GOSTEAM Summer School – Workshop IV

Title: Solar panel placement on Earth, the Moon and Mars!

Thursday 08/07/2021

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Cross-cutting geospatial & environmental STEAM instruments for the new generation

Project Number - 2020-1-SE01-KA201-077972

Co-funded by the Erasmus+ Programme of the European Union

Metadata

Age and language of the students: 15 – 18, Greek

Number of Lessons – Duration (per lesson): 3 Lesson (45 minutes)

Subjects: 2D – 3D Surfaces, Spatial Analysis, Surface characteristics

Curriculum and country:

Country: Greece **Class:** High School **Grade:** 1st grade

Topic: Geography, Physics

Objectives (Max 100 words): Some of the key objectives to be addressed through this activity include: 1) The use of Geographic Information Systems to perform important surface analysis procedures (i.e. estimate slope, aspect) or to recreate 3D surfaces, 2) To understand some crucial aspects and spatial characteristics for Solar PVs placement.

Materials (Max 100 words): QGIS, Global Solar Atlas

Metadata

Spatial concepts, skills and abilities:

Which spatial concepts and skills are covered by the activity?

Location, Orientation, Coordinates, Surface, Aspect

Spatial skills:

Recognizing and understanding patterns/Understand and identify models of spatial organization

Select an ideal location based on the given spatial features

Identify/determine connections/relations

Delineation of spatial regions/ zones based on given features/ properties

Geospatial concepts and spatial abilities documentation (see Section 3.2):
http://www.gosteam.eu/wp-content/uploads/2021/05/GOSTEAM_IO1_A1_final.pdf

Description of the activity in detail

Short Description (Max 500 words):

During this activity students learn how the innovative engineering of photovoltaics enables us to transform the sun's energy into electricity using photovoltaic panels. At first, in this activity we will explain how people use the sun as a renewable energy source for power on Earth as also, how the sun is used as a renewable energy source for power in space and potentially in other planets.
Moreover, students will learn about some major criteria and conditions to be addressed in order to select optimal areas for PV solar panels placement on Earth, Moon and Mars. Further explanations are provided explaining why the photovoltaic technologies have the potential to be just as beneficial on Earth, however, the criteria and the parameters remain the same?

What we do?

Understand the spatial criteria towards maximizing energy generated from solar PVs. Estimate produced energy in different areas worldwide. Try to identify optimal areas on Mars and the Moon.

Keywords (Up to 5):

Spatial Modelling, Surface Analysis, Solar PVs

1. Questions eliciting activities

Provoke curiosity

Usually, the most effective way to provoke students' curiosity is by presenting an exciting video or a series of photos

Generating Power on Mars (Solar Panels on Mars)

What If the Sahara Desert Was Covered With Solar Panels?

What If We Covered the Moon With Solar Panels?

Propose preliminary explanations or hypotheses

It is best to ask these questions in the context of a relative discussion.

- Can you identify the most suitable areas in Sahara dessert?
- Which spatial characteristics must converge?
- All cities worldwide can produce enough energy from solar panels to cover their energy needs?
- What if we cover the entire Lunar surface with PVs?

2. Active investigation

Plan and conduct simple investigation

This is the phase in which students are being prepared for the subsequent phase of evidence gathering during observation.

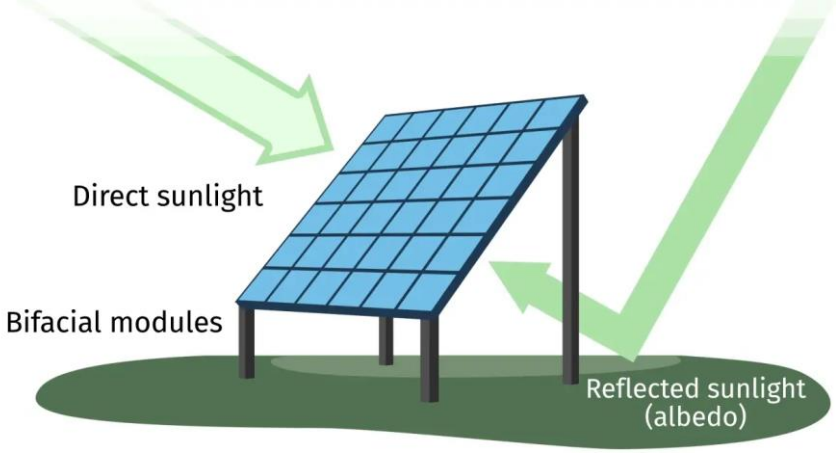
During this step, students may collect evidence regarding multi-criteria decision making and solar panels placement?

What criteria are considered as the most important?

What type of data are needed? How can we analyze these data?

What tools are used?

Can we estimate the produced energy?



3. Creation

Gather evidence from observation

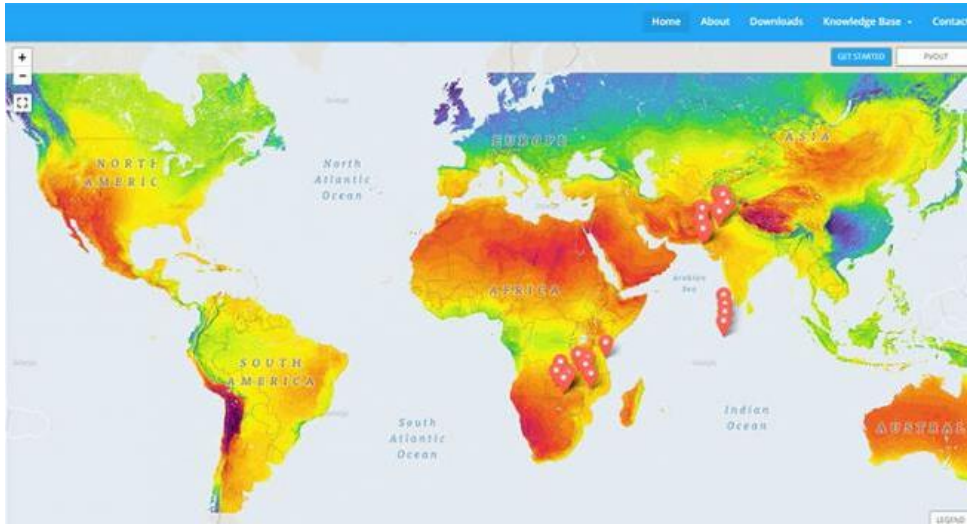
It is recommended to introduce group work at this stage. Guide the teachers to divide students in groups, each of which will be facilitated by the teacher to formulate and to evaluate explanations to the scientific questions based on the collected evidence.

Activity planning

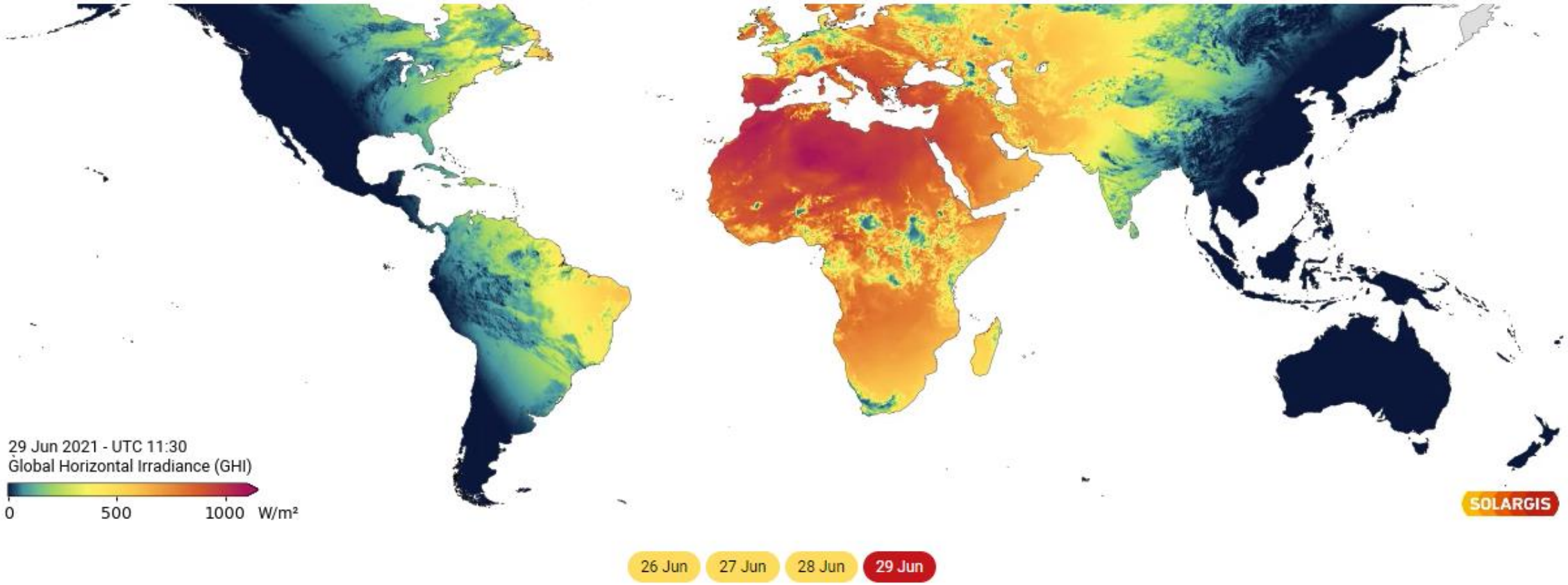
[Determining the Best Location for a PV System]

