

IE290

Alternate Energy Course

Lecture #, 5

Energy and Power,
Solar Energy Resources
Solar Astronomy

Notion of the Cost per peak watt installed

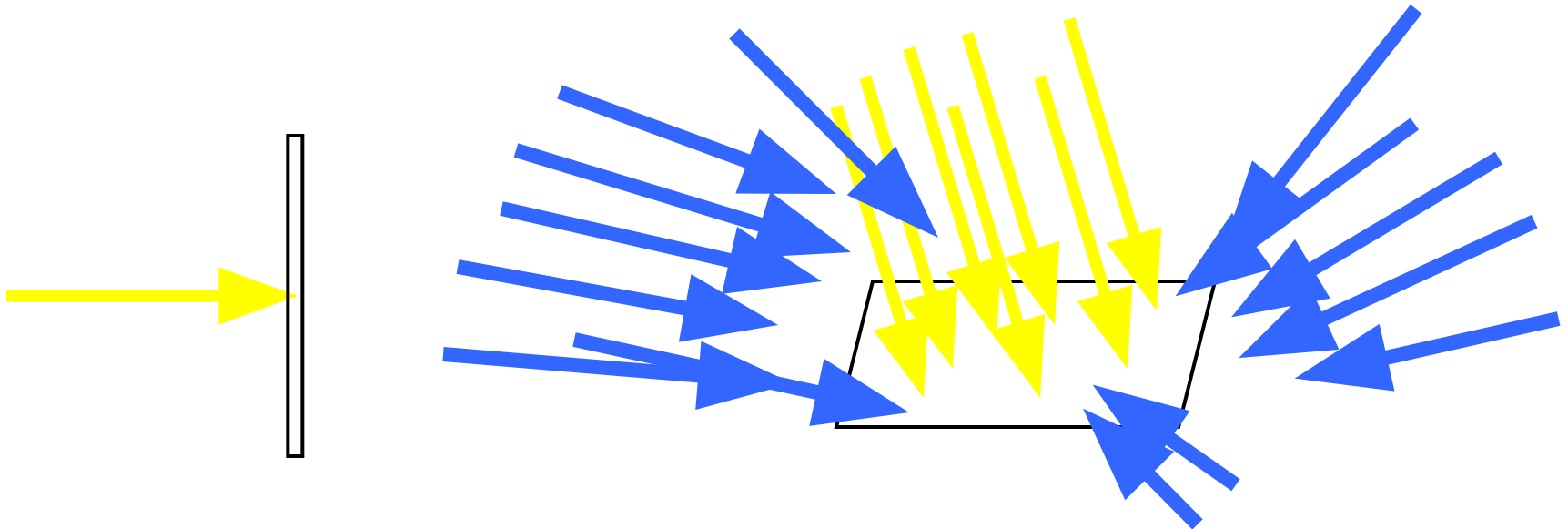
- “Peak Watt” = 1000W = 1kW
- Is the power produced at normal incidence of solar radiation @ 1000W/m².
- $\$/W_p$ - Easy way to compare various solar conversion devices.
- Mostly useful for electric power generation devices, such as for: Hydro; PV; Wind, Solar Thermal Electric, etc.

Solar Monitoring

- However, each geographical location has its characteristic insolation.
- For that purpose we need to have a number of solar monitoring stations
- AUA has the first automated solar monitoring station in Armenia.
- There are >24 SMS-s in San Francisco

Components of Solar Radiation

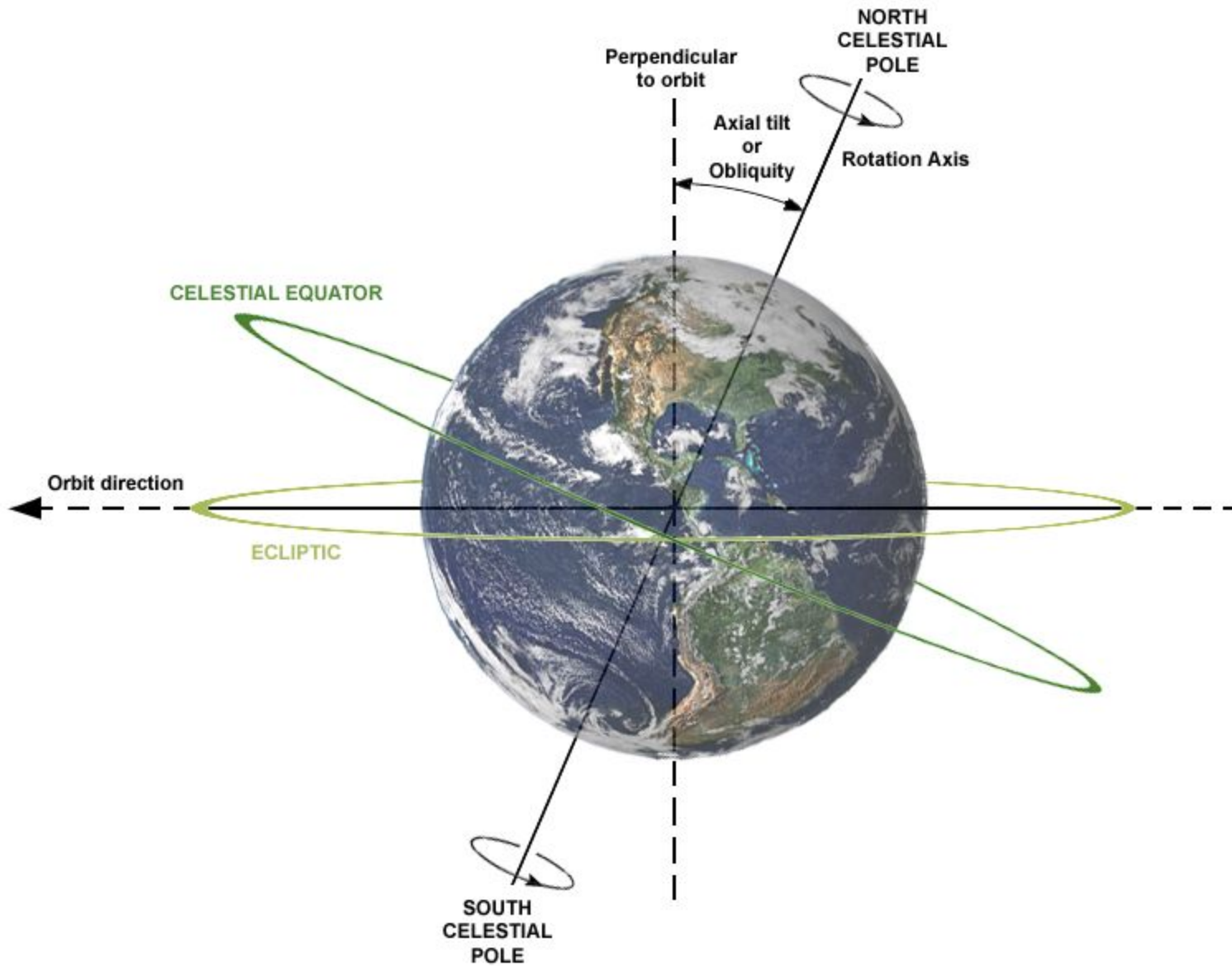
- Direct Normal, DN – pure direct sun rays that hit a surface, normal to the rays.
- Diffuse Horizontal, DH
- Global Horizontal, GH



Direct Normal realization

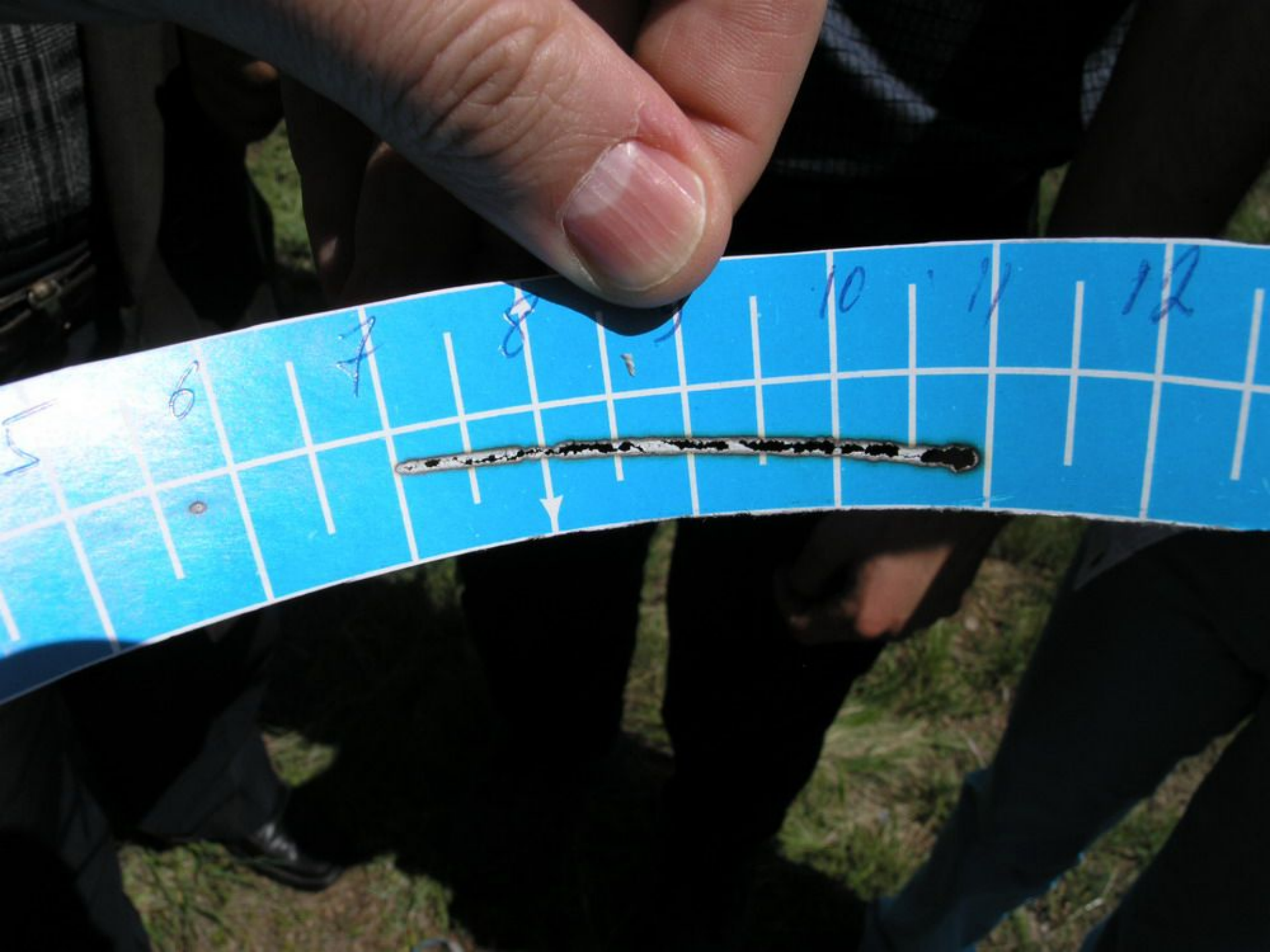


- Concentration
- Tracking: DN + inclined Diffuse (PV panel)













