VSS Project:A Study on Carbon Sequestration of Campus Trees and Solar Power Generation

Members：Kaohsiung Girls' Senior High school

CHIANG,PEI-YU SU,YING-CHI

Instructor：Chien-Hung Chen

Summary

This study established a carbon sequestration database of campus trees using basic data observed on campus trees. After analyzing changes in the power generation of campus solar panels and electricity consumption, the total carbon sequestration of the KGHS campus trees was preliminarily estimated to be 934,797 kg.

Campus solar power generation is higher in summer than in winter, with a solar self-sufficiency rate reaching over 30%, thus achieving a appropriate carbon reduction. However, campus solar power generation is affected not only by seasonal variations but also by weather factors such as cloud cover and dust levels.

In the future, we hope to use a self-made, simple experimental device to capture carbon dioxide, and make some contributions to the issue of campus carbon reduction.

I. Motivation

With the prevalence of industrialization, carbon dioxide emissions are increasing, and global warming is a problem we are faced with. To understand how to reduce carbon emissions, we are dedicated to doing some research on carbon sequestration and the application of the renewable energy. We hope this research will help us have a better understanding of the natural resources around us and make better use of the renewable energy like solar energy.

II. Objectives

1. Observe the trees in our campus and their carbon sequestration data.
2. Discuss the changes in solar power generation.
3. Analyze the electricity consumption data in our campus.
4. Explore the impact of solar radiation on solar power generation

III. Approahes and Preliminary Conclusions(1)

There are many trees on campus. The carbon dioxide they inhale through photosynthesis every day becomes a carbon sink. We want to observe and calculate the carbon sink.

Approaches:

1. Measure the tree height and circumference.
2. Calculate the carbon sink of the plants throughout their lives using the Ministry of Education's campus tree platform.

After calculating the carbon sequestration of each tree (as shown in Appendix 1), the total carbon sequestration is 934,797 kg.

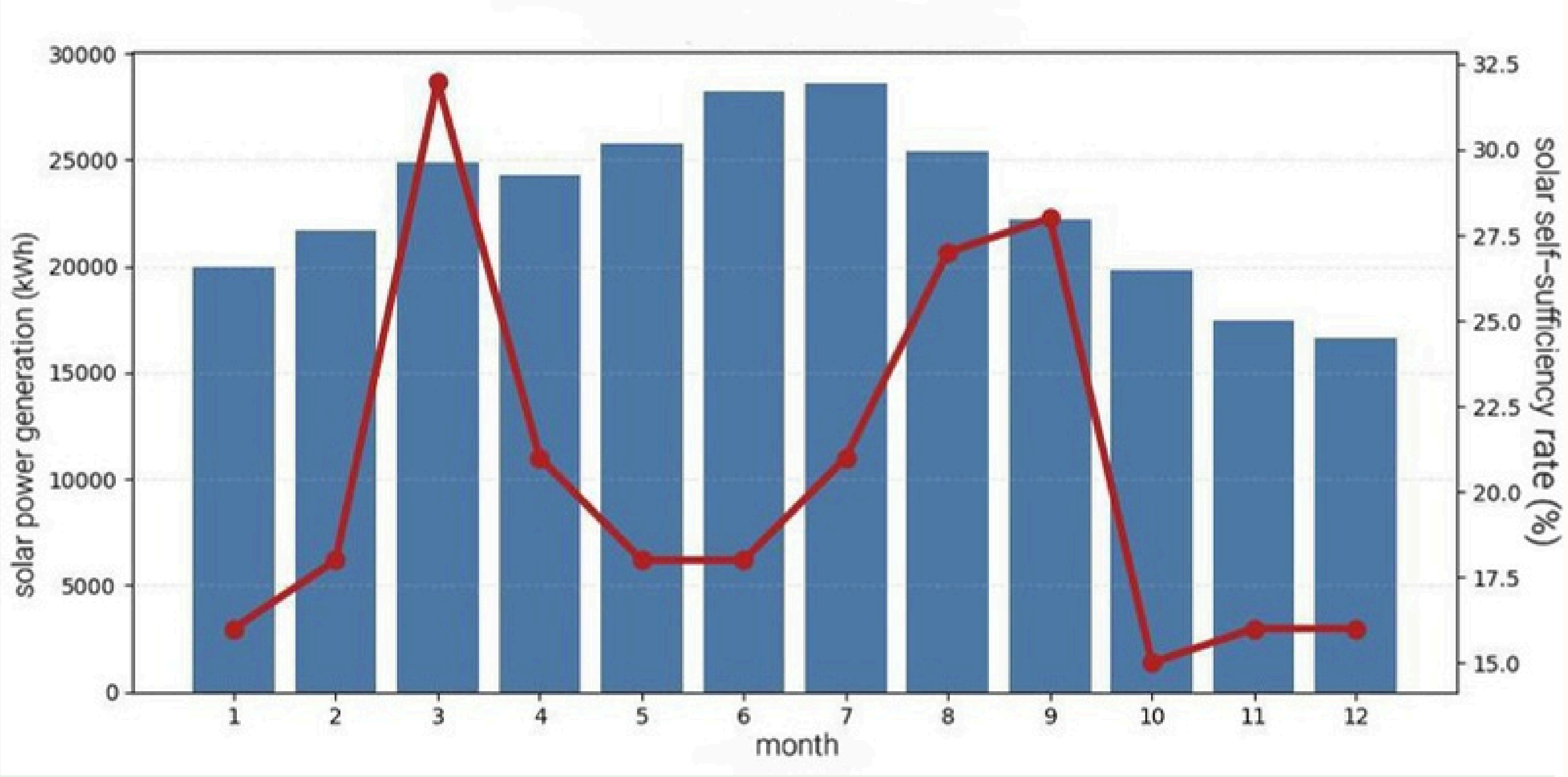
Based on the observation, we would like to convert all electricity consumption into carbon emissions and calculate the carbon offset ratio. Also, can the solar panels installed at the school help reduce carbon emission?

