CLARA

Climate forecast enabled knowledge services

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UNIVERSIDAD D CÓRDOBA

An Approach for the Solar Energy Assessment using Weather Medium-Range Forecasting

Isabel M. Moreno-Garcia, Rafael López-Luque, Marta Varo-Martínez, Luis M. Fernández-Ahumada, José C. Ramírez-Faz and F. Casares de la Torre

Outline

- Introduction: CLARA Project, services
- Methodology
  - SEAP service
  - Planning tool workflow
- Results
  - Data collection
  - Data processing & storage
  - Web application
- Conclusions

Introduction

CLARA

Climate forecast enabled knowledge services

http://www.clara-project.eu/

The aim of CLARA innovation action is to develop a set of **climate services** building upon the newly developed *Copernicus Climate Change Services* (C3S) near term forecasts and sectorial information systems (SIS) and sustain their marketability and value.

Atmosphere (CAMS) | **Marine** (CMEMS) | **Land** (CLMS) | **Climate** (C3S) | **Emergency** (EMS) | **Security**

opernicus Europe's eyes on Earth

Climate Change Service

Introduction

CLARA Services

Disaster risk reduction
- Economic risk assessment of flood risk

Water management
- Water resource management model
- Water supply assessment tool
- Reservoir operation assessment tool

Agriculture
- Water requirements for irrigation
- Soil water budget usable predictor

Renewable energy
- Smart climate hydropower tool
- Smart hydropower assessment tool
- Gwh prediction
- Solar energy assessment and planning tool

Air quality and health
- AirCloud
- Air quality and climate change

Horizontal services
- Post processed decadal predictions
- Clime

SEAP

Solar Energy Assessment and Planning Tool

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Aims of the service

Seasonal forecast

Operational assessment of solar energy on different time scales

Valuable information

Energy production for the coming months

Characterization of variablity

Management of the generation

Economic and environmental benefits

Robust decision-making by planning offices

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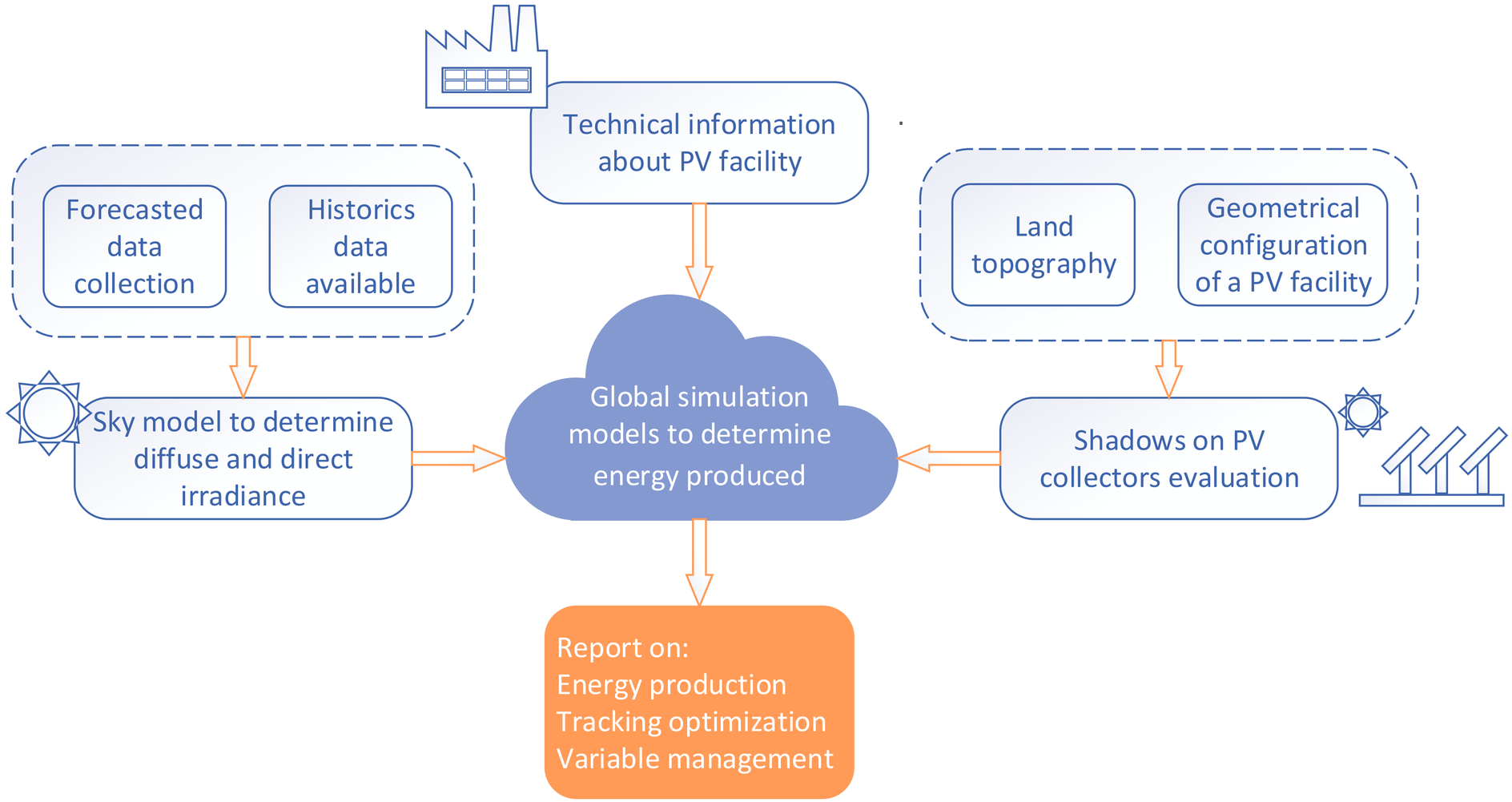
SEAP service



