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Applications of CM SAF solar radiation data in solar energy research

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Overview of presentation

1. Solar radiation data requirements for solar energy
2. Research projects using CM SAF solar radiation data
3. A first attempt at accounting for spectral effects of PV modules using SpecMAGIC data
4. Web-based PV energy estimates with PVGIS
5. Future projects and planned improvements

Solar radiation data needed for solar energy

- Wide spatial extent and high spatial resolution needed for nearly all applications.
- High time resolution is needed in many fields: solar thermal power plants, off-grid PV, electricity grid studies etc.
- High local accuracy is necessary for performance estimates, siting studies, performance evaluation
- DNI is important for concentrating solar power (thermal and PV)
- Spectrally resolved radiation data helps assessing PV performance
- Near-real-time irradiance for system monitoring and nowcasting

Research Applications of CM SAF data

- Mapping of the performance of grid-connected PV systems
- Contribution to international standards work
- Geospatial and web-based estimates of off-grid PV system performance
- Study of PV electricity cost in Europe
- Study of complementarity of wind and solar resource in Italy
- Using spectrally resolved solar radiation data to estimate the influence of spectral variations on PV performance

Effects influencing PV performance

- Reflectivity at shallow angles of incidence
- Irradiance and module temperature. Module temperature is in turn influenced by air temperature, irradiance and wind speed.
- Variations in the spectrum
- Change due to aging, the big unknown

These effects are expressed as a change in the conversion efficiency of PV modules, relative to the nominal efficiency

Data sources

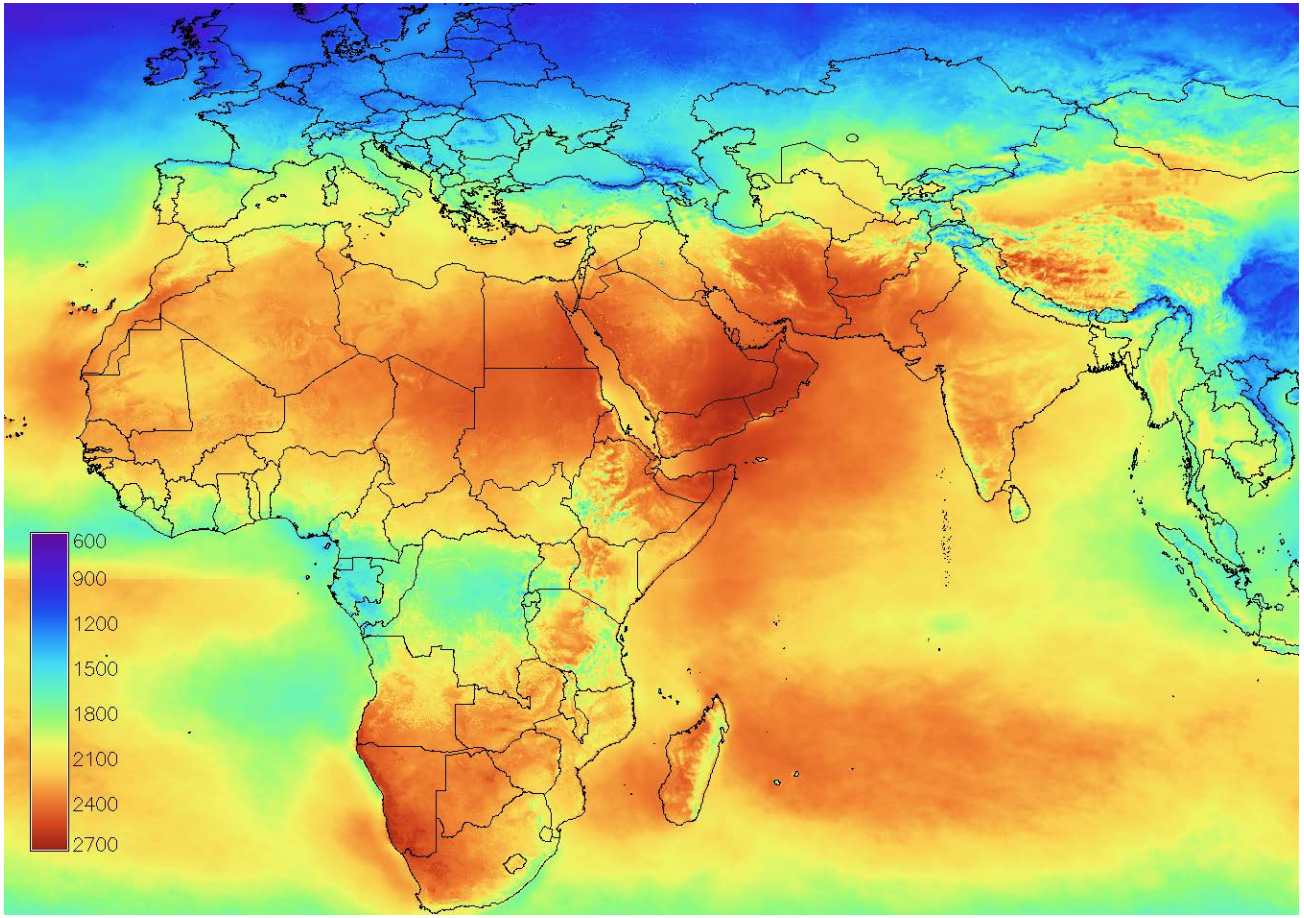
- Irradiation data calculated from satellite by the CM SAF collaboration and JRC Ispra
  - Hourly time resolution
  - Spatial resolution around 3-5km

