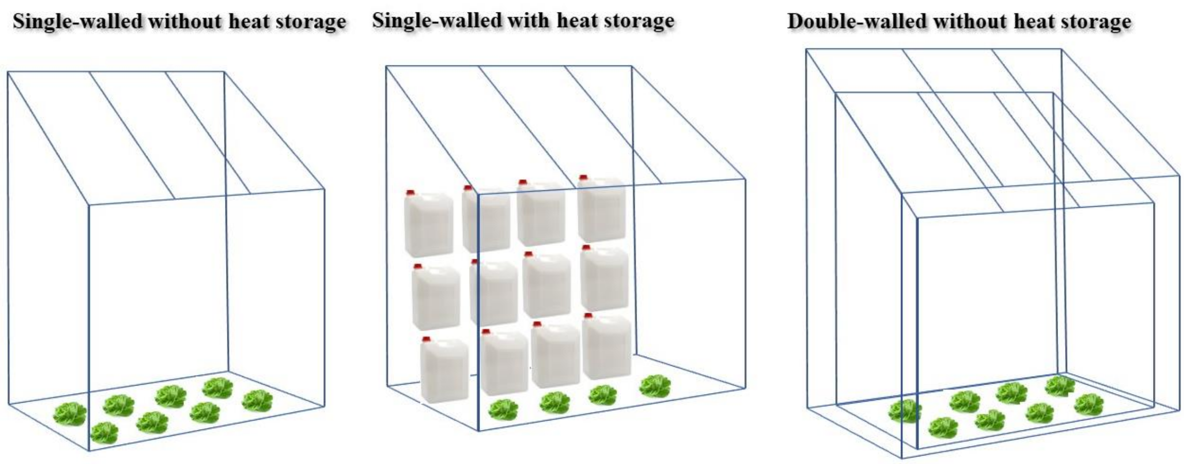


Figure 14 Schematic diagram of the three specially designed experimental film tents

Materials

The following materials were purchased for the production of the film tents:

• Bramach roof rail: 60 m

• Foil

• Foil skirting

• Wood screws

• Door hinges

• Polystyrene sheets

• Balcony boxes

• Flower soil

• Door lock

• Plastic balloon

In batches, the following quantities were purchased from the materials needed to make the foil tent (Table 1).

Table 1 Quantities of materials required to make film tents

	Amount ($m/m^2/db$)	**Unit price (EUR)**	**Totally (EUR)**
Bramach roof batten (m)	68	1.0	68.0
Foil (m2)	14	2.9	40.5
Foil skirting (m)	32	0.7	23.6
Wood screws (pcs)	400	0.037	14.7
Door hinges (pcs)	8	0.5	3.8
Styrofoam sheets (pcs)	3	1.6	4.7
Balcony boxes (pcs)	3	3.6	10.7
Flower soil (pcs)	2	3.2	6.3
Door lock (pcs)	4	0.5	1.9
Plastic balloon	6	5.5	33.2
Total			207.4

We can state that the construction cost of 1 single-walled film tent is approx. 50 Euro. The material cost of the experimental foil tent with a double-walled or heat storage medium is between 75 and 80 Euros.

The completed film tents were placed next to the building of the Faculty of Science. All three are oriented to the south, thus providing a favorable sunlight supply for plant development during the day from morning to late afternoon (Fig. 15). Location, optimal orientation, exposure to sunlight are essential for efficient and economical operation.

Figure 15 Micro greenhouses for efficient use of solar energy

Investigation of the installability of hybrid (solar-wind) systems

When installing hybrid systems, we are primarily looking for the answer to whether the installation of the system improves the efficiency and availability of energy production. In the case of hybrid systems, the two energy production systems (solar and wind) can complement each other, ie. when there is little solar energy, there may be a lot of wind energy available and when there is a lot of solar energy, there is little wind energy. In this case, the installation of hybrid systems is especially recommended. Of course, it can also be the case that when there is little solar energy available, wind energy is also very scarce. If such evenings occur frequently in a given area, the use of hybrid systems may not be the solution for the use of renewable energies. Since solar systems do not generate electricity at night, the question is whether the installation site generates as much wind energy at night as can be used economically. In this way, the hybrid system allows for more continuous energy production than using separate solar and wind energy systems.

Steps for the installation of solar energy production systems

- Climate suitability, assessment of climate potential
- Elimination of local environmental factors unfavorable for energy production, ie. determination of the most suitable site
- Determining the annual dynamics of the solar energy that can be produced at the given installation site
- Determining the annual dynamics of wind energy that can be generated at a given height at a given installation location (using a local database) Hourly SYNOP data is available from www.meteomanz.com
- Production of the annual dynamics of energy that can be produced with hybrid systems

Climate suitability assessment

Finding a location with favourable climatic potential is essential for the installation of solar and wind power generation equipment. Of course, if someone lives, farms and uses renewable energy equipment in the northern part of the country, it is only because the climate potential of the given renewable energy source is more favourable in another part of the country, but it will not install equipment there or directly nearby.

Factors reducing the efficiency of solar energy use

- Areas with more frequent than average cloud cover
- Areas in a deep valley between mountains where the degree of horizon restriction is significant
- City center or where high-rise buildings are located has a significant shading effect on buildings
- A suburban environment with lots of shady trees
- On the edge of parks, in areas next to forests, where the shading effect of canopies is significant

- If solar panels are placed on top of buildings, it is important to orient the building properly

The use of solar energy is very popular in many countries in Europe. Predictable electricity and heat can be generated through solar panels and solar collectors. The only factor of uncertainty in predicting the solar energy that can be produced is the cloud. The amount, type and thickness of the cloud significantly influence the amount of solar energy that can be produced. Consequently, it is not advantageous to install solar installations in areas where cloud cover is common due to local circulation conditions.