[Solar panel orientation]

Global Solar Atlas Platform



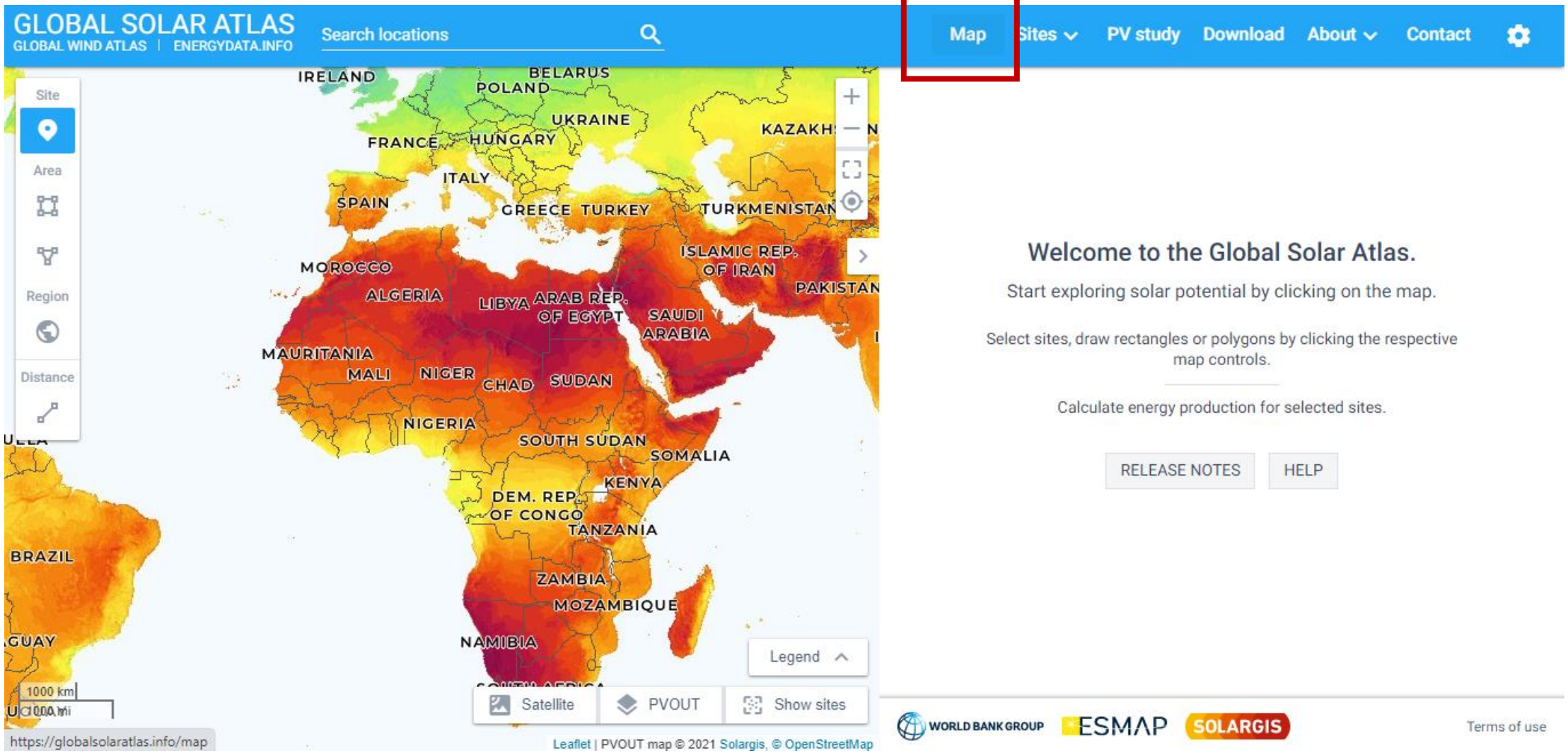
3. Creation (Overview)



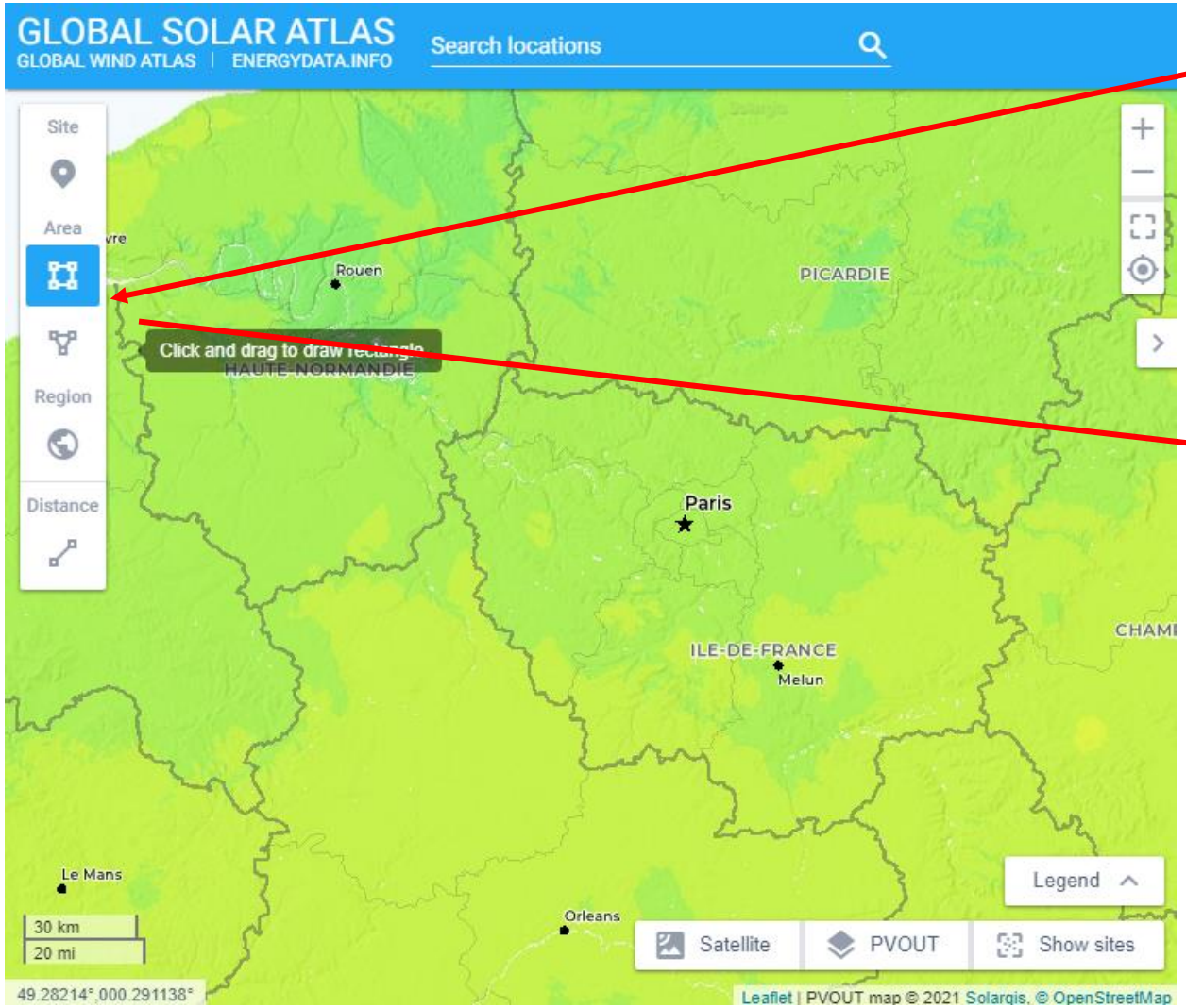
Source: https://solargis.com/products/monitor/overview