- Temperature and wind speed data from ECMWF (www.ecmwf.int) ERA-Interim reanalysis
  - 3-hourly time resolution, linear interpolation to hourly values
  - Spatial resolution 0.75° latitude/longitude (quite low resolution)

- Module power measurements mainly by the ESTI Laboratory

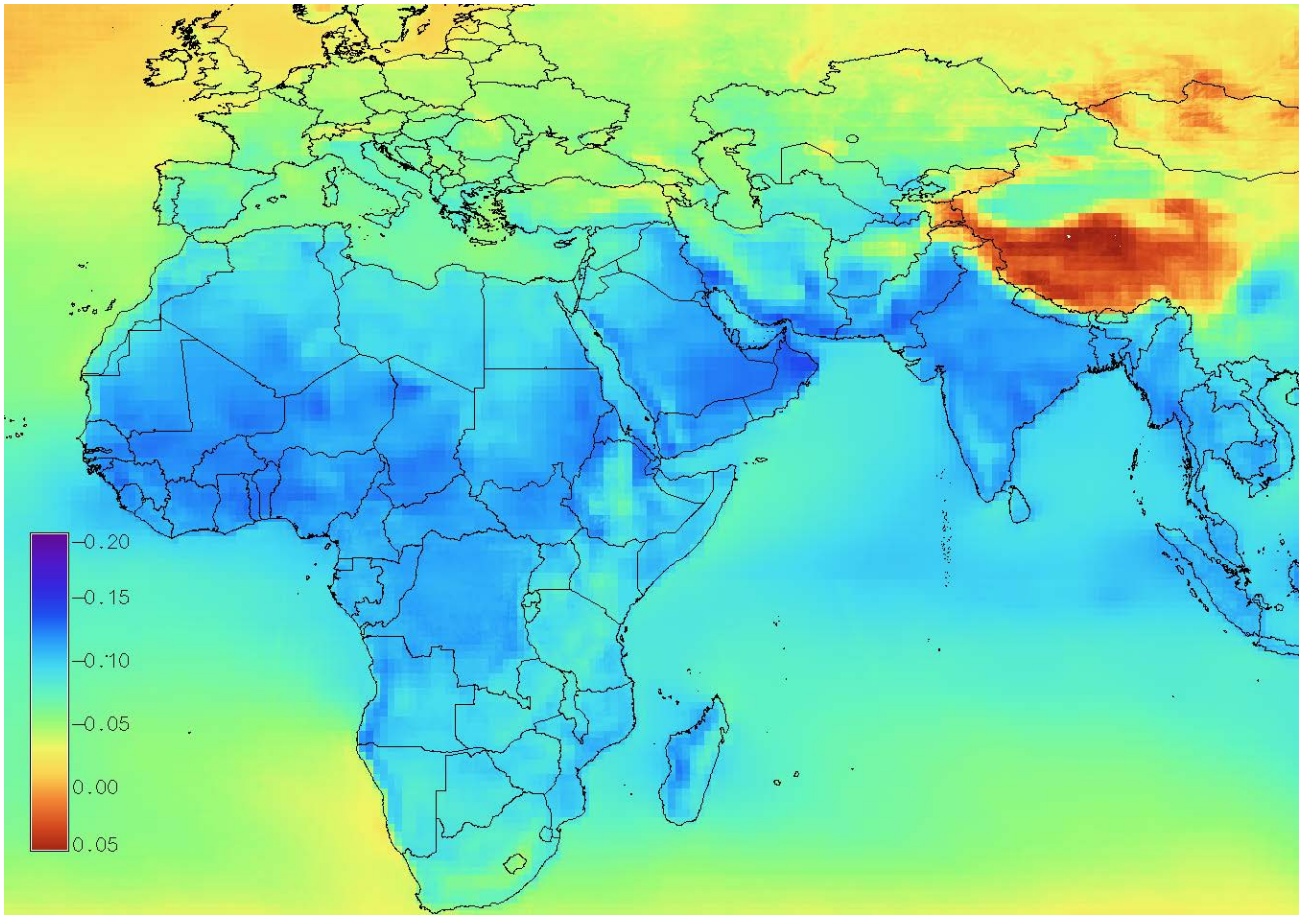
Annual global in-plane irradiation

Total for 2011, kWh/m^2



Change in PV efficiency

Relative change from nominal efficiency



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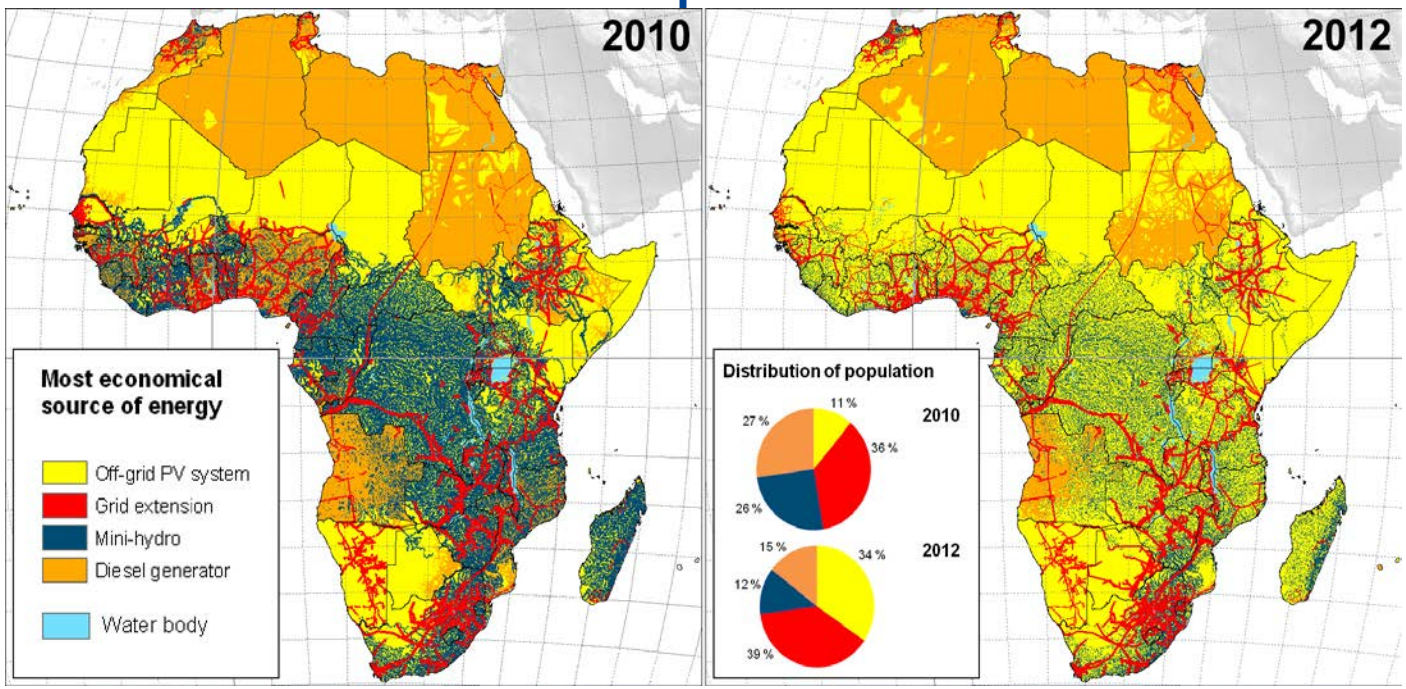
Performance of off-grid PV in Africa

