

Mapping the solar resource in Uruguay: the importance of data quality assesment

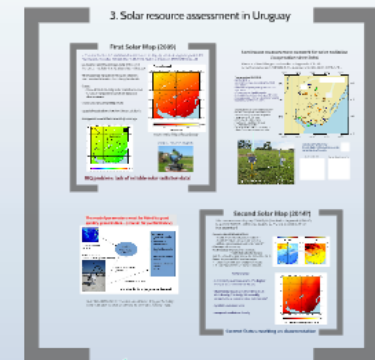
Gonzalo Abal

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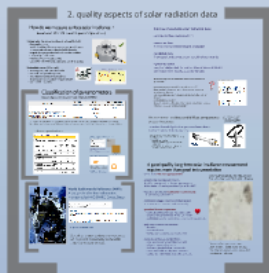
Regional Workshop on Metrology and Technological
Challenge in Climate Science and Renewable Energy
LATU, Montevideo, Uruguay, 2-4 September 2014



Focus: the importance of metrological aspects for the
development of the solar energy sector

Overview

1. Renewable and solar energy: status in Uruguay
 - a fast change takes place ... a look at two examples
2. Need for quality assessment in Solar Radiation measurements
 - Research in solar resource
 - investment risk in PV energy projects
3. Advances in Solar Resource Assessment in Uruguay
 - First Solar Map - MSU v1 (2009)
 - Solar Radiation measurement network effort (2010 - to date)
 - Second Solar Map - MSU v2 (2014)
4. Infrastructure at the new Solar Energy Laboratory
 - pyranometer calibration facility
 - thermal efficiency test bench
5. Current needs to get things going:
 - Tech training, intercomparisons, accreditation process...



In sum:

- Publicly available, good quality, solar radiation data provides a solid foundation for solar resource assessment and minimizes the financial viability of utility scale solar projects.
- The solar radiation network tested by LES/LESLAR should be maintained with the highest quality standards. For at least a decade ahead (beyond 2020).
- The new solar laboratory will allow pyranometer calibrations and thermal efficiency certifications to be done in Uruguay under ISO norm compliance conditions.

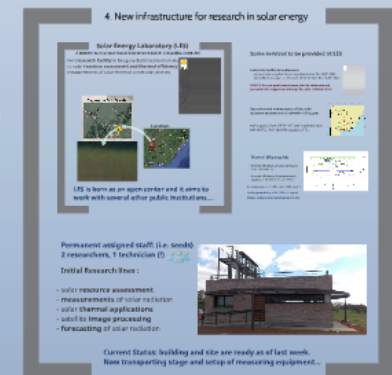
To get things going:

- Restore the process towards ISO 17025 certification provide traceability to the NMIs.
- Interaction with other laboratories in the region, train (young) human resources...

Thanks!

 LABORATORIO DE ENERGÍA SOLAR
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Prices of different forms of energy in the region

PRECIOS DE LA ENERGÍA EN LA REGIÓN							
País	Energía Eléctrica		Combustibles				
	Industrial Media Tensión (USD/MWh)	Residencial (USD/MWh)	Fuel Oil (USD/lt)	Gas Natural Residencial (USD/m ³)	G.L.P. Supergás (USD/kg)	Gas Oil (USD/lt)	Nafta (USD/lt)
Uruguay	133	285	0,89	1,67	1,43	1,73	1,82
Chile	99	181	0,78	1,55	1,63	0,97	1,40
Brasil	121	205	0,68	1,95	1,48	1,12	1,33
Argentina	31	40	0,68	0,08	0,20	1,25	1,39

Nota: USD/MWh equivale a dólares por Megavatio hora.

Source: SEG Ingeniería, Indicadores Energéticos, Julio 2014, No. 73; www.segingenieria.com

- Uruguay leads the wrong table: **highest prices in the region**
- **No fossil energy sources** (so far) in the country...
- 100 % large-scale hydroelectric potential is used

Vulnerability: high dependence on (rising, unstable) oil prices and on weather issues

Work is underway to address the problem:

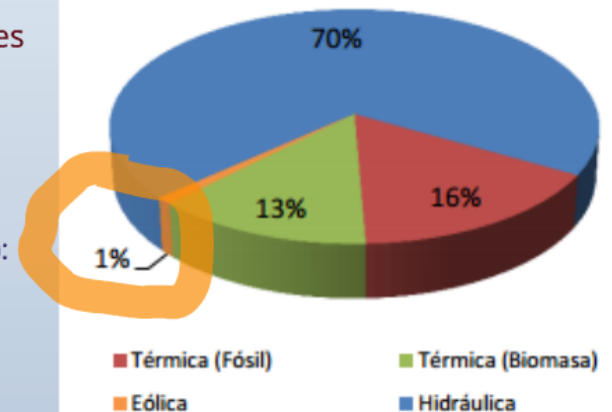
In 2013, electricity was generated using **84 % renewable sources** (expect 90% by 2015)

Nonconventional renewables are developed under long-term energy policy (2010 - 2030):

- Wind
- Solar (PV and thermal)
- Biomass



Generación de electricidad por origen. Año 2013



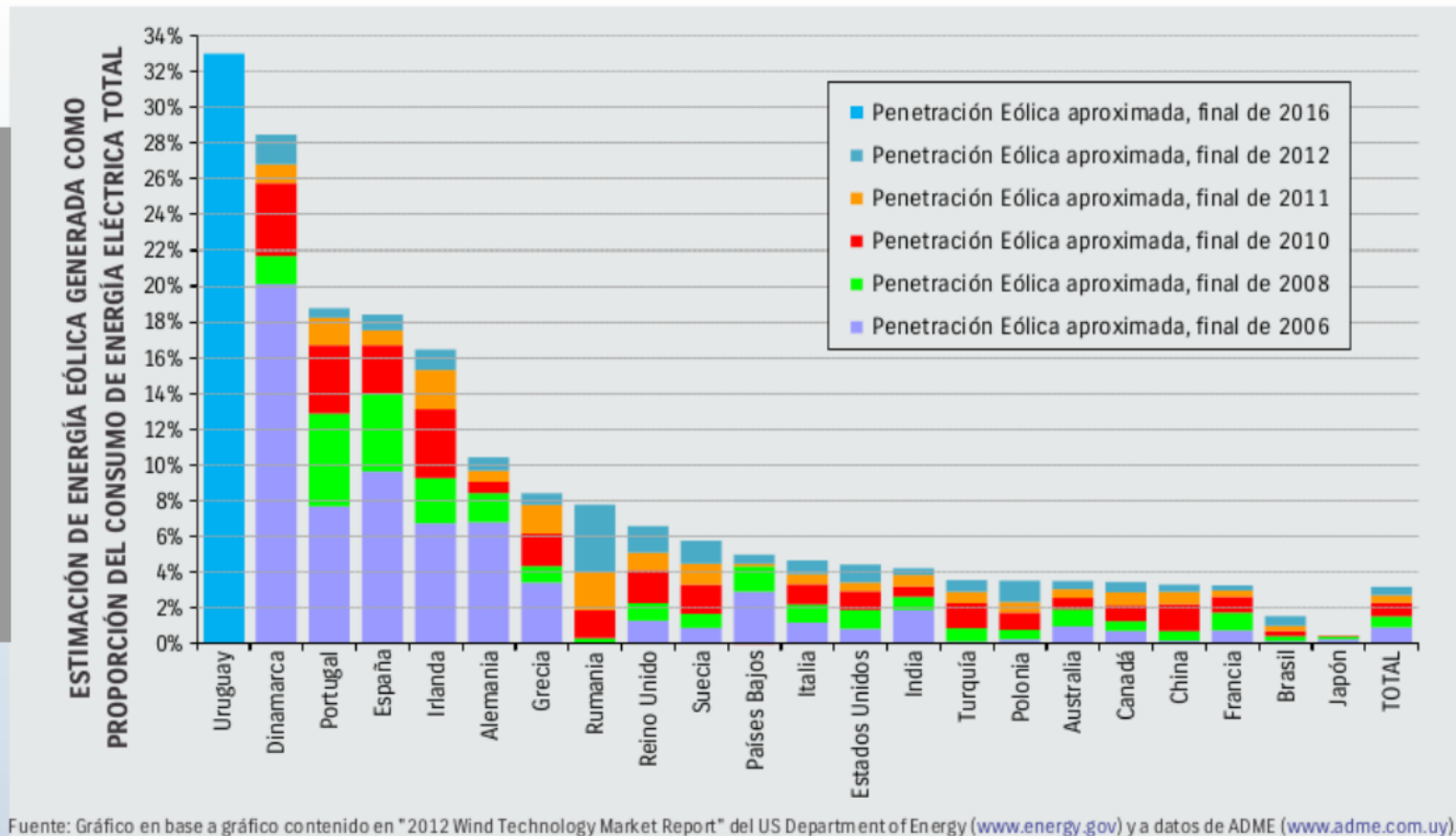
in Uruguay: first steps (2014)



Wind energy in 2016 - Estimated wind fraction for electricity generation

28%

disbeliever...



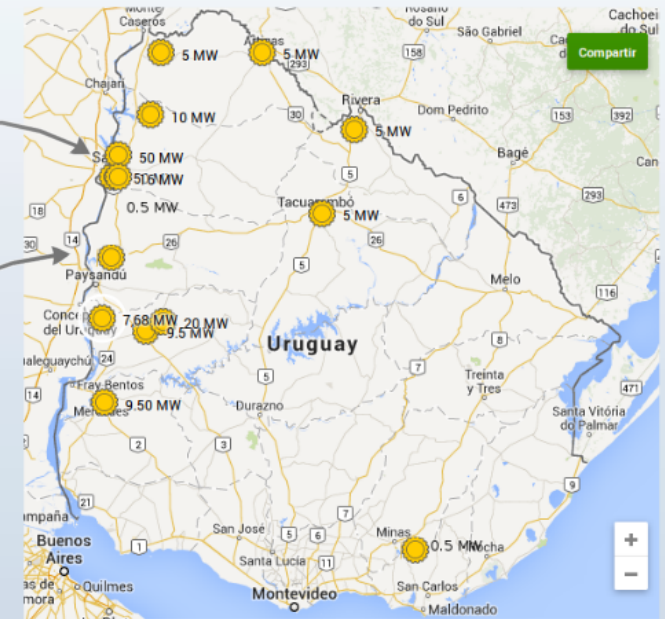
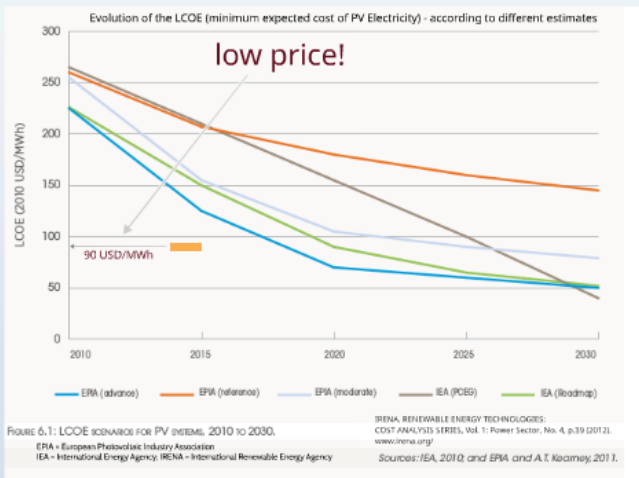
Ref: SEG Ingeniería, Indicadores Energéticos, No. 71, Mayo 2014; www.segingeneria.comuy

Fast change : according to UTE, by 2016 Uruguay would have almost 30% eolic-based electricity generation... (1% -> 30% in 3 years!)