Tree Specie	Quantity	Trunk Circu	Tree Height	Carbon Stor	Total Carbo	Notes	Family
Royal Palm	76	139.5	22.7	436.6	33181.6	★	Arecaceae
Alexandrian	32	17.2	11.06	19.9	636.8	★	Clusiaceae
Blackboard	31	280	18.18	6175.3	191434.3		
Chinese Jun	22	40	2.5	22.7	499.4		
Fan-leaved :	16	209	11.81	2350.8	37612.8		
Orchid Islan	15	26	1.8	6.5	97.5		
Tropical Al	14	222	14.01	3658.5	51219		
Norfolk Isla	14	150	18.05	1625.7	22759.8	★	Araucariace
Golden Sho	14	106	12.83	1270.3	17784.2		
Chinese Ha	13	160	13.03	1970.3	25613.9		
Banyan Tre	13	600	15.83	24161.7	314102.1		
Indian Rose	11	216	15.29	4440.4	48844.4		
Golden Fig	11	49	1.45	14.8	162.8		
Small-leave	10	113	13.11	1054.1	10541		
Kapok Tree	9	173	19.51	1896.9	17072.1		
Sacred Fig	9	249	18.54	6922.6	62303.4	★	Moraceae
Yellow Paln	9	20	5	3.3	29.7	★	Arecaceae
Flame Tree	8	139	9.72	1200.2	9601.6		
Mango Tree	8	119	8.31	660.8	5286.4		
Broadleaf M	7	255	18.31	6417.8	44924.6		
Taiwan Gol	6	64	5	133.2	799.2		
Umbrella Tr	4	34	1.35	7.2	28.8		
Chinese Far	5	71	9.01	56.3	281.5	★	Arecaceae
Bottle Palm	5	110	8.04	114	570	★	Arecaceae
Hairy Persir	5	51	7.51	139.1	695.5		
Camphor Tr	4	86	9.1	368.4	1473.6		
Taiwan Sun	4	113	7.03	541	2164	★	Anacardiac
Soapberry T	4	39	8.15	86.6	346.4		
Chinaberry	4	115	14.69	1114.7	4458.8		
Banana Plar	4	40	2.5	23.9	95.6	★	Musaceae
Chinese Cin	3	85	9.04	341.4	1024.2		
Dillenia	3	75	13.67	463.6	1390.8	★	Dilleniacea
Kassod Tree	3	188	9.14	2350.8	7052.4		
Longan Tree	1	95	6.49	442.1	442.1		
Indian Beec	3	230	17.14	6452.4	19357.2		
Avocado Tr	3	120	3.5	303.3	909.9	★	