3. Creation (Global Solar Atlas)

https://globalsolaratlas.info/map



3. Creation (Global Solar Atlas – 1st area, France)



1. Draw a rectangle to select an area of interest.
Let's start from Paris!

You just created an area with size : 1300.61 km^2

Calculate area statistics

Delete and start drawing a new one

2. Then we select calculate area statistics! A brief description of the solar irradiance characteristics will appear!

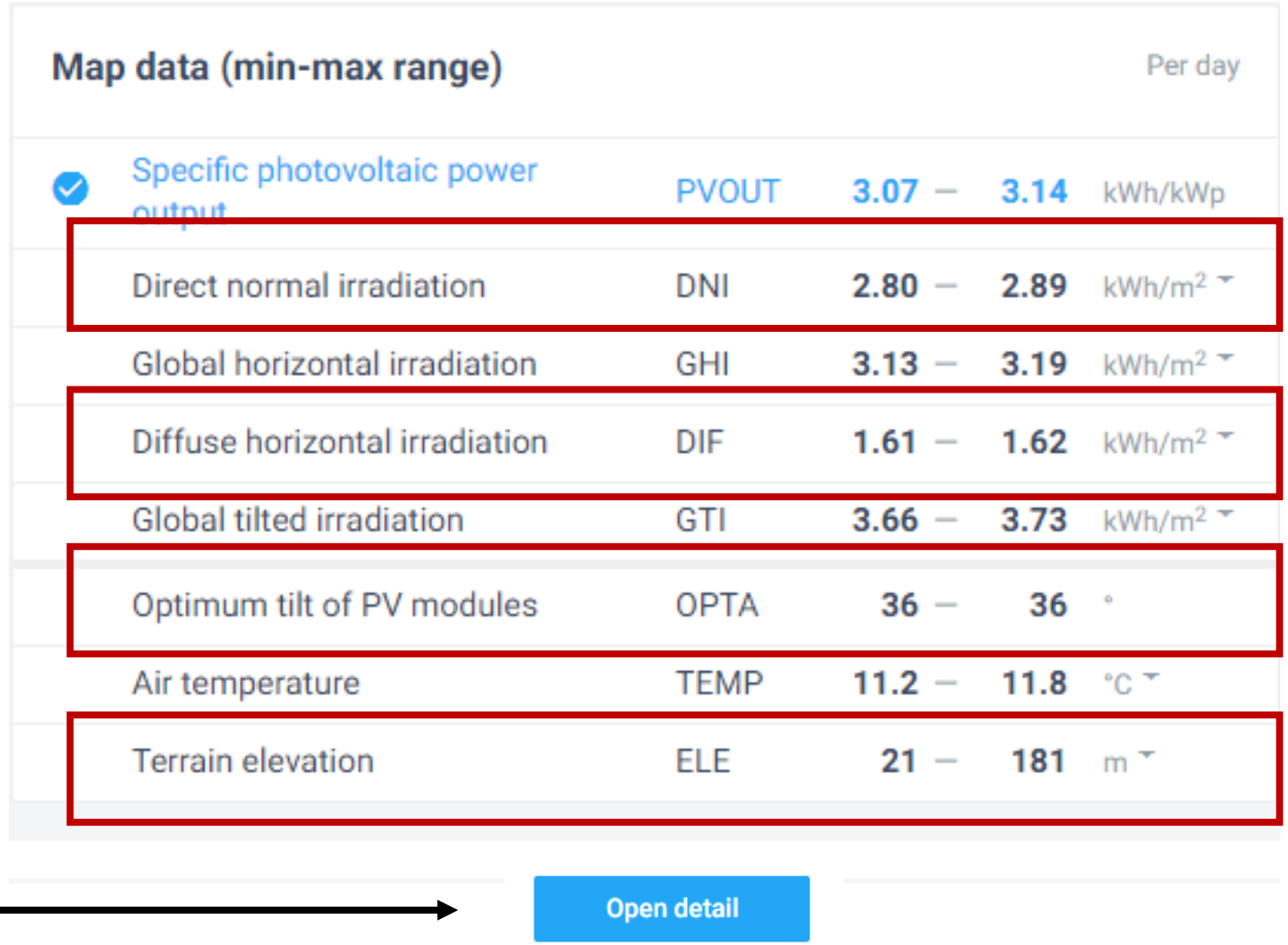
3. Creation (Global Solar Atlas – 1st area, France)

A first cycle of discussion begins by analysing the results!

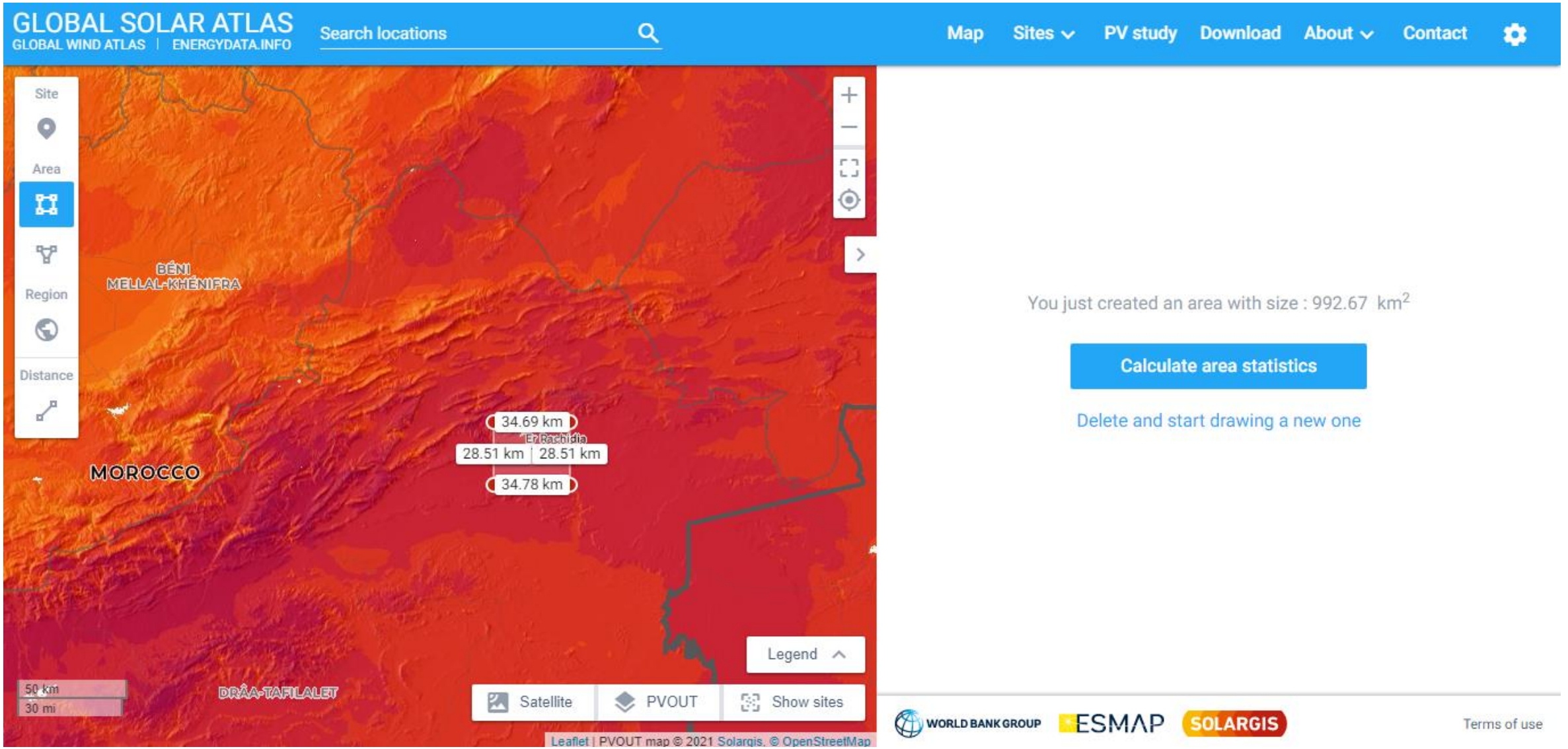
For example, what's the difference between direct and diffuse irradiation?