Numbers:

- 1 GW eolic installed capacity by 2016 --> aprox. 3 TWh/yr
- 28% of 11.2 TWh/yr, total expected electrical demand for 2016

Grid-connected PV electricity in Uruguay: first steps (2014)



Some numbers :

- about 15 PV projects underway (to be operative by the end of 2015)
- aprox. **200 MWp** (10% of peak demand in 2014) of electrical power to the grid
- State-owned utility (UTE) pays **87 - 91 USD/MWh**, depending on inauguration date.
- private investment: **aprox. 300 millones USD**
- total area: **aprox. 400 hectáreas** (about 1000 acres) ... the size of a small farm!

Evolution of the LCOE (minimum expected cost of PV Electricity) - according to different estimates



FIGURE 6.1: LCOE SCENARIOS FOR PV SYSTEMS, 2010 TO 2030.

EPIA = European Photovoltaic Industry Association

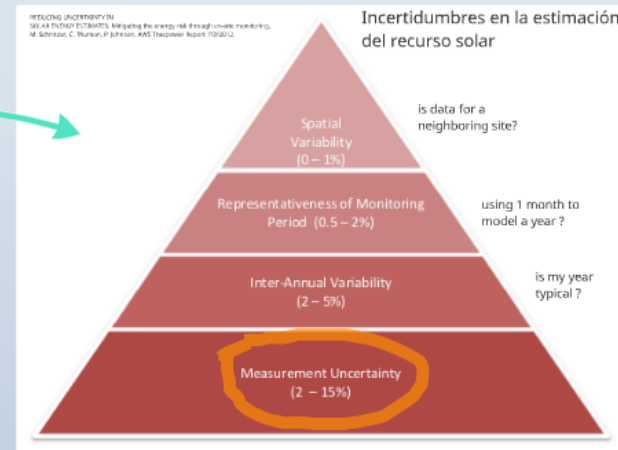
IEA = International Energy Agency; IRENA = International Renewable Energy Agency

IRENA, RENEWABLE ENERGY TECHNOLOGIES:
COST ANALYSIS SERIES, Vol. 1: Power Sector, No. 4, p.39 (2012).
www.irena.org/

Sources: IEA, 2010; and EPIA and A.T. Kearney, 2011.

uncertainty and financial risk

- estimating the **annual yield of a PV plant** involves uncertainties.
- the largest, is associated with the **uncertainty in the estimation of the solar resource** at the chosen site.



from a potential investor's point of view:

uncertainty in plant's annual yield = **risk**
more **risk** => **higher costs** for loans ...



for example:

"Fitch looks for a minimum of one year, hourly, well maintained, onsite data for a complete solar resource supply assessment."

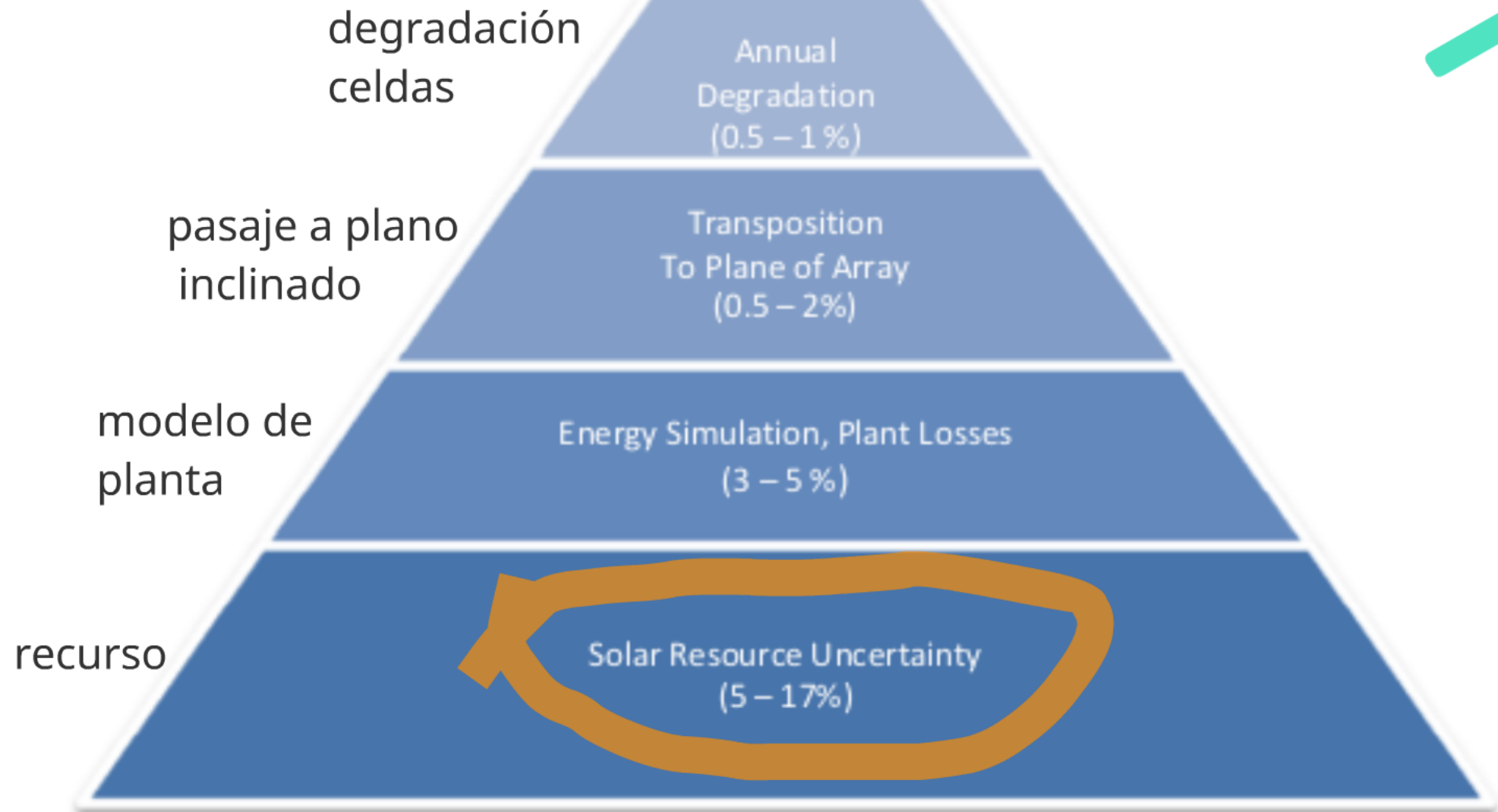
Quote from *Rating Criteria for Solar Power Projects*, Fitch Ratings, 02/2011.

bottom line:

The use of **good quality solar radiation data** improves the economic feasibility of a large PV project

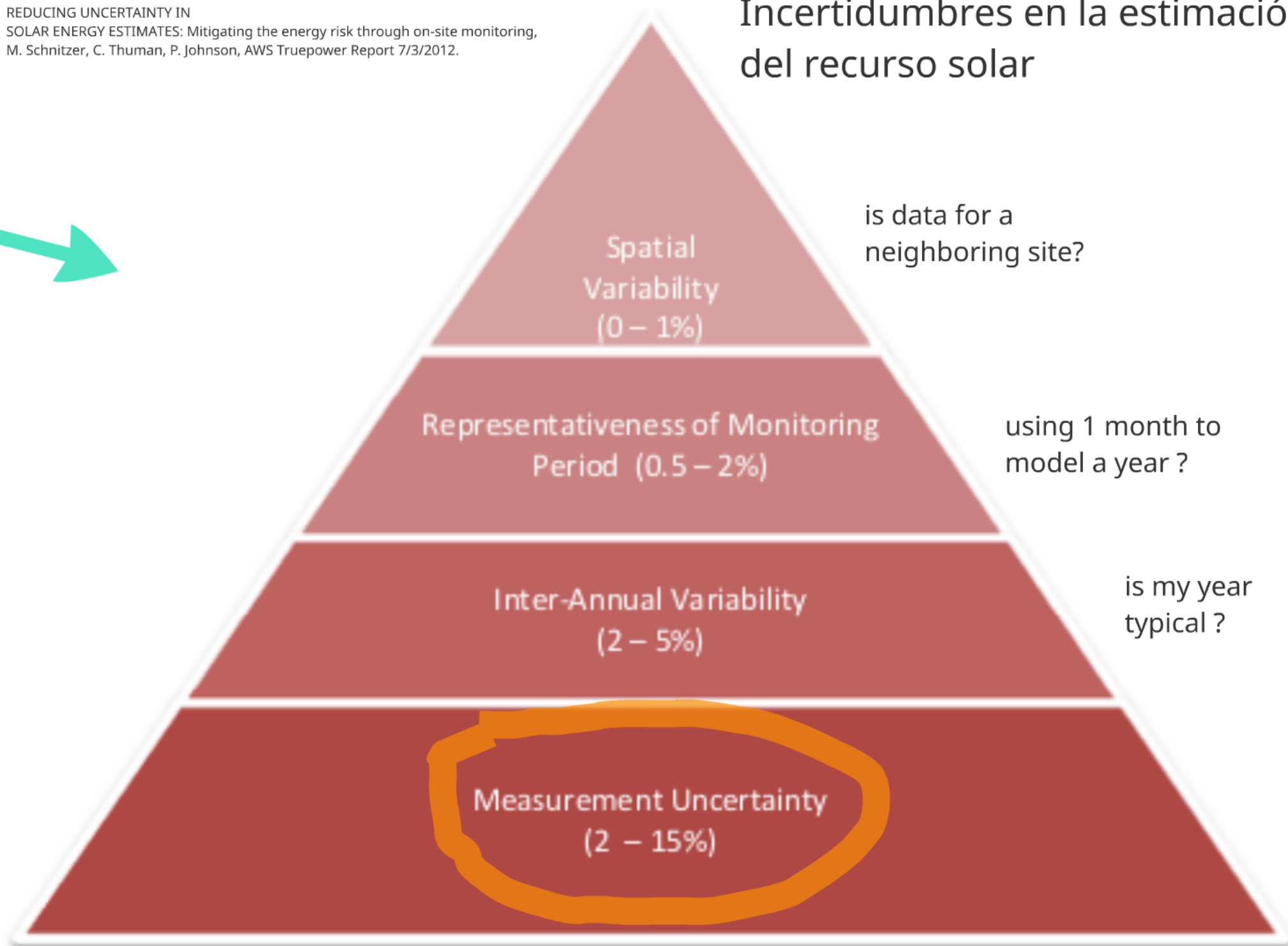
Ref. REDUCING UNCERTAINTY IN SOLAR ENERGY ESTIMATES: Mitigating the energy risk through on-site monitoring, M. Schnitzer, C. Thuman, P. Johnson, AWS Truepower Report 7/3/2012.