Assessing solar potential

1. The first step is to analyse the potential amount of solar energy that can be expected in the given geographical location where we want to install solar panels or solar collectors. Looking at the map of global radiation in Europe, we can see that we can expect higher solar radiation potential in the southern European regions due to the higher angle of incidence. At the same time, we can see that almost the entire European continent, with the exception of the northern parts of the Baltic States, is suitable for solar energy, as even in Estonia the annual radiant energy reaches 1000 kWh / m2 (Figure 1).

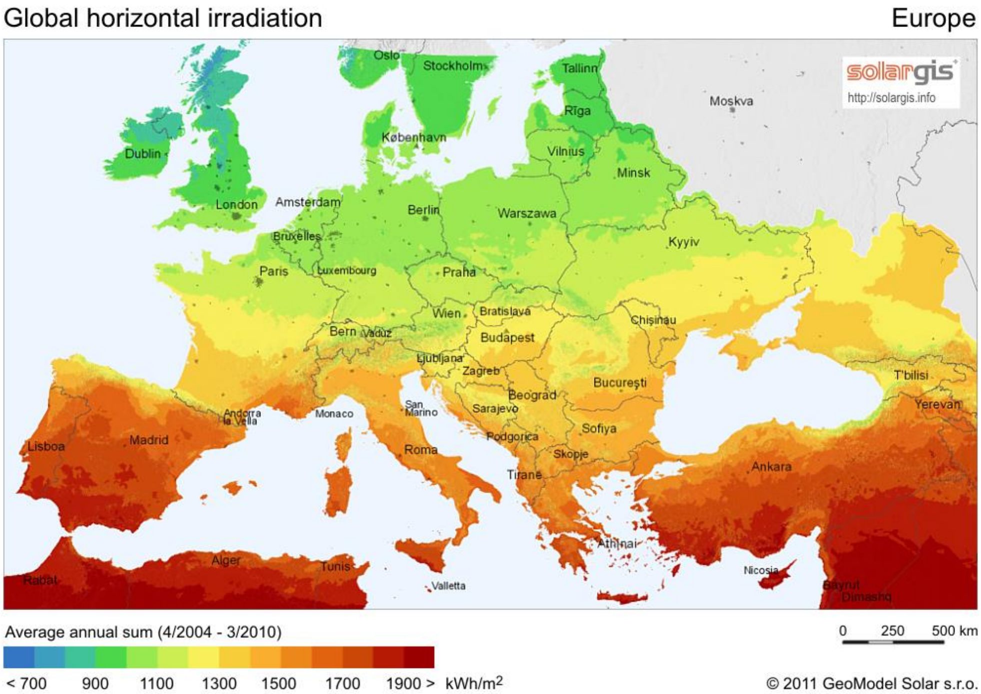


Figure 1. Territorial distribution of the amount of annual radiant energy on the European continent

A specific photovoltaic power map shows the development of the solar power that can be produced. The highest photovoltaic power values occur in the south-east of Spain, while the lowest specific powers occur in the north of Great Britain and Ireland (Figure 2).

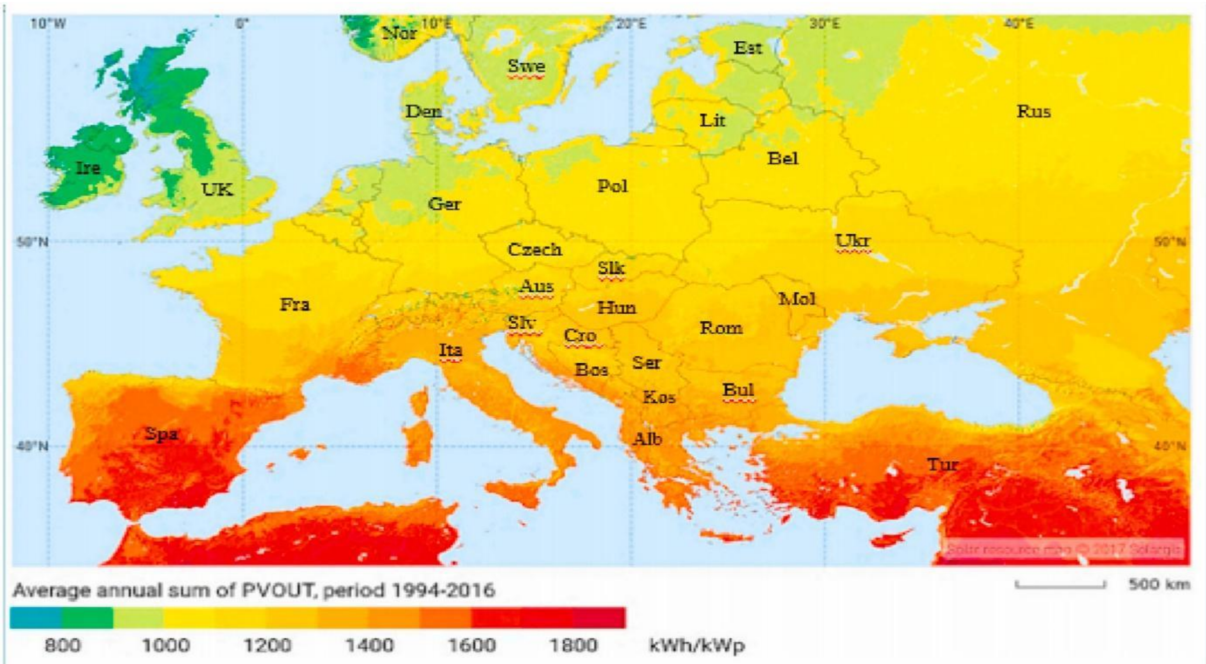


Figure 2 Solar photovoltaic power potential of Europe

Survey of local conditions and endowments

Of course, micro-scale disturbing topography or other shading factors such as the height of the surrounding buildings or the canopy of trees, the improper orientation of the roof structure of the building, which can be ignored, can significantly reduce the amount of energy that can be produced. The photovoltaic potential of a given geographical location for the European area can be analysed with the following software https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#PVPi (Figure 3).