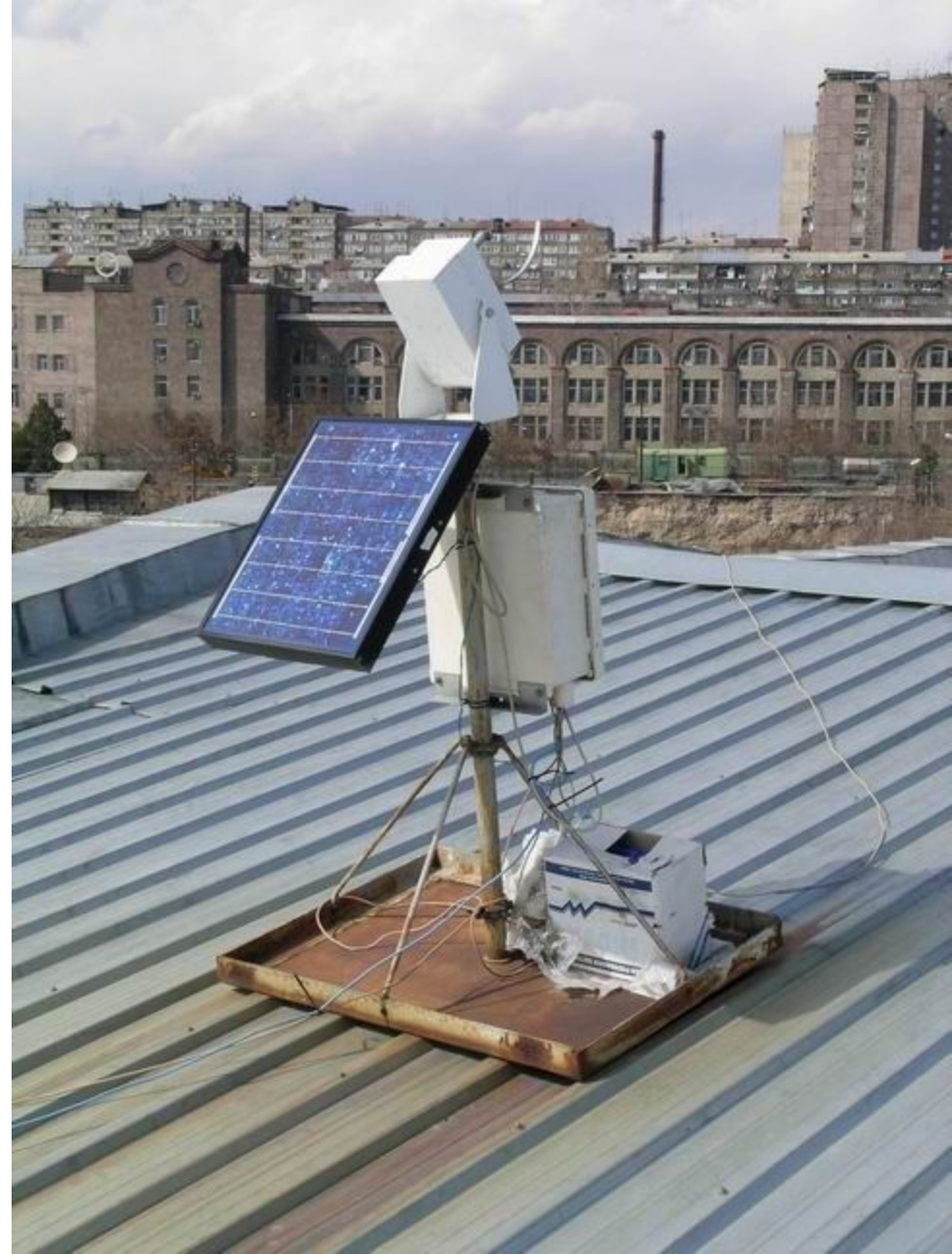
FUN
FOR
YOU

Station	Angle	Distance	Height	Remarks
1	45°	100m	70m	Point A
2	30°	150m	80m	Point B
3	60°	200m	90m	Point C
4	15°	250m	100m	Point D
5	75°	300m	110m	Point E
6	45°	350m	120m	Point F
7	30°	400m	130m	Point G
8	60°	450m	140m	Point H
9	15°	500m	150m	Point I
10	75°	550m	160m	Point J

Solar position Calculator

- http://www.spectralcalc.com/solar_calculator/solar_position.php

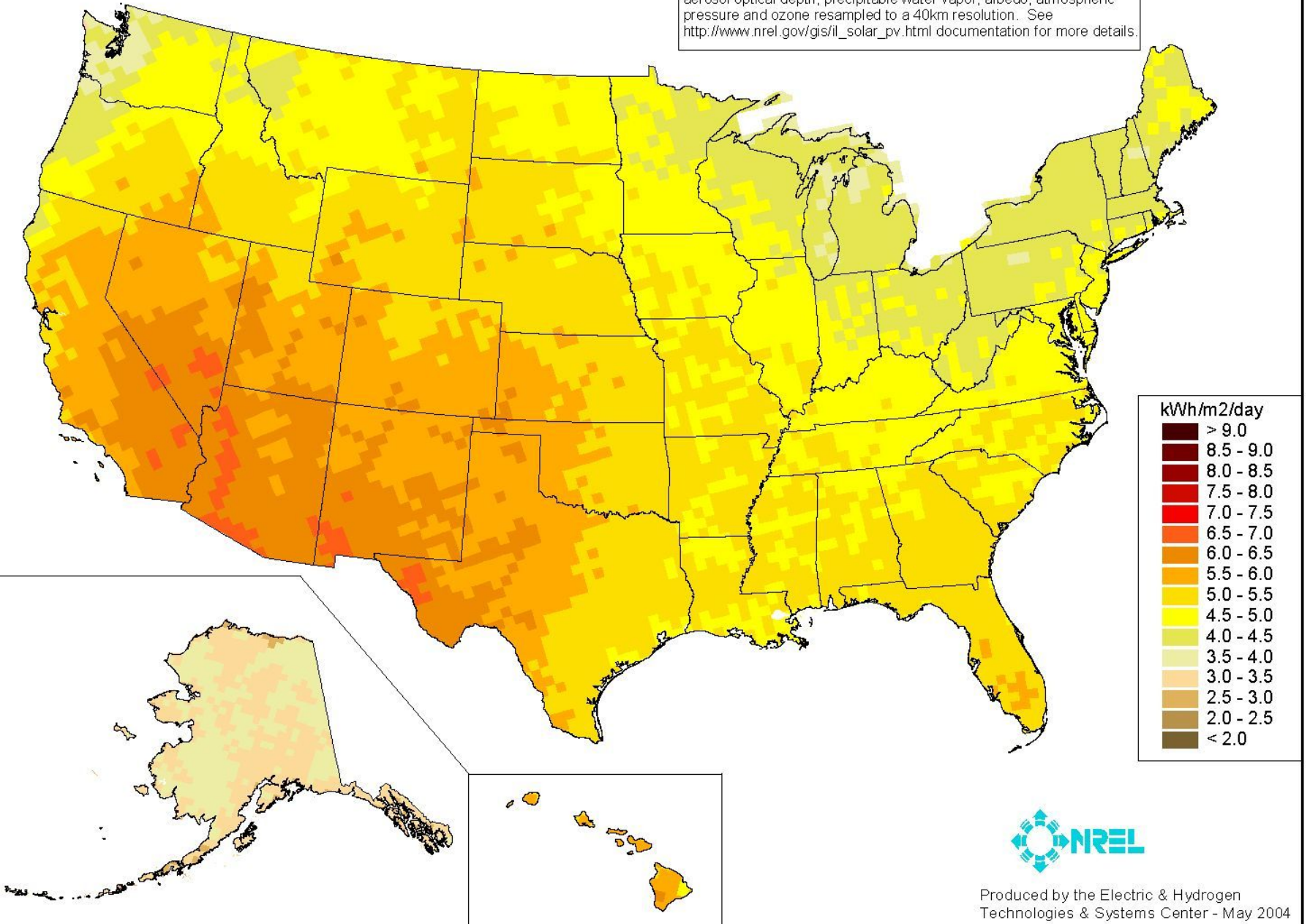
AUA Solar Monitoring Station Collecting data since 1995