Fuentes de incertidumbre en la estimación de la potencia generada



REDUCING UNCERTAINTY IN
SOLAR ENERGY ESTIMATES: Mitigating the energy risk through on-site monitoring,
M. Schnitzer, C. Thuman, P. Johnson, AWS Truepower Report 7/3/2012.

Incertidumbres en la estimación del recurso solar



Spatial
Variability
(0 – 1%)

is data for a
neighboring site?

Representativeness of Monitoring
Period (0.5 – 2%)

using 1 month to
model a year ?

Inter-Annual Variability
(2 – 5%)

is my year
typical ?

Measurement Uncertainty
(2 – 15%)

from a potential investor's point of view:

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2. quality aspects of solar radiation data

How do we measure surface solar irradiance ?

broad band : UV + VIS + near IR (aprox 0.3 μm a 3 μm)

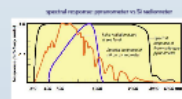
Pyranometer: hemispherical global irradiance (W/m^2)

- thermopile sensor:
 - serial assembly of thermocouples measures difference in temperature between hot and cold elements.
- outputs (mv) proportional to incident solar radiation
- uniform spectral response
- no electronics or voltage source:
- sensitivity (mv/W/m²) is stable over long time periods



Photovoltaic sensor (Silicon cell)

- fast response, economic alternative
- non-uniform spectral response
- important temperature dependence (requires correction, seldom implemented!)
- not so stable over time



Classification of pyranometers

two similar schemes are in use : ISO and WMO

Suggested usage	ISO 9060 classification	WMO classification	Typical uncertainty (P95 – daily irradiation)
Requires directional response and temperature dependent validation. Adequate for research and requires full reference measurement.	Secondary Standard	HQ High Quality	< 2%
Use in general quality technological networks. For calibration applications, the directional response can be reduced.	First Class	GQ Good Quality	< 5%
Nonconformant solution for routine applications, valid measurements in automatic meteorological stations.	Strim Class	M Modest Quality	< 10%

ISO 9060(E):1990 Specification and classification of instruments for measuring hemispherical solar and direct solar radiation.
World Meteorological Organization (WMO) Guide to Meteorological Instruments and Methods of Observation, 7th Ed. Chap. 7-7 (2008)

Technical specifications

PYRANOMETER CLASSIFICATION

ISDCXII and WMO Classification of Hemispherical Solar Instruments

The three marginal integrations of ψ over $\mathbf{r}$, $\mathbf{p}$ and $\mathbf{r}'$ are defined directly by inserting the identity $\int d\mathbf{r} \delta(\mathbf{r} - \mathbf{r}) = 1$ and the corresponding integrations over $\mathbf{p}$ and $\mathbf{r}'$.

[illegible]

Calibration against a reference pyranometer
Newly installed and verified

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World Radiometric Reference (WRR)

A group of 6 absolute radiometers maintained at PMOD/WRC, Davos, Suiza

Physikalisch-Meteorologisches Observatorium Davos
World Radiation Center

References

1. Tolsted, G., "777, Wide-Field-of-View Sensor," in *PHOTONICS/Proc. SPIE Vol. 495, 10-11*, (PHOTONICS Intern. Falls).

2. Tolsted, G., "591, History of some industry and the World Radiation Reference, Metrologia 28, 141-145, (PHOTONICS Intern. 1991).

3. Tolsted, G., Tolsted, R., Roman, J., and Hohl, C., "595, Rasterometry at PHOTONICS In Device," *Optical Engineering* 29, No. 5, 5, 423-426, (PHOTONICS Intern. 1990).

<http://www.pmadwrc.ch/>

Several calibration centers exist worldwide which provide **traceability to the WRR** under norm ISO-EN 17025.

Sources of available solar radiation data

- on site, surface measured data

- measured data from a near-by **reference grid or station**

- modelled data

from satellite observations or sunshine-hour records

- synthetic series

may be interpolated from other sites or even statistically generated from past data at near-by sites

Before using a solar radiation series one should ask questions:

- **measurements or model**, if so, which model?
- **time period** is long enough to characterize long-term irradiance at the site?
- what are **distance and climate relative to the site** of interest?
- Is **metadata** available?
location, sensor, calibration information, units, log of events...
- Which is the assigned **uncertainty**?



Measurements of **direct and diffuse components** of solar irradiance

important knowledge to transport irradiance from horizontal plane to inclined plane

- typical aperture: 5 grades
- requires a precise tracking system for continuous measurement
- can be used with filters to measure atmospheric transmittance at selected wavelengths



A good quality long-term solar irradiance measurement requires more than good instrumentation

- use at least **First Class pyranometers**
- **uncertainty must be well known**,
by calibration against a reference pyranometer
under similar operating conditions (norm ISO 9487)
- if possible, provide for **redundant measurements**
(i.e. two nearby radiometers)
- **reliable datalogger and transmission system**
with an error << measurement uncertainty
- **periodical human supervision**
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Test of SOLYS2 solar tracker, february 2014
Facultad de Ingeniería, Montevideo, Uruguay



For more best practices see:
ISO/TR 9901:1990(E) Solar Energy -
Field pyranometers - recommended
practice for field use

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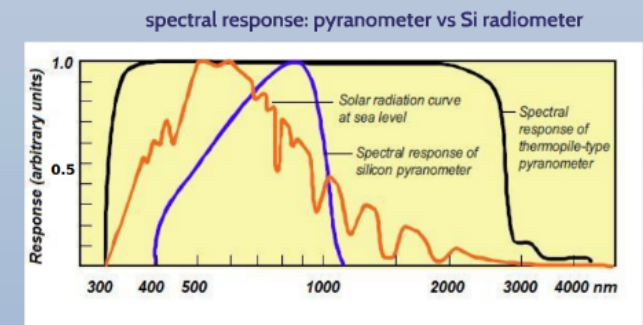
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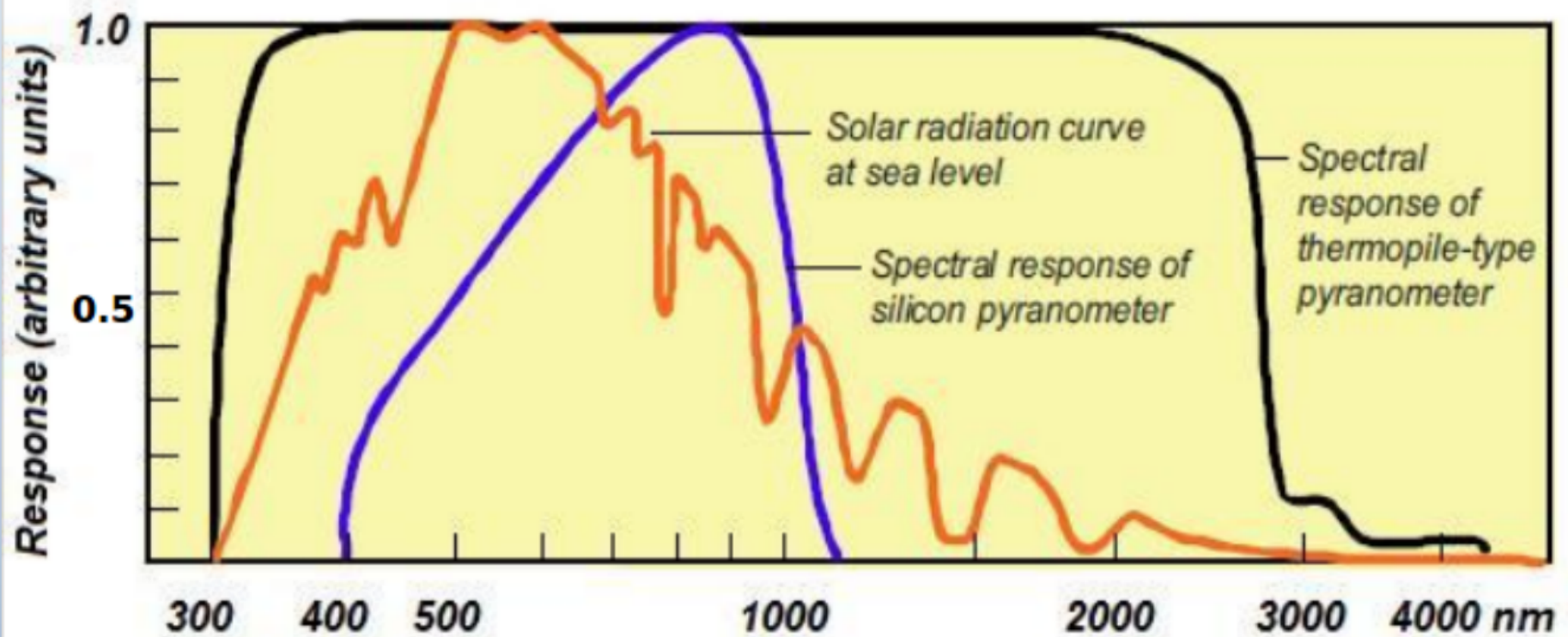
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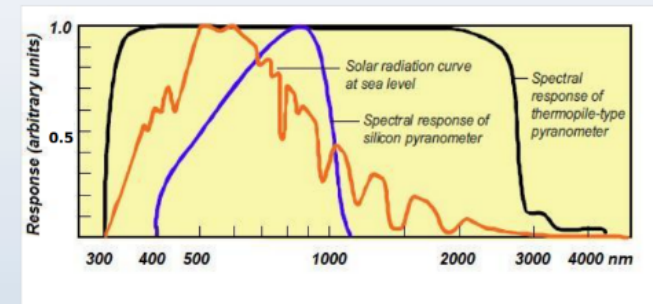


Classification of pyranometers

spectral response: pyranometer vs Si radiometer



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Requires directional response and temperature dependence validation. Adequate for research use. Adequate for a reference measurement.	Secondary Standard	HQ High Quality	< 2 %
For use in good quality meteorological networks. For solar energy applications, the directional response must be validated.	First Class	GQ Good Quality	< 5 %
Economical solution for routine applications. Field measurements in automatic meteorological stations.	Second Class	M Moderate Quality	< 10%

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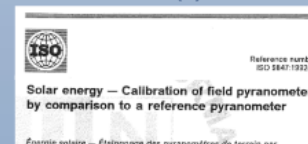
PYRANOMETER CLASSIFICATION

ISO9060 and WMO Classification of Hemispherical Solar Instruments

The three accepted categorizations of pyranometer quality are defined differently by International Standard ISO 9060:1990(E) and the World Meteorological Organisation Guide 6th Edition. This table is derived from all comparable data from both sources.