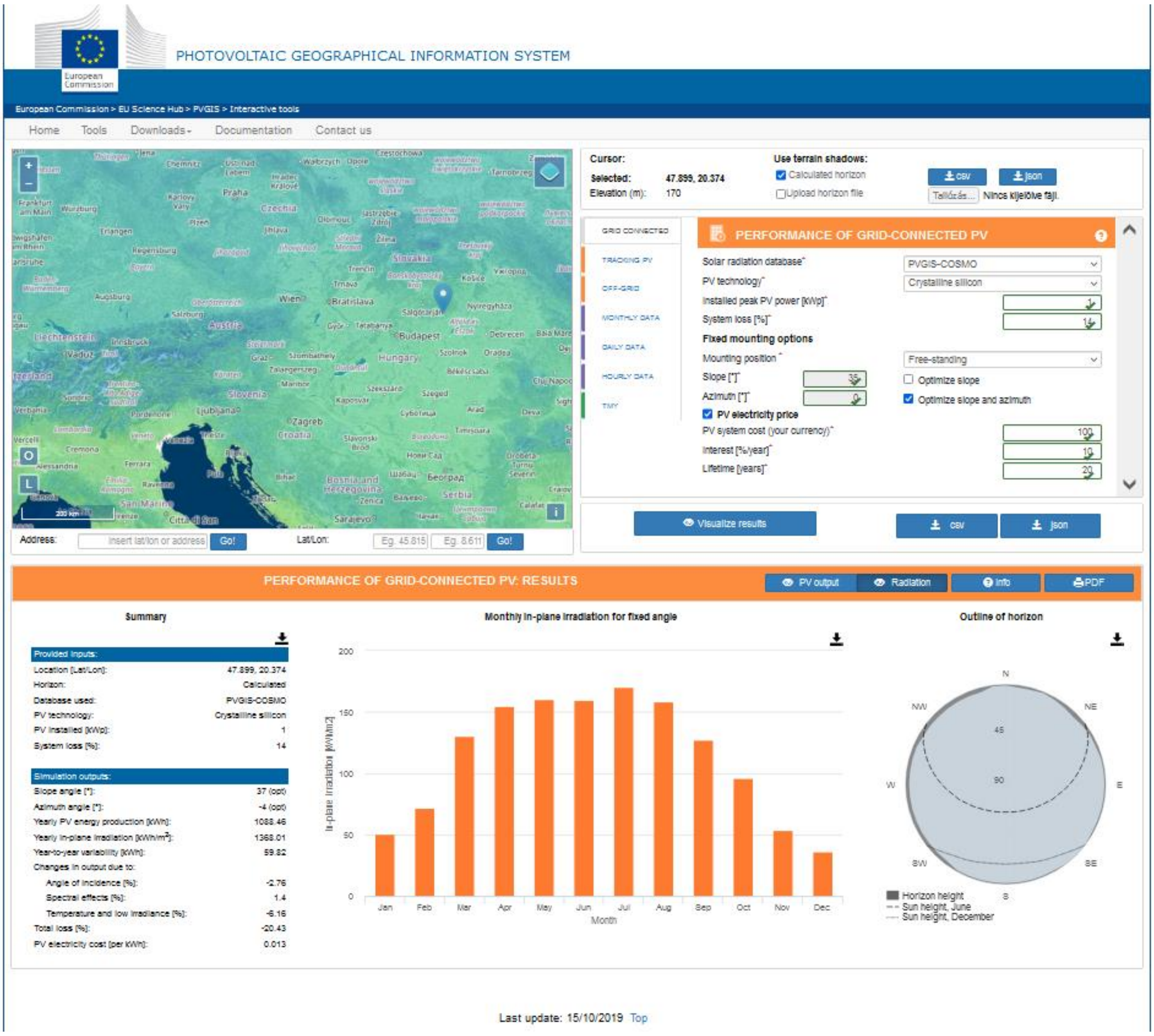


Figure 3. Photovoltaic Geographical Information System

The use of solar energy is very popular in many countries in Europe. Predictable electricity and heat can be generated through solar panels and solar collectors. The only factor of uncertainty in predicting the solar energy that can be produced is the cloud. The amount, type and thickness of the cloud significantly influence the amount of solar energy that can be produced. Consequently, it is not advantageous to install solar installations in areas where cloud cover is common due to local circulation conditions.

Using the Orientation Calculator:

Select the time zone and enter its coordinates (latitude and longitude) to calculate the optimal orientation for the fixed solar cells (Table 1). You can find the geographic coordinates in Google Search[8].

[8] https://solarsena.com/solar-panel-orientation-calculator/

Table 1 Screenshot of the Excel calculator

Input:		Note: Enter positive latitude for north, e.g., 34.05 for Los Angeles (34.05° N) And negative latitude for south, e.g., -33.87 for Sydney (33.87° S)
Latitude	34.05	

Output 1:

Optimal Direction	South

Output 2:

For Fixed Solar Panel	
Optimal Tilt Angle	34°

Output 3:

For Seasonally Adjusted Solar Panel			
Month	**Optimal Tilt Angle**	**Northern hemisphere**	**Southern hemisphere**
March to May	34°	Spring	Fall (or autumn)
June to August	7°	Summer	Winter
September to November	34°	Fall (or autumn)	Spring
December to February	60°	Winter	Summer

Solar cell performance

The performance of solar cells is usually given in Wp (Wattpeak). Wp is the peak power of the solar cell, i.e. it is capable of this peak power under standard measurement conditions. For example, if the manufacturer specifies a nominal power of 245Wp for a panel, a unit of 20 solar panels can be considered a 4.9kWp system.