Why the optimum tilt of PV modules is important?

How terrain elevation affects the site-selection procedures or potential areas for PV siting (i.e. shading)?



3. Creation (Global Solar Atlas – 2st area, Marocco)



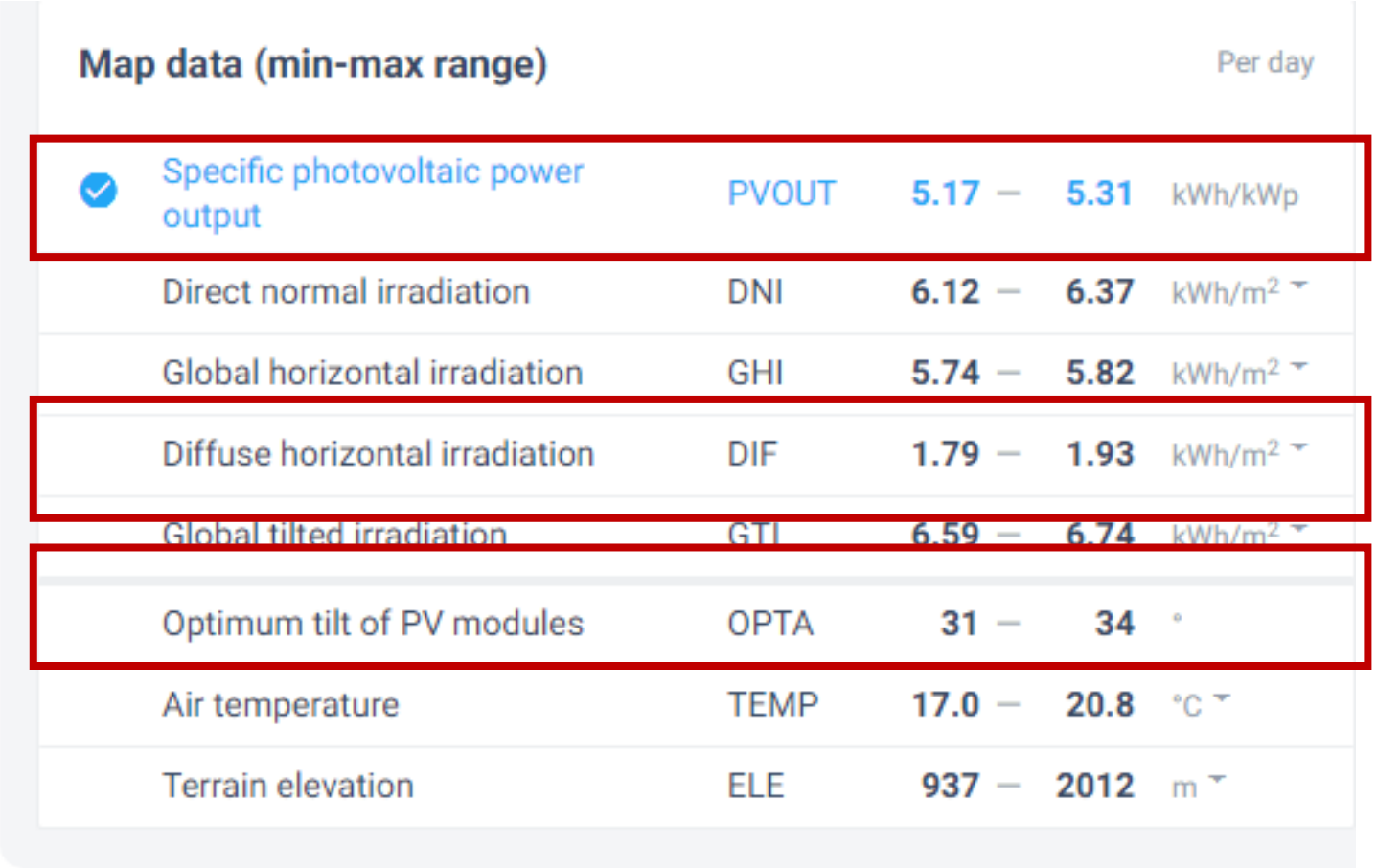
3. Creation (Global Solar Atlas – 2st area, Marocco)

During this step we can start with a few comparison between the two areas:

Differences on the PV power output?

Differences on the diffuse irradiation? (short differences)

The optimum tilt range decreases! But why?



Map data (min-max range)				Per day
Specific photovoltaic power output	PVOUT	5.17	5.31	kWh/kWp
Direct normal irradiation	DNI	6.12	6.37	kWh/m²
Global horizontal irradiation	GHI	5.74	5.82	kWh/m²
Diffuse horizontal irradiation	DIF	1.79	1.93	kWh/m²
Global tilted irradiation	GTI	6.59	6.74	kWh/m²
Optimum tilt of PV modules	OPTA	31	34	°
Air temperature	TEMP	17.0	20.8	°C
Terrain elevation	ELE	937	2012	m

3. Creation (Global Solar Atlas – 2st area, Marocco)

Paris

Er Rachidia

Compare the 2 diagrams!

Which Cumulative distribution function is better? What the slope of the CDF may reveal?

Distribution

Specific photovoltaic power output

more than 3.00	100.0 %	
	100.0 %	

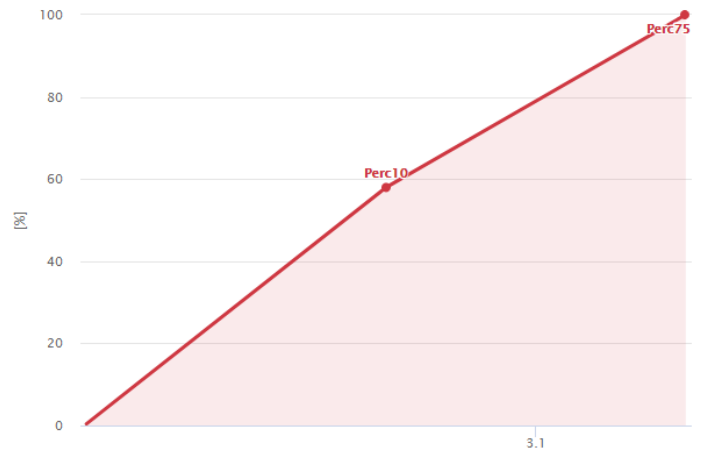
Statistics

Specific photovoltaic power output

Average	3.10 kWh/kWp
Maximum	3.12 kWh/kWp
Percentile 90	3.12 kWh/kWp
Percentile 75	3.11 kWh/kWp
Percentile 50 (Median)	3.10 kWh/kWp
Percentile 25	3.08 kWh/kWp
Percentile 10	3.08 kWh/kWp
Minimum	3.07 kWh/kWp