- Estimating the performance of PV systems that are not grid-connected is more complicated because of the need to store energy for use at night and in cloudy weather
- Hourly solar radiation data from CM SAF were used to study the performance of PV-powered village minigrid systems in Africa
- From these results it was possible to estimate the cost of electricity produced by PV minigrid systems and compare this with the estimated cost of electricity produced by other means

Comparison of PV and other electrification options



Szabo, Bódis,
Huld, Moner-Girona,
Env. Res. Lett. 2013

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Other recent studies

1. Study of the influence of increased renewable energy capacity on cross-border electricity flows in Europe. Hourly CM SAF solar radiation data used to estimate hourly PV energy production in Europe. Brancucci et al., Energy Policy, 2013

2. Study of correlation of wind and solar energy resources in Italy. Hourly solar radiation data from CM SAF (MFG data for 2005) used to estimate hourly PV energy production. Monforti et al., Renewable Energy, 2013

Towards mapping of spectral influence on PV performance

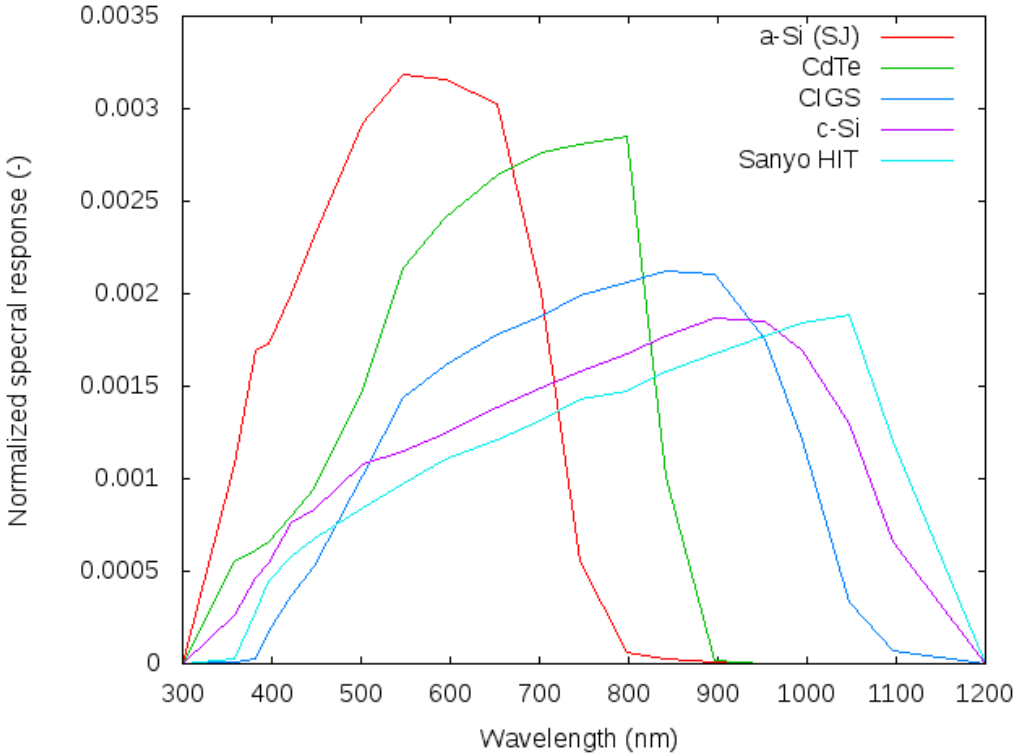
Investigating geographical variation of spectral effects is difficult due to scarcity of spectral measurements.

