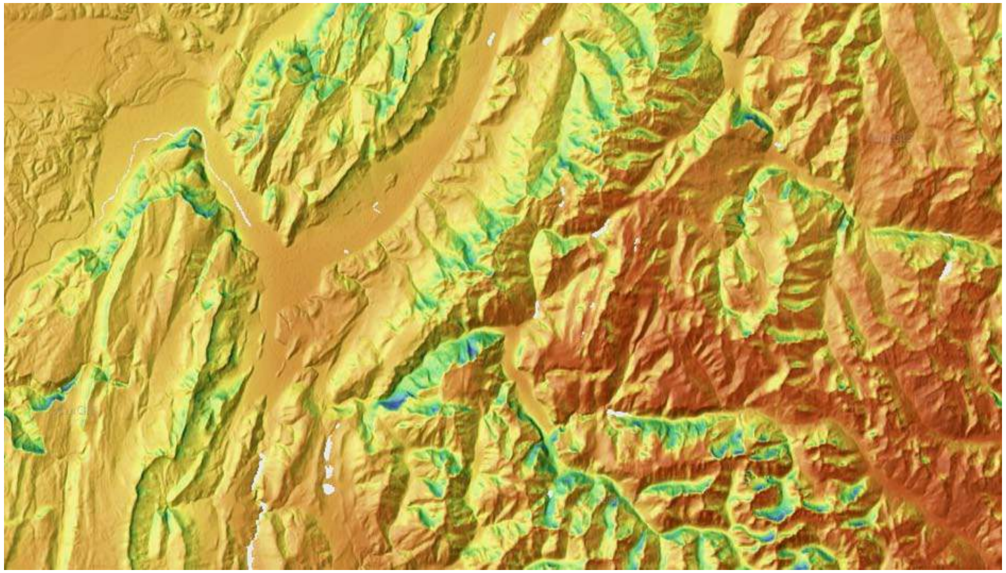
Forum on Bankable Solar Resource Assessment
Best Practices for PV and CSP

Providing bankable solar resource data for PV in Europe



Marcel Suri, Tomas Cebecauer

GeoModel s.r.o., Bratislava, Slovakia

http://geomodel.eu
http://solargis.info

GeoModel

GeoModel

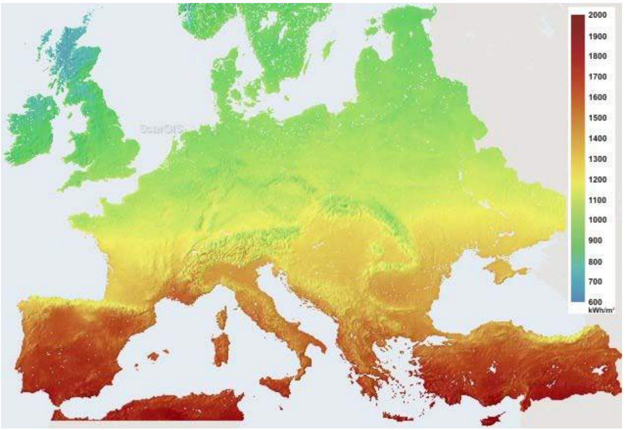
- Data products and geoinformation services for solar industry:
  - Solar and climate data, maps, simulation software
  - Web services
  - Expert consultancy (PV, CSP, CPV)
- Since 2001 in solar research and since 2008 in solar market

International Energy Agency, Solar Heating and Cooling,
Task 36 “Solar Resource Knowledge Management”

EU projects: PVGIS, MESoR, etc.