SEAP

Solar Energy Assessment and Planning Tool

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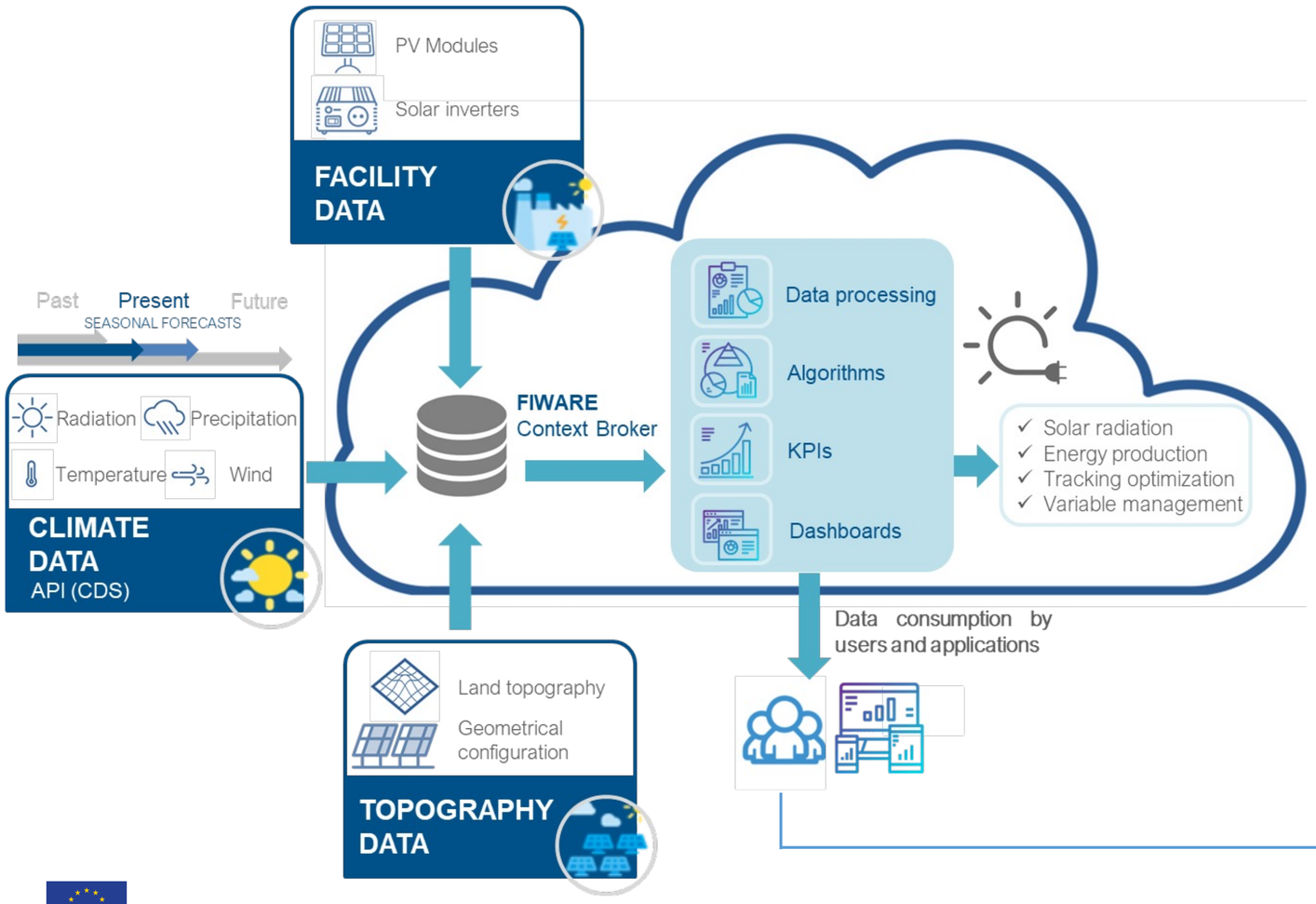
Workflow and system structure



