SOLAR ENERGY INTERNATIONAL

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Exercise: Peak Sun Hours

For questions #1-7, refer to NREL Redbook solar radiation data. A PDF for each state used here is attached to the end of this Exercise. A copy of the full Redbook is available here: https://www.nrel.gov/docs/legosti/old/5607.pdf. Note that "Flat-Plate Collector" data is used for PV purposes.

For questions #1-4 use the attached NREL Redbook data file for Colorado:

1) What is the latitude of Grand Junction, Colorado, USA?

2) A south-facing, fixed-tilt PV array in the Grand Junction, Colorado area is tilted at an angle equal to the latitude minus 15º (approximately 25 degrees from horizontal). There is no shading. How many peak sun hours (kWh/m^2/day) does the array receive on average in May?

3) How many peak sun hours does this same array receive on average in December?

4) How many peak sun hours does this same array receive on average in June?

For questions #5-7 use the attached NREL Redbook data file for Alaska:

5) What is the latitude of Barrow, Alaska, USA?

6) A south-facing, fixed-tilt PV array in the Barrow, Alaska area is tilted at an angle equal to the latitude plus 15º (approximately 86 degrees from horizontal). How many peak sun hours (kWh/m^2/day) does the array receive on average in January?

7) How many peak sun hours does this same array receive on average in April?

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For questions #8-11 use the PVWatts data for Cartago, Costa Rica. Perform your own simulation at https://pvwatts.nrel.gov/pvwatts.php or see the attached printout at the end of this exercise.

8) What is the latitude of Cartago, Costa Rica?

9) A 1 kW array of standard modules is mounted on a fixed roof with default PVWatts losses; this array is south-facing, unshaded, and tilted at an angle of 25º. How many peak sun hours ($kWh/m^2/day$) does the array receive on average in January?

10) How many peak sun hours does this same array receive on average in June?

11) What is the annual average peak sun hours for the same array?

12) Assume the locations above (Grand Junction, CO, Barrow, AK, and Cartago, CR) – need to generate the same amount of electricity on an annual basis. All three locations have unshaded PV arrays that face true South and are tilted at the angles shown below. Which location would need the largest array? Which would need the smallest? Why?

Grand Junction, Colorado array tilt angle = 39º
Barrow, Alaska array tilt angle = 71º
Cartago, Costa Rica array tilt angle = 25º

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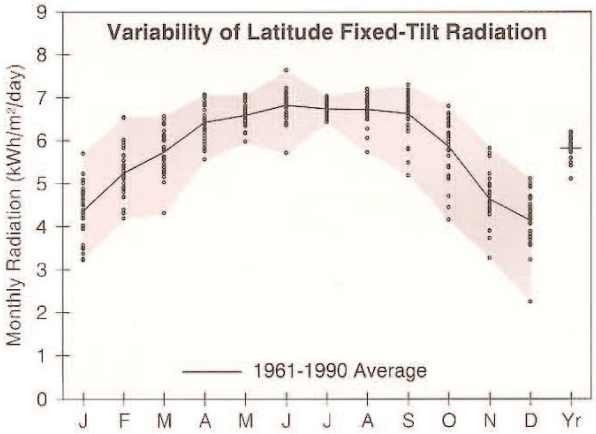

Grand Junction, CO

WBAN NO. 23066

LATITUDE: 39.12° N
LONGITUDE: 108.53° W
ELEVATION: 1475 meters
MEAN PRESSURE: 853 millibars

STATION TYPE: Primary

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	2.5	3.5	4.6	6.0	7.0	7.7	7.4	6.6	5.5	4.1	2.7	2.2	5.0
	Min/Max	2.1/2.9	3.0/4.1	3.8/5.1	5.3/6.5	6.3/7.5	6.4/8.7	7.1/7.7	5.7/7.1	4.5/6.0	3.1/4.5	2.2/3.2	1.5/2.5	4.6/5.2
Latitude -15	Average	3.8	4.7	5.5	6.5	7.0	7.5	7.3	7.0	6.5	5.4	4.1	3.6	5.7
	Min/Max	2.9/4.8	3.9/5.8	4.3/6.3	5.7/7.2	6.3/7.5	6.2/8.4	7.0/7.6	6.0/7.5	5.2/7.2	3.9/6.2	3.0/5.0	2.0/4.3	5.1/6.1
Latitude	Average	4.4	5.2	5.7	6.4	6.6	6.8	6.7	6.7	6.6	5.9	4.6	4.1	5.8
	Min/Max	3.2/5.7	4.2/6.6	4.3/6.6	5.6/7.1	6.0/7.1	5.7/7.6	6.4/7.0	5.7/7.2	5.2/7.3	4.2/6.8	3.3/5.8	2.3/5.1	5.1/6.2
Latitude +15	Average	4.7	5.4	5.6	6.0	5.8	5.8	5.8	6.1	6.4	6.0	4.9	4.5	5.6
	Min/Max	3.4/6.2	4.3/6.9	4.2/6.5	5.1/6.6	5.3/6.2	4.9/6.5	5.6/6.1	5.2/6.5	4.9/7.0	4.2/6.9	3.4/6.2	2.4/5.6	4.8/6.0
90	Average	4.4	4.7	4.2	3.7	3.0	2.7	2.8	3.5	4.4	4.8	4.4	4.3	3.9
	Min/Max	3.0/5.8	3.5/6.4	3.0/4.8	3.2/4.0	2.9/3.2	2.4/2.9	2.7/2.9	3.0/3.7	3.4/4.8	3.3/5.6	3.0/5.7	2.2/5.3	3.3/4.3