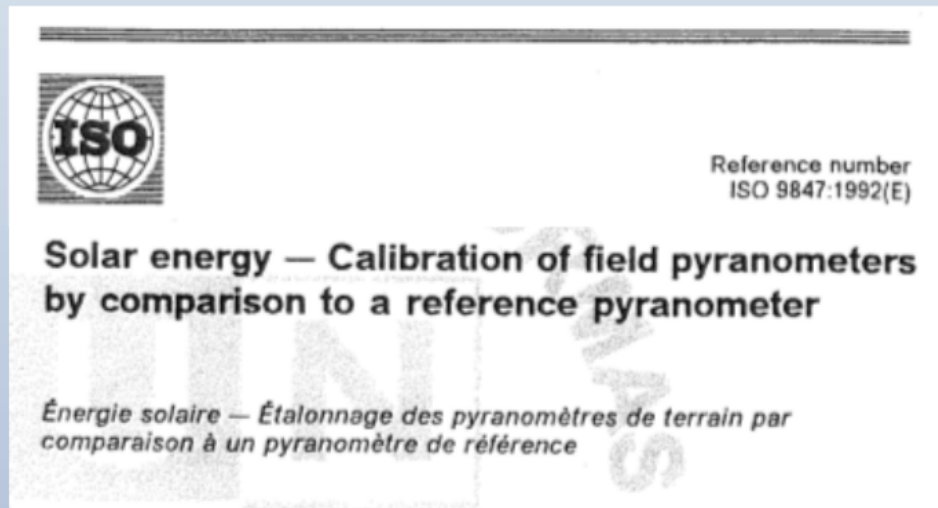
ISO Specification	ISO	secondary standard	first class	second class
WMO Classification	WMO	High	Good	Moderate

Calibration against a reference pyranometer Norm ISO 9847(E):1992



Calibration against a reference pyranometer

Norm ISO 9847(E):1992



At LES, reference pyranometer is a Kipp & Zonen CMP 22



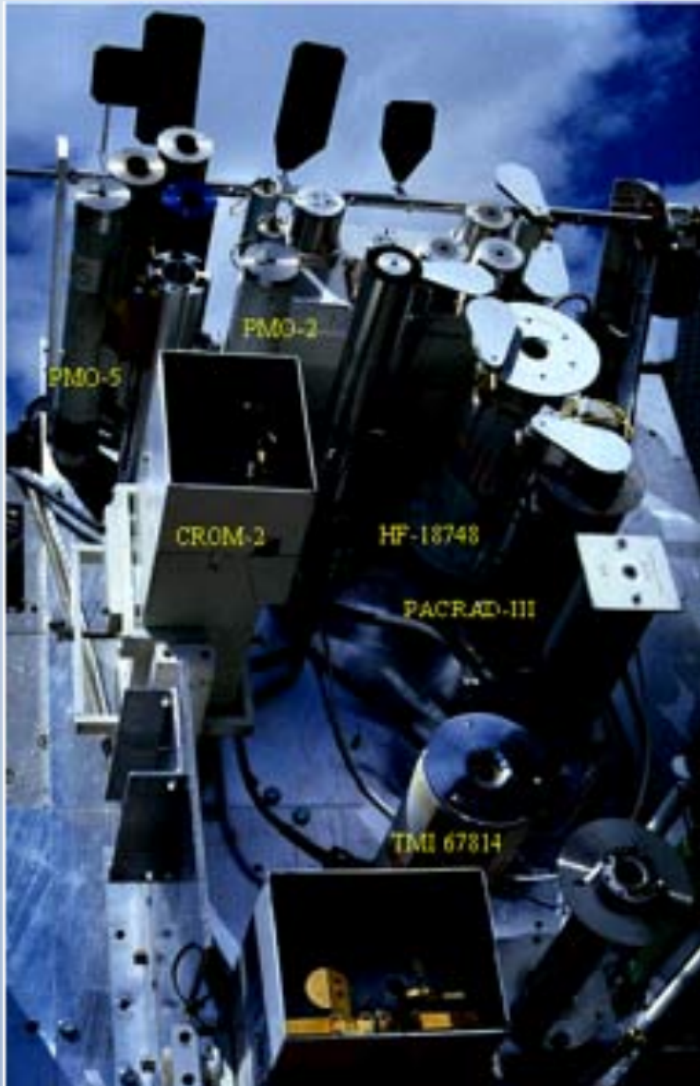
The Solar Energy Lab (LES) maintains two Secondary Standards in Uruguay, capable of measuring horizontal global irradiance (GHI) with 1 % uncertainty (P95).

One of them has been recently calibrated against the primary world standard World Radiometric Reference (WRR) at *PMOD/World Radiation Center* (Abril 2014)



calibration of field pyranometers at Montevideo, October 2013.

Secondary standard CMP22 is very stable



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*Physikalisch-Meteorologisches Observatorium Davos
World Radiation Center*

References

Fröhlich, C., 1977, 'World Radiometric Reference', in: *WMO/CIMO Final Report*, WMO No. 490, 97-110. (PMOD/WRC intern: 545a)

Fröhlich, C., 1991, History of solar radiometry and the World Radiation Reference, *Metrologia* **28**, 111-115. (PMOD/WRC intern: 650)

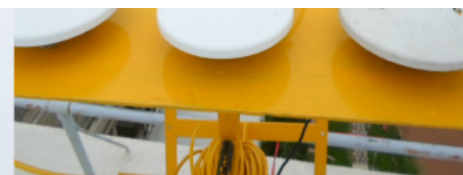
Fröhlich, C., Philipona, R., Romero, J., and Wehrli, C., 1995, Radiometry at PMOD/WRC in Davos, *Optical Engineering* **34**, No. 9, p. 2757-2766. (PMOD/WRC intern: 674)

<http://www.pmodwrc.ch/>

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	KIPP & ZONEN SINCE 1830	
CALIBRATION CERTIFICATE		
CERTIFICATE NUMBER	005615110282	
PYRANOMETER MODEL	CMP 22	
SERIAL NUMBER	110282	
SENSITIVITY	8.93 $\mu\text{V}/\text{W}/\text{m}^2$ at normal incidence on horizontal pyranometer	
IMPEDANCE	27 Ohm	
TEMPERATURE	22 $\pm$ 2 $^{\circ}\text{C}$	
REFERENCE PYRANOMETER	Kipp & Zonen CM 22 snREF1 active from 03/01/2011	
CALIBRATION DATE	12 September 2011 (recalibration is recommended every two years)	
IN CHARGE OF CALIBRATION	S. van Wijk	

changed $1/893 = 0.11 \%$ in 2.5 years
sensitivity variation: $< 0.05 \%$ per year
(ISO 9060 requirement is $< 0.8\%$ per year)

LES target:
comparison against WRR every 5 years

Physikalisch-Meteorologisches Observatorium Davos
World Radiation Center

pmod wrc

Certificate No. 2014-C-02

Calibration procedure

This pyranometer was compared with the sun and sky radiation as source under mainly clear sky conditions using the "continuous sun-and-shade method". The direct solar radiation is determined using the PMO2, member of the World Standard Group (WSG) and the diffuse radiation is measured using the shaded standard pyranometer of the World Radiation Center (WRC). The measurements were performed in Davos (latitude: 46.8143°, longitude: -9.8458°, altitude: 1588m). The readings are referred to the World Radiometric Reference (WRR) as stated in the WMO Technical Regulations. The originally estimated uncertainty of the WRR relative to SI is $\pm 0.3\%$. The inclination of the receiver surfaces versus their horizontal position were set to 0.0 degrees, the instrument signal wire to the north. During the comparisons, the instrument received global radiation intensities ranging from 699 W/m^2 to 1043 W/m^2 , with a mean of 854 W/m^2 . The angle between the solar beam and the normal of the receiver surface varied from 36.3 degrees to 49.9 degrees, with a mean of 41.7 degrees. The ambient temperature ranged from 1.7 $^{\circ}\text{C}$ to 15.3 $^{\circ}\text{C}$, with a mean of 7.8 $^{\circ}\text{C}$. The sensitivity calculation and the single measurements deviation (σ) are based on 236 individual measurements. The obtained sensitivity value is valid for similar conditions.

Calibration results

Sensitivity: **$S = 8.94 \mu\text{V} / (\text{Wm}^{-2})$**

Uncertainty: **$u = \pm 0.06 \mu\text{V} / (\text{Wm}^{-2})$**

The reported expanded uncertainty of measurements is stated as the standard uncertainty of measurement multiplied by the coverage factor $k=2$, which for a normal distribution corresponds to a coverage probability of approximately 95%.