Cumulative distribution function

Specific photovoltaic power output



Distribution

Specific photovoltaic power output

more than 5.20	88.7 %	
less than 5.20	11.3 %	
	100.0 %	

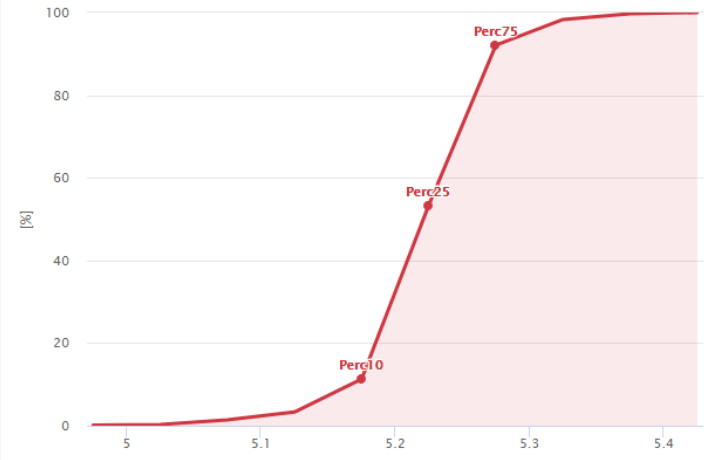
Statistics

Specific photovoltaic power output

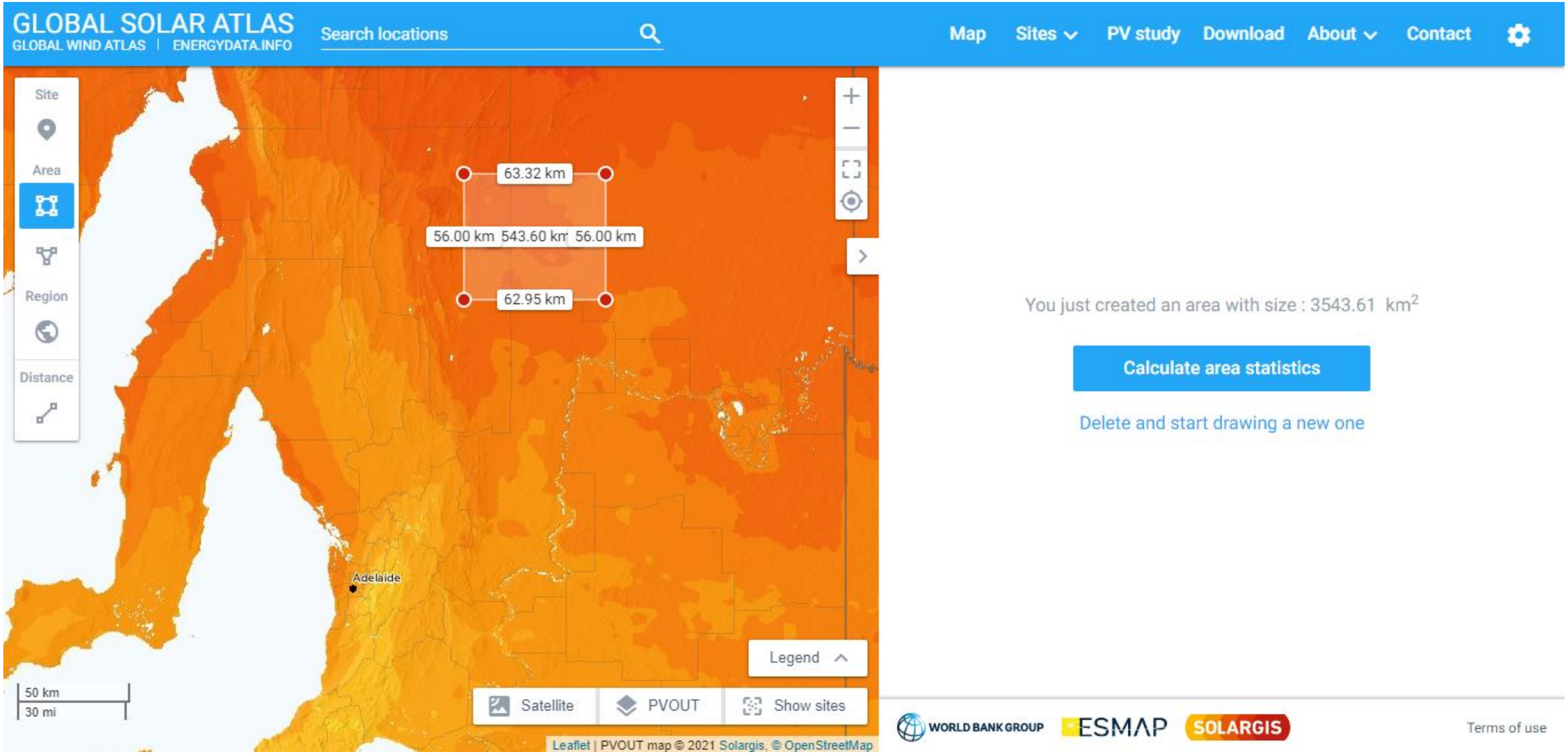
Average	5.25 kWh/kWp
Maximum	5.31 kWh/kWp
Percentile 90	5.29 kWh/kWp
Percentile 75	5.27 kWh/kWp
Percentile 50 (Median)	5.25 kWh/kWp
Percentile 25	5.22 kWh/kWp
Percentile 10	5.20 kWh/kWp
Minimum	5.17 kWh/kWp

Cumulative distribution function

Specific photovoltaic power output



3. Creation (Global Solar Atlas – 3st area, Adelaide)



3. Creation (Global Solar Atlas – 3st area, Adelaide)

For the broader Adelaide area, results seem to be better than Paris and inferior to El Racidia.

Also, the optimum tilt is the same as El Racidia!

But for which orientation?? South, North, West??

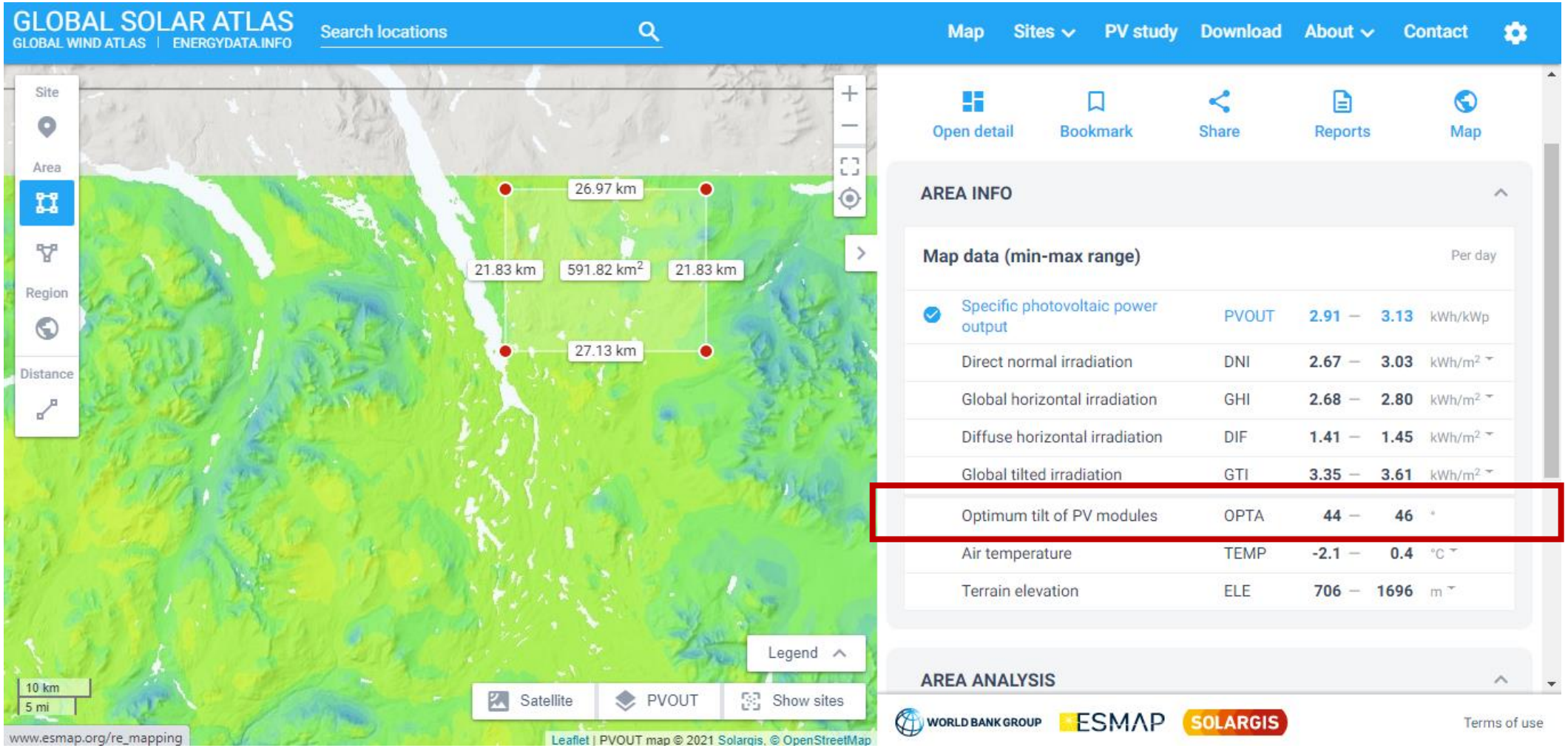
A second cycle of discussion begins for explaining the importance of the surface aspect/orientation for PV site-prospecting worldwide.