Web tool

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SEAP

Solar Energy Assessment and Planning Tool

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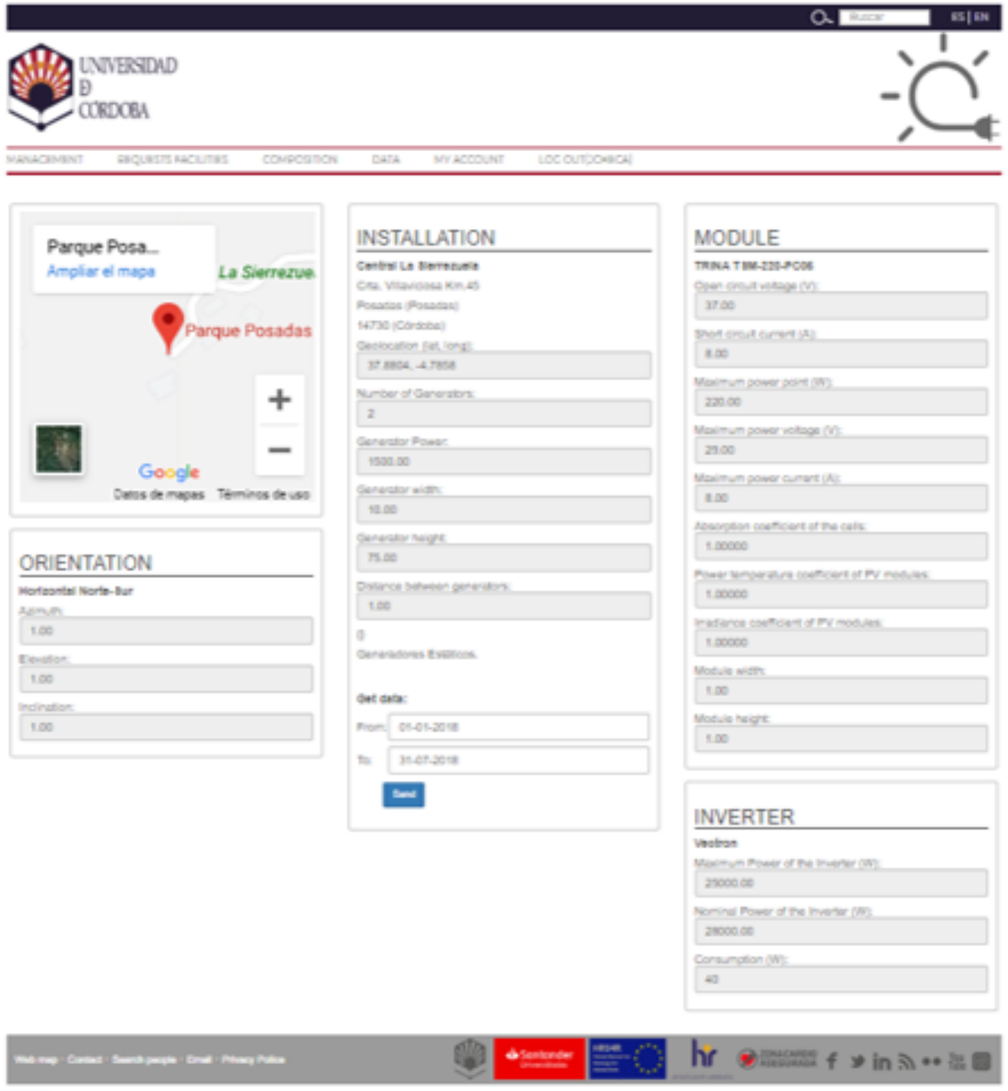
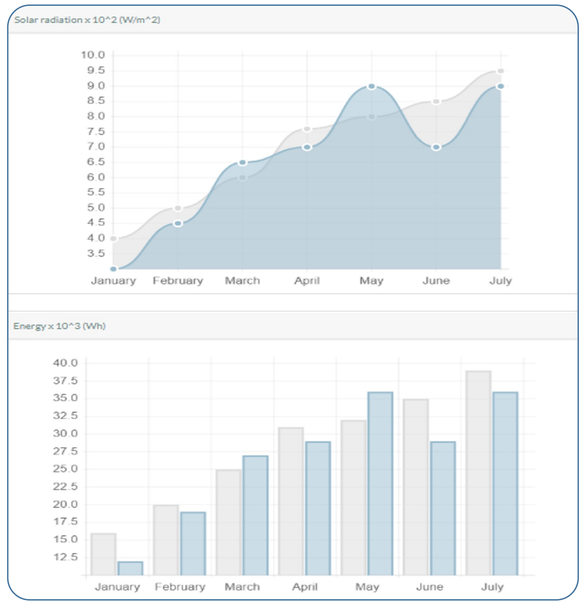
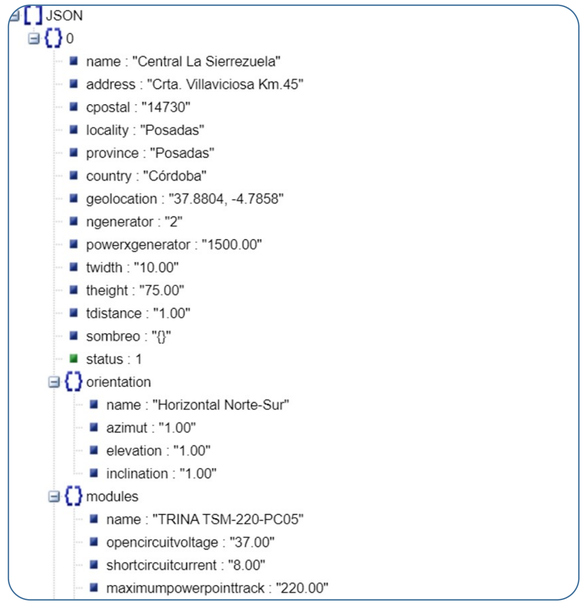