Only a few hours during the year is the period when our solar cell actually reaches its peak performance (typically when the temperature is low and the sun is shining brightly). That's why we need to look at several factors together to have a realistic picture of how powerful a solar system we need on our roof.

What factors can affect the actual performance of a solar system?

By definition, one of the most important factors is how much solar energy reaches the system, i.e., how much solar energy (global radiation) is present at the installation site. In other words, the geographical location of the property and the exact orientation of the roof surface must be taken into account.

It also matters how much our solar panel heats up, because the higher the temperature of the panel, the lower its performance. It is strictly forbidden to cool the heated panels artificially, as the glass plate protecting the panels may even crack due to sudden temperature fluctuations. If a solar panel has a rated power of 300 Wp and the sun reaches 800 W / m2 instead of the ideal 1000 W / m2, which does not keep the laboratory at 25 degrees but heats up to 50 degrees Celsius when exposed to the sun, it is already 70% The peak power is reduced to, i.e., our panel produces 210 W instead of 300.

The factors influencing solar cell performance are as follows

• The amount of solar radiation, global radiation

• Terrain (ideal orientation: south)

• Tilt angle of solar panels (ideal tilt: 35 °)

• Weather conditions (ideal temperature: 25 ° C)

• Solar technology

• Cleanliness of the solar panel surface

• Properly designed solar system

Different types of solar panels may perform better in different climates. In areas with plenty of sunshine, a monocrystalline solar cell performs better, while in more cloudy areas, polycrystalline and thin-film solar cells perform better.

How can we take these factors into account?

First of all, a proper preliminary on-site survey means a lot, so the designer and contractor of the solar system can recommend a customized solar technology taking into account the characteristics of the house.

Excessive heating of the panels can be reduced, for example, with a half-cell solar cell: half as much current flows through half the cell, so it will heat up less. By lowering the temperature of the cells, their lifespan can be increased and the yield will be higher.

Wind climatology conditions

There are specifically windy areas that are created as a result of orographic conditions. In the area of mountain peaks, tops, and canyons and gorges, the air flow accelerates due to the narrowing of the flow field.

The wind created as a result of orography can be catabolic, in which case we can speak of a downwind wind along the slope, which is mainly created at night. While the warmed air flows up the mountain during the daytime, this is called the anabatic wind.

We can speak of lake or sea or coastal winds due to the equalization of the significant temperature difference between the sea and the shore between media with different heat capacities, or between the sea and the seas.

Wind potential assessment

When examining wind energy, it is important to mention that wind speeds are measured at 10m altitude. This height is not suitable for testing wind for energy purposes. The height of the wind turbines is between 80-120m. Energy wind potentials are therefore usually given for these altitude levels.

One of the most accepted and most commonly used methods for determining wind speed at higher altitudes is the Hellman relation, which has the following form:

$$v_2 = v_1 \left(\frac{h_2}{h_1} \right)^{\alpha}$$

(Formula 1)

Where v2 = wind speed estimated at the desired height, v1 = wind speed measured at that height; h2 = desired height; h1 = the given altitude at which the wind speed was measured, α = its function as a function of the articulation of the surface and the equilibrium position of the atmosphere, which has a daily and annual course. Based on literature data, the value of α is generally considered to be between 0.14 and 0.40.

If we look at the estimation error for the different alpha values, we can state that 0.2 showed the best fit, so we calculated 0.2 α in our present study as well. According to several authors, a good approximation of about 250 m can be achieved with a value of 0.2 alpha. Another relation used is the WMO logarithm function, which has the advantage over the Hellmann formula that it does not include a variable depending on the season and environmental parameters:

$$v_h = v_{10}[0.233 + 0.656 \lg(h + 4.75)]$$ (Formula 2)

The movement of the wind increases as it moves upwards along the vertical. The soil nearby is larger due to surface friction, the presence of surface features, buildings, and vegetation. At higher altitudes, this braking effect is less noticeable. The vertical change in wind speed is called the wind profile. The braking effect of buildings and trees as well as the unevenness of the surface and the surface friction itself create a vortex wind structure. A smaller vortex size near the ground and a larger vortex diameter moving upwards characterize the movement of the air. Due to the formation of vortices, the wind usually does not blow at a constant speed, but makes a fluctuating, fluctuating motion. We can talk about gusts of wind due to fluctuating wind speeds.

Wind performance can be calculated from the mass and velocity of air flowing through a given surface over a given period of time. From these, the energy content of the air can be calculated based on the following equation:

$$P_{fajl.elm} = \frac{\rho}{2} * v^3$$

(Formula 3)

Where ρ is the density of the air, v is the wind speed (in m / s)

Albert Betz has calculated that the theoretically obtainable maximum efficiency for wind turbines is 59.3%, in practice these values are significantly lower. Most authors typically calculate efficiencies of 30%.

Analysing the European energy wind potential, which is determined at an altitude of 100 m above the surface, we can conclude that the areas with the best wind potential are in the northern and mainly coastal areas of the continent. Above-average wind potential is also observed in the higher peaks of the Alps, in the Aegean region, in the peaks of the Pyrenees and on the Mediterranean coast of France (Figure 4).