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

MESOR



Factors determining performance of PV power plant

- solar resource → „fuel“
- ambient temperature
- terrain and local horizon
- position of roof/land

} environment & operational conditions

- PV modules
- inverter
- mounting type (fixed, suntracking)
- design

} PV system parameters

- quality of construction and operation

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• quality of construction and operation

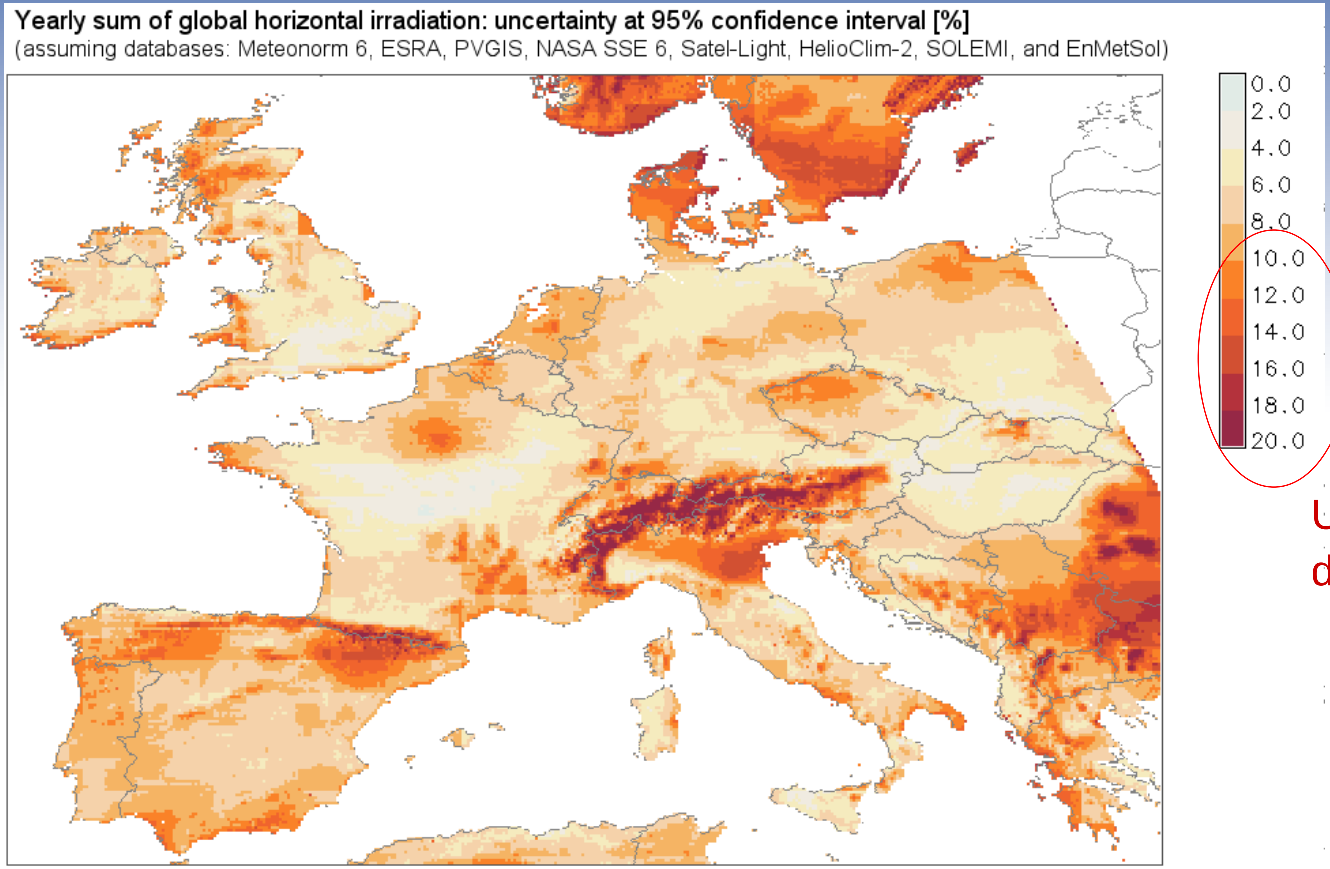
solar resource - highest uncertainty!