Solar Radiation for 1-Axis Tracking Flat-Plate Collectors with a North-South Axis (kWh/m²/day), Uncertainty ±9%

Axis Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	3.7	5.1	6.4	8.2	9.5	10.6	10.1	9.2	8.1	6.1	4.2	3.4	7.0
	Min/Max	2.7/4.8	3.9/6.5	4.4/7.5	7.0/9.4	7.7/10.5	8.3/12.4	9.3/10.7	7.6/10.2	6.0/9.0	4.1/7.1	2.8/5.2	1.9/4.2	6.0/7.5
Latitude -15	Average	4.7	6.0	7.1	8.7	9.6	10.6	10.1	9.5	8.9	7.1	5.1	4.4	7.7
	Min/Max	3.4/6.2	4.6/7.8	4.9/8.4	7.3/10.0	7.9/10.7	8.3/12.3	9.4/10.7	7.9/10.6	6.5/9.9	4.8/8.4	3.4/6.6	2.3/5.5	6.4/8.2
Latitude	Average	5.2	6.4	7.3	8.7	9.3	10.1	9.8	9.4	9.0	7.5	5.6	4.9	7.8
	Min/Max	3.7/6.9	4.8/8.4	4.9/8.7	7.2/9.9	7.6/10.4	7.9/11.9	9.0/10.4	7.7/10.4	6.6/10.0	5.0/8.8	3.7/7.2	2.5/6.1	6.4/8.3
Latitude +15	Average	5.4	6.6	7.2	8.3	8.8	9.5	9.2	8.9	8.8	7.5	5.8	5.2	7.6
	Min/Max	3.8/7.3	4.9/8.6	4.8/8.6	6.9/9.6	7.2/9.8	7.4/11.1	8.4/9.7	7.4/10.0	6.4/9.8	5.0/8.9	3.8/7.5	2.6/6.5	6.3/8.2

Solar Radiation for 2-Axis Tracking Flat-Plate Collectors (kWh/m²/day), Uncertainty ±9%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	5.5	6.6	7.3	8.8	9.7	10.8	10.3	9.6	9.0	7.6	5.8	5.2	8.0
	Min/Max	3.8/7.4	4.9/8.6	5.0/8.7	7.3/10.0	8.0/10.9	8.4/12.7	9.5/10.9	7.9/10.7	6.6/10.0	5.0/8.9	3.8/7.5	2.6/6.6	6.7/8.6

Direct Beam Solar Radiation for Concentrating Collectors (kWh/m²/day), Uncertainty ±8%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1-Axis, E-W Horiz Axis	Average	3.3	3.7	3.7	4.3	5.0	5.9	5.5	5.1	4.9	4.5	3.6	3.4	4.4
	Min/Max	1.9/5.3	2.3/5.2	1.8/4.9	3.2/5.4	3.5/6.0	4.3/7.6	4.8/6.2	3.7/5.8	3.0/5.9	2.6/5.6	2.1/5.2	1.2/4.7	3.3/4.9
1-Axis, N-S Horiz Axis	Average	2.5	3.4	4.3	5.7	6.7	7.9	7.4	6.7	6.2	4.6	2.9	2.3	5.1
	Min/Max	1.5/4.0	2.0/4.9	1.9/5.7	4.0/7.2	4.5/8.2	5.6/10.2	6.3/8.2	4.7/7.9	3.7/7.3	2.5/5.8	1.6/4.2	0.8/3.3	3.7/5.6
1-Axis, N-S Tilt=Latitude	Average	3.6	4.5	5.0	6.0	6.5	7.5	7.0	6.9	6.9	5.8	4.1	3.6	5.6
	Min/Max	2.2/5.8	2.7/6.4	2.3/6.6	4.3/7.5	4.4/8.0	5.3/9.6	6.0/7.8	4.8/8.0	4.1/8.1	3.2/7.2	2.3/5.9	1.2/5.0	4.1/6.2
2-Axis	Average	3.9	4.7	5.0	6.1	6.9	8.1	7.6	7.1	6.9	5.8	4.4	3.9	5.9
	Min/Max	2.3/6.3	2.8/6.5	2.3/6.6	4.3/7.7	4.6/8.4	5.8/10.4	6.4/8.4	4.9/8.3	4.1/8.2	3.2/7.3	2.4/6.3	1.3/5.5	4.3/6.5