Calibrations Remarks

Reference: WRR represented by the absolute pyrliometer: PMO2
WRR-Factor of PMO2: 0.998623
(from the last International Pyrliometer Comparison, IPC-2010
Diffuse radiation: Pyranometer CM22 S.N. 020059 with calibration factor: 8.88
(Ventilated with heated air, automatic shading disk, instrument-wire opposite sun)

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For more best practices see:
ISO/TR 9901:1990(E) Solar Energy -
Field pyranometers - recommended
practice for field use

3. Solar resource assessment in Uruguay

First Solar Map (2009)

First comprehensive determination of solar resource in Uruguay, based on long-term ground data
Team based at Facultad de Ingeniería - UDELAR (G. Abal et al.) Support: MIEM/DNE (Uruguay)

• provides: **monthly average daily GHI** (global horizontal irradiation) at 12 urban sites in Uruguay

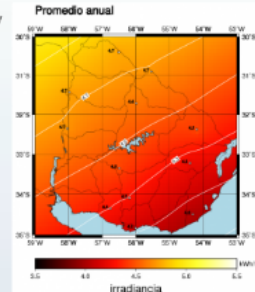
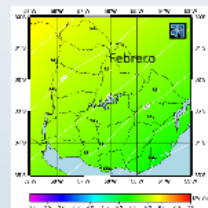
• Methodology: **Angstrom-Prescott relation**
see Technical Memoir at les.edu.uy for details

• Data:
- three historical daily solar radiation series
- 12 sets of long-term sunshine-duration observations

• estimated uncertainty: **15 %**

• spatial resolution: **100 km** (interpolation)

• temporal resolution: **monthly average**



more info: <http://les.edu.uy>



BIG problem: lack of reliable solar radiation data!

Continuous measurement network for solar radiation (in operation since 2010)

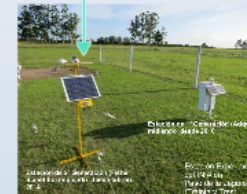
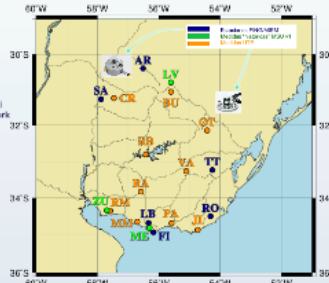
Maintained from Solar group at Facultad de Ingeniería (UDELAR)
partial financial support: MIEM/DNE; Collaboration with INIA, DNM, ANTEL, UTE ...

First generation (2010-2013):

- 10 sites (in blue)
- ISO 9000 First Class or Secondary Standard pyranometers
- calibrated every two years against reference pyranometer
- post-measurement quality checks
- data acquisition system: adpx logger (FNUITE)
- data transmission: GSM and 3G cellular network
- autonomous (battery + PV panel)

Second generation (since February 2014):

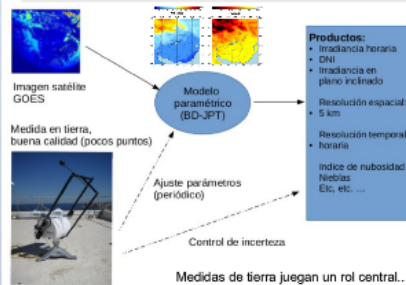
- two more sites (Parsuembó and Colonia)
- Fischer Scientific data acquisition systems
- redundancy in GHI (all sites)
- diffuse radiation (three sites)
- irradiance on tilted plane (all sites)
- air temperature (all sites)
- special point with diffuse, direct (Solys 2 tracing) and global irradiance at Salto



OUR POLICY WITH DATA:
- Data is FREE, available at les.edu.uy
- up to 5 years of records



The model parameters must be fitted to good quality ground data... (crucial for performance)



More than 100000 files are stored in our database. They give the ability to estimate solar radiation on demand for any hour since 01.01.2000.

Second Solar Map (2014?)

Solar resource research group (GMARS), LES, Facultad de Ingeniería (UDELAR)
Support: MIEM/DNE, ANII (Fondo Sectorial de Energía) and CSIC (UDELAR)

Due: yesterday !!

• Provides **MORE INFORMATION**:

- hourly GHI (horizontal global irradiation)
- hourly GTI (tilted plane global irradiation)
- diffuse - direct components of GHI and GTI

• Coverage: all the country

• Methodology: improved Turpley model

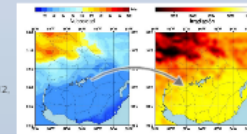
• GOES East satellite images

Ref: B. Alonso et al. Solar Energy, 86, 3205-3215, 2012.

• Data: 14+ years of GOES satellite images

• 4 years hourly GHI ground data from 4 sites

• Diffuse measurements (4 years, three sites)



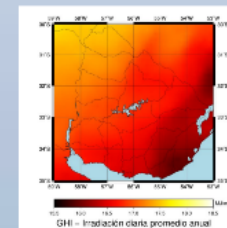
Performance

• GHI monthly estimates are **5 - 7 % higher** than previous estimates (MSUV1)

• **Uncertainty** (against independent data):
12 % hourly, 7 % daily, 2 % monthly
comparable to a second class pyranometer!

• spatial resolution: **5 km**

• temporal resolution: **hourly**

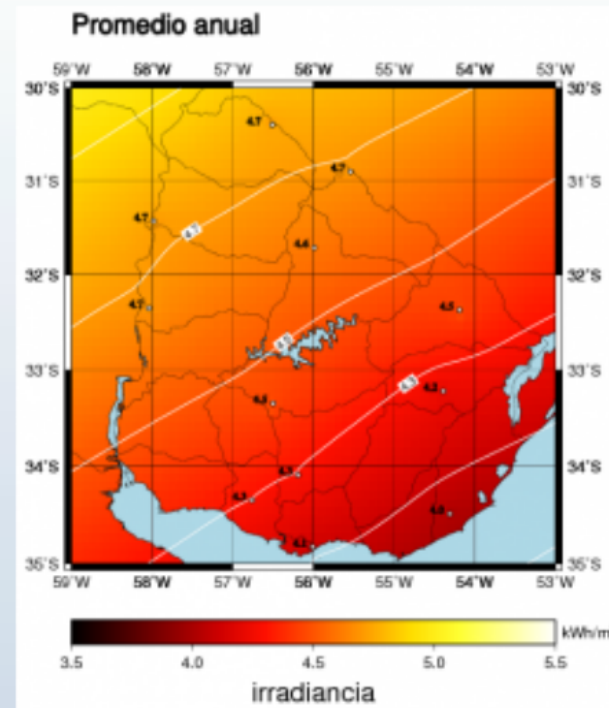
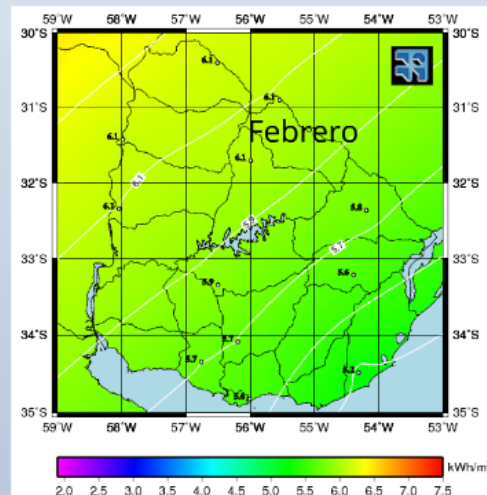


Current Status: working on documentation

First Solar Map (2009)

First comprehensive determination of solar resource in Uruguay, based on long-term ground data
Team based at Facultad de Ingeniería - UDELAR (G. Abal et al.) Support: MIEM/DNE (Uruguay)

- **provides: monthly average daily GHI** (global horizontal irradiation) at 12 urban sites in Uruguay
- **Methodology: Angstrom-Prescott relation**
see Technical Memoir at les.edu.uy for details
- **Data:**
 - **three historical daily solar radiation series**
 - **12 sets of long-term sunshine-duration observations**
- estimated **uncertainty: 15 %**
- **spatial resolution: 100 km** (interpolation)
- **temporal resolution: monthly average**



more info: <http://les.edu.uy>

Campbell-Stokes heliograph



BIG problem: lack of reliable solar radiation data!

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- six sites (i
- ISO 9060 R
- pyranome
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Continuous measurement network for solar radiation (in operation since 2010)

Maintained from Solar group at Facultad de Ingeniería (UDELAR)

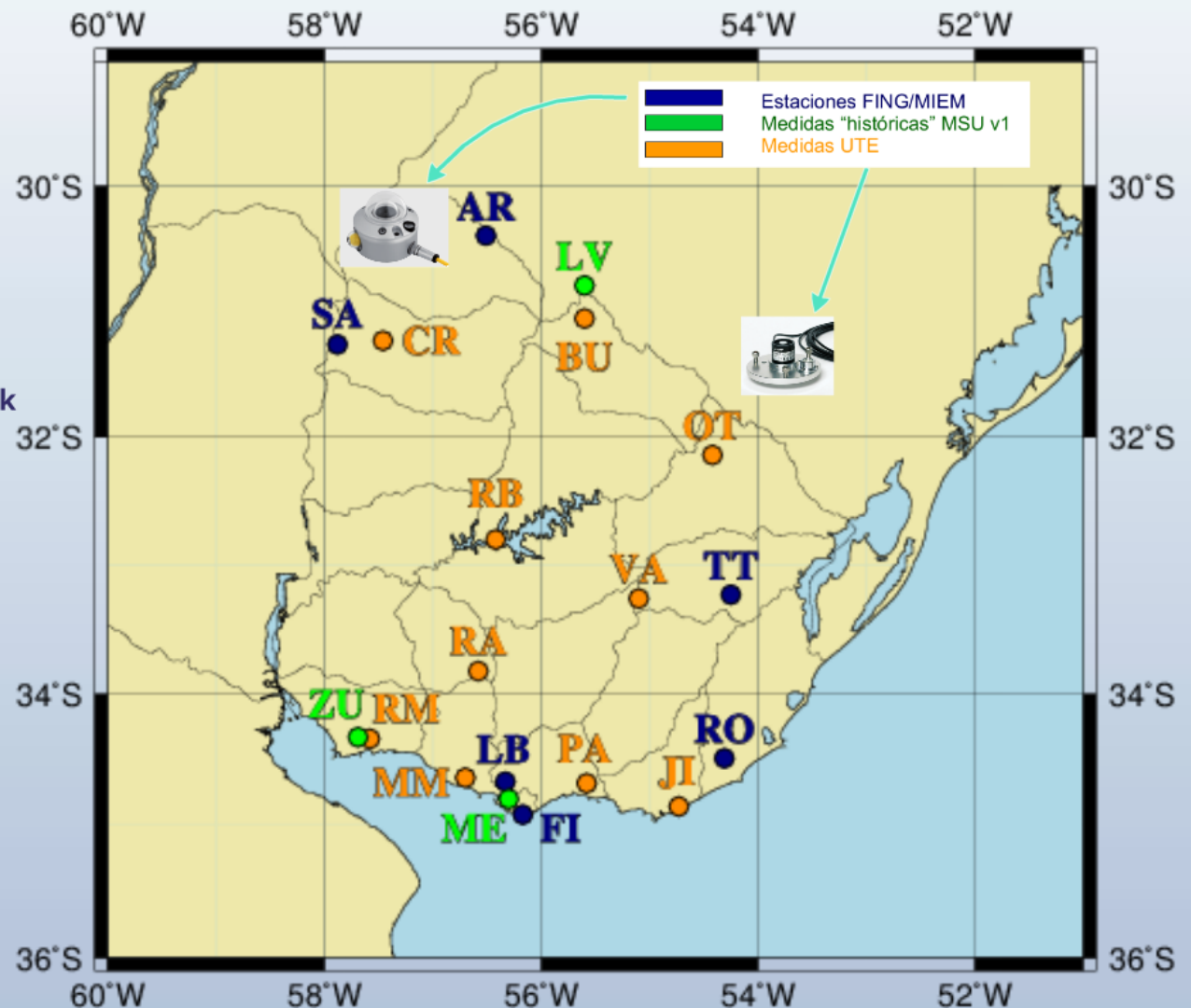
partial financial support: MIEM/DNE; Collaboration with INIA, DNM, ANTEL, UTE ...

