CSP: Solar Resource Assessment



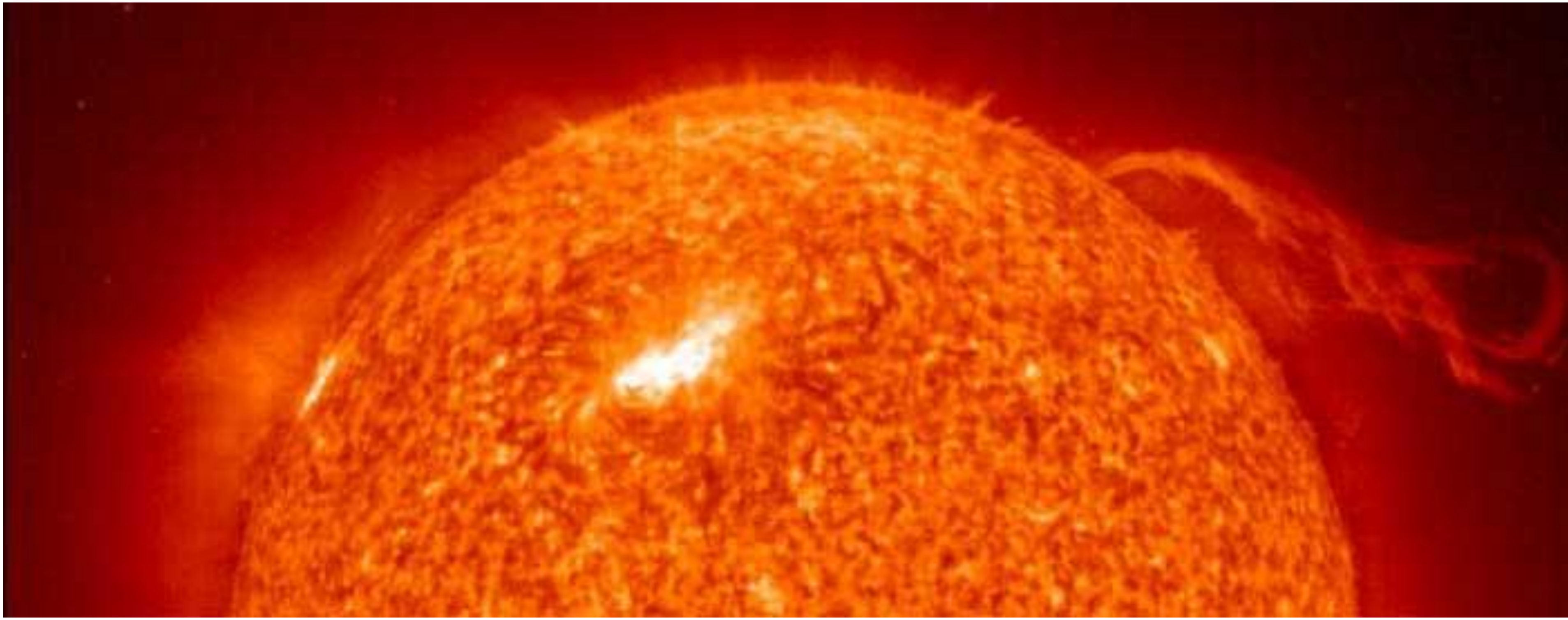

Agenda

- THE POWER OF THE SUN
- Solar Datasets
- The need for ground measurements
- Output quality: CSP vs. PV

ESMAP
Energy Sector Management Assistance Program

The power of the sun

In less than one hour the sun delivers more energy to the Earth's surface than the whole world is consuming within a year.



Source Image: http://nineplanets.org/sol.html

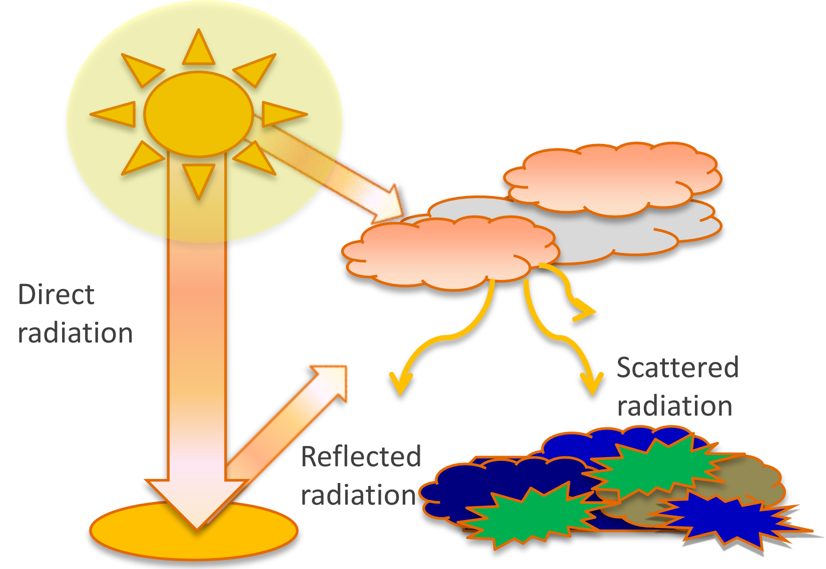
http://www.youtube.com/watch?v=OIP9FTWEpy4