Average Climatic Conditions

Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-3.9	1.4	6.3	11.2	16.7	22.4	26.0	24.7	19.4	12.6	4.7	-1.8	11.7
Daily Minimum Temp	-9.7	-4.7	-0.4	3.6	8.8	13.9	17.7	16.8	11.6	5.3	-1.4	-7.4	4.5
Daily Maximum Temp	1.9	7.4	13.1	18.8	24.4	30.9	34.2	32.5	27.3	19.8	10.8	3.7	18.8
Record Minimum Temp	-30.6	-27.8	-15.0	-11.7	-3.3	1.1	7.8	6.1	-1.7	-7.8	-18.9	-27.2	-30.6
Record Maximum Temp	15.6	20.0	27.2	29.4	35.0	40.6	40.6	39.4	36.7	31.1	23.9	17.8	40.6
HDD, Base 18.3°C	689	474	372	216	73	7	0	0	31	184	410	625	3082
CDD, Base 18.3°C	0	0	0	0	22	131	238	196	64	7	0	0	657
Relative Humidity (%)	70	60	50	40	36	29	34	37	39	46	58	68	47
Wind Speed (m/s)	2.5	2.9	3.6	4.1	4.2	4.2	4.1	3.9	3.8	3.4	3.0	2.5	3.5

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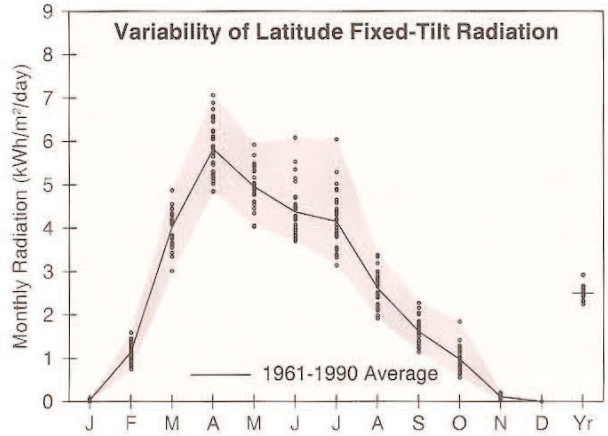
Barrow, AK

WBAN NO. 27502

LATITUDE: 71.30° N
LONGITUDE: 156.78° W
ELEVATION: 4 meters
MEAN PRESSURE: 1016 millibars

STATION TYPE: Secondary



Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	0.0	0.3	1.6	3.7	4.7	4.9	4.5	2.6	1.3	0.5	0.0	0.0	2.0
	Min/Max	0.0/0.0	0.2/0.3	1.4/1.7	3.3/4.1	4.0/5.3	4.4/6.2	3.7/5.9	2.2/3.0	1.2/1.5	0.4/0.6	0.0/0.0	0.0/0.0	1.9/2.1
Latitude -15	Average	0.0	1.1	3.8	5.8	5.2	4.8	4.6	2.8	1.7	0.9	0.1	0.0	2.6
	Min/Max	0.0/0.1	0.7/1.5	2.9/4.6	4.9/7.0	4.3/6.2	4.1/6.6	3.5/6.6	2.1/3.6	1.2/2.3	0.6/1.7	0.0/0.2	0.0/0.0	2.3/3.0
Latitude	Average	0.0	1.1	4.0	5.8	4.9	4.4	4.2	2.6	1.6	1.0	0.1	0.0	2.5
	Min/Max	0.0/0.1	0.8/1.6	3.0/4.9	4.8/7.1	4.0/5.9	3.7/6.1	3.1/6.0	1.9/3.4	1.1/2.3	0.6/1.8	0.0/0.2	0.0/0.0	2.2/2.9
Latitude +15	Average	0.0	1.2	4.0	5.6	4.6	3.8	3.6	2.3	1.5	1.0	0.1	0.0	2.3
	Min/Max	0.0/0.1	0.8/1.6	3.0/4.8	4.6/6.7	3.6/5.5	3.2/5.4	2.7/5.2	1.7/3.0	1.0/2.1	0.5/1.9	0.0/0.2	0.0/0.0	2.1/2.7
90	Average	0.0	1.2	3.9	5.4	4.5	3.6	3.4	2.2	1.4	1.0	0.1	0.0	2.2
	Min/Max	0.0/0.1	0.8/1.6	2.9/4.8	4.5/6.6	3.5/5.4	3.0/5.1	2.6/5.0	1.6/2.9	1.0/2.0	0.5/1.8	0.0/0.2	0.0/0.0	2.0/2.6