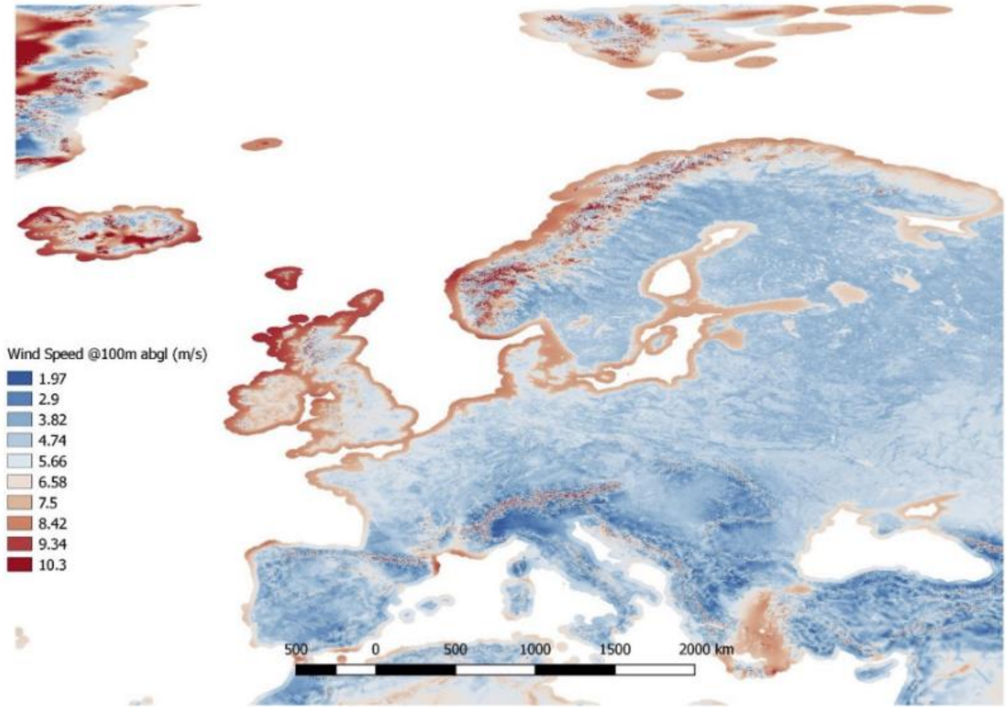


Figure 4 Annual mean wind speeds at 100 m above ground level in Europe
Source: Wind data from (The Global Wind Atlas, 2017)

The potential for wind energy is also favourable across Europe. The conditions for wind energy production are particularly favourable in the northern European region (Figure 5). The favourable wind energy potential in many countries does not mean that favourable wind conditions are being used to a significant degree. Also, the fact that a country does not have a particularly high wind potential may still be particularly popular for energy produced from wind, and overall, this country may also produce significant amounts of energy using wind.

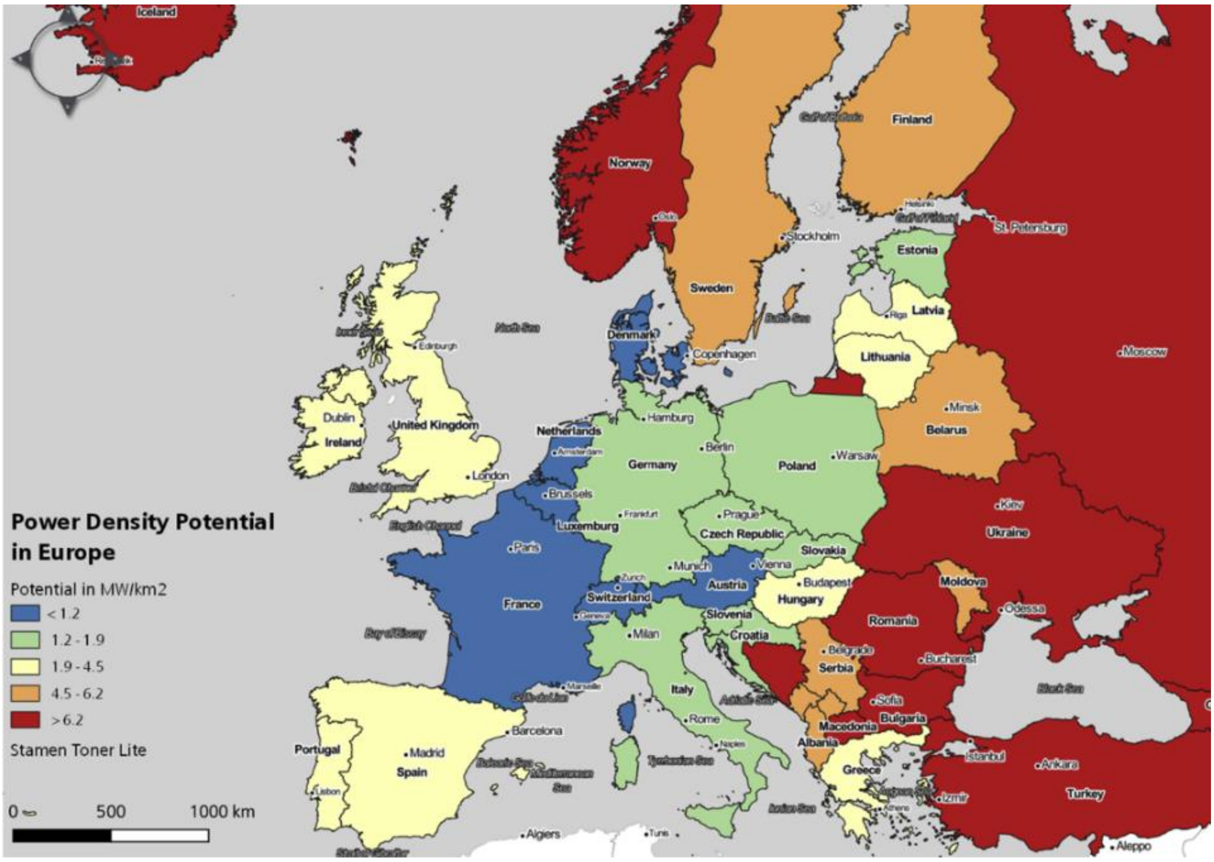


Figure 5. The onshore potential for wind energy in Europe (MW/km^2)
(Source: Enevoldsen et al. 2019)

Factors reducing the efficiency of wind energy use

• In the shadow of the mountains, the speed of air movement inside the pools usually decreases. The slope of the valleys and the direction of the prevailing air flow have a fundamental effect on the magnitude of the wind potential.