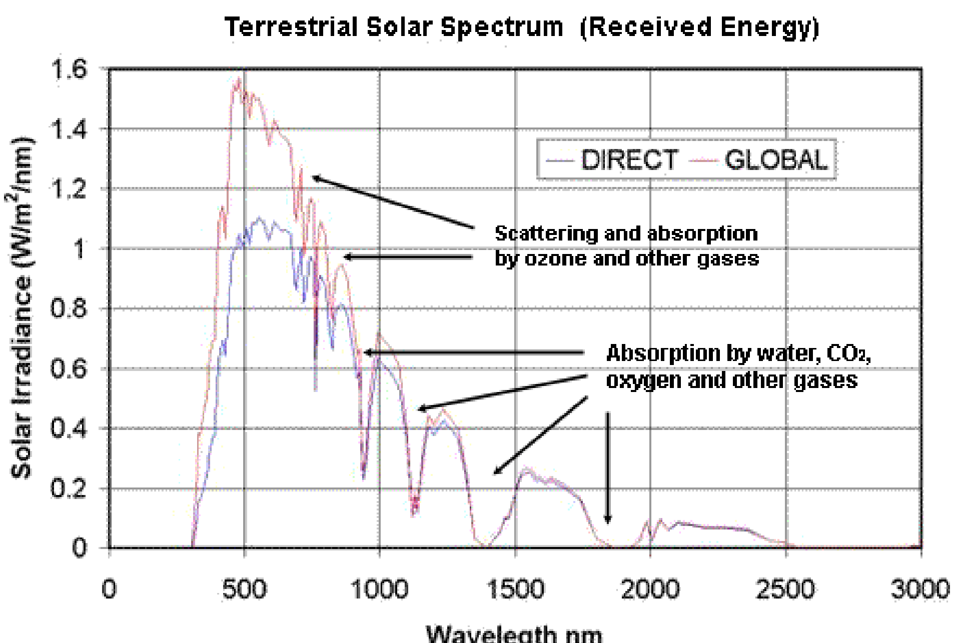
Solar Radiation

• **Direct** solar radiation is the radiation that comes directly from the sun, with minimal attenuation by the Earth's atmosphere or obstacles.

• **Diffuse** solar radiation is that which is scattered, absorbed, and reflected within the atmosphere, mostly by clouds, but also by particulate matter and gas molecules.

•The direct and diffuse components together are referred to as **total or global radiation.**





*Source :SECO

*Source: mppoweruk.com

Solar Data

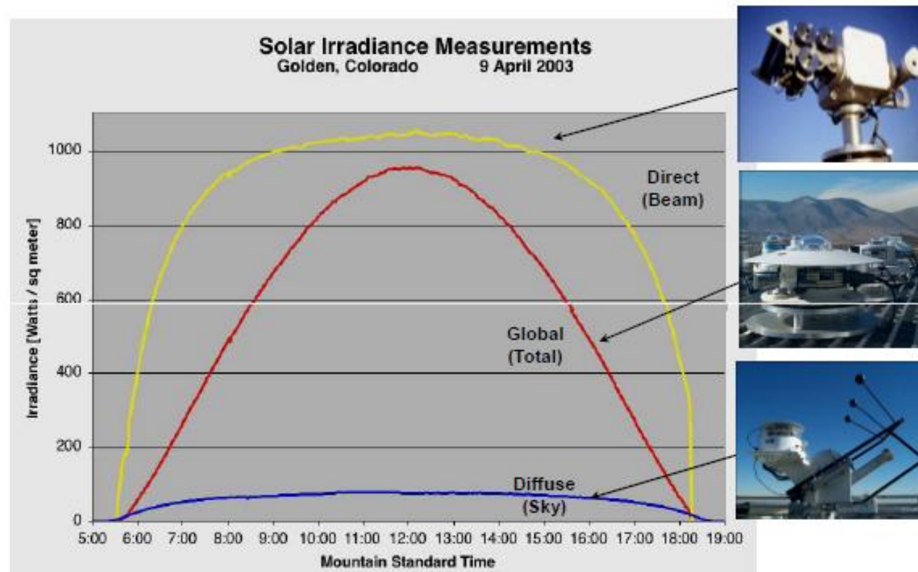
Global Horizontal (GHI) = Direct Normal (DNI) x cos(θ) + Diffuse Horizontal (DHI)

- **Global horizontal insolation (GHI):** Solar radiation measured with an instrument mounted horizontally, so that it sees the whole sky (direct plus diffuse).(**Pyranometer)**

- **Diffuse horizontal insolation (DHI):** Measured using an instrument that has a shade to block out the direct radiation.