Solar Radiation for 1-Axis Tracking Flat-Plate Collectors with a North-South Axis (kWh/m²/day), Uncertainty ±9%

Axis Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	0.0	0.5	3.2	6.5	6.3	6.4	6.0	3.2	1.6	0.7	0.0	0.0	2.9
	Min/Max	0.0/0.0	0.4/0.7	2.5/3.9	5.4/8.3	4.7/7.6	5.0/9.1	4.4/9.3	2.3/4.1	1.2/2.3	0.4/1.1	0.0/0.1	0.0/0.0	2.5/3.3
Latitude -15	Average	0.0	1.2	4.9	8.2	7.0	6.9	6.6	3.5	1.9	1.0	0.1	0.0	3.5
	Min/Max	0.0/0.1	0.8/1.6	3.6/6.0	6.8/10.6	5.1/8.7	5.2/10.3	4.6/10.6	2.3/4.8	1.3/2.9	0.6/2.0	0.0/0.2	0.0/0.0	3.0/4.1
Latitude	Average	0.0	1.2	5.0	8.2	6.9	6.7	6.4	3.4	1.9	1.1	0.1	0.0	3.4
	Min/Max	0.0/0.1	0.8/1.7	3.7/6.1	6.8/10.6	5.0/8.6	5.0/10.1	4.4/10.4	2.2/4.7	1.2/2.9	0.6/2.1	0.0/0.2	0.0/0.0	3.0/4.1
Latitude +15	Average	0.0	1.3	5.0	8.0	6.7	6.4	6.1	3.2	1.8	1.1	0.1	0.0	3.3
	Min/Max	0.0/0.1	0.8/1.8	3.7/6.1	6.7/10.4	4.8/8.3	4.8/9.7	4.1/10.0	2.0/4.4	1.2/2.8	0.6/2.1	0.0/0.2	0.0/0.0	2.9/4.0

Solar Radiation for 2-Axis Tracking Flat-Plate Collectors (kWh/m²/day), Uncertainty ±9%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	0.0	1.3	5.0	8.3	7.1	7.3	6.9	3.6	1.9	1.1	0.1	0.0	3.6
	Min/Max	0.0/0.1	0.8/1.8	3.7/6.1	6.9/10.6	5.2/8.8	5.5/10.7	4.8/11.1	2.4/4.9	1.3/3.0	0.6/2.1	0.0/0.2	0.0/0.0	3.1/4.2

Direct Beam Solar Radiation for Concentrating Collectors (kWh/m²/day), Uncertainty ±8%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1-Axis, E-W Horiz Axis	Average	0.0	0.8	2.7	3.6	2.0	2.6	2.8	1.1	0.5	0.4	0.1	0.0	1.4
	Min/Max	0.0/0.1	0.4/1.2	1.6/3.5	2.6/5.1	0.8/3.2	1.3/4.8	1.4/5.6	0.4/1.9	0.2/1.2	0.1/1.1	0.0/0.2	0.0/0.0	1.1/1.8
1-Axis, N-S Horiz Axis	Average	0.0	0.3	2.0	3.9	2.4	3.0	3.2	1.2	0.5	0.2	0.0	0.0	1.4
	Min/Max	0.0/0.0	0.2/0.5	1.3/2.7	2.7/5.8	0.9/3.8	1.5/5.4	1.5/6.4	0.5/2.2	0.1/1.2	0.1/0.6	0.0/0.0	0.0/0.0	1.0/1.8
1-Axis, N-S Tilt=Latitude	Average	0.0	0.9	3.4	5.1	2.8	3.4	3.6	1.5	0.7	0.4	0.1	0.0	1.8
	Min/Max	0.0/0.1	0.5/1.3	2.2/4.6	3.7/7.5	1.0/4.4	1.7/6.1	1.8/7.3	0.6/2.7	0.2/1.7	0.1/1.3	0.0/0.2	0.0/0.0	1.4/2.4
2-Axis	Average	0.0	0.9	3.4	5.2	2.9	3.7	3.9	1.6	0.7	0.5	0.1	0.0	1.9
	Min/Max	0.0/0.1	0.5/1.3	2.2/4.6	3.7/7.6	1.1/4.7	1.8/6.6	1.9/7.9	0.6/2.8	0.2/1.8	0.1/1.3	0.0/0.2	0.0/0.0	1.5/2.5