• In the city centre, narrow, alley-like streets significantly reduce wind speeds

• Forest strips, wooded groves and in the vicinity of park sites wind speeds can also be significantly reduced.

Installation of hybrid systems (Solar + wind energy together)

If the conditions for solar installations are favourable at a certain time of the year, ie in one season, while the wind potential increases in another time of the year, it is worth considering that the installation of hybrid systems in this place is a more economical technical solution (Figure 6). Of course, it is not a problem if both forms of energy are available at the same time, because even in this case the amount of energy increases that can be produced.

Figure 6. Hybrid (solar + wind) energy service system

In areas where the incidence of cloud cover increases significantly during the time of day or at certain times of the year, less solar energy can be expected during this period, however, in these areas, the magnitude of wind potential usually increases during this period. Therefore, hybrid systems allow much more efficient energy production in these regions than installing solar or wind-only equipment.

The presence of cloud cover in the confluence areas, which is located along the equator and the latitude 60, is significantly more common (Figure 7).

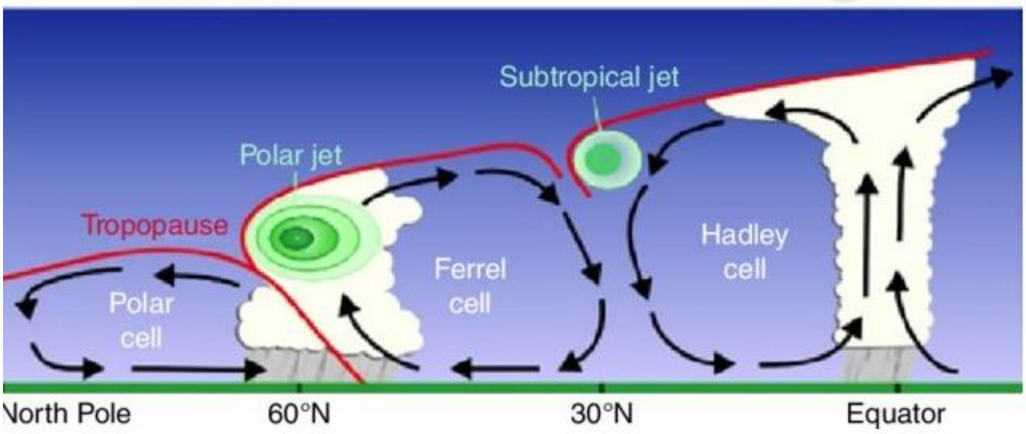


Figure 7. Global wind circulation patterns. 1, Hadley cell; 2, Ferrel cell; 3, Polar cell
(Source: NOAA's National Weather Service, Southern Region Headquarters, Fort Worth, Texas)

In the areas along the slopes, the so-called anabatic wind occurs on a daily basis, as a result of which we can expect the occurrence of anabatic clouds. Due to the favourable radiation exposure, solar energy can be produced efficiently at certain times of the day, especially in the morning, but as anabatic clouds thicken in the early afternoon, conditions for wind energy production will improve significantly. Therefore, the most stable way to produce energy in these areas is to install hybrid systems (Figure 8).

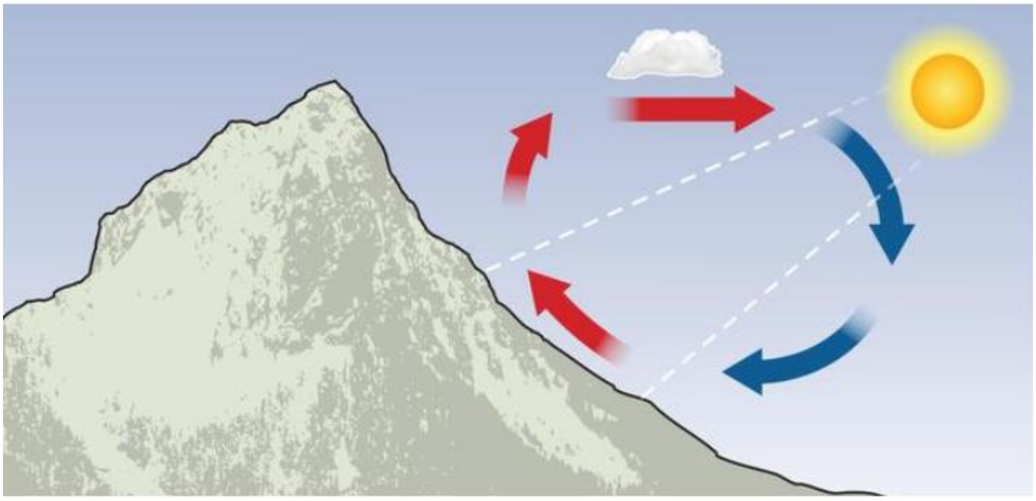


Figure 8. Formation of anabatical clouds on a mountainside exposed to air flow during the daytime hours

In the areas affected by lake or sea winds, the conditions for the production of solar energy in the morning are particularly favourable, followed by the resulting clouds.