- **Direct normal insolation (DNI)** is measured using an instrument that tracks the sun and shades out the diffuse, it only records the direct component.(**Pyrheliometer)**

Clear Sky Measurements



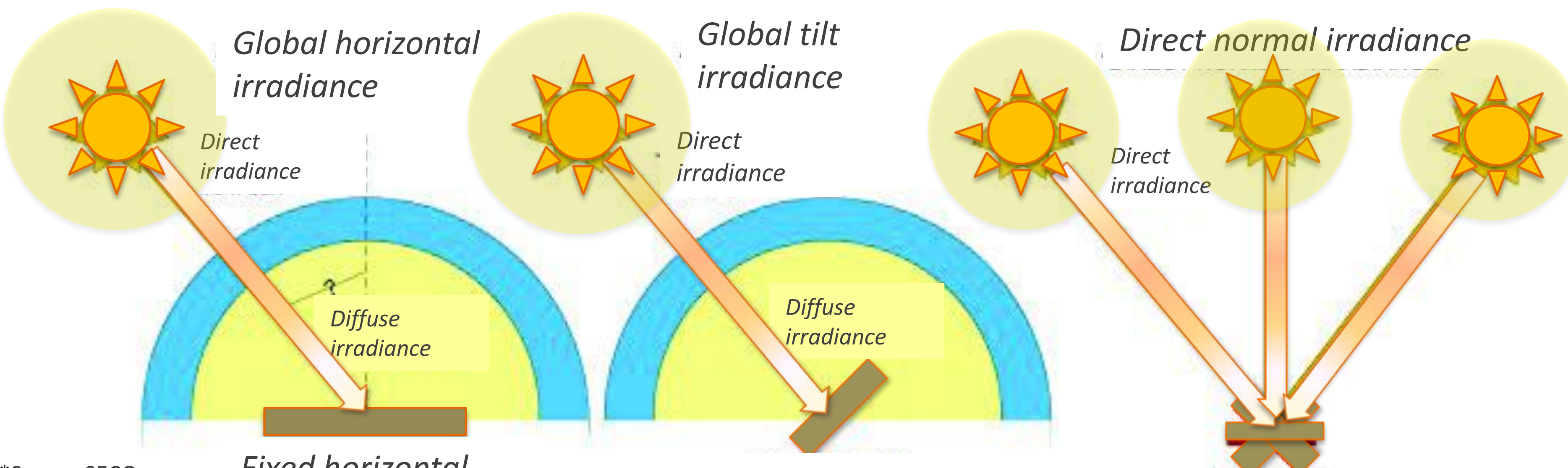
http://www.nrel.gov/midc/srrl_bms

Solar Resources

Flat-plate photovoltaic devices utilize both diffuse and direct radiation. The pertinent radiation is the global horizontal insolation (GHI).

Commonly, solar equipment is tilted relative to horizontal. DNI and GHI data can be used to estimate or model the solar radiation in the plane of interest, global tilt insolation (GTI).

Mirrors and other concentrating optics is only able to effectively focus the direct component, so “direct normal” solar radiation (DNI) is most relevant to these collectors.