First generation (2010-2013):

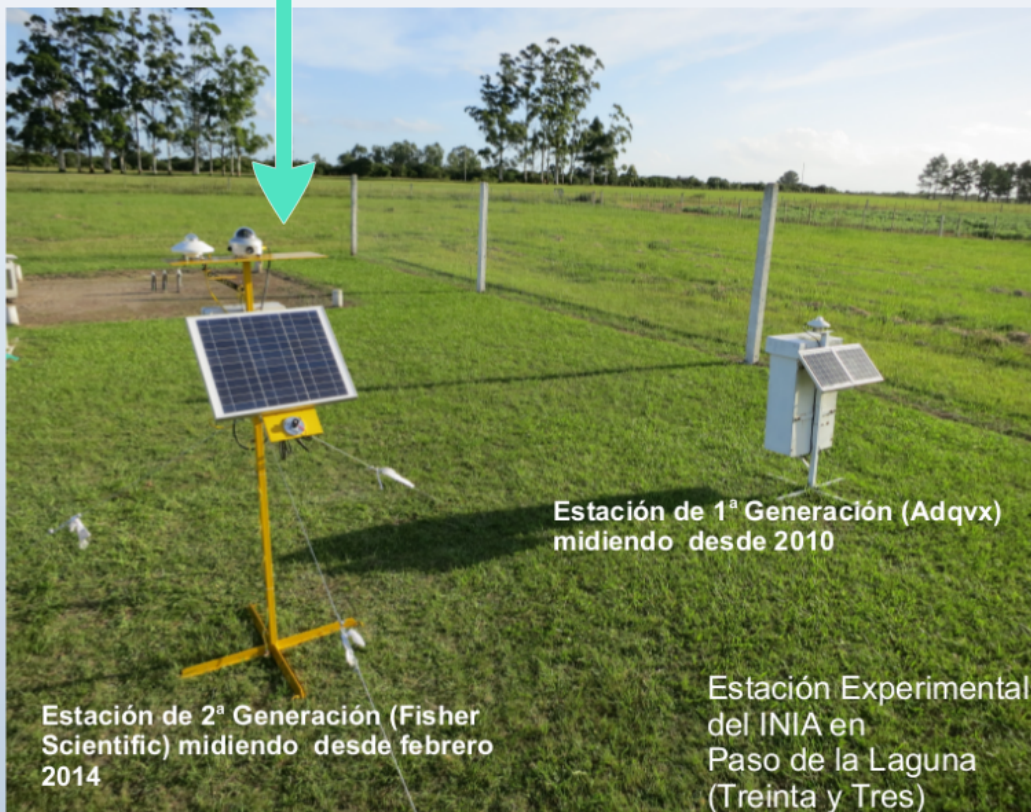
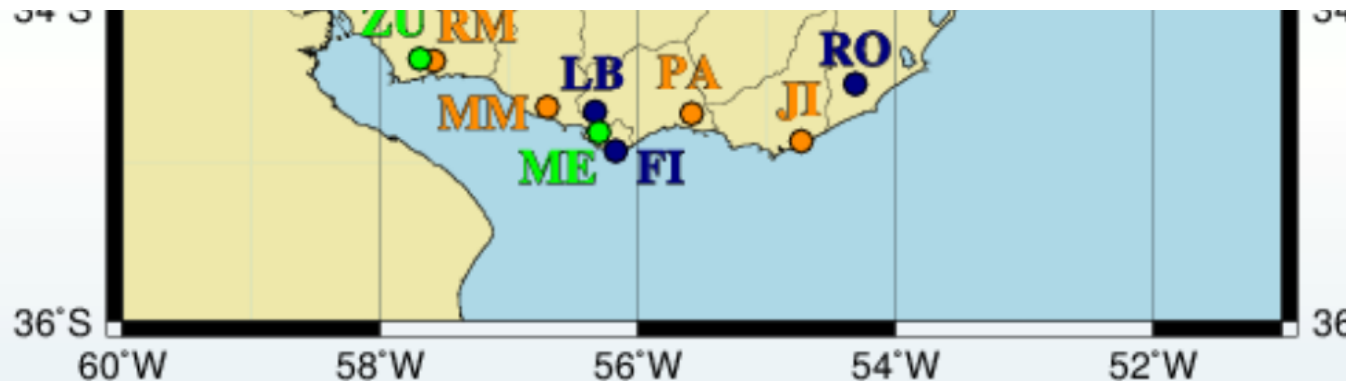
- **six sites** (in blue)
- ISO 9060 **First Class or Secondary Standard** pyranometers
- **calibrated every two years** against reference pyranometer
- post-measurement **quality checks**
- **data acquisition system: adqx** logger (FING/IEE)
- data transmission: GSM and 3G **cellular network**
- **autonomous** (battery + PV panel)

Second generation: (since february 2014)

- two more sites (Tacuarembó and Colonia)
- Fischer Scientific data acquisition systems
- redundancy in GHI (all sites)
- diffuse radiation (three sites)
- irradiance on tilted plane (all sites)
- air temperature (all sites)
- special point with diffuse, direct (Solys 2 tracking) and global irradiance at Salto

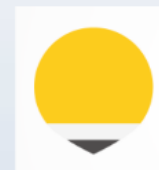


• Global irradiance in GHI (all sites)
 • Diffuse radiation (three sites)
 • Radiation on tilted plane (all sites)
 • Air temperature (all sites)
 • Special point with diffuse, direct (Solys 2 tracking) and global irradiance at Salto

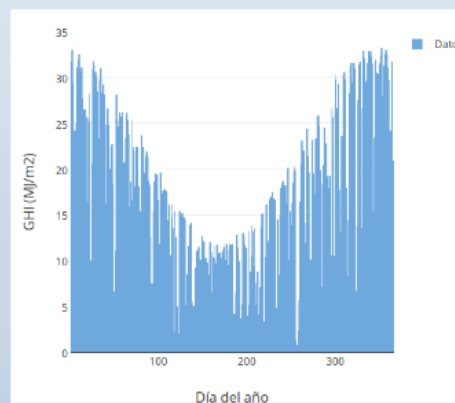


OUR POLICY WITH DATA:

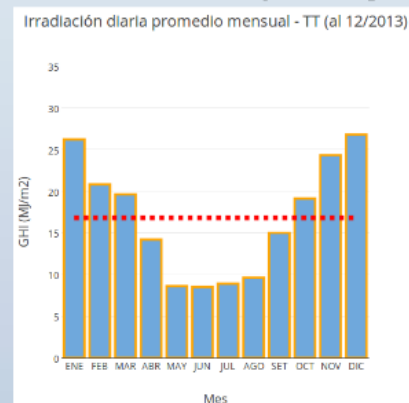
- Data is FREE, available at les.edu.uy
- up to 5 years of records



daily records 2013



historical monthly average



Second Solar Map (2014?)

Solar resource research group (GMARS), LES, Facultad de Ingeniería (UDELAR)

Support: MIEM/DNE , ANII (Fondo Sectorial de Energía) and CSIC (UDELAR)

Due: yesterday !!

- **Provides MORE INFORMATION:**

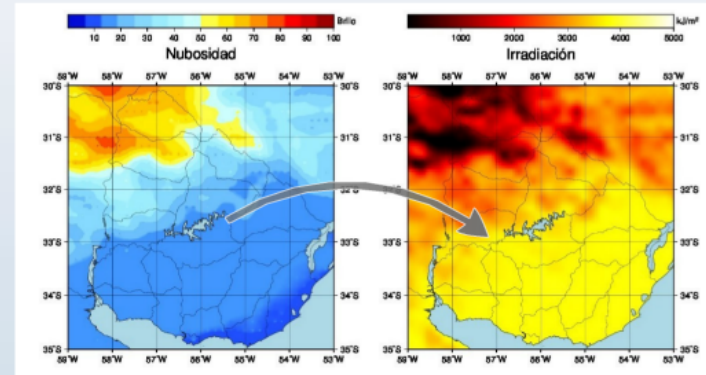
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- hourly GTI (tilted plane global irradiation)
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- **Coverage:** all the country

- **Methodology:** improved Tarpley model
+ **GOES East satellite images**

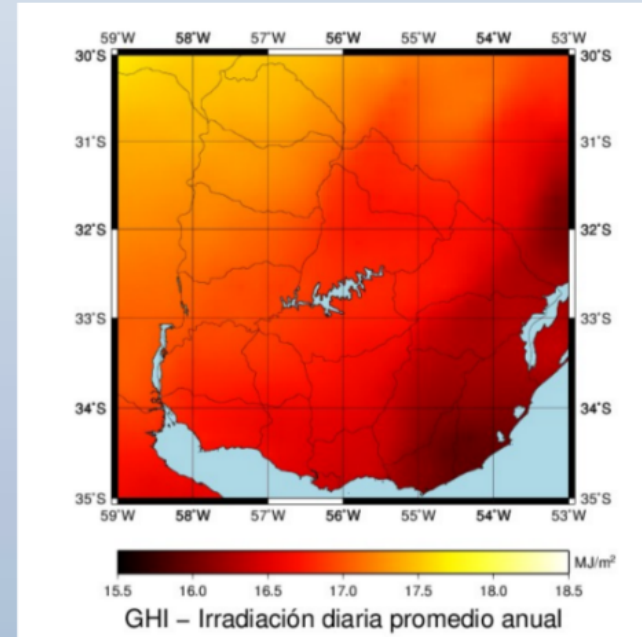
Ref: R. Alonso et al. Solar Energy, 86, 3205–3215, 2012.