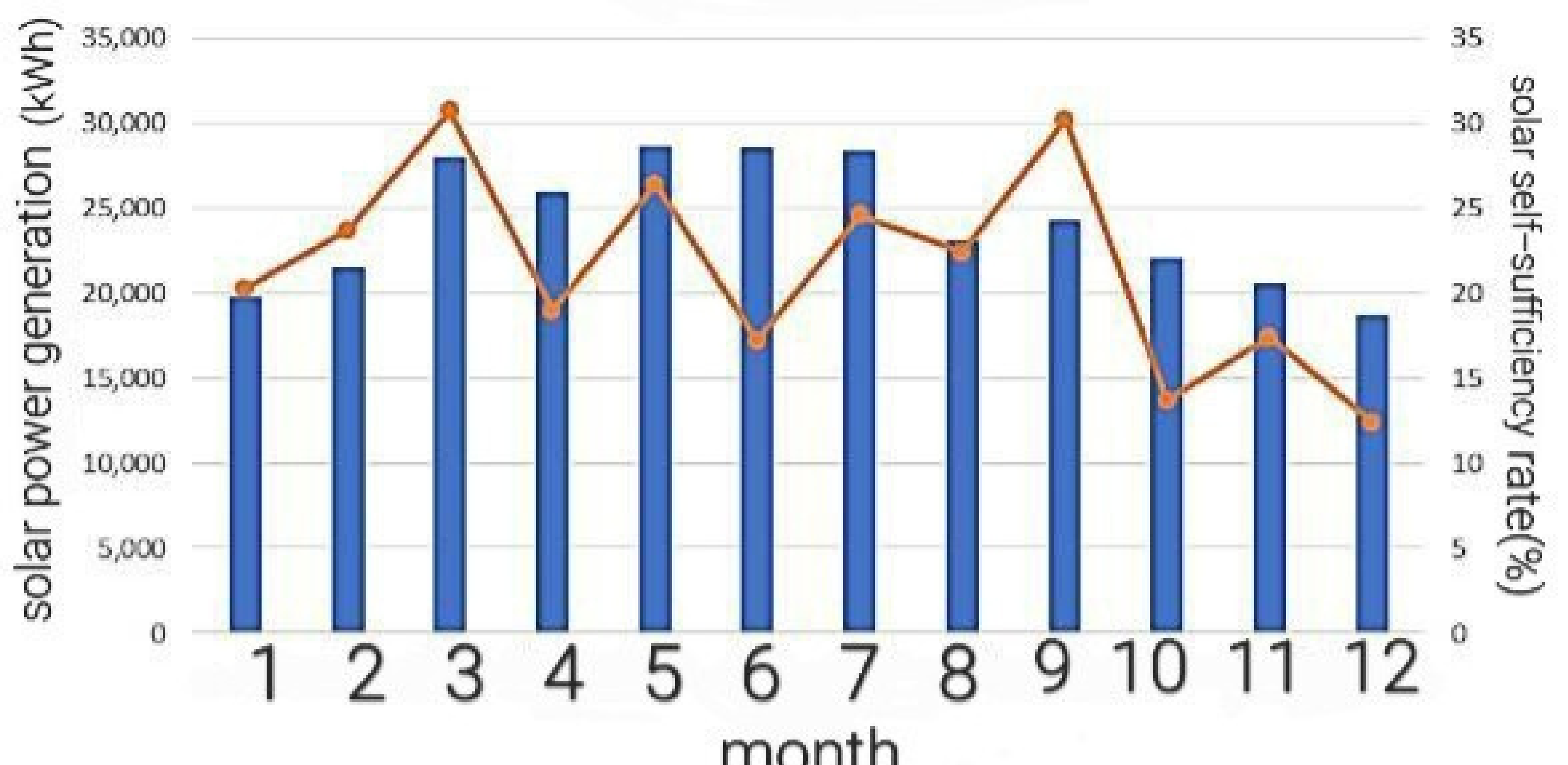
Approaches and Preliminary Conclusions(2)

Using solar power generation data from 2023 and 2024, we analyzed the amount of power generated in different months and the changes in the solar self-sufficiency rate.

The relationship between solar power generation and self-sufficiency rate in 2024



The relationship between solar power generation and self-sufficiency rate in 2023



After comparing the data, the findings are as follows:

1. Solar Power generation in January and December is relatively low (for detailed analysis, please see Approaches and Preliminary Conclusions(4)).
2. Solar Power generation in May, June, and July is higher than in the other months.
3. In terms of solar self-sufficiency rates, July and August have higher rates.(Because it is summer vacation in Taiwan)
4. In April, June, October, November, and December of 2023, the solar self-sufficiency rates are below 20%.
5. In January, February, May, June, October, November, and December of 2024, the solar self-sufficiency rates are below 20%

Approaches and Preliminary Conclusions(3)

We analyzed the changes in campus electricity consumption and calculated the net electricity consumption in 2023 and 2024 to estimate campus carbon dioxide emissions.

Calculation Method:

1. 2023 Total Electricity Consumption 1,420,526 kWh - Solar Power Generation 289,596 kWh = Net Electricity Consumption 1,130,930 kWh

2. Net electricity consumption converted into carbon dioxide emissions: 1,130,930 x 0.494 = 558,679.42 kg

2023 electricity carbon emission factor = 0.494 kg CO_2e/kWh Source: Ministry of Economic Affairs

4. Total electricity consumption: 1,409,596 kWh - Solar power generation: 274,992 kWh=Total Electricity consumption: 1,134,604 kWh

Total carbon dioxide emissions (converted to CO2 emissions):1,134,604 x 0.474 = 537,802.296 kg

5. The sum of these two sets of data, compared with the previously calculated carbon sequestration of campus trees

(the next page……)

2024 electricity carbon emission factor = 0.474 kg CO2e/kWh Source: Ministry of Economic Affairs (the amount of carbon intake throughout their lifetime), is roughly equivalent to our carbon emissions over these two years. It means that our our carbon emissions over two years are almost equal to the carbon sequestration of a tree throughout its life.