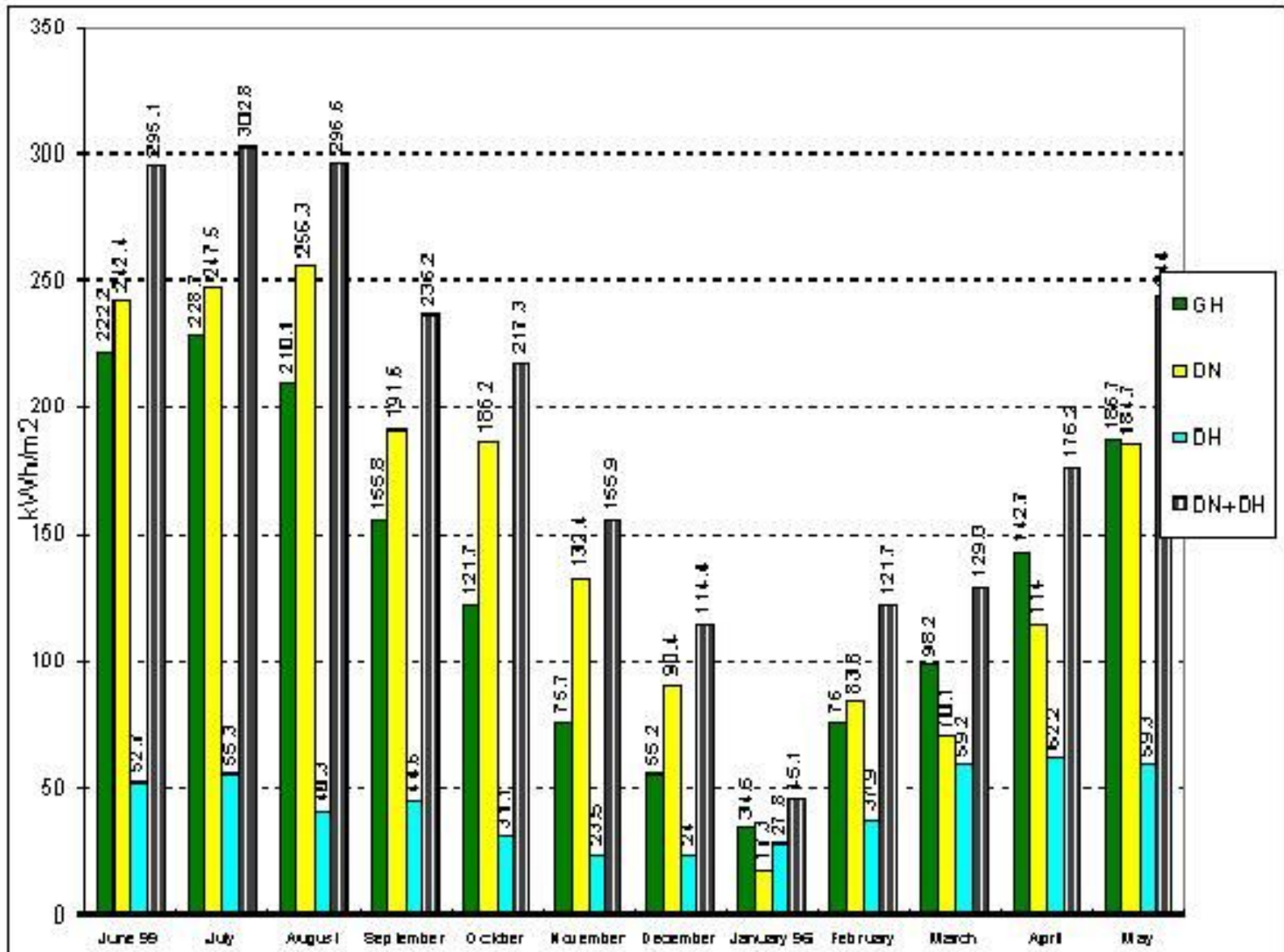
PV Solar Radiation (Flat Plate, Facing South, Latitude Tilt)

Annual

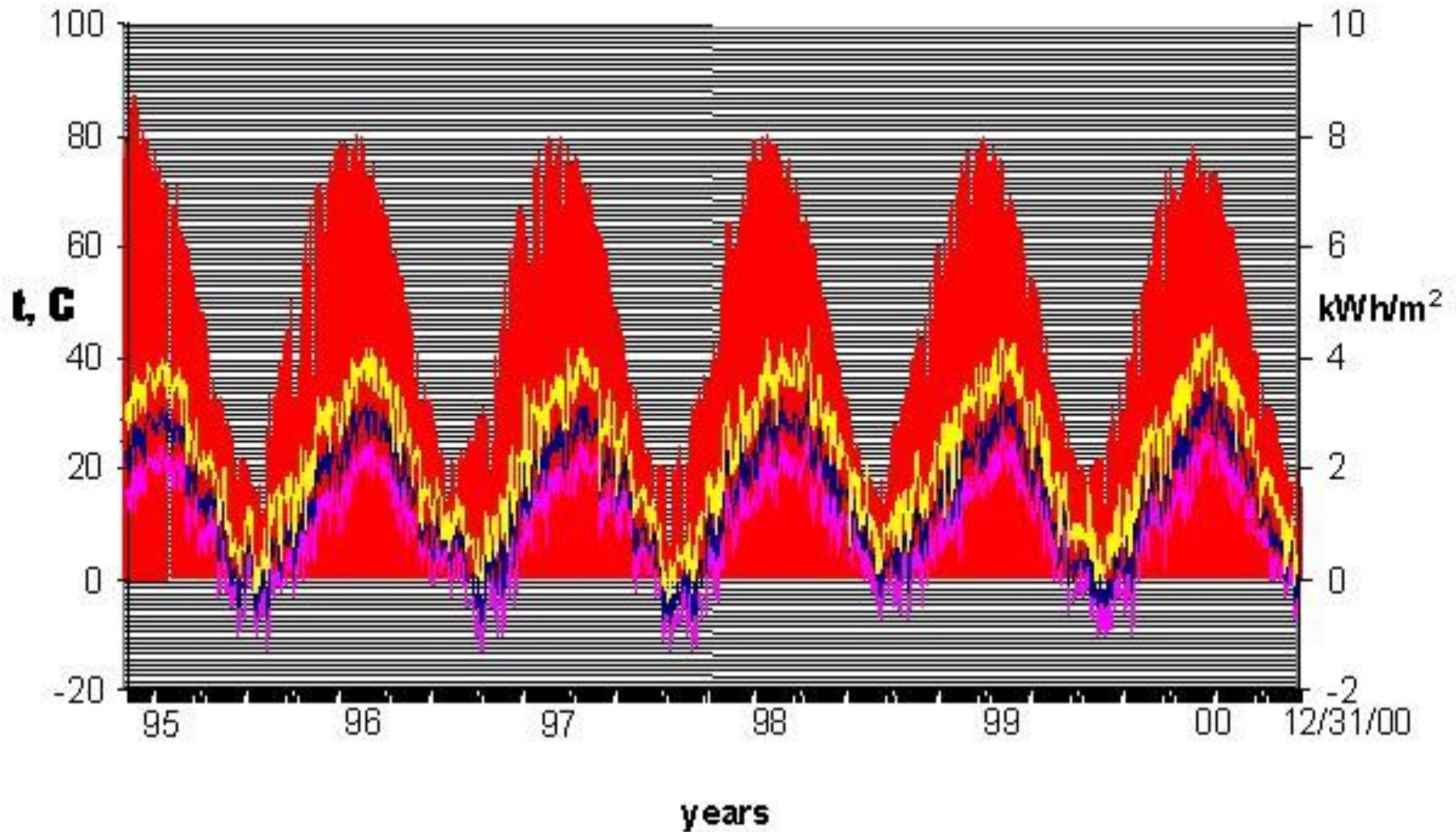
Model estimates of monthly average daily total radiation using inputs derived from satellite and/or surface observations of cloud cover, aerosol optical depth, precipitable water vapor, albedo, atmospheric pressure and ozone resampled to a 40km resolution. See http://www.nrel.gov/gis/il_solar_pv.html documentation for more details.