Recently, an algorithm has been developed to derive spectrally-resolved irradiance from satellite data (Richard Müller, DWD)

Processing is heavy, so full maps are not yet available

Validation of results still ongoing, first results are encouraging

PV modules for simulation



Normalized spectral response curves for 5 different modules, measured at the ESTI laboratory

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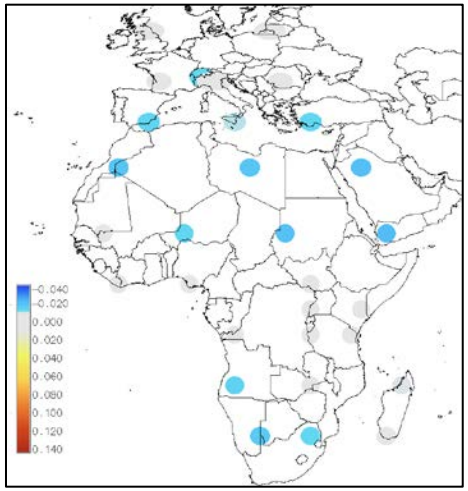
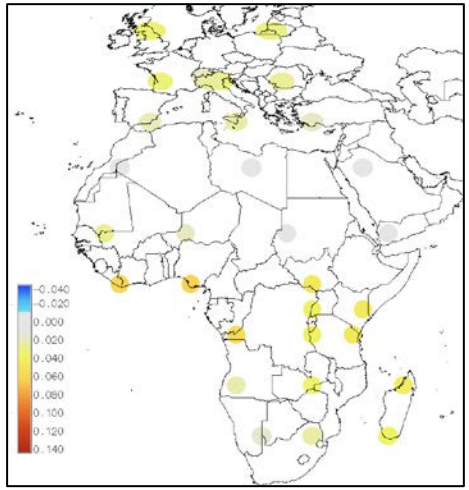
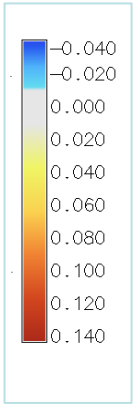
CIGS

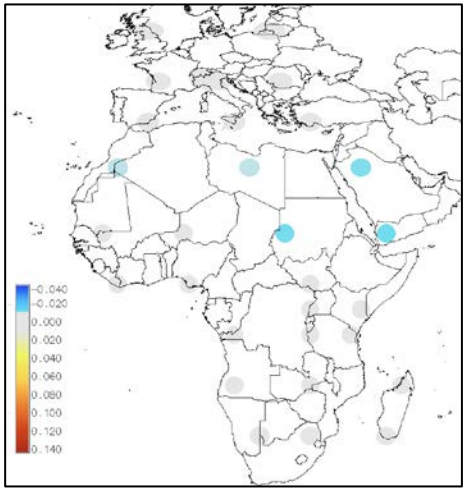


CdTe

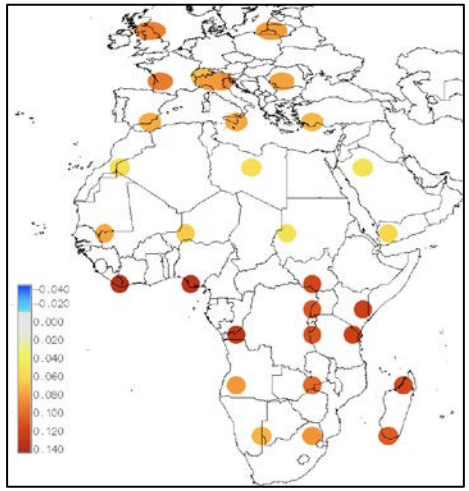




C-Si



a-Si (SJ)