Accuracy and reliability of solar resource data

Optimum data

- no bias, low RMSE, perfect match of histogram (probability distribution)
- time coverage 15-20 years
- high time frequency (15-min. or hourly)
- well representing local climate (ground data or high-res satellite)
- all components (global, direct, diffuse)
- quality checked, harmonized
- no gaps
- available at any place

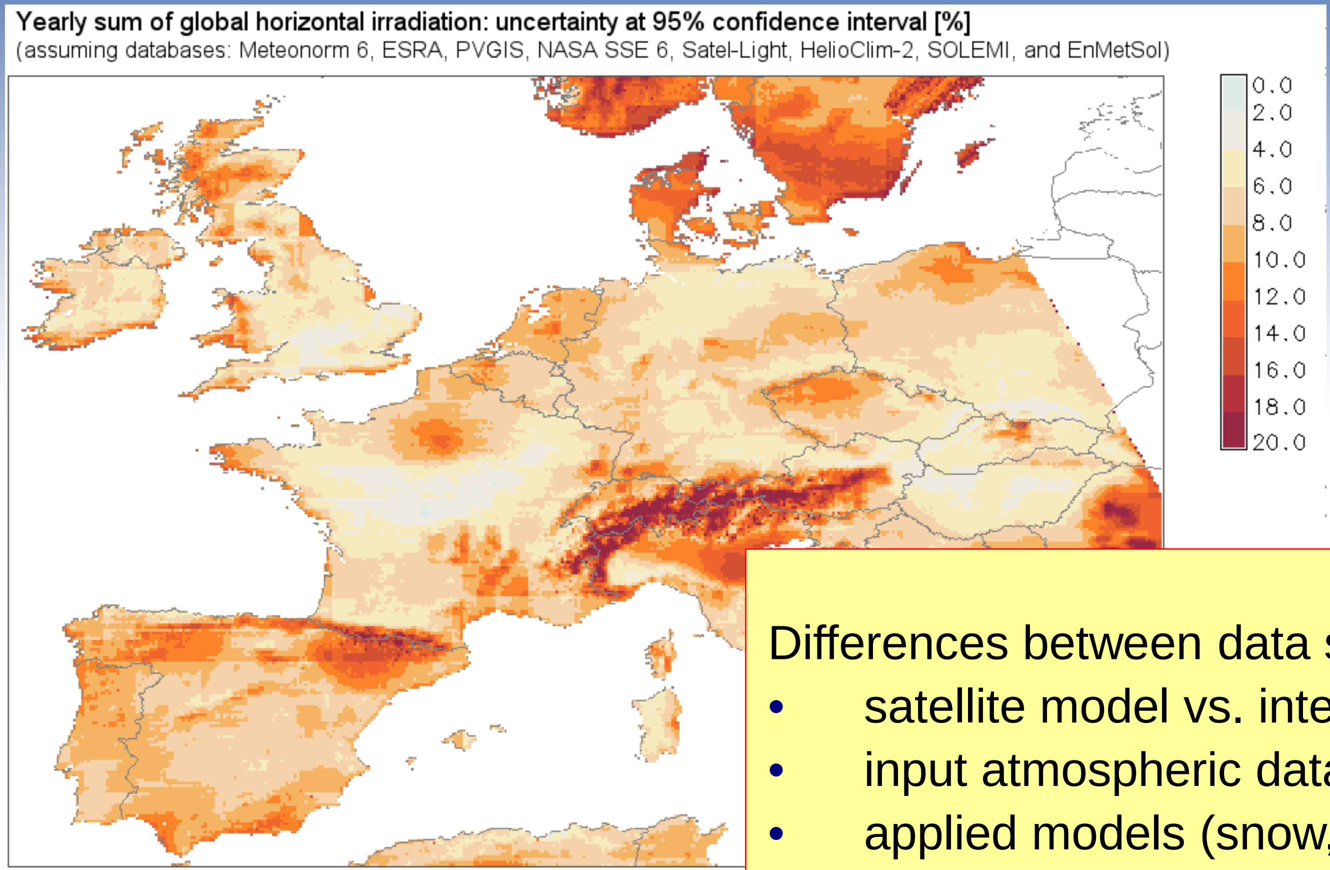
Comparison of data in Europe



Uncertainty (%) from using different data sources

Source: project MESoR 2009

Comparison of data in Europe



Source: project MESoR 2009

Differences between data sources:

- satellite model vs. interpolation of ground data
- input atmospheric data (aerosols, water vapour)
- applied models (snow, terrain, etc.)
- time coverage
- temporal and spatial resolution

expert knowledge needed!