AUA Solar Monitoring Station



AUA Solar Monitoring Station



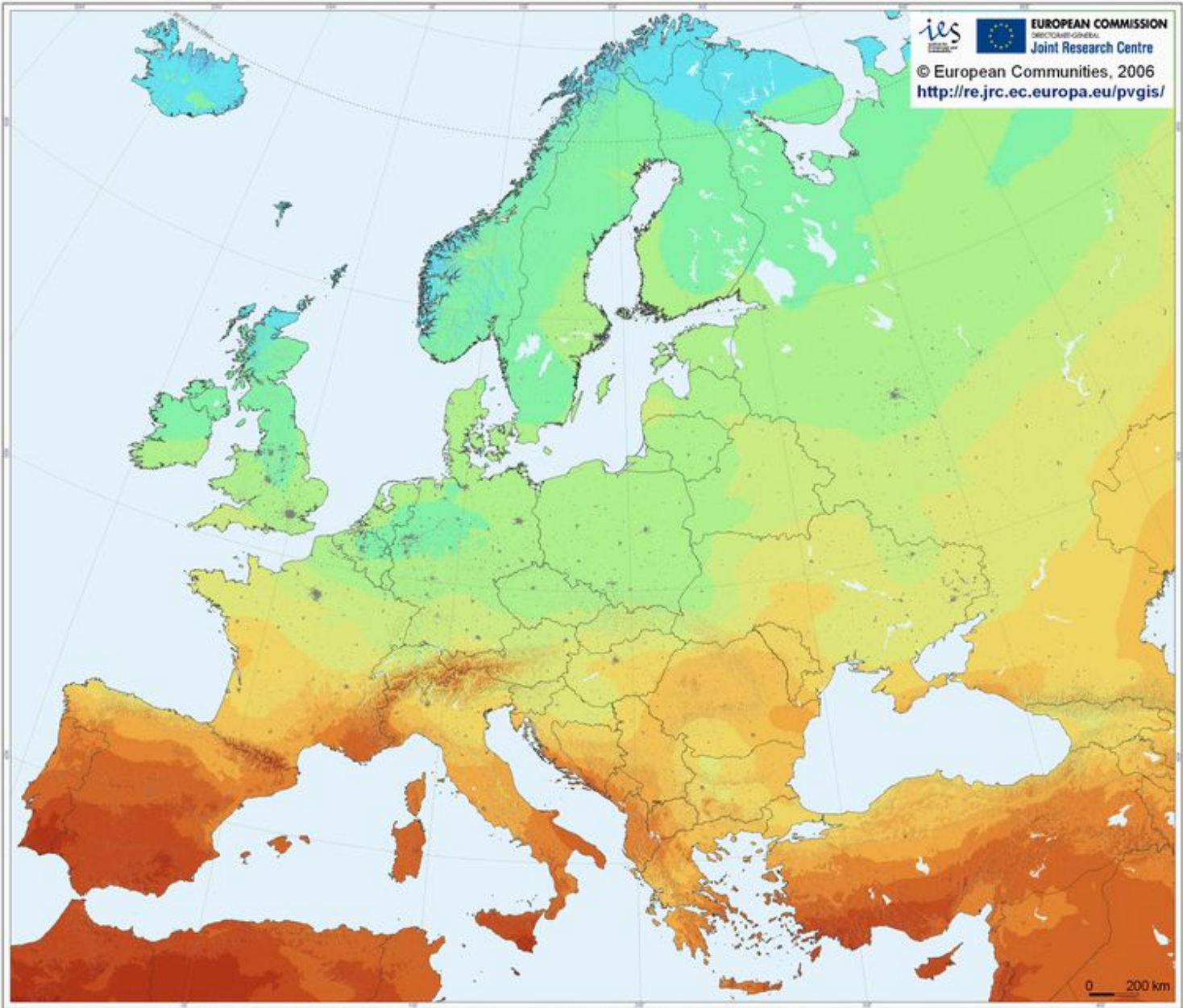
AUA SMS RESULTS

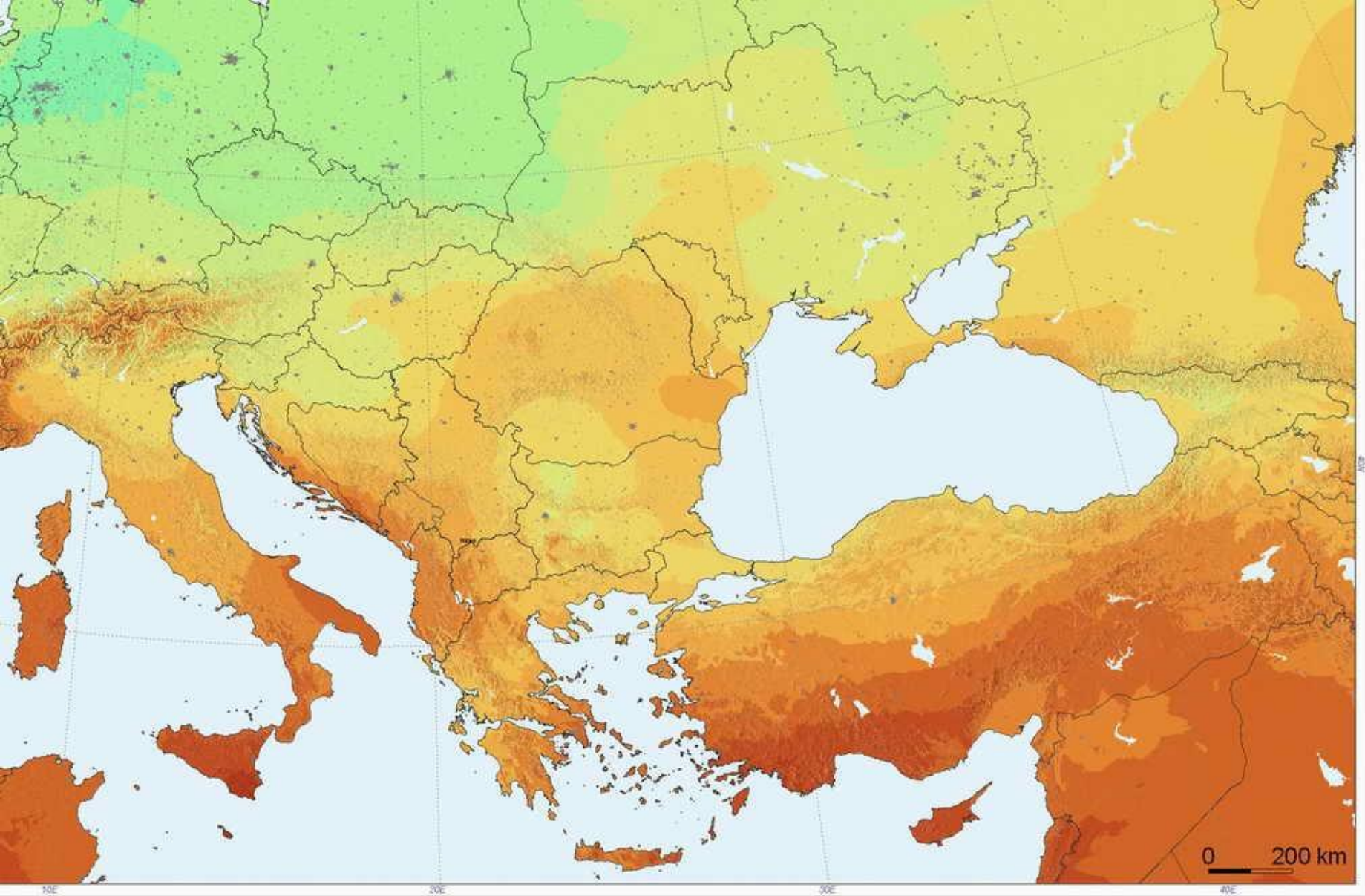
- Total Annual Global horizontal: 1720kWh/m².
- Average of 4.7 kWh/m² per day across years (DN+DH).
- January about 6.6 times less than in June:
- January: ≈ 1.1 kWh/m² per day.
- June: ≈ 8.3 kWh/m² per day.

Photovoltaic Solar Electricity Potential in European Countries

PVGIS -
Europe

<http://re.jrc.ec.europa.eu/pvgis>





Optimally-inclined south-oriented photovoltaic modules

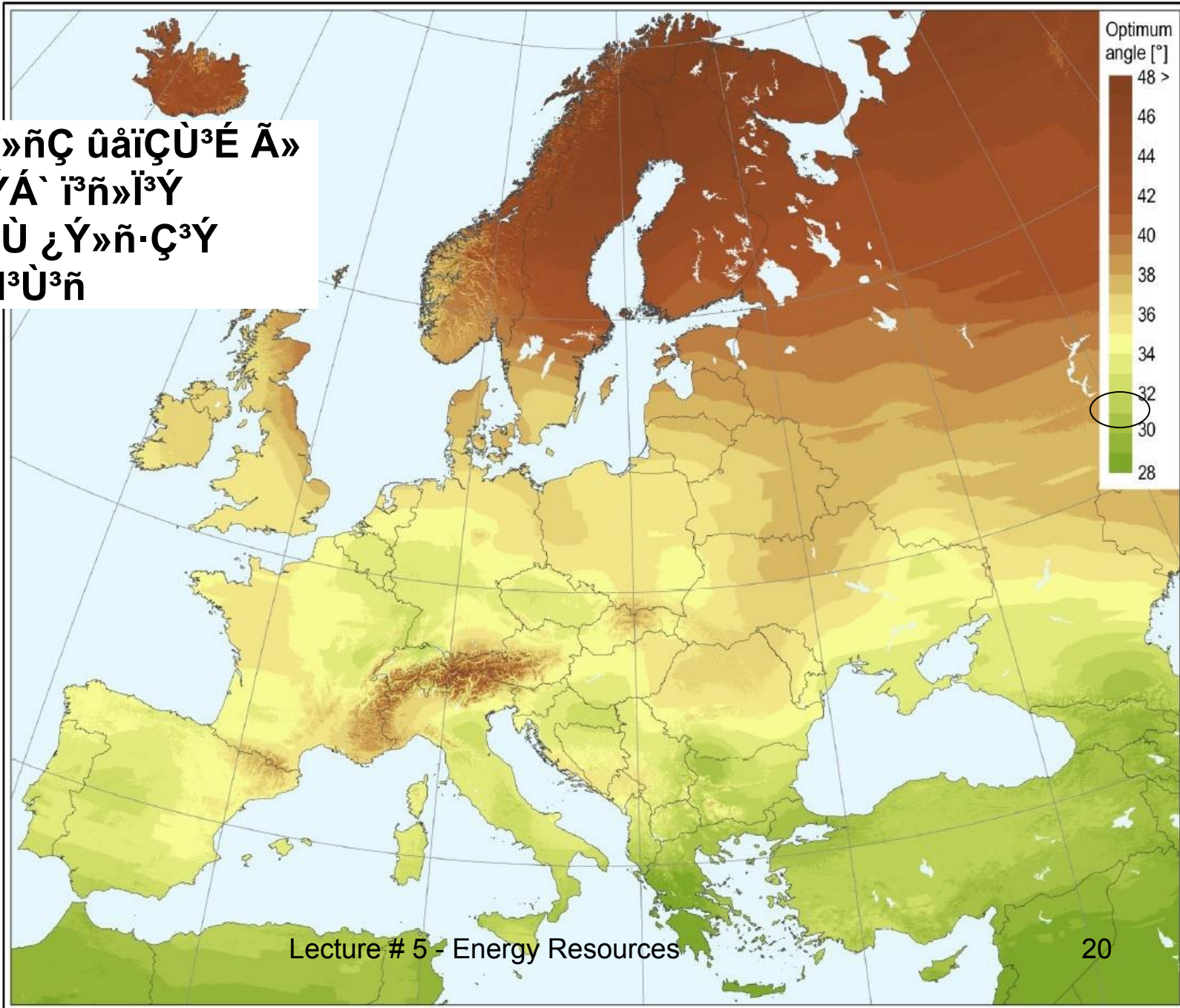


System with optimally-inclined modules and performance ratio 0.75



Optimum inclination of PV modules to maximize yearly energy yield

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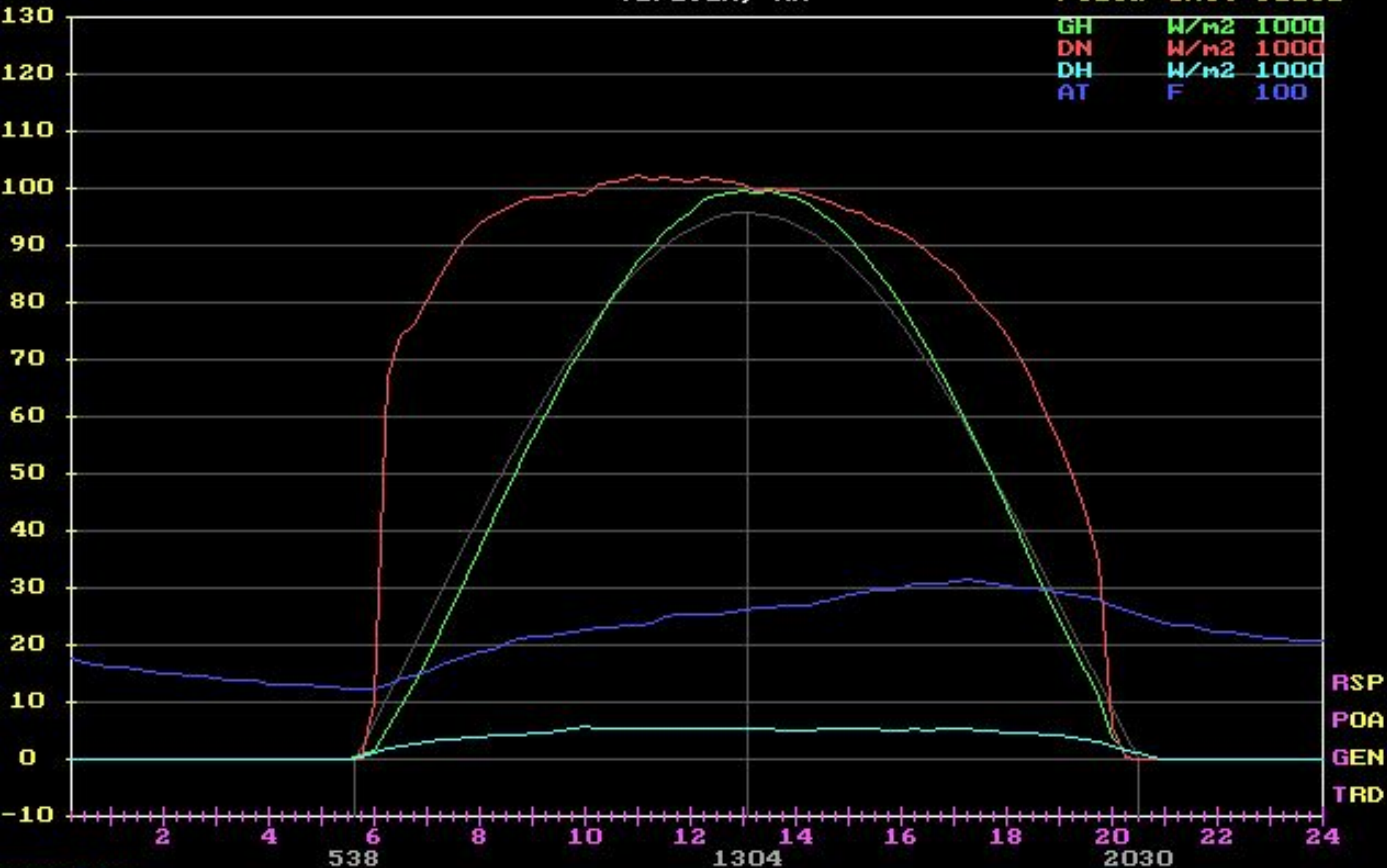
Ascension Technology Solar Monitoring Network