*Source SECO

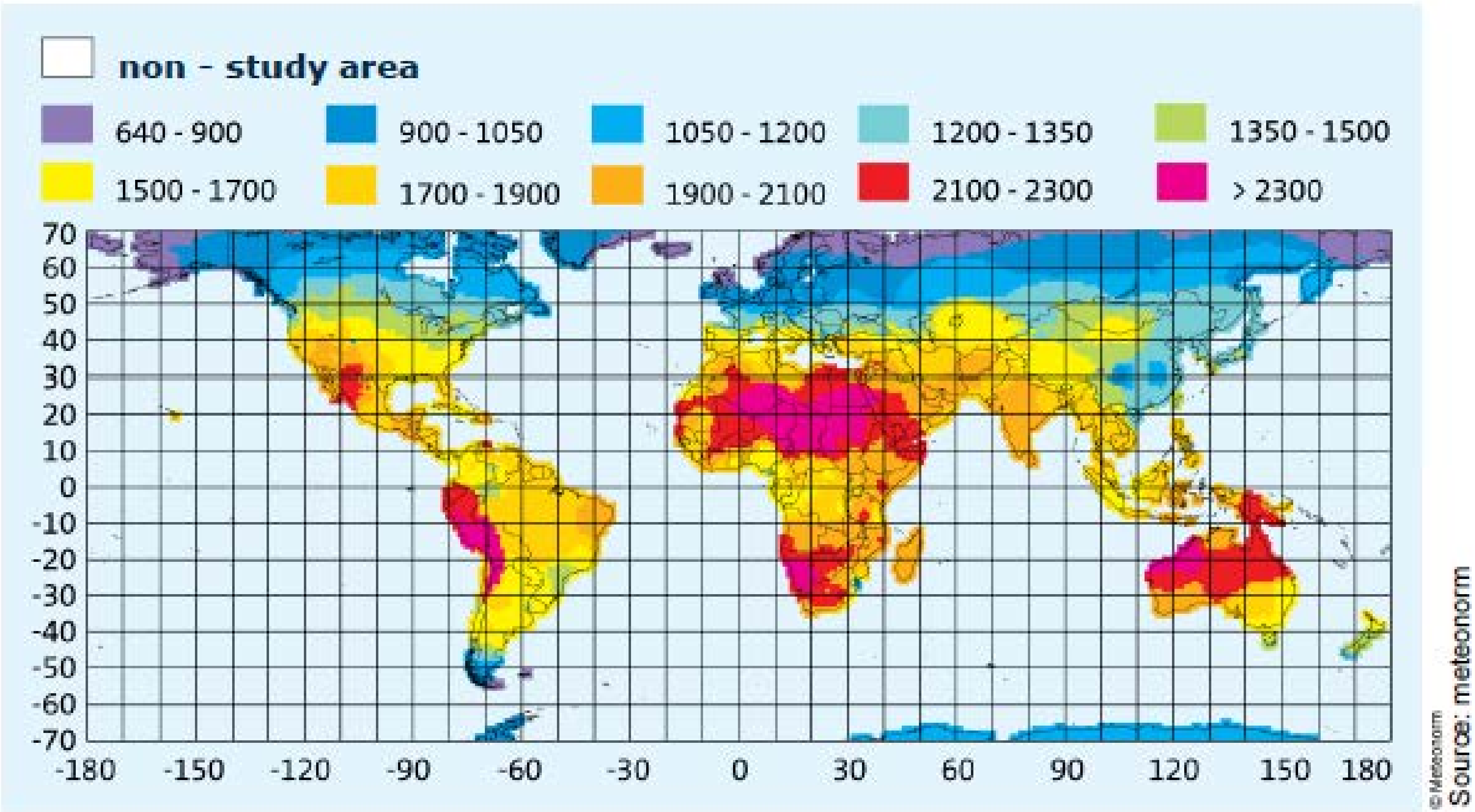
Fixed horizontal collecting surface

Fixed tilted collecting surface

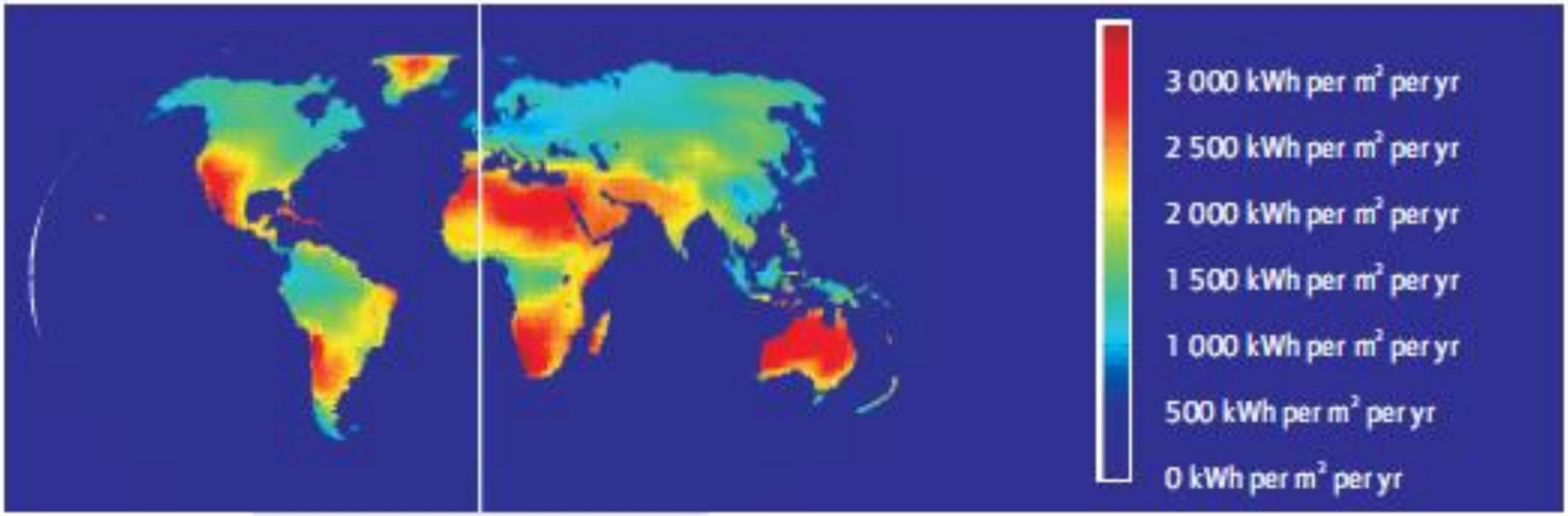
Tracking collecting surface

Selection of proper DNI sites is critical to Dish Projects Successful output

Global Annual Solar Radiation (KWh/sq m.y)



Solar resource for CSP technologies (DNI in Kwh/m2/y)



Source: (IEA, 2010) from Breyer & Kenies, 2009 based on DNI data from DLR-ISIS (Lohman, et al. 2006)

- Most favourable areas for CSP are: North Africa, southern Africa, the Middle-East, southern Europe, north western India, the south western United States, Mexico, Peru, Chile, the western part of China and Australia.

- The IEA estimates CSP could provide up to 11.3% global electricity by 2050.

What is good DNI?

- Financial viability of projects will depend upon the resource, technology and project costs, and the extent of government driven financial support.

- Current costs of the technology and constraints on financial support indicate that only projects that are located in the areas with the highest direct normal irradiation are likely to be viable in the near future with annual average direct normal irradiation values of greater than 2.2 MWh/m2/year or 6.0 kWh/m2/day.