Offshore wind is caused by the temperature difference between the ocean, sea and land. Due to its lower heat capacity, the land heats up faster than the water surface. Air above the warmed land or coastal area begins to rise, forming a low-pressure area near the mainland. As a result, the high-pressure cold air above the colder water surface spreads over the water and flows over the land. Where it warms up and rises. When it reaches higher heights, it cools down, the water vapor inside it precipitates and a cloud or even precipitation may form. The cooled air flows back to the ocean or sea surface. This creates a closed circulation cell (Figure 9). This process lasts until equilibrium is established. In this cycle, warm, rising air can form a cloud. Under suitable conditions, smaller thunderstorms may occur along the sea breeze.

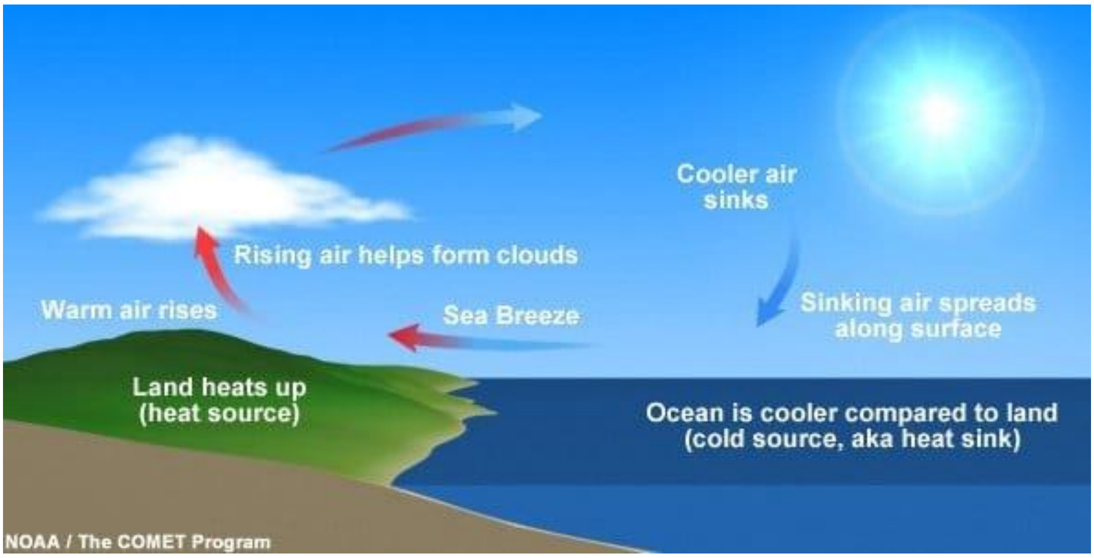


Figure 9. Tengeri szél nappali áramlási iránya

Before the clouds form in the morning and after the clouds subside in the late afternoon, the coastal areas are excellent for producing solar energy, and in the intervening periods it is possible to produce wind energy efficiently (Figure 10).

Figure 10. Summer Sea Breeze Drives Cloud Formation Over Land, Western France by Ross Salawitch Taken on 24 July 2018

The so-called coastal wind blowing from the mainland at night makes the coastal areas particularly suitable for the wind energy production.

It is a particularly important the complementarity in energy production when installing hybrid systems. When one form of energy, such as solar energy, is not available, the other energy source, the wind, provides an adequate amount of energy. Since the sun does not shine at night, an important question is whether a sufficient amount of wind energy can be produced at night. As solar energy also plays a significant role in the generation of wind energy, it is not surprising that the wind energy of the day exceeds the amount of wind energy that can be produced at night. At the same time, our studies also show that the amount of wind energy that can be produced at night during the lower daytime periods (from September to April) exceeds the amount of solar energy that can be produced during the day (Figure 11). This means that hybrid systems enable more efficient energy production than separate solar and wind power generation systems.

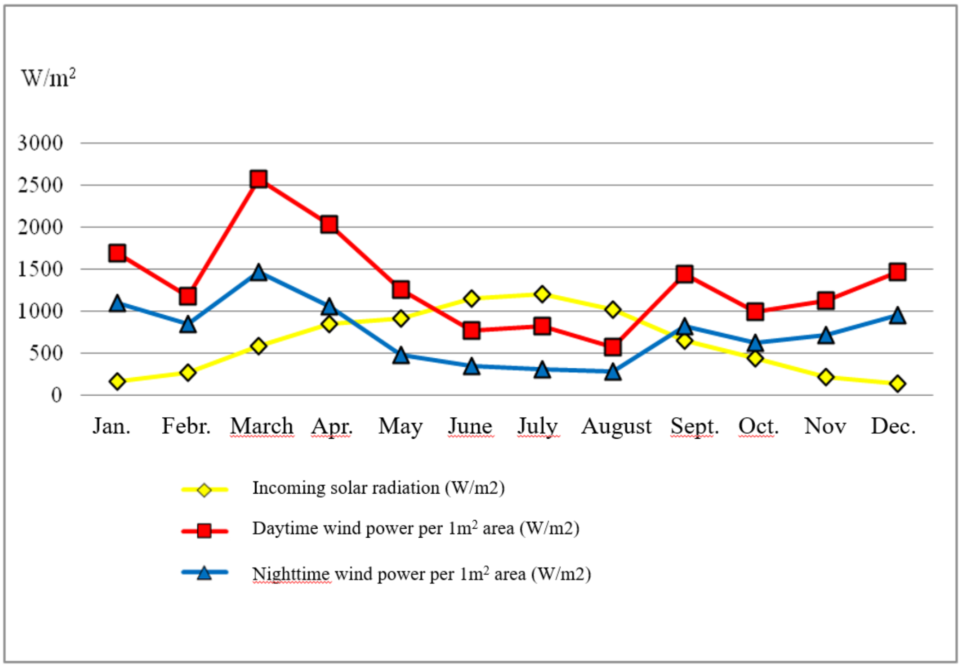


Figure 11. Annual distribution of 80m altitude wind power and solar radiation per unit area in Szolnok between 2011-2020

Looking at the development of the hybrid performances that can be obtained every month, we can observe the March maximum and the August minimum (Figure 12). That is, energy yields range from 2000 to 4500 W/m2. The amount of energy that can be generated from the night wind exceeds the amount of solar energy in the period from autumn to spring, which means that hybrid systems mean more efficient and continuous energy production not only in seasonal but also in daily energy production cycles.