% of Scale

Yerevan, AM

Field Unit Scale

GH	W/m2	1000
DN	W/m2	1000
DH	W/m2	1000
AT	F	100



06/23/95
 Julian Day 174
 24 Records

press ack, <n>ext, <c>olors, <f>ields <s>caling or <q>uit

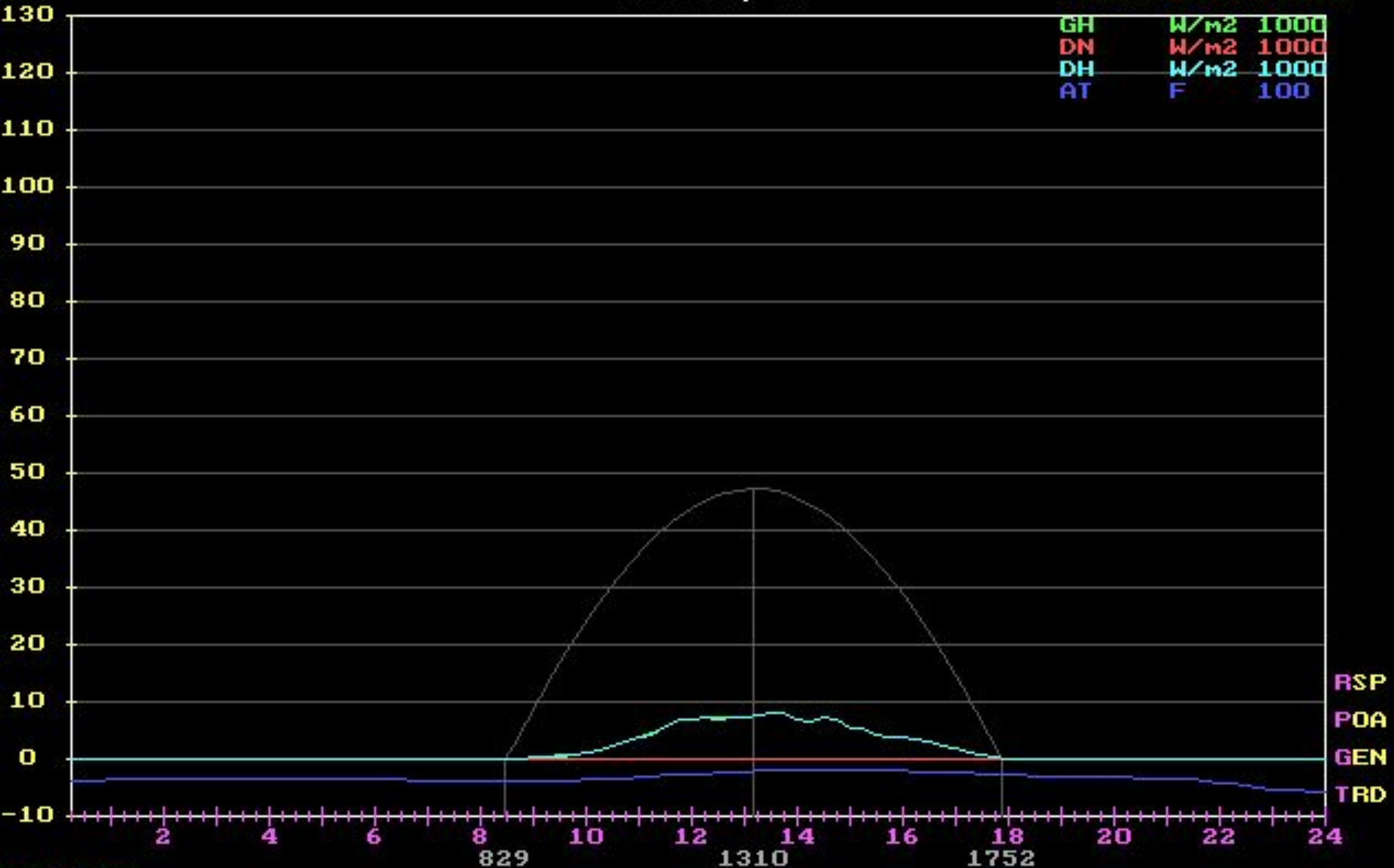
Ascension Technology Solar Monitoring Network

% of Scale

Yerevan, AM

Field Unit Scale

GH	W/m2	1000
DN	W/m2	1000
DH	W/m2	1000
AT	F	100



01/13/96
 Julian Day 13
 71 Records

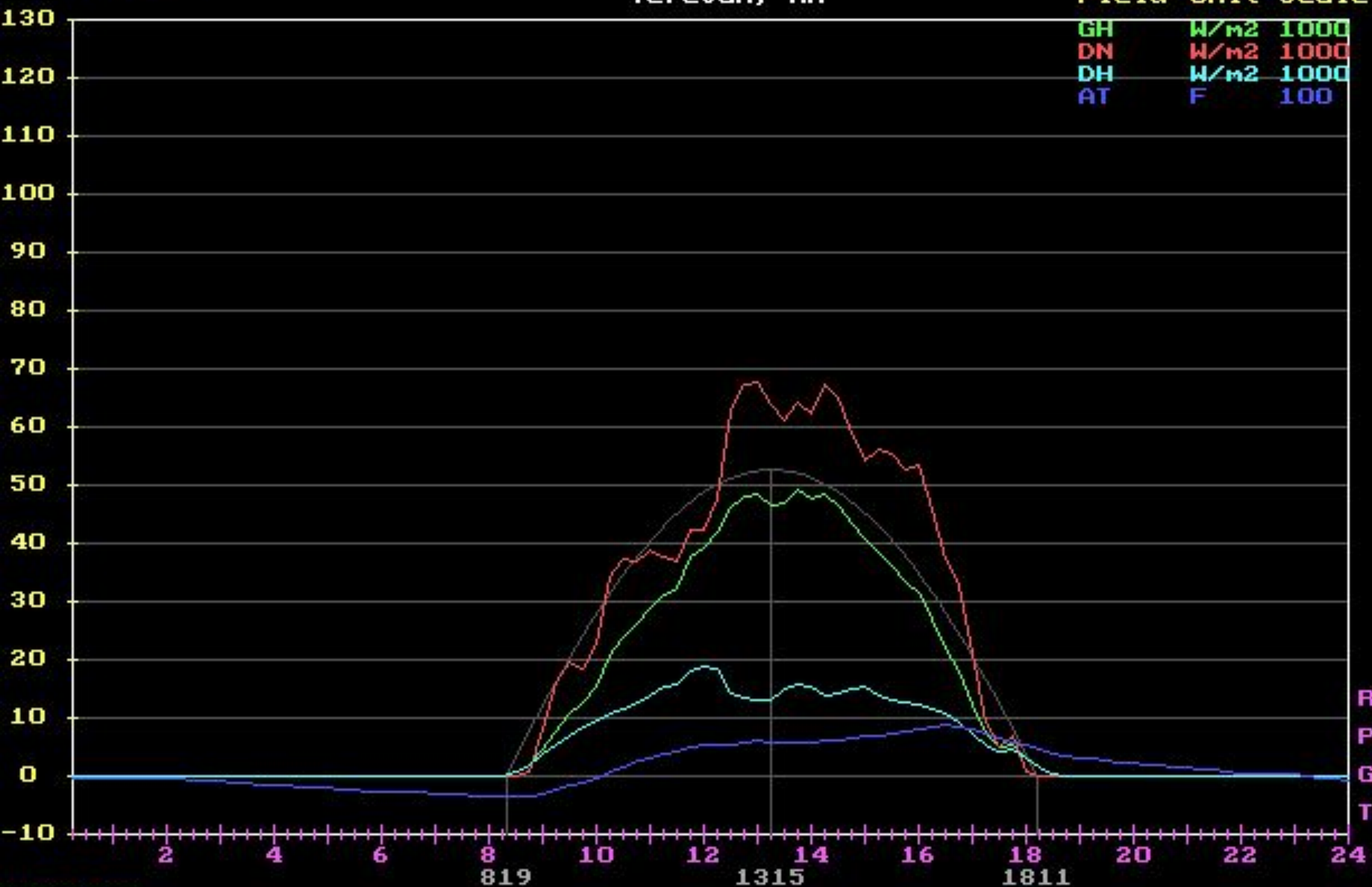
press ack, <n>ext, <c>olors, <f>ields <s>caling or <q>uit