Average Climatic Conditions

Element	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-25.2	-27.7	-26.2	-19.0	-7.1	1.1	4.1	3.3	-0.8	-10.3	-18.7	-24.0	-12.6
Daily Minimum Temp	-28.5	-30.9	-29.5	-22.8	-9.8	-1.3	0.9	0.7	-2.8	-12.9	-21.6	-27.3	-15.5
Daily Maximum Temp	-21.9	-24.3	-22.8	-15.2	-4.3	3.5	7.2	5.7	1.0	-7.7	-15.8	-20.7	-9.6
Record Minimum Temp	-47.2	-48.9	-46.7	-41.1	-28.3	-15.6	-5.6	-6.7	-17.2	-35.6	-40.0	-48.3	-48.9
Record Maximum Temp	2.2	2.2	0.6	5.6	7.2	21.7	25.6	24.4	16.7	6.1	3.9	1.1	25.6
HDD, Base 18.3°C	1350	1288	1379	1120	787	517	443	467	575	887	1112	1312	11237
CDD, Base 18.3°C	0	0	0	0	0	0	0	0	0	0	0	0	0
Relative Humidity (%)	73	70	71	77	87	89	88	91	91	86	79	74	81
Wind Speed (m/s)	5.5	5.0	5.1	5.2	5.3	5.3	5.2	5.6	6.0	5.8	5.6	5.2	5.4

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PVWatts® Calculator

NREL

My Location | Cartago, Costa Rica » Change Location | English | Español | HELP | FEEDBACK

RESOURCE DATA | SYSTEM INFO | RESULTS

SOLAR RESOURCE DATA

The latitude and longitude of the solar resource data site is shown below, along with the distance between your location and the center of the site grid cell. Use this data unless you have a reason to change it.

Solar resource data site: Lat, Lng: 9.81, -83.7 — 1.2 mi

Go to system info

RESOURCE DATA | SYSTEM INFO | RESULTS

SYSTEM INFO

RESTORE DEFAULTS

Modify the inputs below to run the simulation.

DC System Size (kW):	1
Module Type:	Standard
Array Type:	Fixed (roof mount)
System Losses (%):	14.08
Tilt (deg):	25
Azimuth (deg):	180

Loss Calculator

Draw Your System

Click below to customize your system on a map. (optional)

Advanced Parameters

Go to resource data

Go to PVWatts results

RESOURCE DATA | SYSTEM INFO | RESULTS

RESULTS

Print Results

1,133 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	4.70	104
February	4.77	94
March	4.67	101
April	4.41	93
May	4.03	89
June	3.86	82
July	3.76	83
August	4.20	93
September	4.61	98
October	4.77	106
November	4.32	93
December	4.42	97
Annual	4.38	1,133

Go to system info

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Exercise Key: Peak Sun Hours

1) 39.12º N

Explanation

Grand Junction, CO

WBAN NO. 23066

LATITUDE: 39.12° N
LONGITUDE: 108.53° W
ELEVATION: 1475 meters
MEAN PRESSURE: 853 millibars

STATION TYPE: Primary

2) 7.0

Explanation

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	2.5	3.5	4.6	6.0	7.0	7.7	7.4	6.6	5.5	4.1	2.7	2.2	5.0
	Min/Max	2.1/2.9	3.0/4.1	3.8/5.1	5.3/6.5	6.3/7.5	6.4/8.7	7.1/7.7	5.7/7.1	4.5/6.0	3.1/4.5	2.2/3.2	1.5/2.5	4.6/5.2
Latitude -15	Average	3.8	4.7	5.5	6.5	7.0	7.5	7.3	7.0	6.5	5.4	4.1	3.6	5.7
	Min/Max	2.9/4.8	3.9/5.8	4.3/6.3	5.7/7.2	6.3/7.5	6.2/8.4	7.0/7.6	6.0/7.5	5.2/7.2	3.9/6.2	3.0/5.0	2.0/4.3	5.1/6.1
Latitude	Average	4.4	5.2	5.7	6.4	6.6	6.8	6.7	6.7	6.6	5.9	4.6	4.1	5.8
	Min/Max	3.2/5.7	4.2/6.6	4.3/6.6	5.6/7.1	6.0/7.1	5.7/7.6	6.4/7.0	5.7/7.2	5.2/7.3	4.2/6.8	3.3/5.8	2.3/5.1	5.1/6.2
Latitude +15	Average	4.7	5.4	5.6	6.0	5.8	5.8	5.8	6.1	6.4	6.0	4.9	4.5	5.6
	Min/Max	3.4/6.2	4.3/6.9	4.2/6.5	5.1/6.6	5.3/6.2	4.9/6.5	5.6/6.1	5.2/6.5	4.9/7.0	4.2/6.9	3.4/6.2	2.4/5.6	4.8/6.0
90	Average	4.4	4.7	4.2	3.7	3.0	2.7	2.8	3.5	4.4	4.8	4.4	4.3	3.9
	Min/Max	3.0/5.8	3.5/6.4	3.0/4.8	3.2/4.0	2.9/3.2	2.4/2.9	2.7/2.9	3.0/3.7	3.4/4.8	3.3/5.6	3.0/5.7	2.2/5.3	3.3/4.3