What solar resource info is needed in a PV project?

Site selection & prefeasibility

Decision about the site and technology

find the site, get overview info
compare alternatives

Project planning & design

Design optimisation and project financing

energy audit, forecast of long-term yield
incl. variability and uncertainty

Performance assessment

Acceptance test and financial close after project completion

assurance of performance ratio

Long-term monitoring

Payment of bonuses to the operator
Exit (selling the power plant)

long-term assessment of performance ratio
availability, degradation trends

Site selection and preliminary decision about technology

Site selection & prefeasibility

↓

Project planning & design

↓

Performance assessment

↓

Long-term monitoring

Needs

- find the site, get overview info
- compare alternatives

- fast and easy access to information
- simple simulation tools
- simple report

Data requirements

- annual and monthly values
- historical time coverage 5+ years
- lower accuracy (bias) acceptable

satellite data typically used

Site selection and preliminary decision about technology

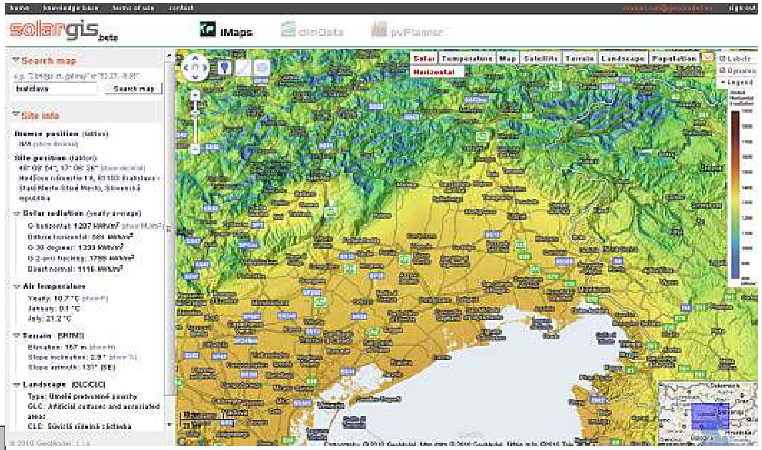
Site selection
& prefeasibility

Project planning
& design

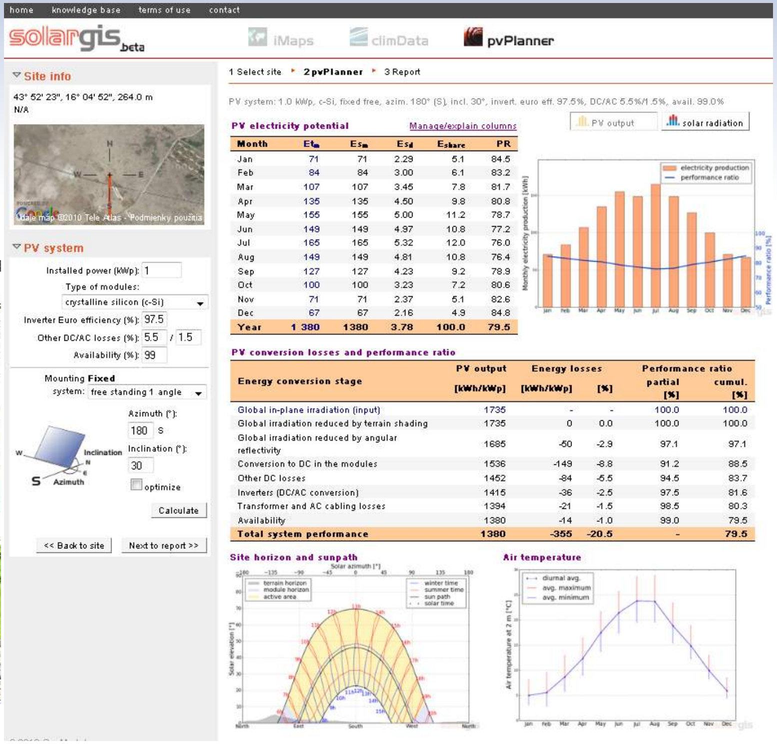
Performance
assessment

Long-term
monitoring

Comparison of candidate sites and technology options



iMaps



pvPlanner

example: SolarGIS

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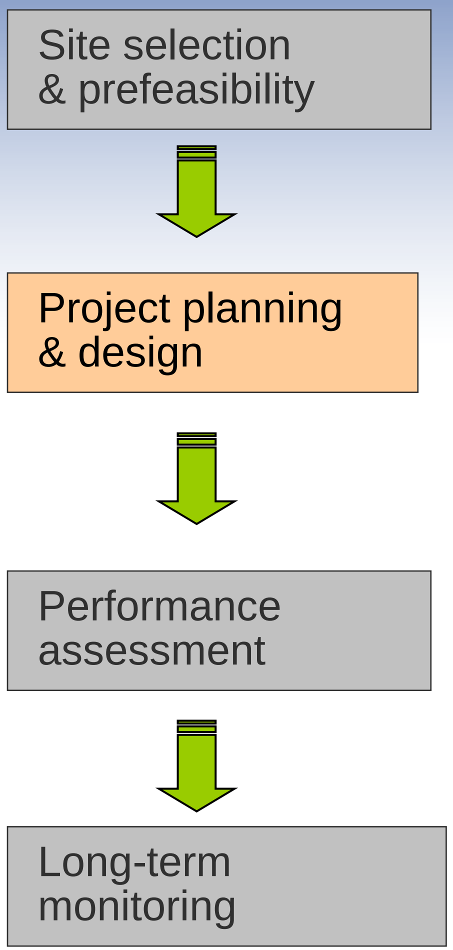
Project planning, design optimisation & financing



Needs

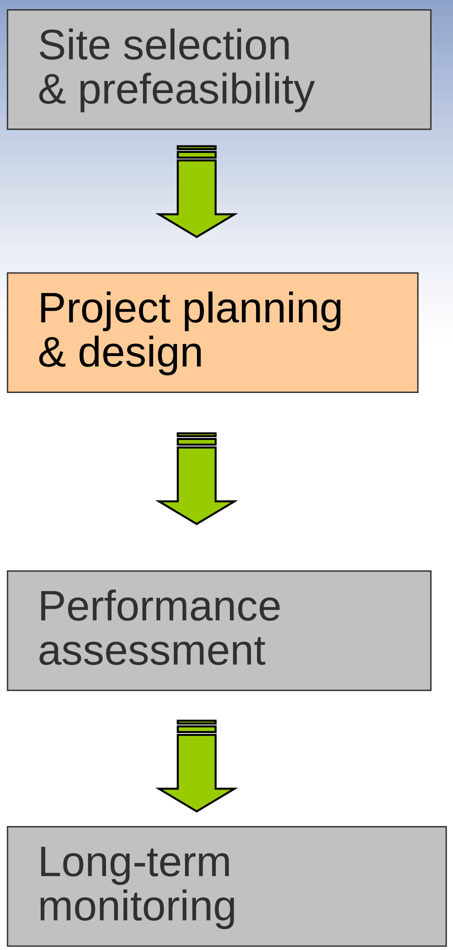
- yield and performance ratio over economic lifetime
- probability statistics and P(90) exceedance
- uncertainty (return of investment)
- seasonal and interannual variability (cash flow)