Ascension Technology Solar Monitoring Network

% of Scale

Yerevan, AM

Field Unit Scale



RSP
POA
GEN
TRD

01/30/96
Julian Day 30
56 Records

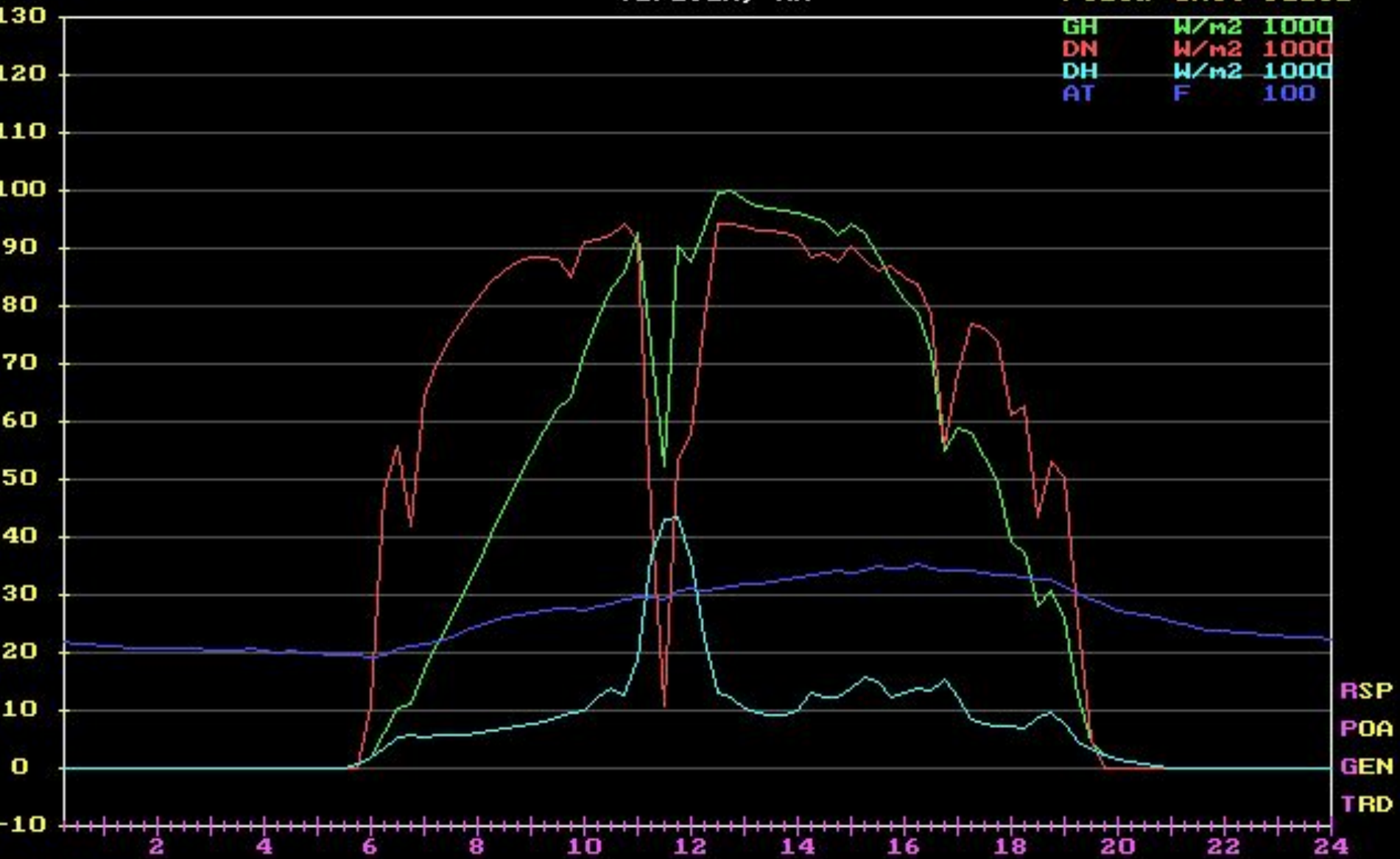
press ack, <n>ext, <c>olors, <f>ields <s>caling or <q>uit

Ascension Technology Solar Monitoring Network

Yerevan, AM

Field	Unit	Scale
GH	W/m2	1000
DN	W/m2	1000
DH	W/m2	1000
AT	F	100

% of Scale



06/18/95
 Julian Day 169
 85 Records

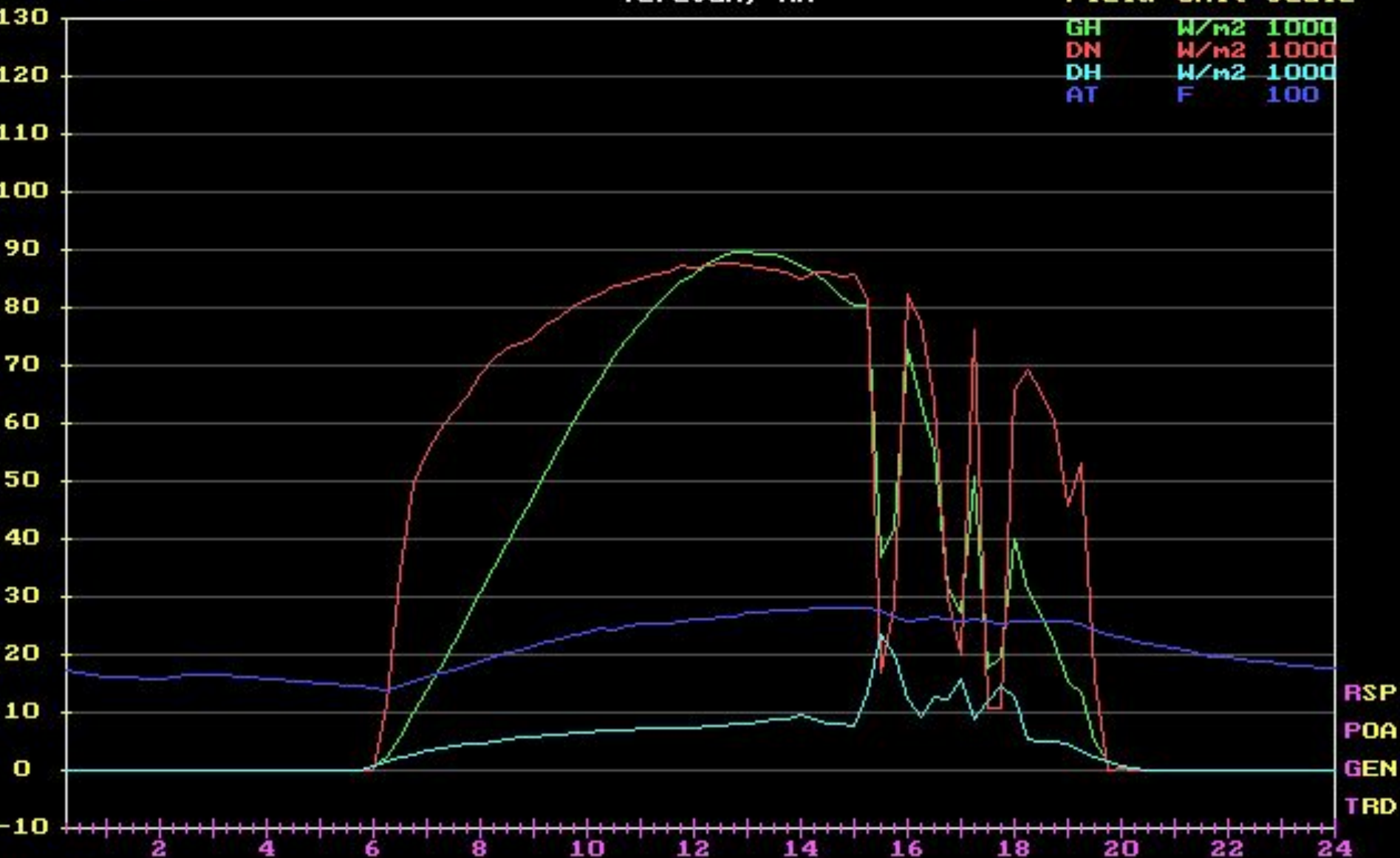
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Ascension Technology Solar Monitoring Network

% of Scale

Yerevan, AM

Field	Unit	Scale
GH	W/m2	1000
DN	W/m2	1000
DH	W/m2	1000
AT	F	100



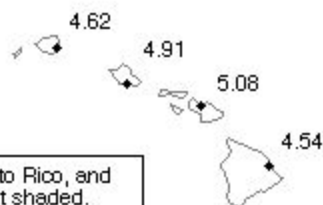
05/17/96
 Julian Day 138
 22 Records

press ack, <n>ext, <c>olors, <f>ields <s>caling or <q>uit

Alaska



Hawaii



Hawaii, Puerto Rico, and Guam are not shaded.

San Juan, PR

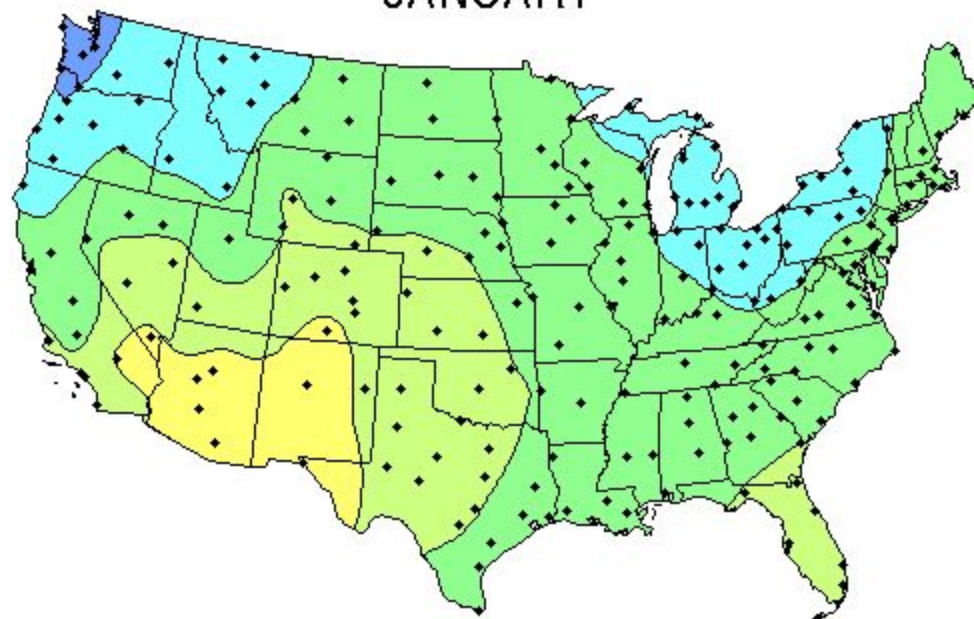


Guam, PI



Average Daily Solar Radiation Per Month

JANUARY



Flat Plate Tilted South at Latitude

Collector Orientation

Flat-plate collector facing south at fixed tilt equal to the latitude of the site: Capturing the maximum amount of solar radiation throughout the year can be achieved using a tilt angle approximately equal to the site's latitude.

This map shows the general trends in the amount of solar radiation received in the United States and its territories. It is a spatial interpolation of solar radiation values derived from the 1961-1990 National Solar Radiation Data Base (NSRDB). The dots on the map represent the 239 sites of the NSRDB.

Maps of average values are produced by averaging all 30 years of data for each site. Maps of maximum and minimum values are composites of specific months and years for which each site achieved its maximum or minimum amounts of solar radiation.

Though useful for identifying general trends, this map should be used with caution for site-specific resource evaluations because variations in solar radiation not reflected in the maps can exist, introducing uncertainty into resource estimates.