Outputs



Graphs



JSON

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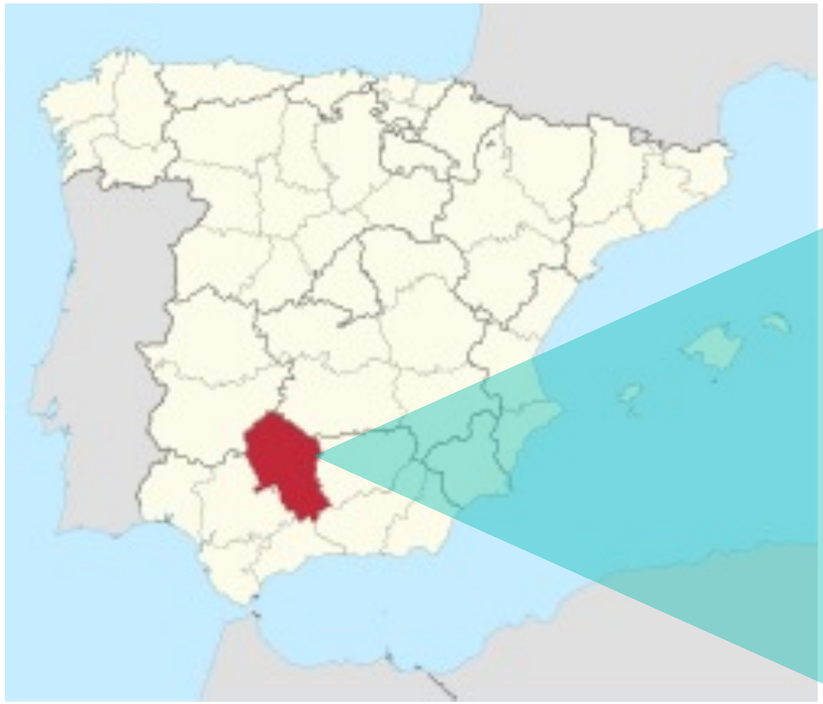
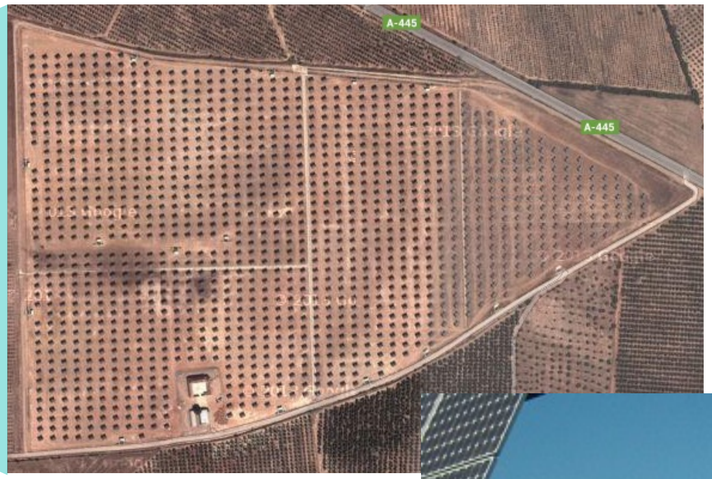
Pilot plant



Magtel Operaciones



- 6.1 MW
- 8 transformer center of 400 kW
- Two-axis solar trackers

Data collection

Python script to retrieve data from Copernicus Climate Change Service

```python
import cdsapi

c = cdsapi.Client()

c.retrieve(
    'seasonal-original-single-levels',
    {
        'originating_centre':'cmcc',
        'system':'3',
        'area':'39/-5/37/-3', # North, West, South, East. Specify as North/West/South/East in Geographi
        'grid': '1.0/1.0',
        'variable':[
            '10m_u_component_of_wind','10m_v_component_of_wind','2m_temperature',
            'surface_solar_radiation_downwards','total_precipitation'
        ],
        'year':'2018',
        'month':'01',
        'day':'01',
        'format':'grib',
        'leadtime_hour':[ ...
        ]
    },
    'data.grib')
```

```
a501 0000 120b 0100 0001 0600 0000 0000
1562 0000 0000 0000 0000 0000 0000 0000
0f1f 0904 c430 3030 3100 0000 0300 0100
0000 0000 0000 2000 ff00 0002 0002 0096
6480 1194 8000 927c 800d ac03 e803 e800
0000 0000 0000 1808 8017 c030 b400 1800
0000 4eda 0084 e560 c5a7 e000 3737 3737
0000 0000 0000 0000 0000 0000 0000 0000
0000 0000 0000 0000 0000 0000 0000 0000
0000 0000 0000 0000 0000 0000 0000 0000
0000 0000 0000 0000 0000 0000 0000 0000
0000 0000 0000 0000 0000 0000 0000 0000
0000 0000 0000 0000 0000 0000 0000 0000
0000 0000 0000 0000 0000 0000 0000 0000
4752 4942 0000 8001 0000 3c80 5080 ff80
a601 0000 120b 0100 0001 0600 0000 0000
1562 0000 0000 0000 0000 0000 0000 0000
0f1f 0904 c430 3030 3100 0000 0300 0100
0000 0000 0000 2000 ff00 0002 0002 0096
6480 1194 8000 927c 800d ac03 e803 e800
0000 0000 0000 1808 8018 412c 1390 18ba
3100 0264 c061 1bc0 0000 0000 3737 3737
0000 0000 0000 0000 0000 0000 0000 0000
```