3) 3.6

Explanation

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	2.5	3.5	4.6	6.0	7.0	7.7	7.4	6.6	5.5	4.1	2.7	2.2	5.0
	Min/Max	2.1/2.9	3.0/4.1	3.8/5.1	5.3/6.5	6.3/7.5	6.4/8.7	7.1/7.7	5.7/7.1	4.5/6.0	3.1/4.5	2.2/3.2	1.5/2.5	4.6/5.2
Latitude -15	Average	3.8	4.7	5.5	6.5	7.0	7.5	7.3	7.0	6.5	5.4	4.1	3.6	5.7
	Min/Max	2.9/4.8	3.9/5.8	4.3/6.3	5.7/7.2	6.3/7.5	6.2/8.4	7.0/7.6	6.0/7.5	5.2/7.2	3.9/6.2	3.0/5.0	2.0/4.3	5.1/6.1
Latitude	Average	4.4	5.2	5.7	6.4	6.6	6.8	6.7	6.7	6.6	5.9	4.6	4.1	5.8
	Min/Max	3.2/5.7	4.2/6.6	4.3/6.6	5.6/7.1	6.0/7.1	5.7/7.6	6.4/7.0	5.7/7.2	5.2/7.3	4.2/6.8	3.3/5.8	2.3/5.1	5.1/6.2
Latitude +15	Average	4.7	5.4	5.6	6.0	5.8	5.8	5.8	6.1	6.4	6.0	4.9	4.5	5.6
	Min/Max	3.4/6.2	4.3/6.9	4.2/6.5	5.1/6.6	5.3/6.2	4.9/6.5	5.6/6.1	5.2/6.5	4.9/7.0	4.2/6.9	3.4/6.2	2.4/5.6	4.8/6.0
90	Average	4.4	4.7	4.2	3.7	3.0	2.7	2.8	3.5	4.4	4.8	4.4	4.3	3.9
	Min/Max	3.0/5.8	3.5/6.4	3.0/4.8	3.2/4.0	2.9/3.2	2.4/2.9	2.7/2.9	3.0/3.7	3.4/4.8	3.3/5.6	3.0/5.7	2.2/5.3	3.3/4.3

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4) 7.5

Explanation

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average Min/Max	2.5 2.1/2.9	3.5 3.0/4.1	4.6 3.8/5.1	6.0 5.3/6.5	7.0 6.3/7.5	7.7 6.4/8.7	7.4 7.1/7.7	6.6 5.7/7.1	5.5 4.5/6.0	4.1 3.1/4.5	2.7 2.2/3.2	2.2 1.5/2.5	5.0 4.6/5.2
Latitude -15	Average Min/Max	3.8 2.9/4.8	4.7 3.9/5.8	5.5 4.3/6.3	6.5 5.7/7.2	7.0 6.3/7.5	7.5 6.2/8.4	7.3 7.0/7.6	7.0 6.0/7.5	6.5 5.2/7.2	5.4 3.9/6.2	4.1 3.0/5.0	3.6 2.0/4.3	5.7 5.1/6.1
Latitude	Average Min/Max	4.4 3.2/5.7	5.2 4.2/6.6	5.7 4.3/6.6	6.4 5.6/7.1	6.6 6.0/7.1	6.8 5.7/7.6	6.7 6.4/7.0	6.7 5.7/7.2	6.6 5.2/7.3	5.9 4.2/6.8	4.6 3.3/5.8	4.1 2.3/5.1	5.8 5.1/6.2
Latitude +15	Average Min/Max	4.7 3.4/6.2	5.4 4.3/6.9	5.6 4.2/6.5	6.0 5.1/6.6	5.8 5.3/6.2	5.8 4.9/6.5	5.8 5.6/6.1	6.1 5.2/6.5	6.4 4.9/7.0	6.0 4.2/6.9	4.9 3.4/6.2	4.5 2.4/5.6	5.6 4.8/6.0
90	Average Min/Max	4.4 3.0/5.8	4.7 3.5/6.4	4.2 3.0/4.8	3.7 3.2/4.0	3.0 2.9/3.2	2.7 2.4/2.9	2.8 2.7/2.9	3.5 3.0/3.7	4.4 3.4/4.8	4.8 3.3/5.6	4.4 3.0/5.7	4.3 2.2/5.3	3.9 3.3/4.3