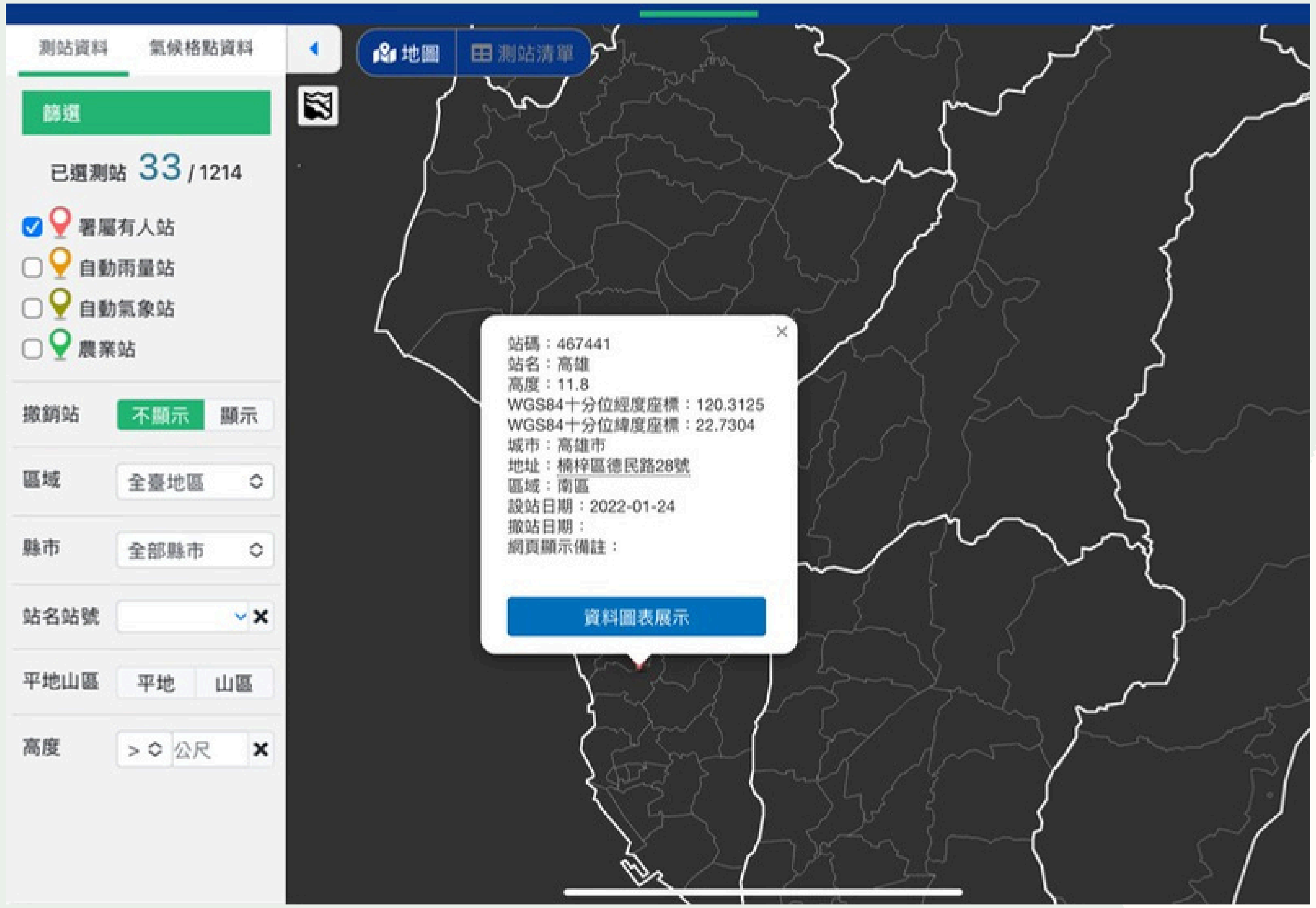
Approaches and Preliminary Conclusions(4)

Since we discovered that the carbon emission from regular electricity consumption far exceeds the carbon intake from trees, we wanted to conduct a more in-depth study of solar energy, a renewable energy source, and explore the amount of solar power generation under different conditions.

1. Our hypothesis was that higher cloud cover leads to lower solar power generation.
2. We plotted the relationship between cloud cover and solar power generation in 2023 and 2024.

3.We used the analysis results from Study 2 to deduce the reasons.

4.We then used the data from CODiS (Climate Observation Data Inquiry Service) to observe the variables.