Data collection

Data standardisation

GRIB to CSV → CSV to XLS → XLS to JSON

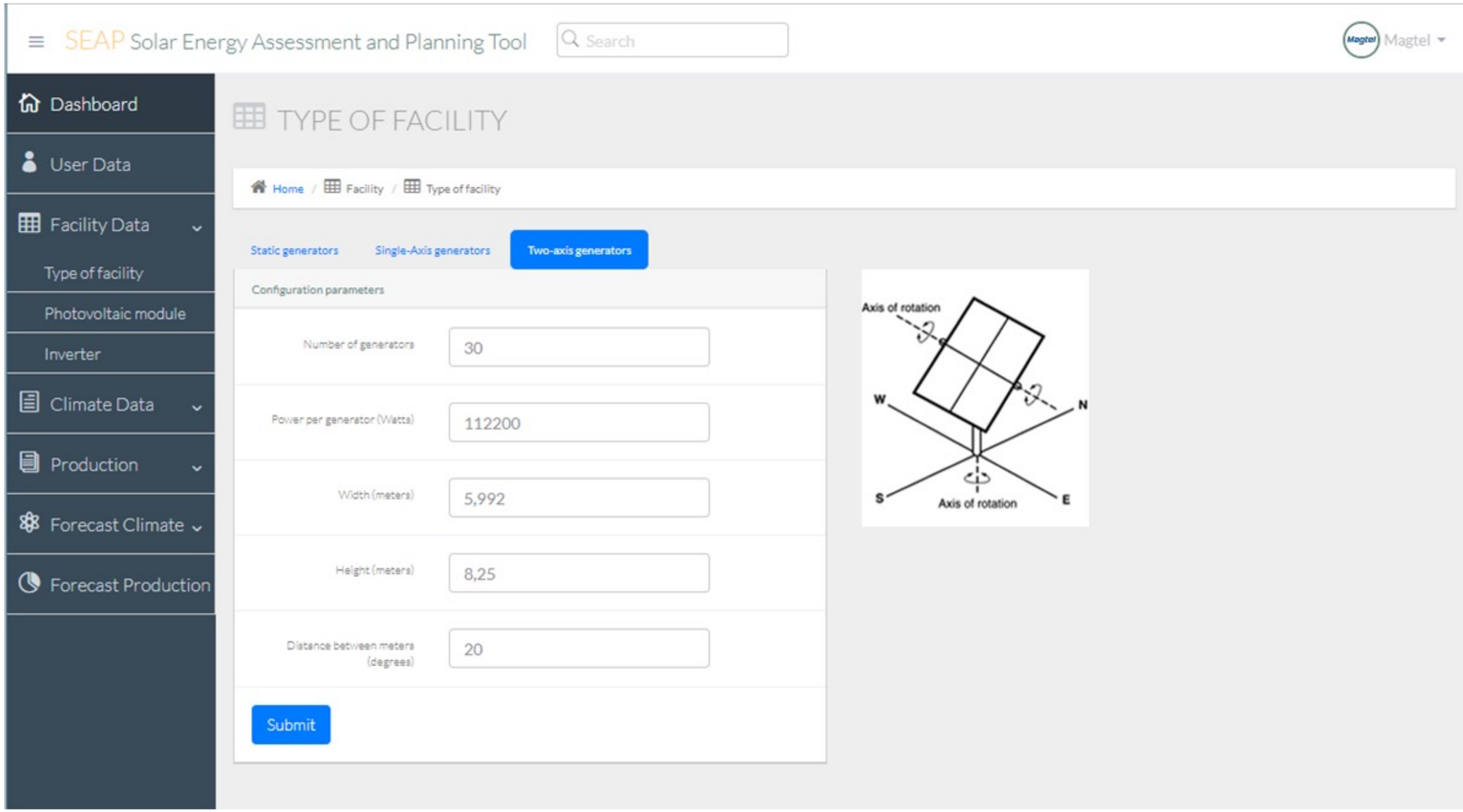
*20181101, **6** , 10u, 1.92*
*20181101, **6** , 10v, 4.20*
*20181101, **6** , 2t, 283.81*
---
*20181101, **12** , 10u, 3.5*
*20181101, **12** , 10v, 3.9*
*20181101, **12** , 2t, 285.7*
---
*20181101, **18** , 10u, 3.5*
*20181101, **18** , 10v, 3.9*
*20181101, **18** , 2t, 285.7*
---
*20181101, **24** , 10u, 3.5*
*20181101, **24** , 10v, 3.9*
*20181101, **24** , 2t, 285.7*
*20181101, **24** , ssrd, 285.7*
*20181101, **24** , tp, 285.7*
---
*20181101, **30** , 10u, 1.92*
*20181101, **30** , 10v, 4.20*
*20181101, **30** , 2t, 283.81*