Data requirements

- accurate 15-min. (hourly) time series
- historical time coverage 10+ years with known accuracy
- critical comparison of data sources
- shading
- in-depth analysis and elaborated report

satellite data typically used

Project planning, design optimisation & financing



uncertainty of annual $G_{in\text{-}plane}$

Energy conversion stage	Energy output [kWh/kWp]	Energy loss [kWh/kWp]	Energy loss [%]	Uncertainty [%]	Performance ratio Partial [%]	Performance ratio Cumul. [%]
Global irradiation - inclined plane (input)	1435			3.3	100.0	100.0
Global irradiation (reduced by terrain shading)	1435	-0	-0.0	0.2	100.0	100.0
Global irradiation (reduced by angular reflectivity)	1391	-44	-3.1	0.3	96.9	96.9
Conversion to DC in the modules (effect of irradiation and module temperature)	1290	-101	-7.2	2.0	92.8	89.9
Other losses (DC cabling, mismatch, dirt, snow, self-shading)	1200	-90	-7.0	2.5	93.0	83.6
Inverters (DC/AC conversion)	1152	-48	-4.0	0.5	96.0	80.3
Transformer and AC cabling losses	1135	-17	-1.5	0.5	98.5	79.1
Availability	1129	-6	-0.5	0.5	99.5	78.7
Total system performance	**1129**	**-306**	-	**4.7**	-	**78.7**

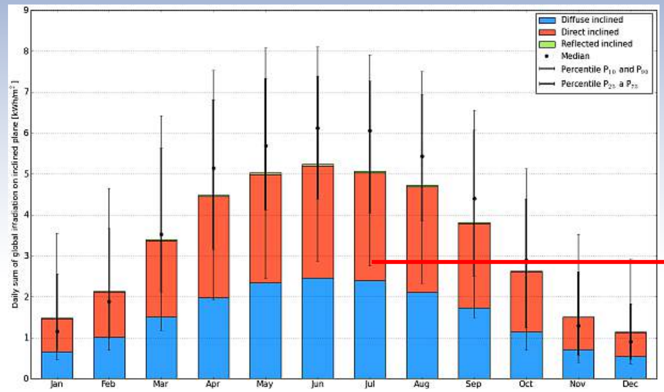
Project planning, design optimisation & financing

Site selection & prefeasibility

Project planning & design

Performance assessment

Long-term monitoring



Probability statistics P(90)

Years	1	2	3	4	5	6	7	8	9	10	15
Variability [±%]	4.2	3.0	2.4	2.1	1.9	1.7	1.6	1.5	1.4	1.3	1.1
P(90) uncertainy [±%]	5.4	3.8	3.1	2.7	2.4	2.2	2.0	1.9	1.8	1.7	1.4
Minimum PV at P(90) [kWh/kWp]	**1068**	**1086**	**1094**	**1099**	**1102**	**1104**	**1107**	**1108**	**1109**	**1110**	**1113**

in the first year *in 15 years*

Interannual variability – minimum production at P(90)

Performance validation and financial close

Site selection
& prefeasibility

Project planning
& design

Performance
assessment

Long-term
monitoring

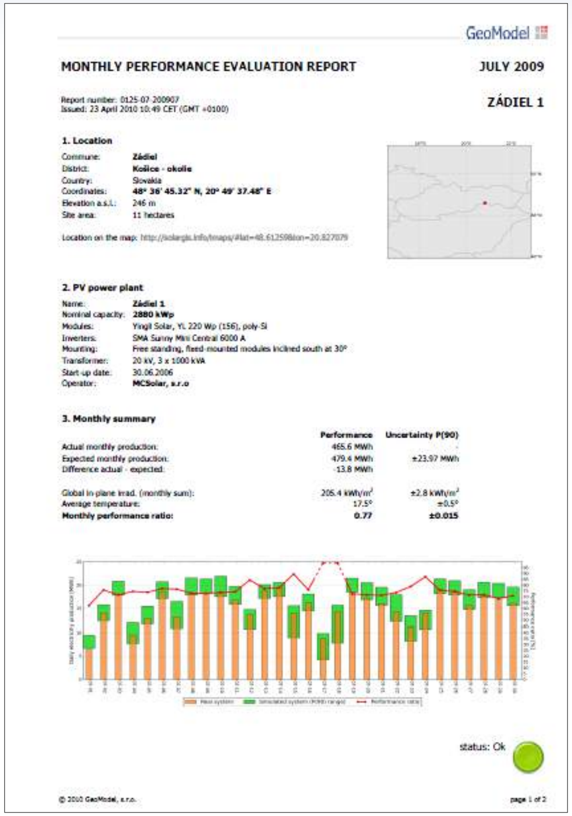
Needs

- assessment of performance ratio
- confirmation of the expected long-term production