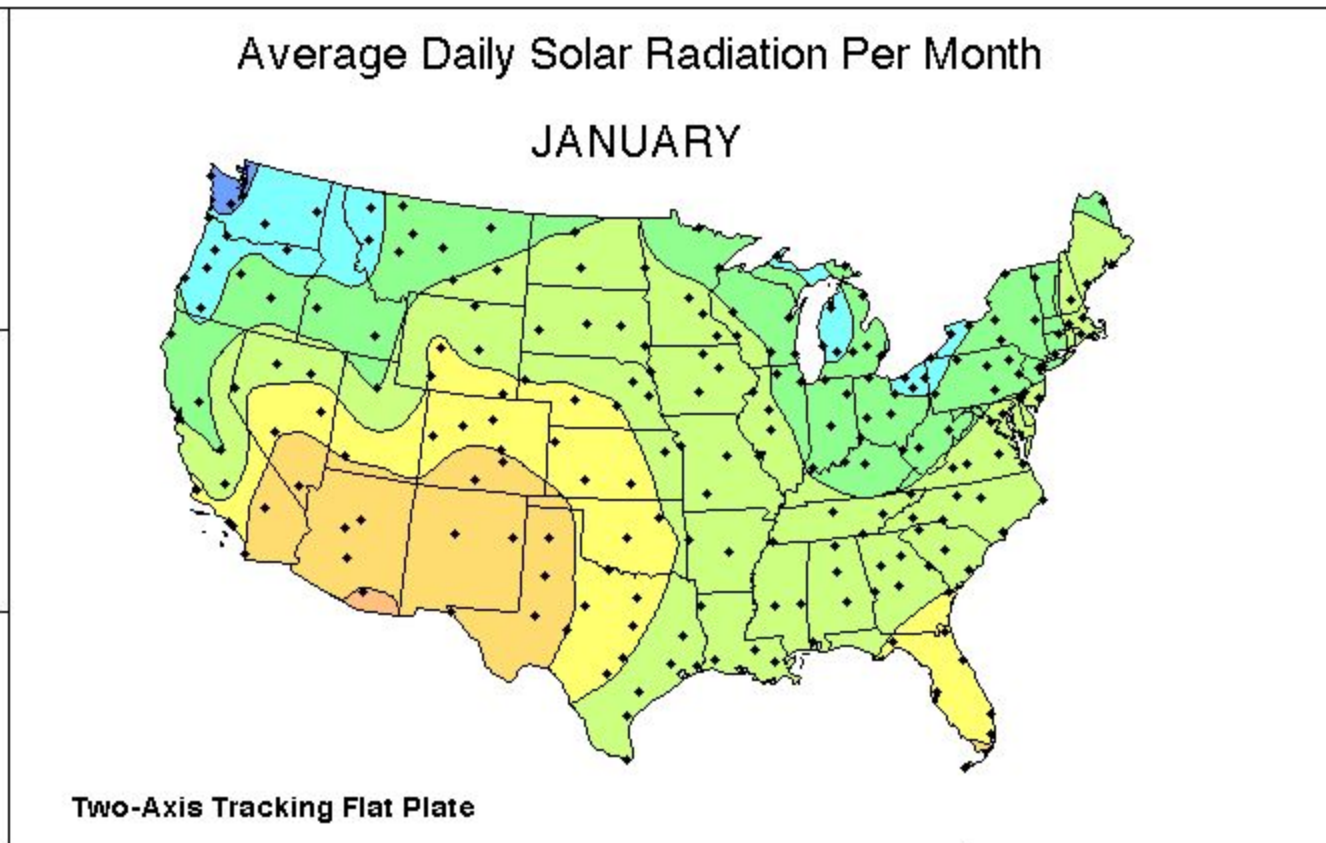
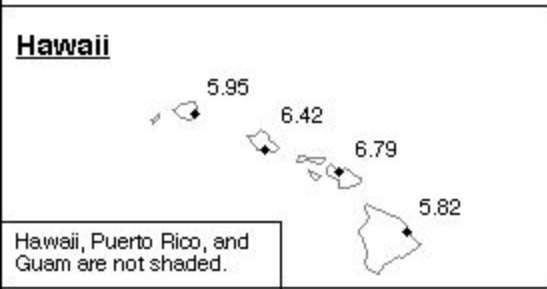
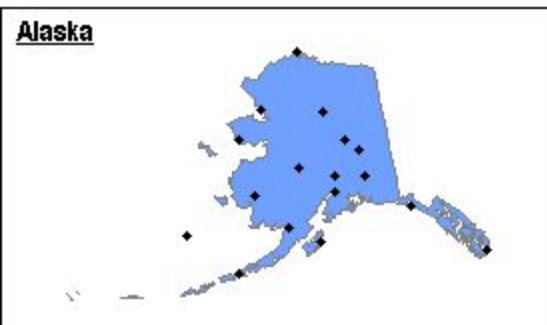
Maps are not drawn to scale.



National Renewable Energy Laboratory
Resource Assessment Program

kWh/m²/day





Collector Orientation

Two-axis tracking flat-plate collector:
 Data used to generate this map represent the maximum solar radiation at a site available to a collector. Tracking the sun in both azimuth and elevation, these collectors keep the sun's rays perpendicular to the collector surface.

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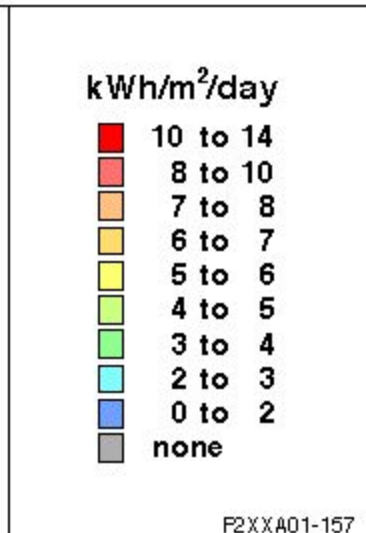
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NREL

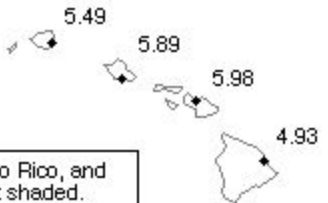
National Renewable Energy Laboratory
Resource Assessment Program



Alaska



Hawaii



Hawaii, Puerto Rico, and Guam are not shaded.