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comparable to a second class pyranometer!
- **spatial resolution:** 5 km
- **temporal resolution:** hourly



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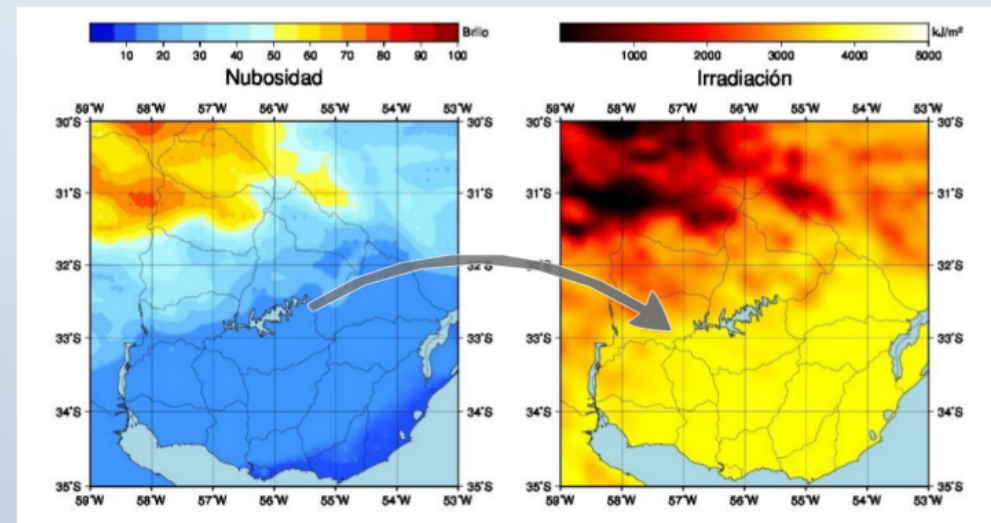
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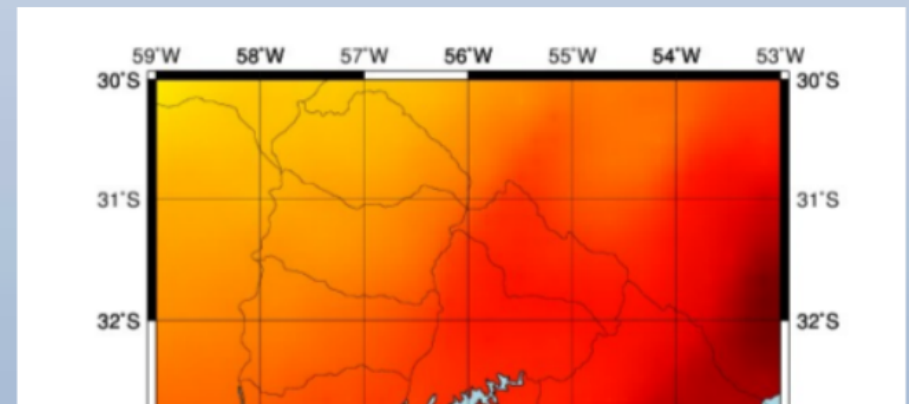
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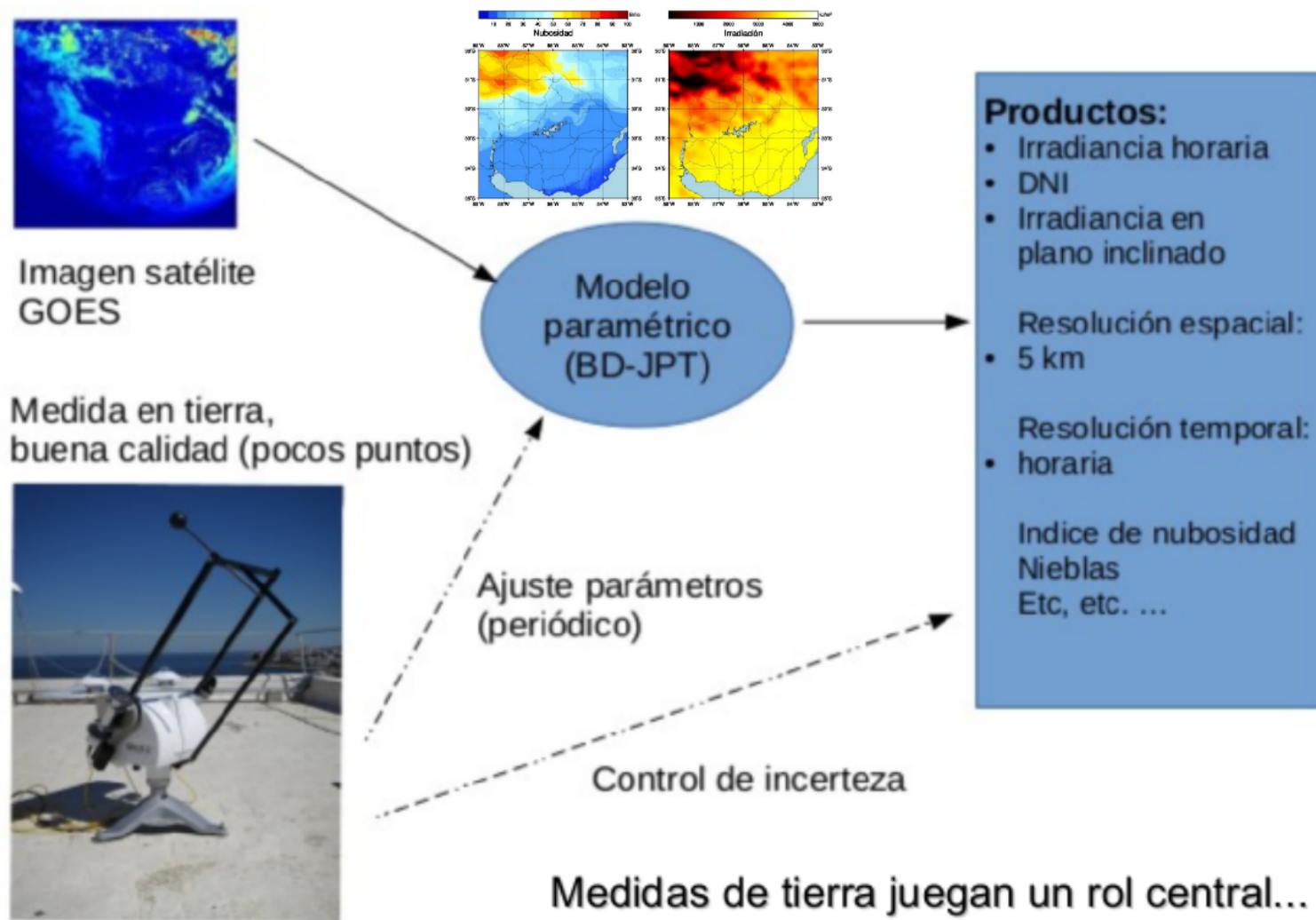


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The model parameters must be fitted to good quality ground data... (crucial for performance)

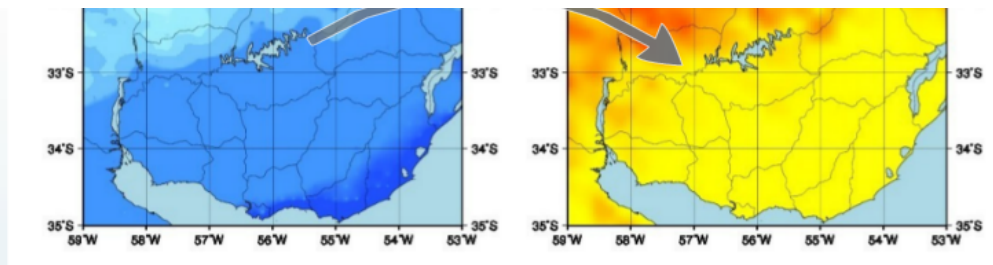


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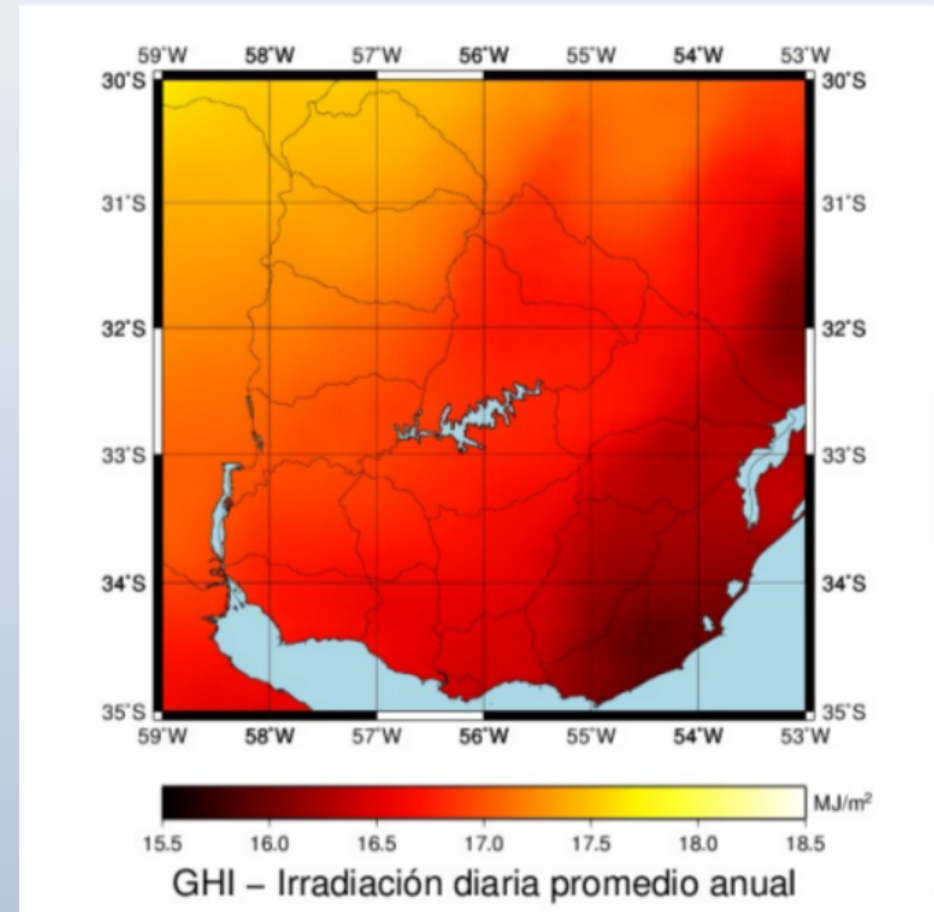
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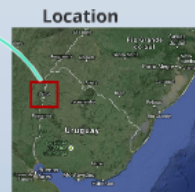
Current Status: working on documentation

4. New infrastructure for research in solar energy

Solar Energy Laboratory (LES)

A MODEST scale project founded by Universidad de la República (UDELAR)

First **research facility** in Uruguay dedicated exclusively to solar **resource assessment and thermal efficiency** measurements of solar-thermal conversion devices



LES is born as an open center and it aims to work with several other public institutions....