Map data (min-max range) — Per day

Specific photovoltaic power output	PVOUT	4.73	4.84	kWh/kWp
Direct normal irradiation	DNI	6.35	6.56	kWh/m²
Global horizontal irradiation	GHI	5.22	5.30	kWh/m²
Diffuse horizontal irradiation	DIF	1.41	1.44	kWh/m²
Global tilted irradiation	GTI	5.90	6.04	kWh/m²
Optimum tilt of PV modules	OPTA	30	31	°
Air temperature	TEMP	15.8	17.3	°C
Terrain elevation	ELE	49	420	m

3. Creation (Global Solar Atlas – 4st area, Canada)

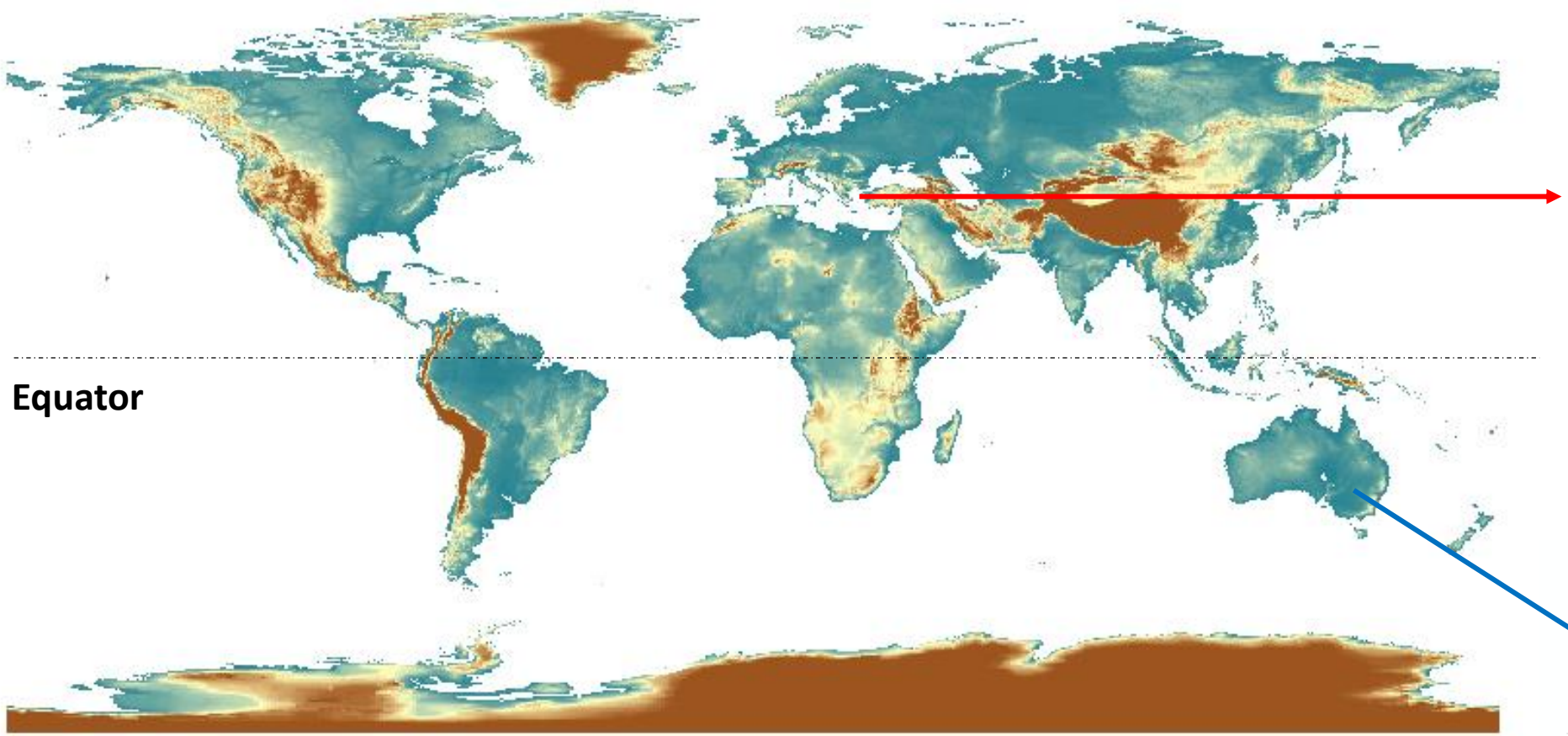
Before we move on to the aspect explanation, let's try to guess which is the optimum tilt for the higher latitudes areas, i.e. North Canada? Or even for the North Pole or Antarctica?

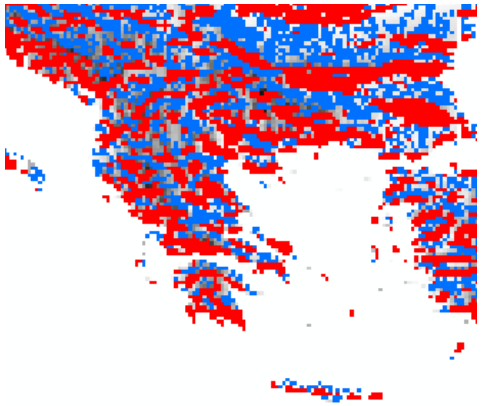


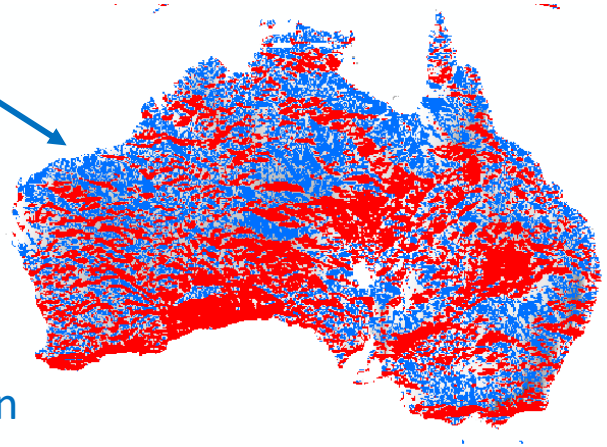
Chapter Break (Any Questions?)