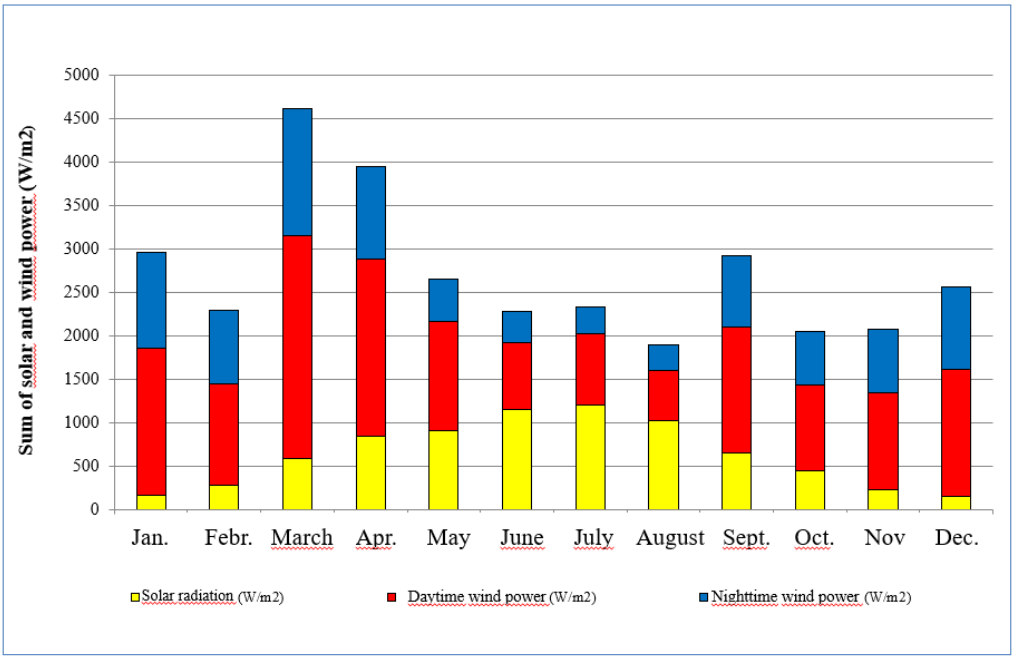


Figure 12. Annual distribution of the total energy supply that can be extracted from the solar and the wind power at an altitude of 80 m, in Szolnok (2011-2020)

In many European countries, hybrid systems have already been used at the level of family farms and households, which provide effective help to reduce the energy costs of households, and in many cases can fully cover the energy used.

The countries on the North Sea coast are known to have much more favourable conditions for the use of wind energy. Many people believe that pools are not suitable for generating wind energy. This statement is by no means correct. The pool-like location has the potential to utilize wind energy. Think of downwind, downhill drains, valley winds, or catabolic winds. These are all local opportunities that occur with high frequency and have not yet been sufficiently exploited in the areas in the basin.

Solar systems are known to be very space consuming, meaning they can take up a large area. Wind turbines require less space and agricultural production can be carried out even under the turbine propellers. In the case of hybrid systems, the use of space can be improved, which can be further improved by the special placement of solar panels. Today, we can even grow crops under solar energy supply systems (Figure 13) (Scott, 2019).

Figure 13. Agrivoltaics" studies in Massachusetts are finding many crops that pair well with solar panels.

Although the south-facing solar module gives the highest electrical energy value for all selected angles, it can be dispensed with in some cases due to the multi-purpose utilization. The orientation of solar panels is an important part of the sizing of photovoltaic and solar systems. Because the solar energy produced is directly proportional to the orientation of the solar panels, proper orientation not only maximizes solar energy but also reduces installation costs. Orientation consists of two parameters: direction and angle of inclination.

Certain plants, such as beans and cucumbers, tolerate semi-shady conditions well and can be grown successfully under scattered radiation. Thus, these plants are particularly suitable for cultivation under solar panels (Corbley, 2021) (Figure 14).

Figure 14. Jack's Solar Farm – Photo by Werner Slocum: NREL

Annex

Glossary

Density: also called volumetric mass density, it is the mass per unit volume of a substance. It is usually represented by the ρ symbol. Mathematically, density is defined as mass (m) divided by volume (V):

$$p = \frac{m}{V}$$

Natural Circulation: the ability of a fluid in a system to circulated continuously, because of gravity, density, etc.

Natural Convection: motion of liquid that is not generated by any external source, but because of the density of the liquid.

Stratification: when different parts are arranged into separate groups.

Syphoning effect: a syphon is a tube that transports liquid up and out of a container at one level to a second container at a lower level. The syphoning effect it when the atmospheric pressure pushes the liquid up and gravity pulls the liquid down.

Thermosiphon: a system in which a coolant is circulated by convection caused by a difference in density between the hot and cold portions of the liquid.

List of abbreviations

H: humidity

LED: light emitting diode

PV: photovoltaic

PVC: polyvinyl chloride

T: temperature

VET: Vocational Education and Training

Wp: Wattpeak

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