San Juan, PR

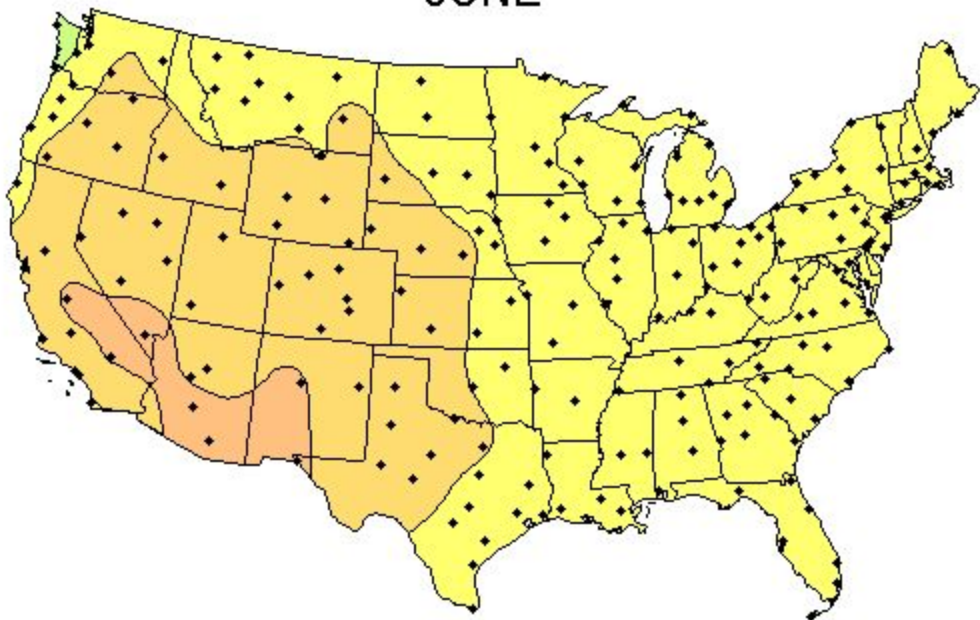


Guam, PI



Average Daily Solar Radiation Per Month

JUNE



Flat Plate Tilted South at Latitude

Collector Orientation

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kWh/m²/day

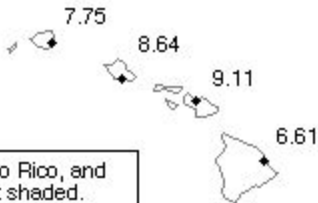


National Renewable Energy Laboratory
Resource Assessment Program

Alaska



Hawaii



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San Juan, PR

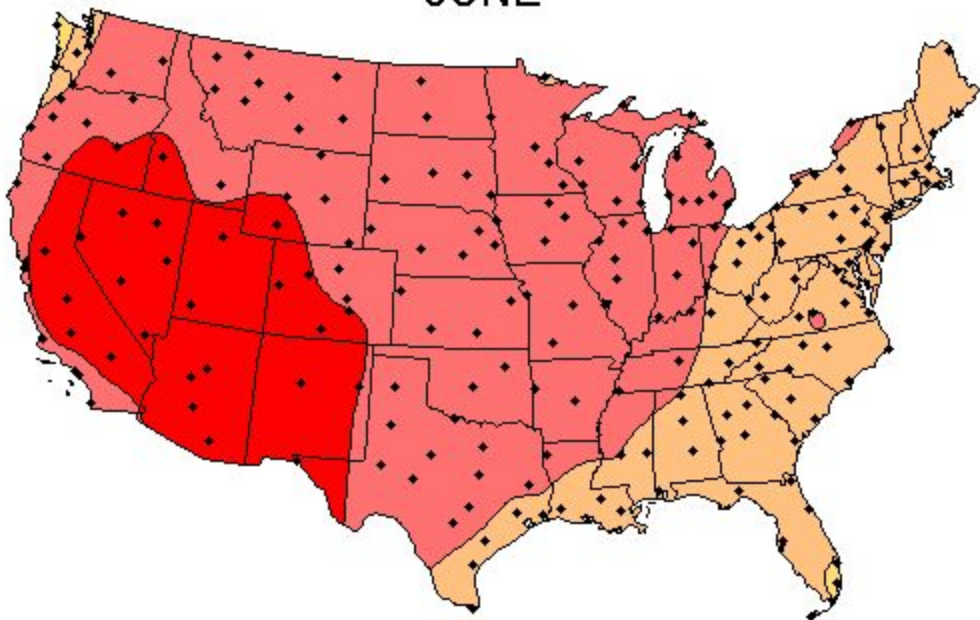


Guam, PI



Average Daily Solar Radiation Per Month

JUNE



Two-Axis Tracking Flat Plate

Collector Orientation

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National Renewable Energy Laboratory
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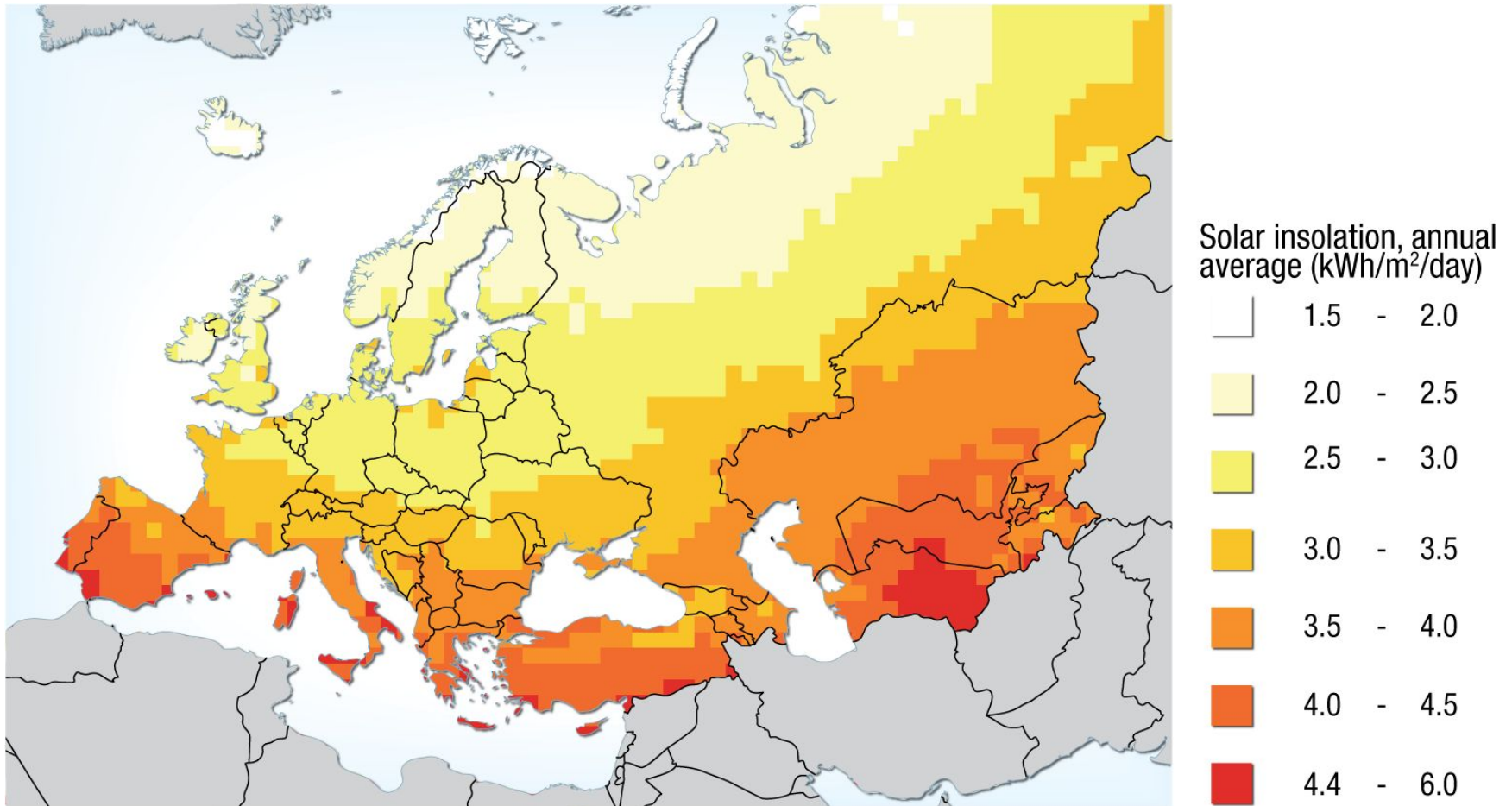
kWh/m²/day



This info is available @:

http://rredc.nrel.gov/solar/old_data/nsrdb/1961-1990/redbook/atlas/

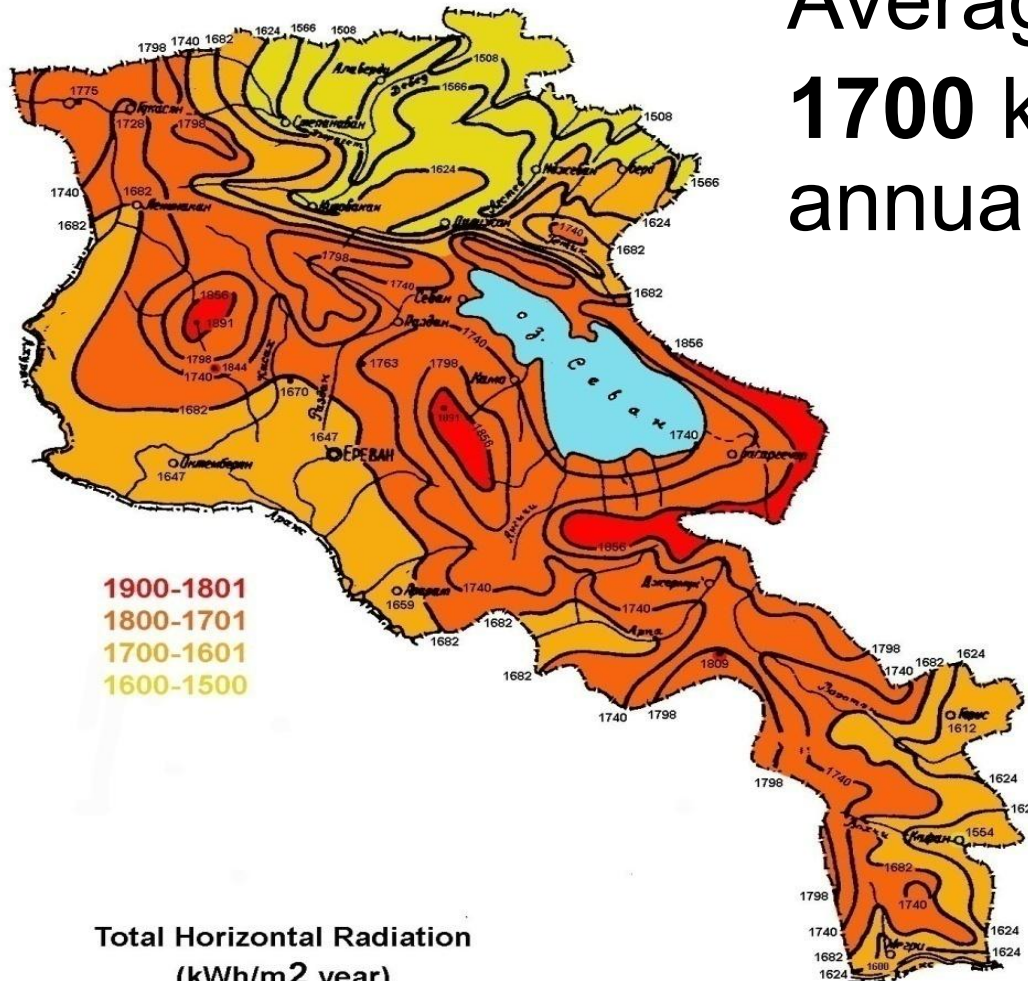
European Global Horizontal



ØÇÇÇÝ »íñáá³í³ÝÁ ßaðñç 1000 ìñÁ/(Ù².ĩñç)

Global Horizontal in Armenia

Average:
1700 kWh/m²
annually



Total Horizontal Radiation
(kWh/m² year)

Solar Radiation in Armenia

- Ճանժ $\frac{1}{2}$ áÝ³İ³Ý Ù³İ»ñłáõÛÃÇ ³é³í»É³·áõÛÝ ·áõÙ³ñ³ÛÇÝ
Ö³é³·³ÛÃáõÛÁ ÛÇÇÇÝ ³Ùá³Û³ÍáõÃÛ³Ý á³ÛÛ³ÝÝ»ñáõÛ`
1740-1770 İiiÅ/(Û²·İ³ñÇ) êÇëÇ³Ý, æ»ñÛáõİ, Â³ÉÇÝ ı
³ÛÉÝ,
- ÛáõÛÝÁ Ýí $\frac{1}{2}$ ³·áõÛÝÁ` 1230-1240 İiiÅ/(Û²·İ³ñÇ)
İ³Ý³Óáñ, İ³ßÇñ, êİ»ı³Ý³İ³Ý, ÇÉÇÇ³Ý ı ³ÛÉÝ,
- ØÃÝáÉáñİÇ ÛÇÇÇÝ İ³ñ»İ³Ý “Ã³ı³Ýó»ÉÇáõÃÛáõÝÁ”
0.73-0.78,
- °ñł³ÝáõÛ ÑáõÉÇëÇÝ` 0.94, ÑáõÝİ³ñÇÝ` 0.62,
- İ³Ý³ÓáñáõÛ ÑáõÉÇëÇÝ` 0.51, ÑáõÝİ³ñÇÝ` 0.67,
- êł³ÝáõÛ ÑáõÉÇëÇÝ` 0.78, ÑáõÝİ³ñÇÝ` 0.72

Solar Radiation in Armenia

- $\text{H}_0 = \frac{1}{r^2} \int_0^{\pi/2} I_0 \sin^3 \theta \cos \theta d\theta = \frac{1}{2} I_0$ (for $\theta = 0$ to $\pi/2$)
 $\text{H}_0 = 8.14 \text{ kWh/m}^2 \cdot \text{day}$
- $\text{H}_0 = \text{H}_c \cdot \text{H}_d$ (20-22% or less)
- $\text{H}_0 = \text{H}_c \cdot \text{H}_d \cdot \text{H}_r$ (30-40% for $\theta = 0$ to $\pi/2$)
 $\text{H}_0 = 900 \text{ kWh/m}^2 \cdot \text{day}$
- $\text{H}_0 = \text{H}_c \cdot \text{H}_d \cdot \text{H}_r \cdot \text{H}_s$ (30-40% for $\theta = 0$ to $\pi/2$)
 $\text{H}_0 = 900 \text{ kWh/m}^2 \cdot \text{day}$

Homework 5

1. calculate the maximum theoretical difference between direct normal (DN) and direct horizontal (DH) for 12 hour daytime period on a location at equator @ March 21 equinox. Assume AM0.
2. Go to http://rredc.nrel.gov/solar/old_data/nsrdb/1961-1990/redbook/atlas/. Explain why radiation values decrease with “**Two Axis Tracking Concentrator**” compared to “**Two Axis Tracking Flat Plate**”. Illustrate by maps.