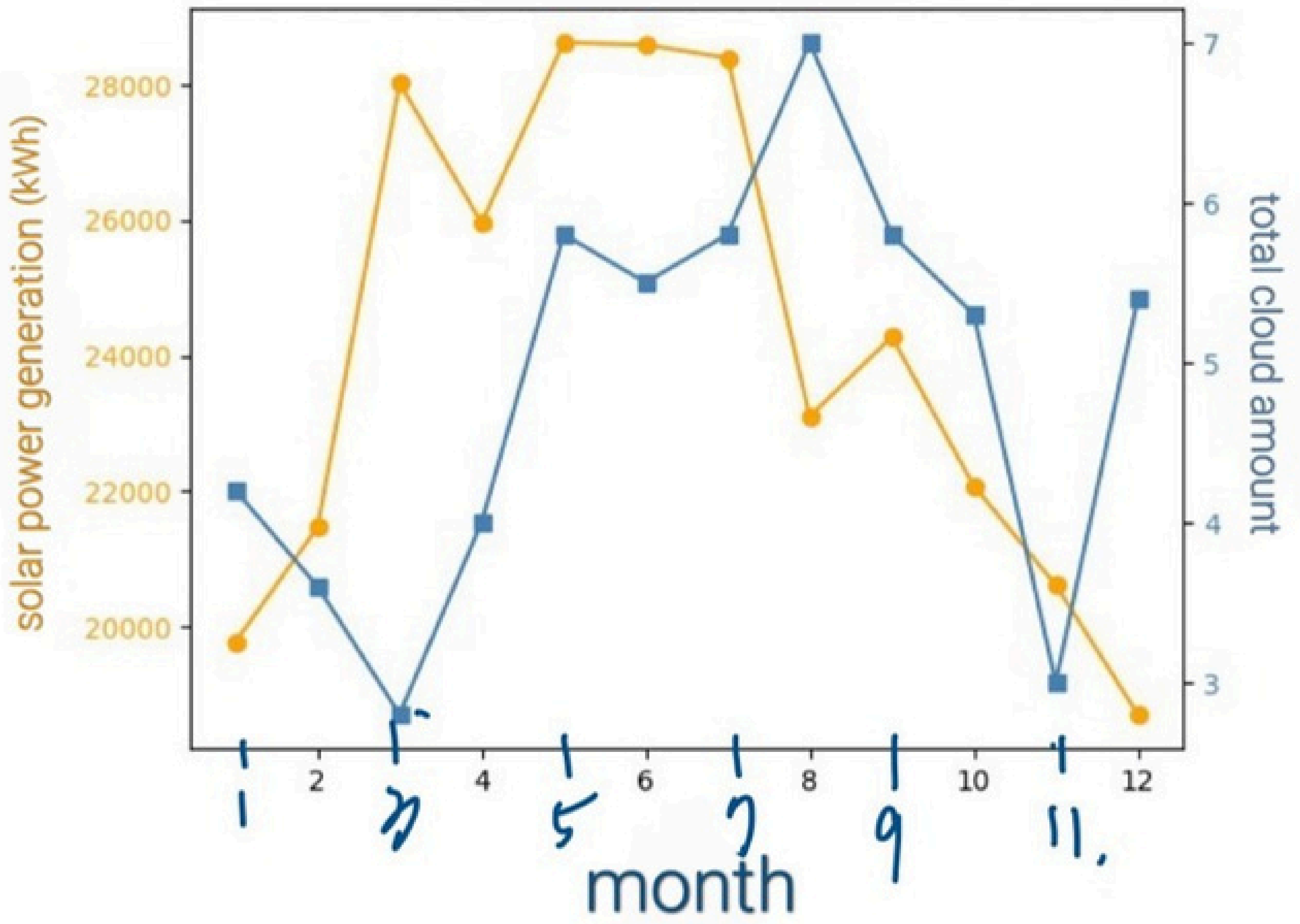
This is a screenshot from the CODiS Kaohsiung station.

Meteorological data from the Kaohsiung monitoring station

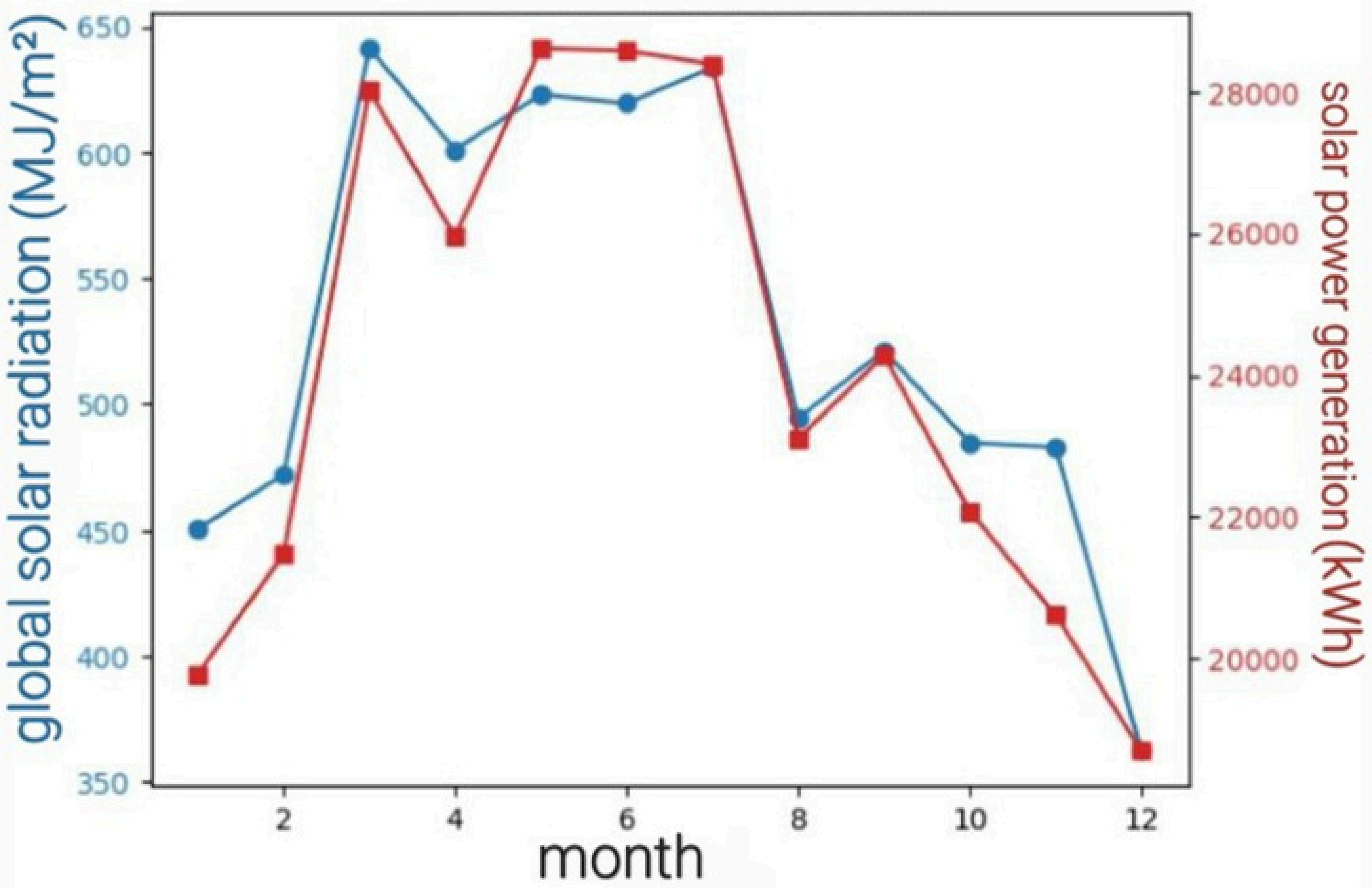
1.Observing that power generation was lower in January and December, we decided to begin our discussion here.