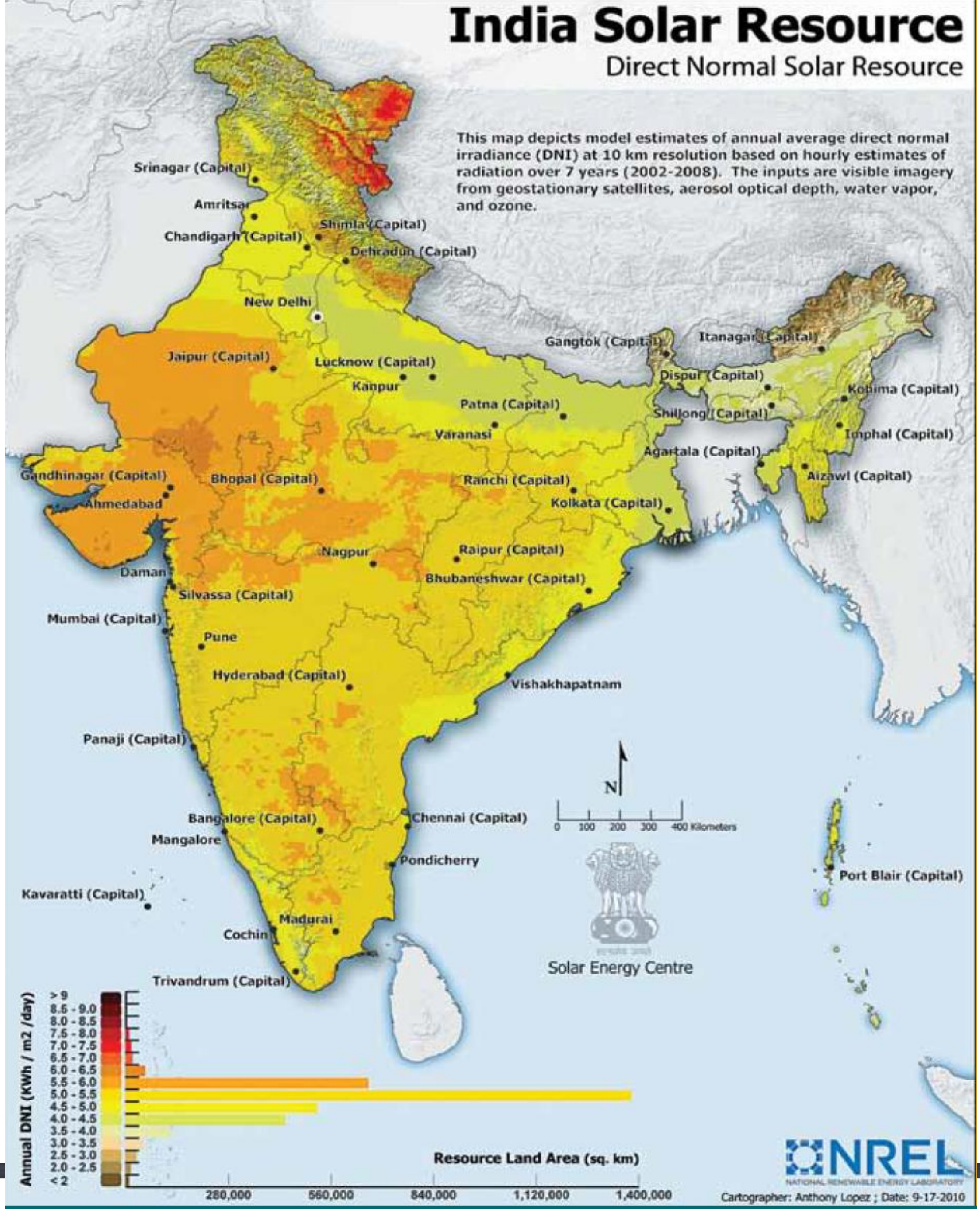


Figure 1: Average Daily Direct Normal Solar Irradiation in India (kWh/m²/day)[3]

This diagram was created by the National Renewable Energy Laboratory for the Department of Energy (USA)

Solar Datasets

Several satellite-derived DNI datasets with international coverage are available, but their properties (input data source, data generation method, grid resolution, spatial and time resolution, uncertainty, etc.), are not always well known or understood by the stakeholders involved in the planning process.

•**Public datasets:** SSE v6 (NASA), CSR (NREL), SUNY (NREL) or Satel-Light (ENTPE). They cover several countries, growing in extension each year.

•**Partially public datasets**: SoDa/HelioClim (Ecole de Mines) and DLR-Solemi

•**Commercial datasets**: Meteonorm, Focus Solar, solargis (GeoModel), EnMetSol, Ir-SOLaV, s2m or 3TIER. These datasets have mostly global coverage, and are reportedly based on better radiative models and input data. It has to be shown whether this translates into higher-accuracy DNI results.

Solar Resources – TMY3 and others

[NREL's TMY3 Data]

•TMY3 dataset is made up of historical observations from a 10-30 year history that are selected as representative of the location and concatenated into a typical meteorological year.[NSRDB Database]

• This data can be very good for monthly averages but is terrible for hourly and daily data. **NREL says "*The TMY should not be used to predict weather for a particular period of time, nor is it an appropriate basis for evaluating real-time energy production or efficiencies for building design applications or solar conversion systems.*"** ([TMY3 User Manual]).