5) 71.30º N

Explanation

Barrow, AK

WBAN NO. 27502

LATITUDE: 71.30° N
LONGITUDE: 156.78° W
ELEVATION: 4 meters
MEAN PRESSURE: 1016 millibars

6) 0.0

Explanation

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average Min/Max	0.0 0.0/0.0	0.3 0.2/0.3	1.6 1.4/1.7	3.7 3.3/4.1	4.7 4.0/5.3	4.9 4.4/6.2	4.5 3.7/5.9	2.6 2.2/3.0	1.3 1.2/1.5	0.5 0.4/0.6	0.0 0.0/0.0	0.0 0.0/0.0	2.0 1.9/2.1
Latitude -15	Average Min/Max	0.0 0.0/0.1	1.1 0.7/1.5	3.8 2.9/4.6	5.8 4.9/7.0	5.2 4.3/6.2	4.8 4.1/6.6	4.6 3.5/6.6	2.8 2.1/3.6	1.7 1.2/2.3	0.9 0.6/1.7	0.1 0.0/0.2	0.0 0.0/0.0	2.6 2.3/3.0
Latitude	Average Min/Max	0.0 0.0/0.1	1.1 0.8/1.6	4.0 3.0/4.9	5.8 4.8/7.1	4.9 4.0/5.9	4.4 3.7/6.1	4.2 3.1/6.0	2.6 1.9/3.4	1.6 1.1/2.3	1.0 0.6/1.8	0.1 0.0/0.2	0.0 0.0/0.0	2.5 2.2/2.9
Latitude +15	Average Min/Max	0.0 0.0/0.1	1.2 0.8/1.6	4.0 3.0/4.8	5.6 4.6/6.7	4.6 3.6/5.5	3.8 3.2/5.4	3.6 2.7/5.2	2.3 1.7/3.0	1.5 1.0/2.1	1.0 0.5/1.9	0.1 0.0/0.2	0.0 0.0/0.0	2.3 2.1/2.7
90	Average Min/Max	0.0 0.0/0.1	1.2 0.8/1.6	3.9 2.9/4.8	5.4 4.5/6.6	4.5 3.5/5.4	3.6 3.0/5.1	3.4 2.6/5.0	2.2 1.6/2.9	1.4 1.0/2.0	1.0 0.5/1.8	0.1 0.0/0.2	0.0 0.0/0.0	2.2 2.0/2.6

7) 5.6

Explanation

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average Min/Max	0.0 0.0/0.0	0.3 0.2/0.3	1.6 1.4/1.7	3.7 3.3/4.1	4.7 4.0/5.3	4.9 4.4/6.2	4.5 3.7/5.9	2.6 2.2/3.0	1.3 1.2/1.5	0.5 0.4/0.6	0.0 0.0/0.0	0.0 0.0/0.0	2.0 1.9/2.1
Latitude -15	Average Min/Max	0.0 0.0/0.1	1.1 0.7/1.5	3.8 2.9/4.6	5.8 4.9/7.0	5.2 4.3/6.2	4.8 4.1/6.6	4.6 3.5/6.6	2.8 2.1/3.6	1.7 1.2/2.3	0.9 0.6/1.7	0.1 0.0/0.2	0.0 0.0/0.0	2.6 2.3/3.0
Latitude	Average Min/Max	0.0 0.0/0.1	1.1 0.8/1.6	4.0 3.0/4.9	5.8 4.8/7.1	4.9 4.0/5.9	4.4 3.7/6.1	4.2 3.1/6.0	2.6 1.9/3.4	1.6 1.1/2.3	1.0 0.6/1.8	0.1 0.0/0.2	0.0 0.0/0.0	2.5 2.2/2.9
Latitude +15	Average Min/Max	0.0 0.0/0.1	1.2 0.8/1.6	4.0 3.0/4.8	5.6 4.6/6.7	4.6 3.6/5.5	3.8 3.2/5.4	3.6 2.7/5.2	2.3 1.7/3.0	1.5 1.0/2.1	1.0 0.5/1.9	0.1 0.0/0.2	0.0 0.0/0.0	2.3 2.1/2.7
90	Average Min/Max	0.0 0.0/0.1	1.2 0.8/1.6	3.9 2.9/4.8	5.4 4.5/6.6	4.5 3.5/5.4	3.6 3.0/5.1	3.4 2.6/5.0	2.2 1.6/2.9	1.4 1.0/2.0	1.0 0.5/1.8	0.1 0.0/0.2	0.0 0.0/0.0	2.2 2.0/2.6