2. Based on data from the Meteorological Service, our goal is to identify the extreme values for January and December and compare them with power generation data

3.Based on the data, we found that the trends of "total solar radiation" and solar power generation are almost identical (taking 2023 data as an example). (on the next page)



The relationship between cloud cover and solar power generation

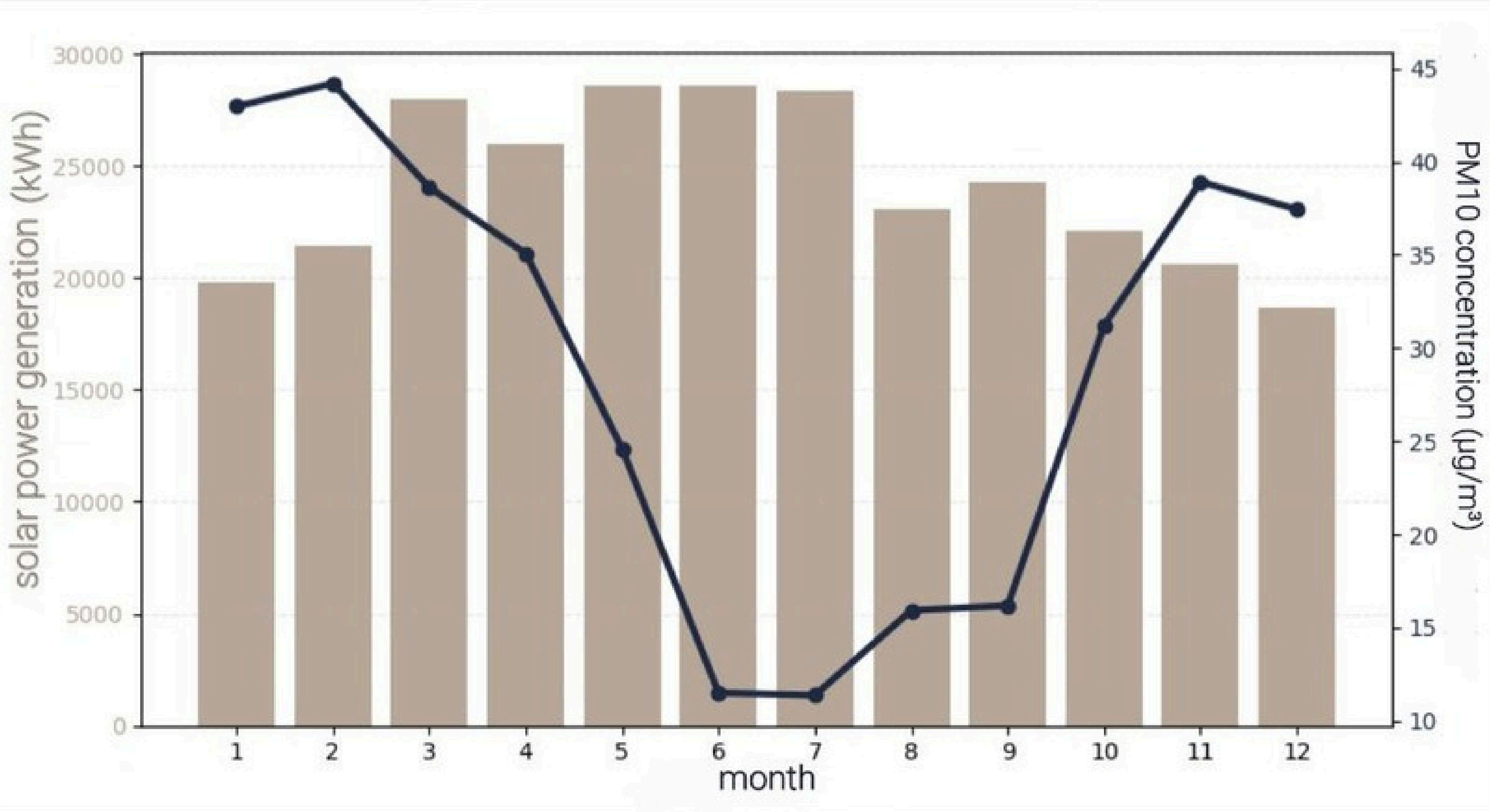


The relationship between total sky solar radiation and solar power generation

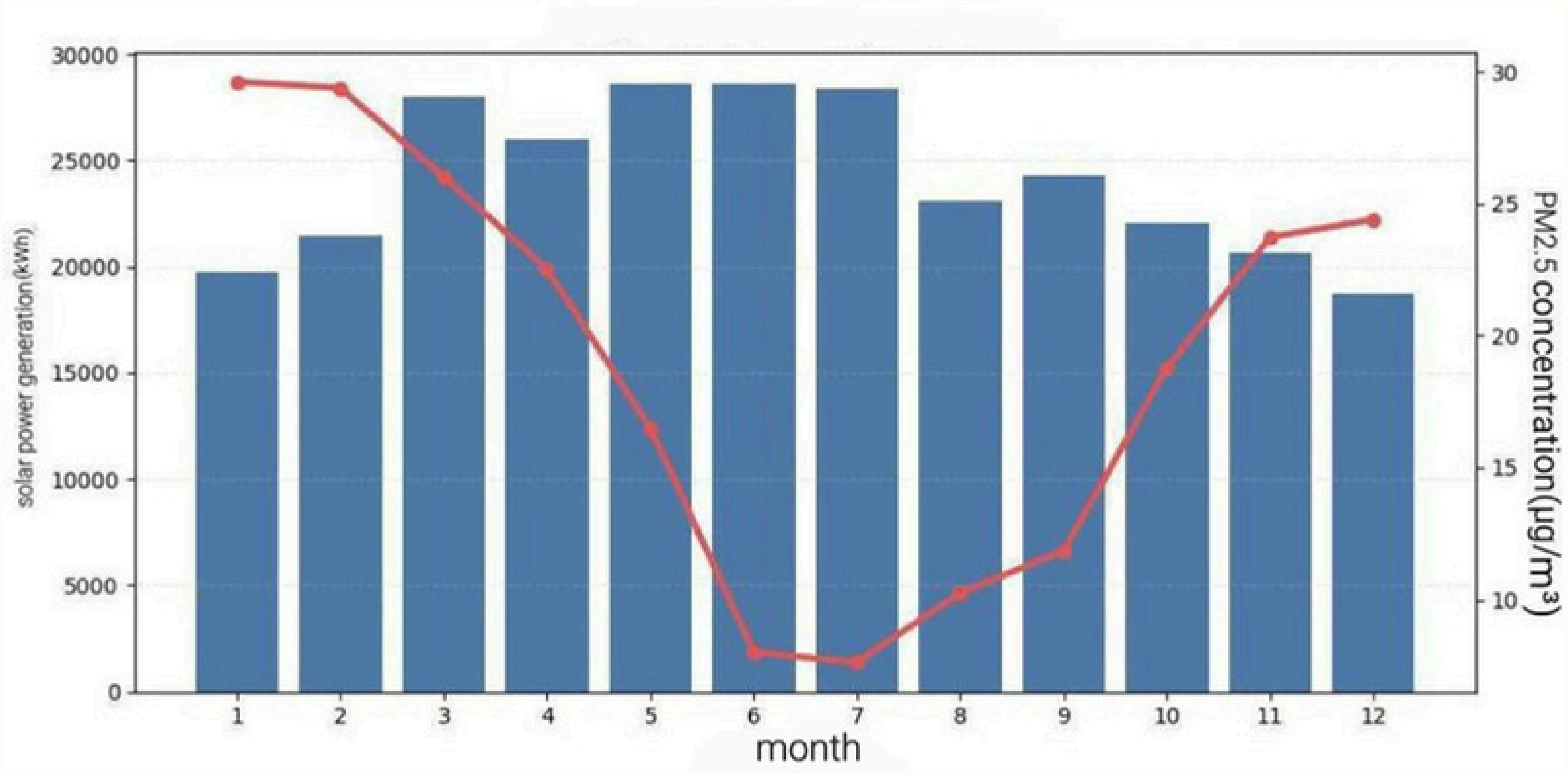
- Total sky solar radiation is defined as the total solar radiation energy received per unit area per unit time from the entire sky (including direct, scattered, and reflected radiation). The unit is commonly megajoules per square meter (MJ/m^2) or kWh/m^2. It is an important indicator for evaluating solar power generation and climate research, and is mainly measured by instruments such as all-sky solar meters.

This is likely related to the sun's angle of incidence. In winter, the sun shines directly on the Tropic of Capricorn, while in Taiwan, in the Northern Hemisphere, the sun's angled rays disperse the energy, thus reducing the total solar radiation across the sky in winter.

In addition, we also considered the relationship between haze and power generation (assuming that haze concentration is high and power generation is low). Therefore, we compared the monthly concentrations of PM2.5 and PM10 in Qianjin District, Kaohsiung City, as reported by the Ministry of Environment to explore their relationship (using 2023 data as an example).



The relationship between solar energy and PM10 concentration



The relationship between solar energy and PM2.5 concentration

Forth: Research Results

1. Kaohsiung is located on the leeward side of the northeast monsoon, resulting in weaker air diffusion capabilities. Therefore, pollutants tend to remain, leading to haze.
2. Particulate matter in haze can affect the efficiency of solar power generation.