Solar Resources – TMY3 and others

Solar Resource
TMY3
Actual Data

NREL's TMY3 Data

•TMY3 dataset is made up of historical observations from a 10-30 year history that are selected as representative of the location and concatenated into a typical meteorological year.[NSRDB Database]

• This data can be very good for monthly averages but is terrible for hourly and daily data. **NREL says "*The TMY should not be used to predict weather for a particular period of time, nor is it an appropriate basis for evaluating real-time energy production or efficiencies for building design applications or solar conversion systems.*"** (TMY3 User Manual).

Class of NSRDB Data	Uncertainty	Remarks
I	Lowest uncertainty data	Less then 25% of the data for the 15-year period of record exceeds an uncertainty of 11%
II	Higher uncertainty data	Greater then 25% of the data for the 15-year period of record exceeds an uncertainty of 11%
III	Incomplete period of record.	Algorithm used to complete data set

Measuring DNI: Pyrheliometers

- 5.7º Field of View
- Mounted in Solar Tracker
- Broadband Response
- 0.3 - 3.0 mm (Quartz window)
- Responsivity: 8-10 mV/Wm-2
- Around 2% uncertainty

Source: The Eppley Laboratory, Inc.

The need for ground MEASUREMENTS

•Datasets are considered adequate for planning purposes, but planners should be aware of the uncertainty associated to the data. Annual DNI sums and yearly distribution differ very much among datasets for the same specific sites since the models apply different atmospheric corrections.

•Locations with similar average DNIs can see variations of up to ± 9% in annual electricity production due to differences in DNI frequency distribution. (IEA, 2010).

•Ambient temperature, wind speed and direction and relative humidity conditions at the site AFFECT the performance.

•Therefore, satellite based datasets must be scaled with ground measurements in order to obtain reliable and “bankable resource assessments” during the project development phase.

•Solar resource uncertainty risk is perceived as one of the highest by financiers. A minimum of one year of on-site measurements is required.
•The information obtained, together with satellite and historic data, must be analyzed to produce long term estimates of the solar resource.

Measurement Instruments

DNI meters:

DR01

First Class Pyrheliometer

Temperature range: -40 to +80° C
Temperature dependence: < ± 0.1 %/°C
Non stability (drift): < ± 1% per year
Calibration traceability: WRR

- Thermopile sensor output voltage change proportional to DNI at 20C, but needs temperature correction at other ambient temperatures

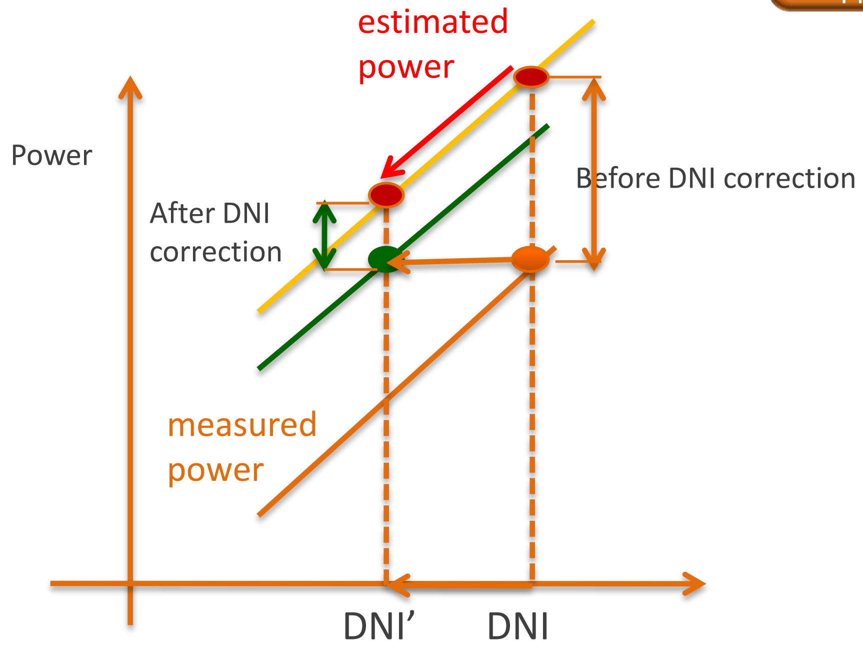
MSP DNI meters do not have temperature compensated outputs.
Manufacturer advises the following temperature correction:
DNI corrected= DNI*(1+0.8%*(20-T(°C))