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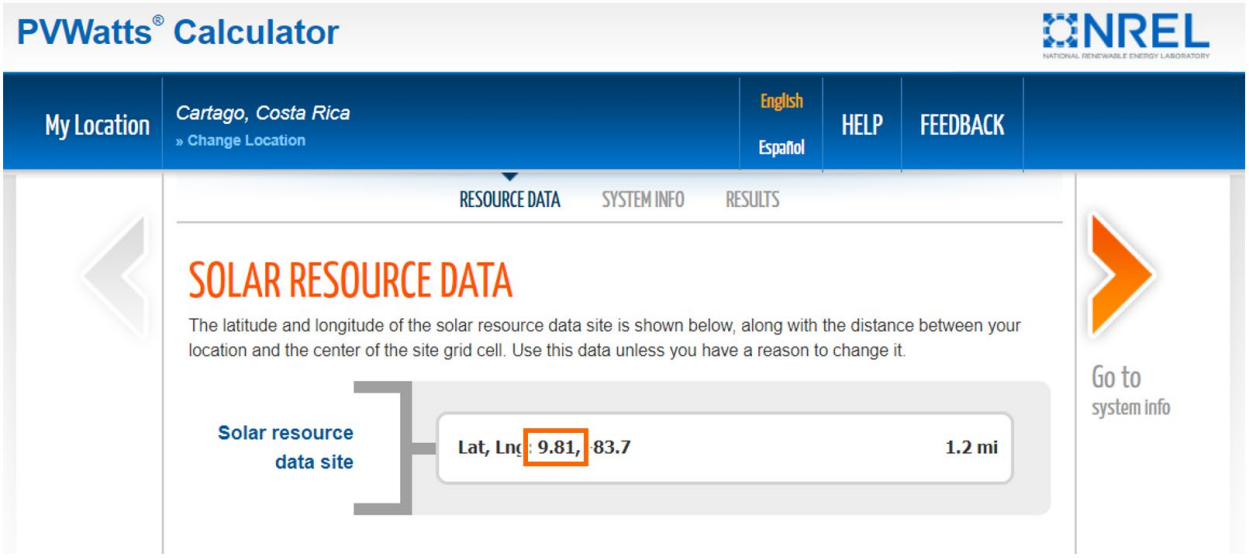
8) 9.81º N
Explanation



9) 4.70
Explanation

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	4.70	104
February	4.77	94
March	4.67	101
April	4.41	93
May	4.03	89
June	3.86	82
July	3.76	83
August	4.20	93
September	4.61	98
October	4.77	106
November	4.32	93
December	4.42	97
Annual	4.38	1,133

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10) 3.86
Explanation

RESOURCE DATA SYSTEM INFO RESULTS

Go to system info

RESULTS

Print Results

1,133 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	4.70	104
February	4.77	94
March	4.67	101
April	4.41	93
May	4.03	89
June	3.86	82
July	3.76	83
August	4.20	93
September	4.61	98
October	4.77	106
November	4.32	93
December	4.42	97
Annual	4.38	1,133

11) 4.38
Explanation

RESOURCE DATA SYSTEM INFO RESULTS

Go to system info

RESULTS

Print Results

1,133 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	4.70	104
February	4.77	94
March	4.67	101
April	4.41	93
May	4.03	89
June	3.86	82
July	3.76	83
August	4.20	93
September	4.61	98
October	4.77	106
November	4.32	93
December	4.42	97
Annual	4.38	1,133

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12) The array in Barrow, AK would have to be the largest. The array in Grand Junction would be the smallest. Based on the array specifications, the array in Barrow would receive the fewest peak sun hours, and the one in Grand Junction would receive the most.

Explanation

Average annual peak sun hours for a south-facing, unshaded array in Barrow, AK, tilted at an angle equivalent to the latitude (71º) is 2.5 kWh/m^2/day. A south-facing, unshaded array in Cartago, Costa Rica, titled to 25º, would receive 4.38 peak sun hours per day. And a south-facing, unshaded array at 39º (the latitude) in Grand Junction, CO averages would receive an annual average of 5.8 hours per day. This means that the same size PV system will generate more energy in Grand Junction than in Cartago, and more in Cartago than in Barrow. This difference is primarily due to differences in weather between the two locations.

In order to produce the same number of kWh annually the array in Barrow will need to be larger than the one in Cartago and the Cartago array will need to be larger than the one in Grand Junction.

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