3. Creation (Global Solar Irradiation, Orientation)

Europe, North America, China: Southern orientation





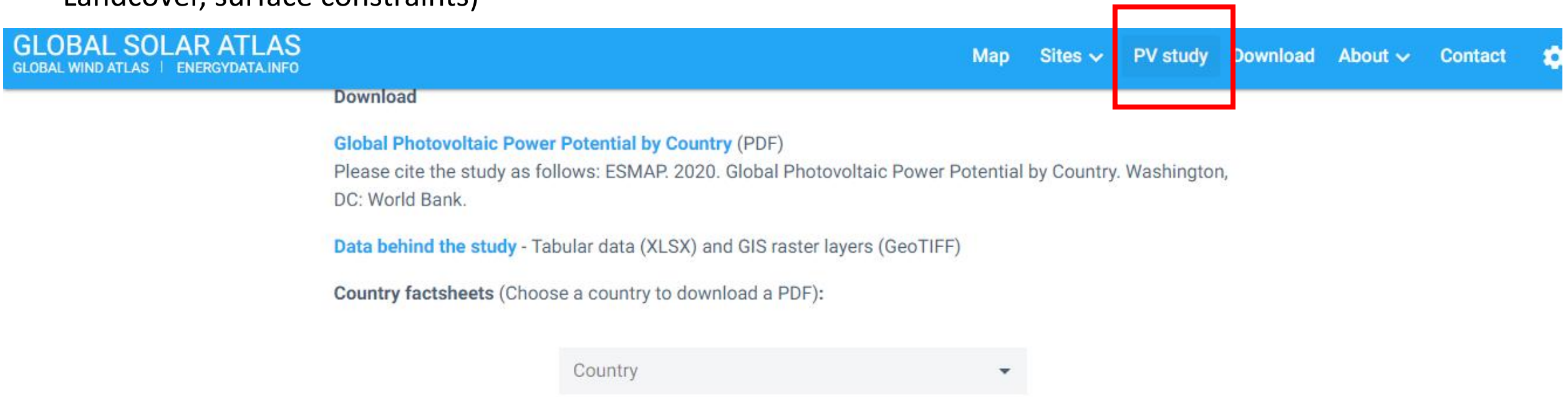


Argentina, South Africa, Australia: Northern orientation

3. Creation (PV Study – Analytical report)

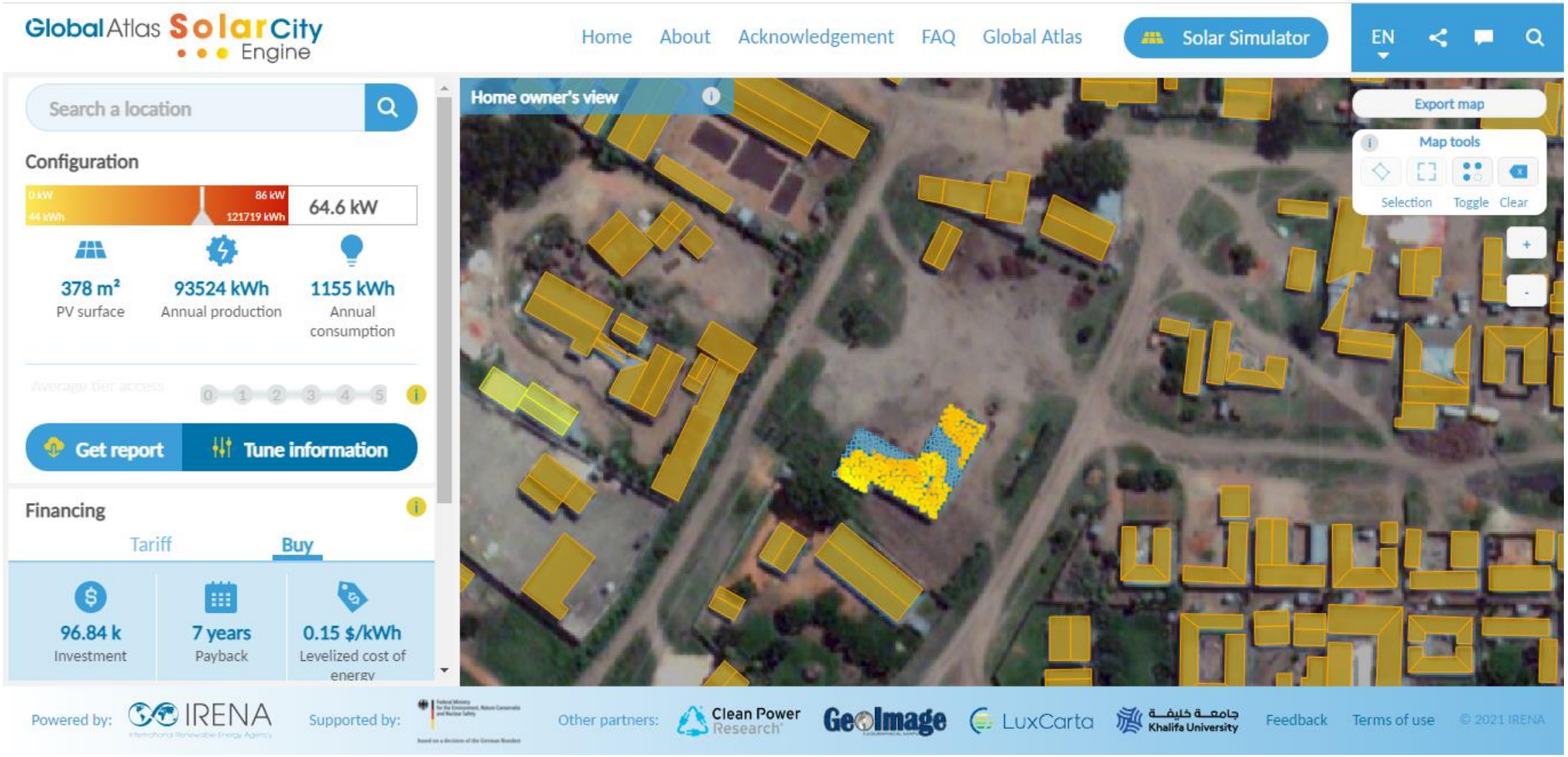
Now that we explained many different spatial aspects of the produced energy by solar PVs, we can move on to the analytical reporting of a PV study among different countries.

- Different graphs and diagrams will be analyzed, explained and discussed! How Lat Lon affects the energy variability?
- Can you estimate how many solar panels must be placed in order to cover the national energy demands in each selected country?
- There is enough space? Can you estimate the available space per country? What data are needed? (i.e., Landcover, surface constraints)



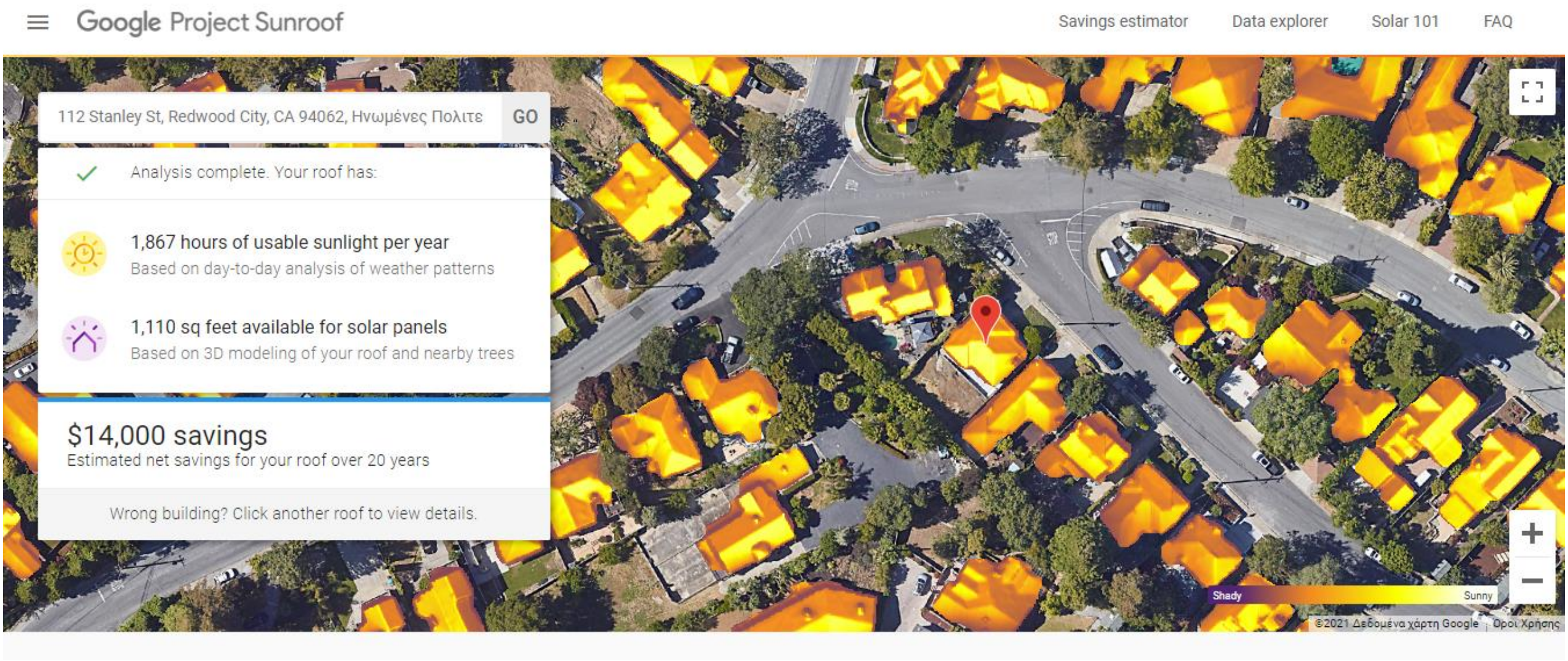
3. Creation (Additional apps and Websites)