- Based on the study of these two variables, we found that the solar panels on campus have already achieved maximum efficiency, and their installation angle is suitable for the local geographical environment.

Fifth : Conclusions

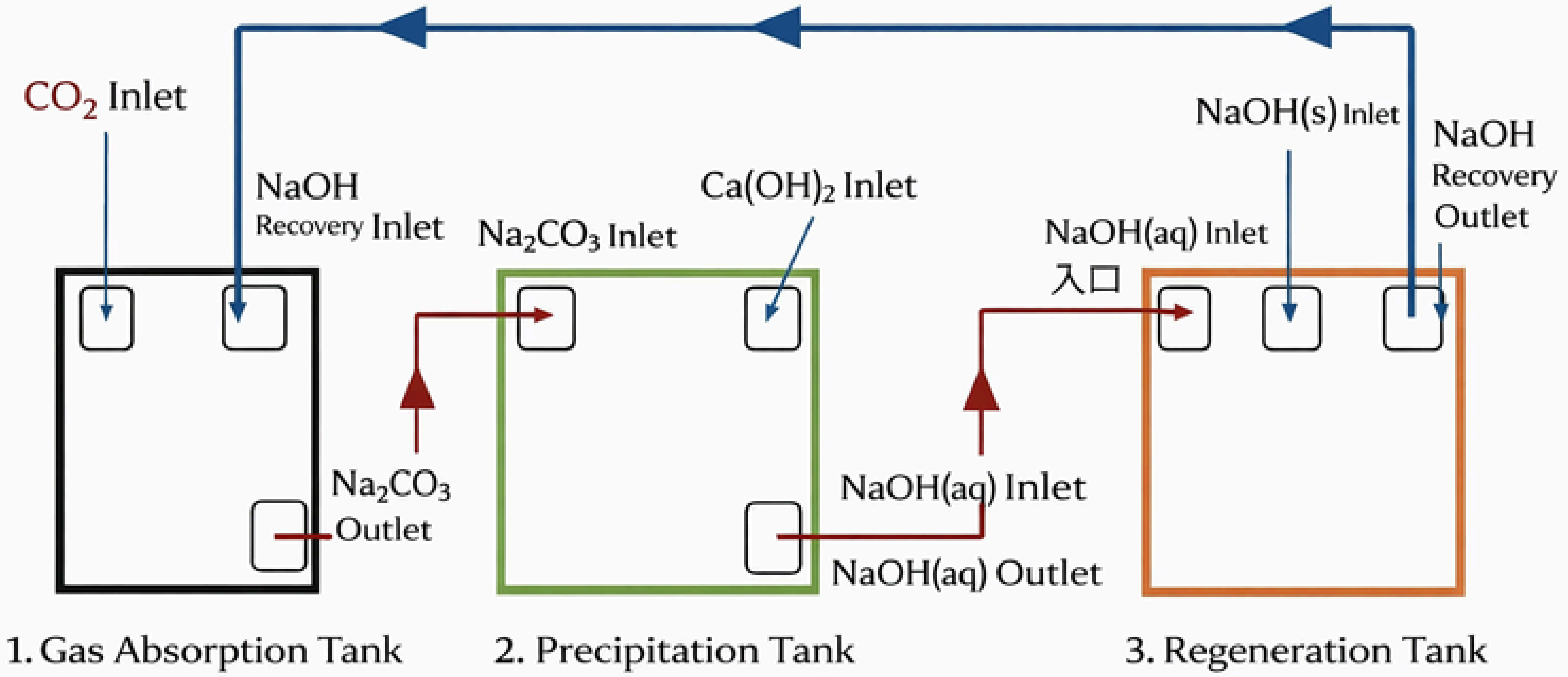
1.After calculation, we preliminarily estimated the total carbon sequestration of trees on the Kaohsiung Girls' High School campus to be 934,797 kg.

2.Solar power generation is higher in summer and lower in winter; the solar-self sufficiency rate is lower in June, October, and November (possibly related to high electricity consumption due to air conditioning use), and particularly high in July and August.

3. By calculating net electricity consumption and converting it into carbon dioxide emissions, and then comparing it with previously estimated carbon sequestration, we found that the campus's carbon emissions in just two years already exceed the carbon sequestration accumulated by trees over decades.
4. Through data analysis and comparison, we found a high correlation between total solar radiation (the total energy of solar radiation per unit time and area) and solar power generation, while cloud cover and winter dust haze also affect solar power generation.

Future Outlook

Following this investigation, we discovered that it is difficult for all emitted carbon dioxide to be absorbed and transformed into environmentally harmless substances. Therefore, we devised an experimental method to capture it. Unfortunately, due to time constraints, we have not yet reached the experimental stage. We hope to present this research in its entirety next year and help the world recover some carbon dioxide and transform it into usable materials.



That is our plan ! We hope that we can do this experiment next year!

References:

1. Campus Tree Information Platform.
https://edutreemap.moe.edu.tw/trees/#/Carbon
2. CODiS Climate Observation Data Query Service.
https://codis.cwa.gov.tw/StationData
3. Historical Monitoring Data. Air Quality Monitoring Network of Ministry of Environment.
https://airtw.moenv.gov.tw/cht/Query/His_Data.aspx