Impact from using temperature corrected DNI vs. raw DNI data

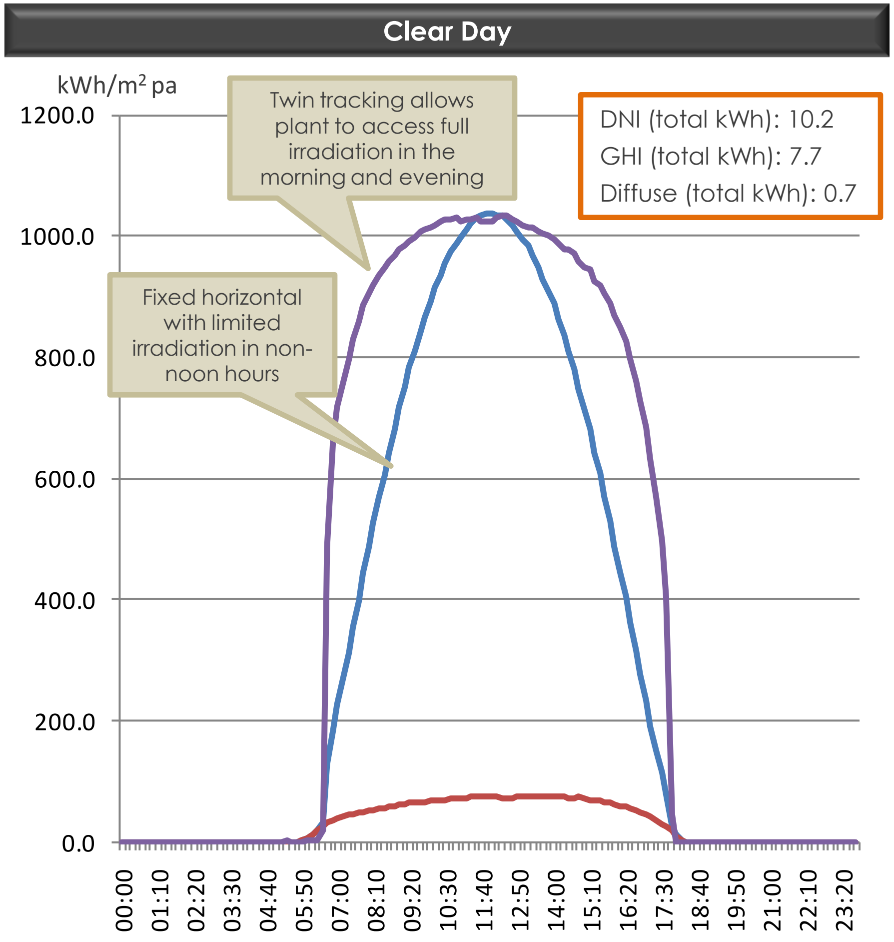
SunCatcher Energy Production

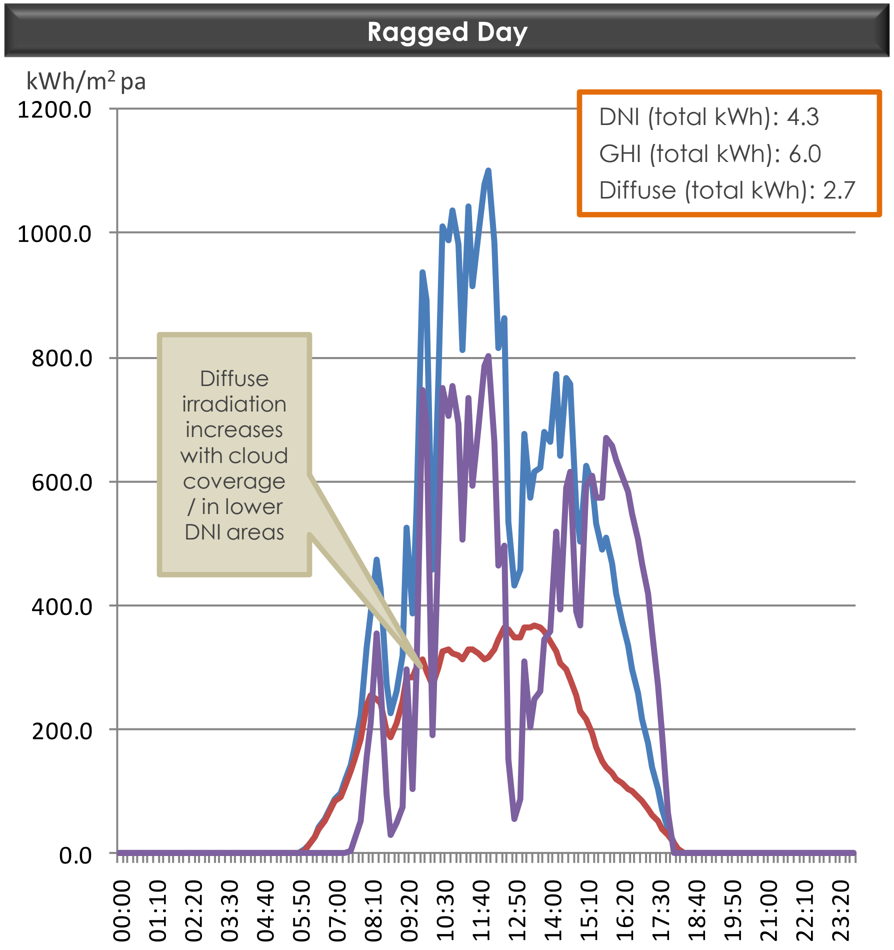
RAW DNI	Ambient Temperature, C	DNI error %	Corrected DNI
300	0	-1.6%	305
600	0	-1.6%	610
950	0	-1.6%	965
300	20	0.0%	300
600	20	0.0%	600
950	20	0.0%	950
300	44	1.9%	294
600	44	1.9%	588
950	44	1.9%	932