Some services to be provided at LES

Calibration facility for radiometers

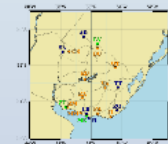
- pyranometers against reference pyranometer (ISO 9847:1992)
- pyrheliometers against reference pyrheliometer (ISO 9059:1990)

POLICY: for non-profit institutions, the lab calibrates and provides tech support in exchange for solar radiation data.



Operation and maintenance of the solar radiation measurement network in Uruguay

with support from MIEM/DNE and in collaboration with ANTEL, INIA, DNM (Uruguay), LATU...



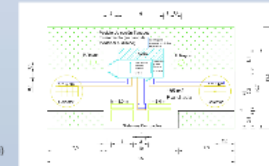
Thermal Efficiency lab

- thermal efficiency of solar collectors (UNIT-ISO 9806-1)
- thermal efficiency of compact solar systems (UNIT-ISO 9459-2 y 9459-5)

In cooperation with LATU and CENER (Spain)

funding provided by: MIEM/DNE (Uruguay)

Status: ready to start construction at site



Permanent assigned staff: (i.e. seeds)
2 researchers, 1 technician (!)



Initial Research lines :

- solar **resource assessment**
- **measurements** of solar radiation
- solar **thermal applications**
- satellite **image processing**
- **forecasting** of solar radiation



Current Status: building and site are ready as of last week.
Now transporting stage and setup of measuring equipment...

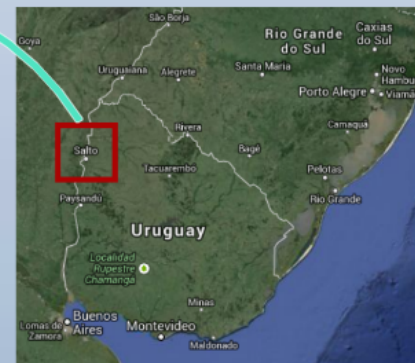
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Location



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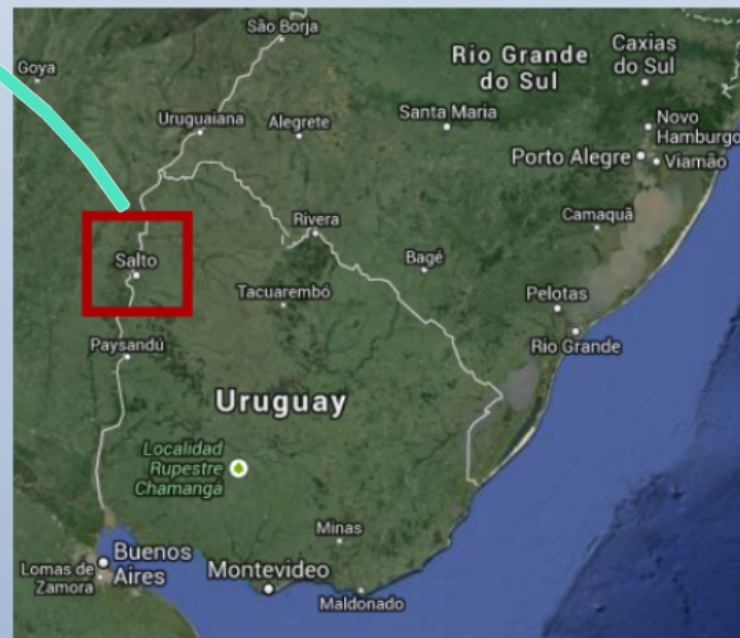
- thermal
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Status: rea

Represa de Salto Grande



Location





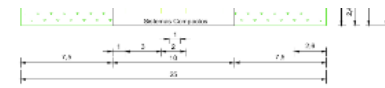
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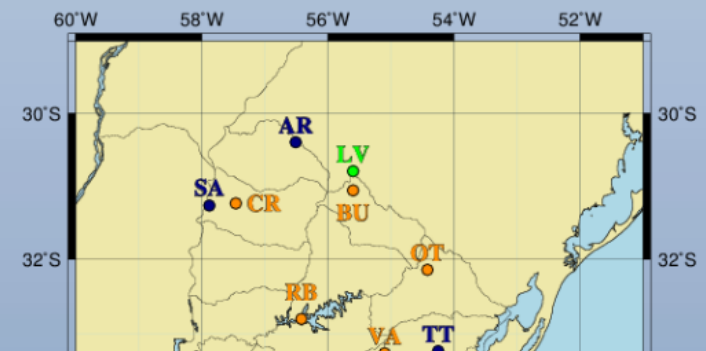
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Operation and maintenance of the solar radiation measurement network in Uruguay



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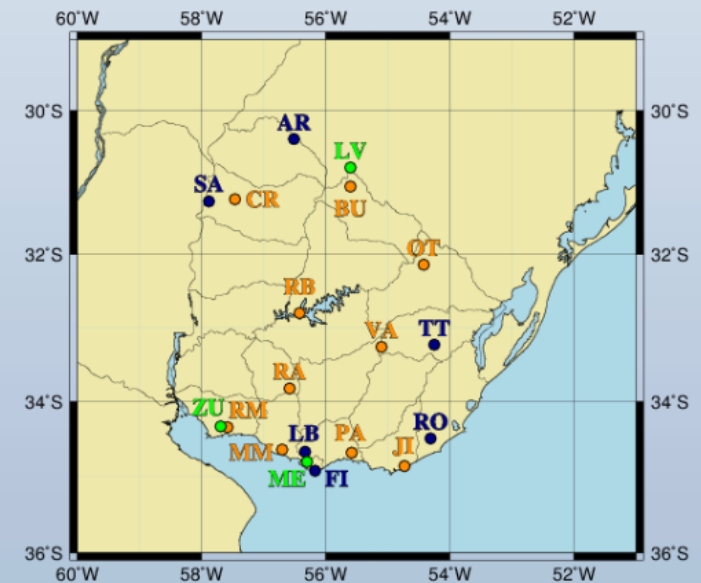
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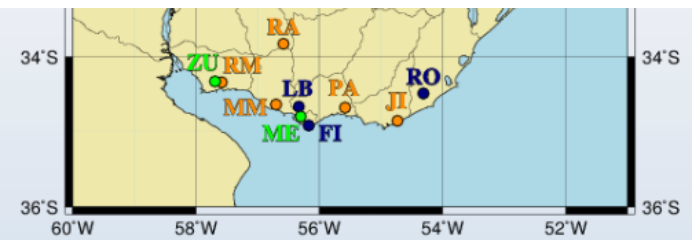


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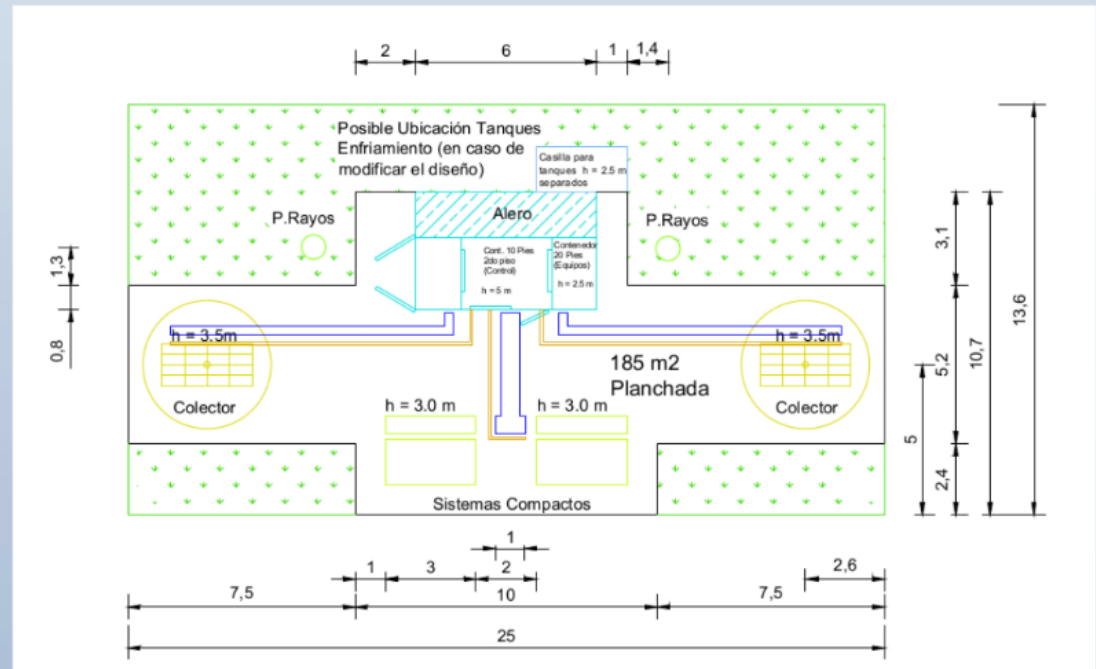
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Status: ready to start construction at site



In sum:

- Publicly available, good quality, solar radiation data provides a solid foundation for solar resource assessment and increases the financial viability of utility-scale solar projects.
- The solar radiation network hosted by LES/UDELAR should be maintained with the highest quality standards, for at least a decade ahead (target is 2030).
- The new solar laboratory will allow pyranometer calibrations and thermal efficiency certifications to be done in Uruguay under ISO-norm compliant conditions.

To get things going:

- Initiate the process towards ISO 17025 certification (provide traceability to the WRR).
- Interaction with other laboratories in the region, train (young) human resources...

Thanks!



Gonzalo Abal
abal@fing.edu.uy
<http://les.edu.uy>