Data requirements

- high frequency data (15-min)
- from the most recent time (last 3-6 months)
- no bias, low RMSE
- uncertainty

Satellite data: higher RMSE than ground data, but good (better) aggregated stats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MONTHLY PERFORMANCE EVALUATION REPORT — JULY 2009

ZÁDIEL 1

Report number: 0125-07-200907
Issued: 23 April 2010 10:49 CET (GMT +0100)

1. Location

Commune:	**Zádiel**
District:	**Košice - okolie**
Country:	Slovakia
Coordinates:	**48° 36' 45.32" N, 20° 49' 37.48" E**
Elevation a.s.l.:	246 m
Site area:	11 hectares

Location on the map: http://solargis.info/imaps/#lat=48.612598lon=20.827079

2. PV power plant

Name:	**Zádiel 1**
Nominal capacity:	**2880 kWp**
Modules:	Yingli Solar, YL 220 Wp (156), poly-Si
Inverters:	SMA Sunny Mini Central 6000 A
Mounting:	Free standing, fixed-mounted modules inclined south at 30°
Transformer:	20 kV, 3 x 1000 kVA
Start-up date:	30.06.2006
Operator:	**MCSolar, s.r.o**

3. Monthly summary

	Performance	Uncertainty P(90)
Actual monthly production:	465.6 MWh	-
Expected monthly production:	479.4 MWh	±23.97 MWh
Difference actual - expected:	-13.8 MWh	
Global in-plane irrad. (monthly sum):	205.4 kWh/m²	±2.8 kWh/m²
Average temperature:	17.5°	±0.5°
Monthly performance ratio:	**0.77**	**±0.015**

status: Ok

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Long-term monitoring

Site selection
& prefeasibility

Project planning
& design

Performance
assessment

Long-term
monitoring

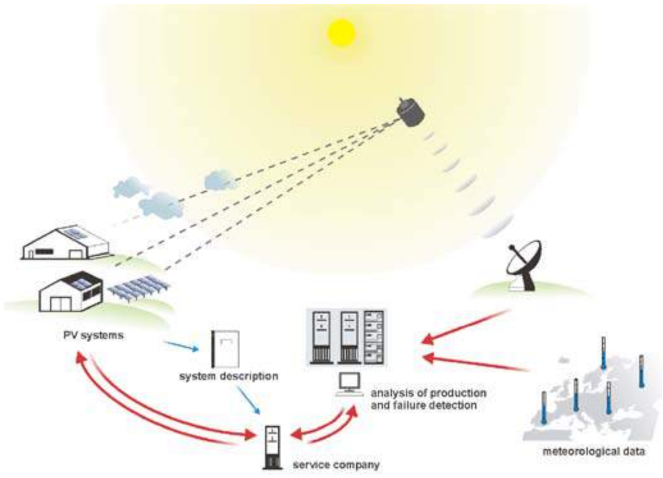
Needs

- daily monitoring and early warning
- long-term performance assessment

Data requirements

- high frequency data (15-min)
- aggregated statistics
- no bias, low RMSE
- uncertainty

Satellite data: higher RMSE than ground data, but good (better) aggregated stats



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Summary: bankable solar resource for PV

Site selection & prefeasibility

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Project planning & design

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Performance assessment

↓

Long-term monitoring

Satellite
- shorter time coverage (5+ yrs)
- “lower” accuracy

Satellite (more sources)
- high quality longer time coverage (10+ yrs)
- time series, variability, uncertainty
- data cross-comparison

On-site measurement/satellite
- data from “yesterday”
- accurate assessment of short time series
- low uncertainty

On-site measurement/satellite
- recent time series and aggregated stats
- provision of service and accuracy to be guaranteed in long-term