Impact of DNI correction at high T



Solar Resource Basics





Global Horizontal Irradiation (W/m²)
PV

Diffuse Irradiation (W/m²)
PV

Direct Normal Irradiation(W/m²)
CSP / CPV

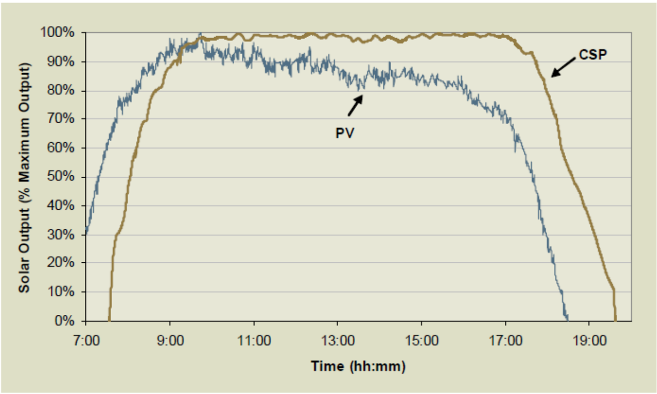
Tracking enables technologies to access more resource and higher capacity factors
CSP / CPV require direct radiation – PV operates with direct and diffuse radiation (global)

2. Output Quality

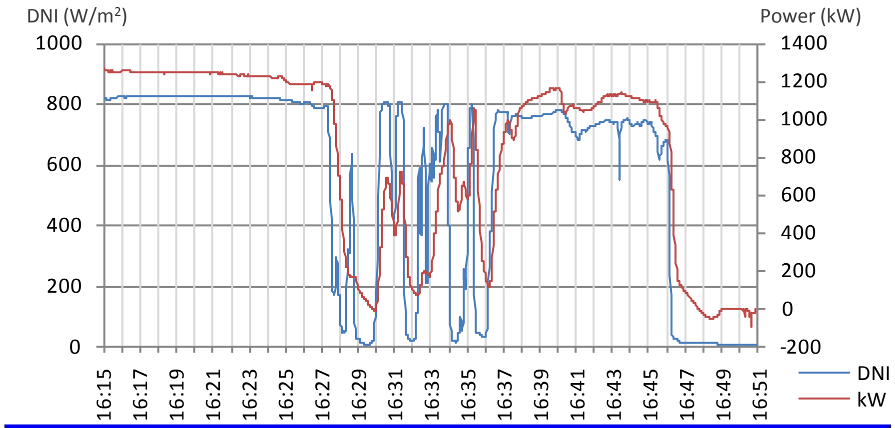
- Traditional CSP plants have higher output quality due to thermal inertia and thermal storage

PV vs. CSP

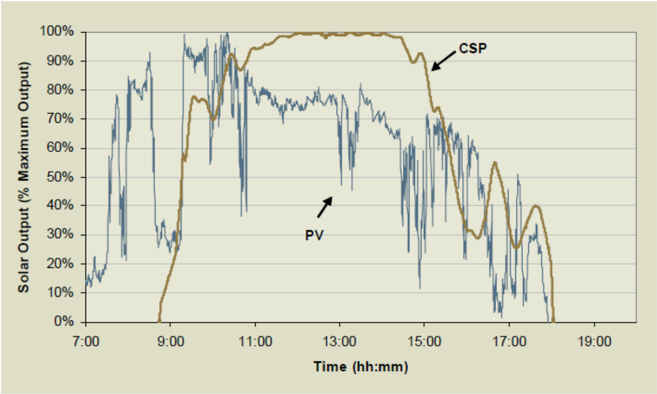
Production on a Sunny Day*



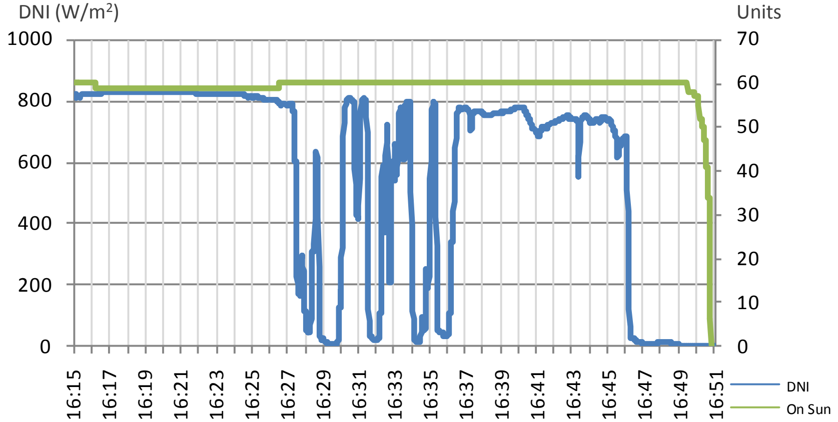
Power Output vs. DNI



Production on a Cloudy Day*



Engine Ride-Trough Capability



*Source: Black & Veatch

Even though SunCatcher units can stay on sun 5mins+ after DNI drops under threshold (300W/m2) actual power output is comparable to PV

SILVIA MARTINEZ ROMERO

SMARTINEZROMERO@WORLDBANK.ORG

Thank You.

The World Bank | 1818 H Street, NW | Washington DC, USA
www.esmap.com | esmap@worldbank.org