http://solarcityengine.irena.org/#homeview



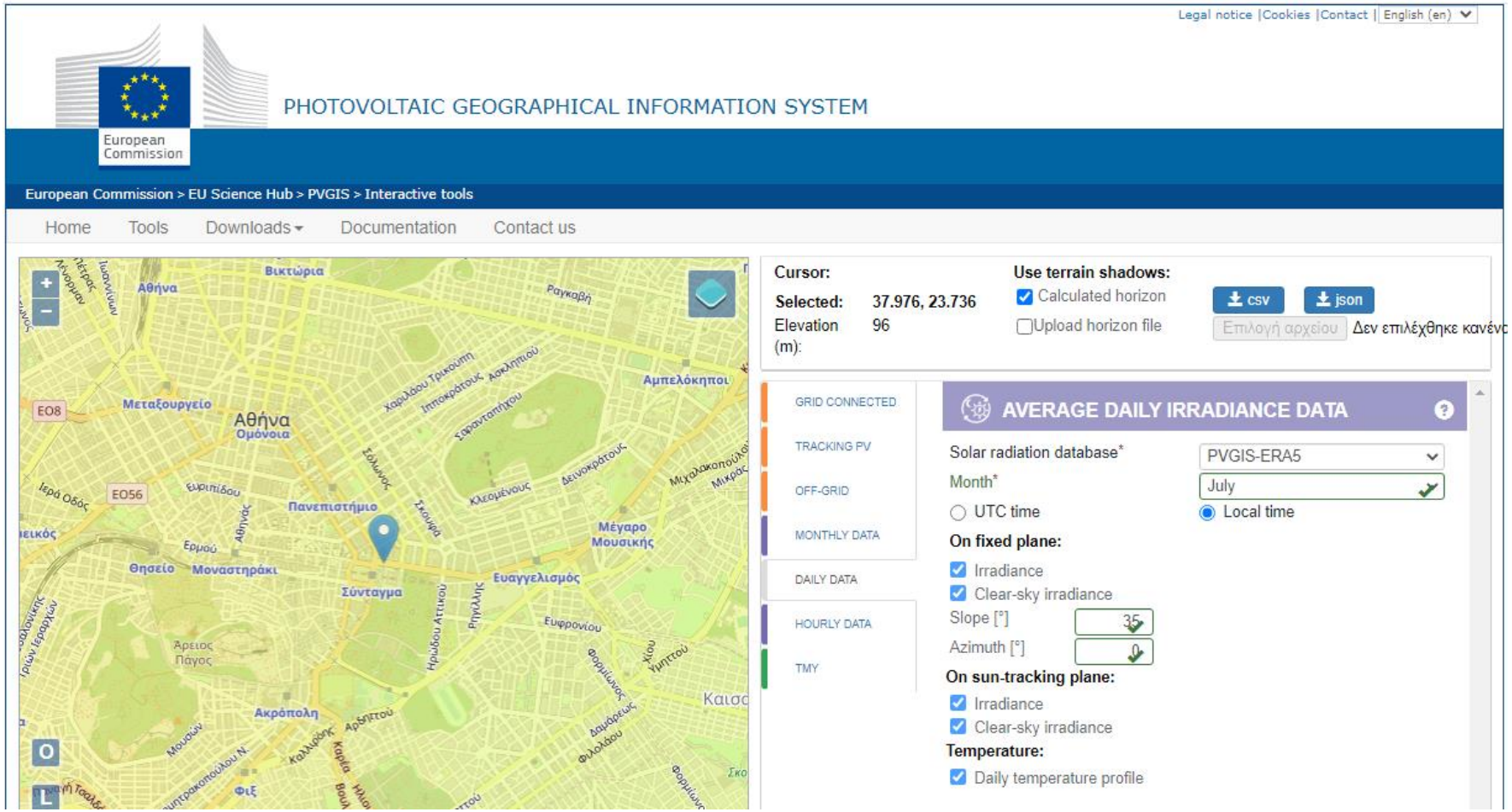
3. Creation (Additional apps and Websites)

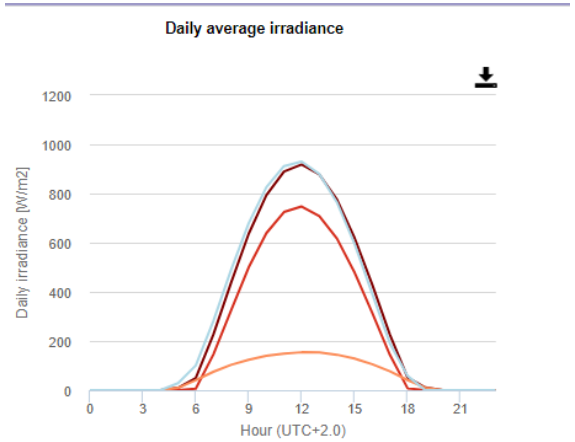
https://sunroof.withgoogle.com/building/37.476876/-122.253535/#?f=buy

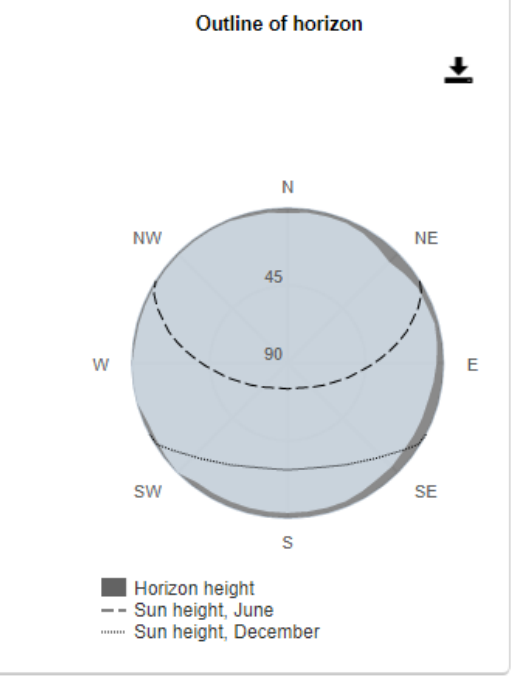


3. Creation (Additional apps and Websites)

https://re.jrc.ec.europa.eu/pvg_tools/en/#DR







4. Discussion

Explanation based on evidence

Describe ways and they can use to this end and give them directions how to discover them.

Consider other explanations

Can we estimate the solar irradiation in the Mars and the Moon surface?

What parameters we must consider in order to make estimates and accurate calculations compared to the Earth surface? (atmosphere, distance from the Sun, shading – Moon etc.)?

5. Reflection

Communicate explanation

Provide content which the teacher can use to help the students to get familiarized and to become efficient in scientific writing.

The teacher may ask from the students to prepare a short report in order to demonstrate and discuss their results. Also, students may be guided to follow the appropriate steps in terms of the report outline including:

An introduction and scope of the Activity

The study area (countries level) and data representation

The Methodology outline

Results and Discussion and finally,

Their conclusions

Chapter Break (Any Questions?)

Useful links

Estimated solar energy production: https://re.jrc.ec.europa.eu/pvg_tools/en/#DR

Solar City Engine: http://solarcityengine.irena.org/#simulatorview/1

Sun roof solar power estimation:
https://sunroof.withgoogle.com/building/42.399692/-71.128802/#?f=buy

Global Solar Atlas: https://globalsolaratlas.info/download

North Virginia Solar Map:
https://nvrc.maps.arcgis.com/apps/webappviewer/index.html?id=ef5c5dc969f341cc986cd431d94cdfe9

Estimate solar power potential: https://learn.arcgis.com/en/projects/estimate-solar-power-potential/ (ArcGIS Pro using free trial)

Thank you for your attention!

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