Change in efficiency, four module types

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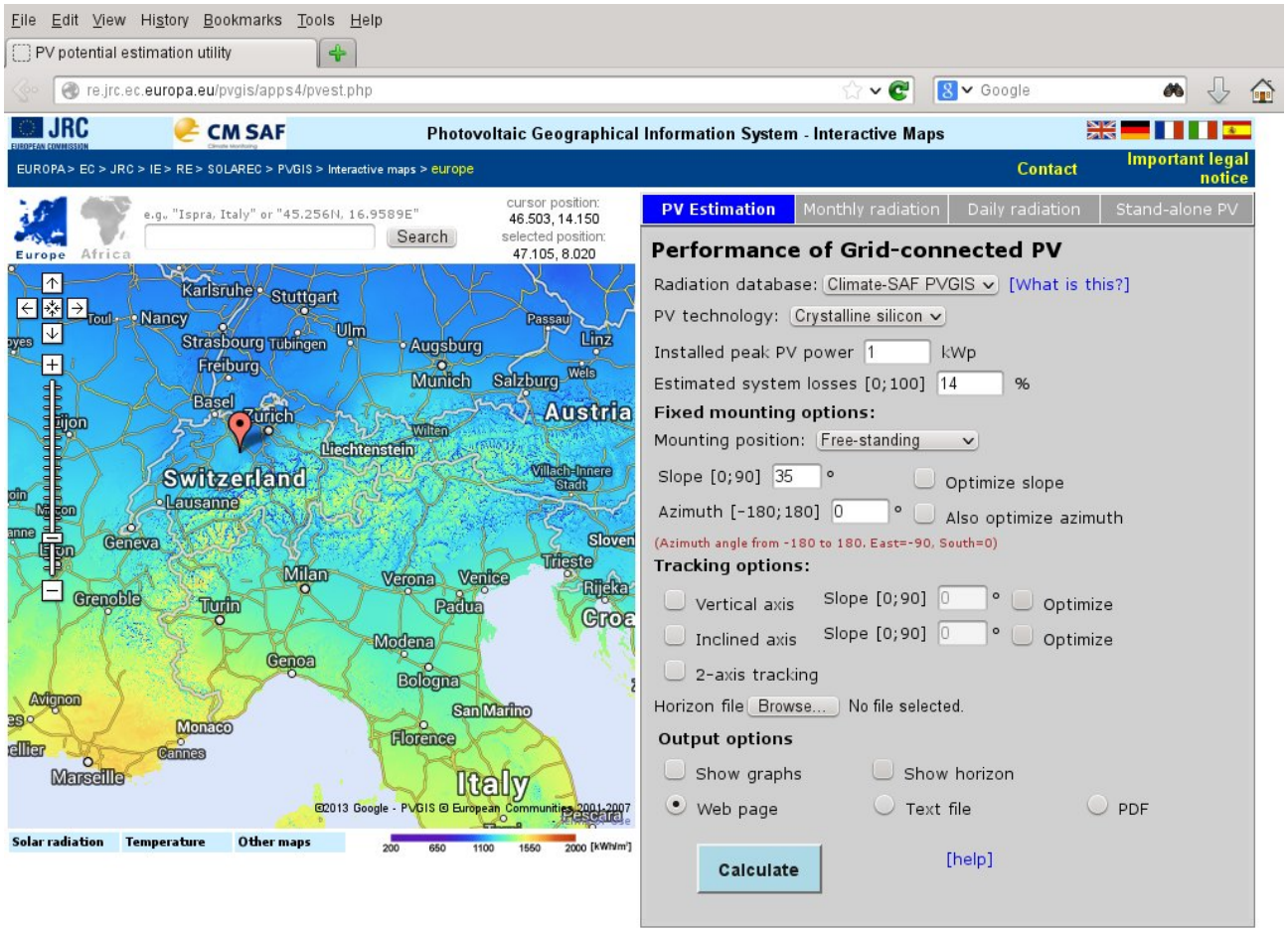
Present and future applications

- Study of the effects of climate change on PV system performance. The study uses climate model data but uses CM SAF data for comparison with present-day model output
- Extend maps to Asia and, if possible, to the rest of world (see poster by Gracia Amillo et al.)
- Spectral effects results are intriguing, but need more validation. How to account for the complex spectral behaviour of multi-junction cells?
- Investigation of grid-connected PV systems with battery storage.
- Mapping of factors contributing to PV module degradation (high module temperature, UV radiation)

PVGIS online PV performance estimation

- Freely available web-based calculator for making simple estimates of PV energy output
- Based on CM SAF solar radiation data + ancillary data (temperature, elevation, wind to be added soon)
- Available for Europe and Africa, Asia soon
- Includes the effects of shadows from terrain (mountains/hills)
- Calculations of grid-connected PV systems using long-term average solar radiation data
- Calculations of off-grid PV systems using hourly time series of solar radiation data



PVGIS web interface, front page with Google Maps interface

Thank you for your patience!

Acknowledgements

- To the CM SAF team for producing and freely distributing the solar radiation data sets

- To Richard Müller of DWD for making the Heliosat and SPECMAGIC toolchains available

- To our colleagues at ESTI who can instantly pull a spectral response curve or PV power matrix out of the hat and explain what it means.