*cliente-0000, 2018-11-01 **06:00:00**, 10u=1.92, 10v=4.20, 2t=283.81*
---
*cliente-0000, 2018-11-01 **12:00:00**, 10u=3.5, 10v=3.9, 2t=285.7*
---
*cliente-0000, 2018-11-01 **18:00:00**, 10u=3.5, 10v=3.9, 2t=285.7*
---
*cliente-0000, 2018-11-02 **00:00:00**, 10u=3.5, 10v=3.9, 2t=285.7, ssrd=285.7, tp=285.7*
---
*cliente-0000, 2018-11-02 **06:00:00**, 10u=1.92, 10v=4.20, 2t=283.81*

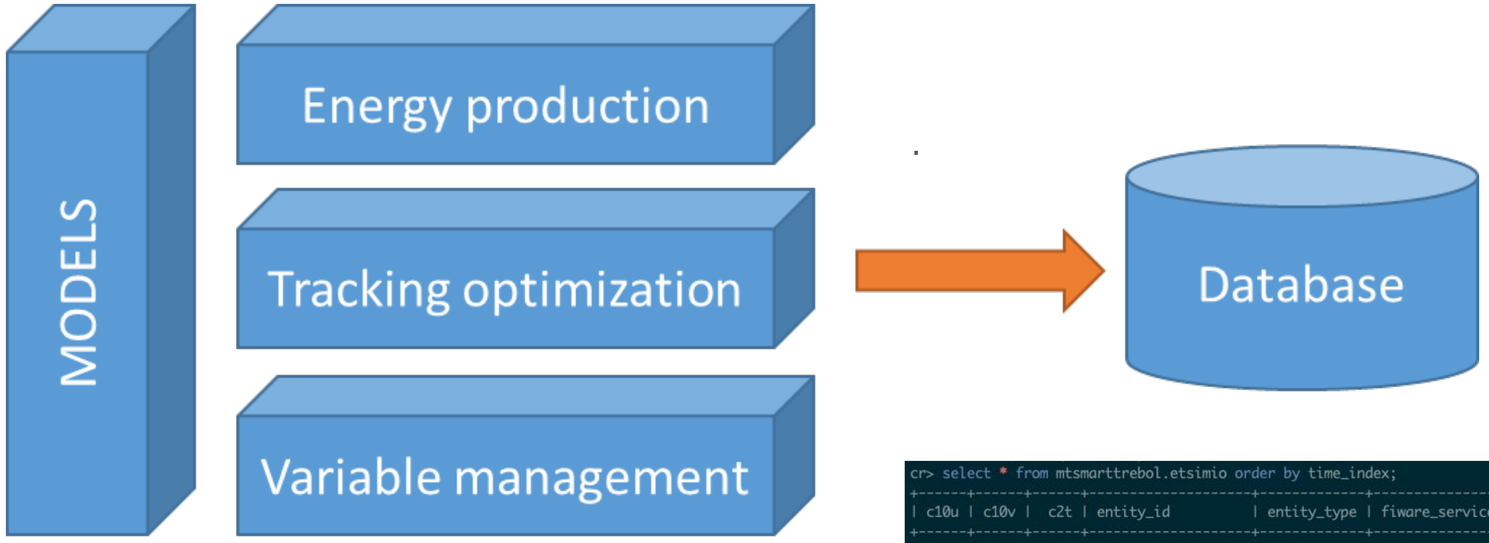
```
{
"devices": [
{
"device_id":
"cliente:simio:0000",
"entity_name":
"cliente:simio:0000",
"entity_type": "Simio",
"timezone": "Europe/Madrid",
"attributes": [
{
"object_id": "c10u",
"name": "c10u",
"type": "Number"
},
{
"object_id": "c10v",
"name": "c10v",
"type": "Number"
},
---
```

Data collection

Data facility introduced by users



Data processing & storage

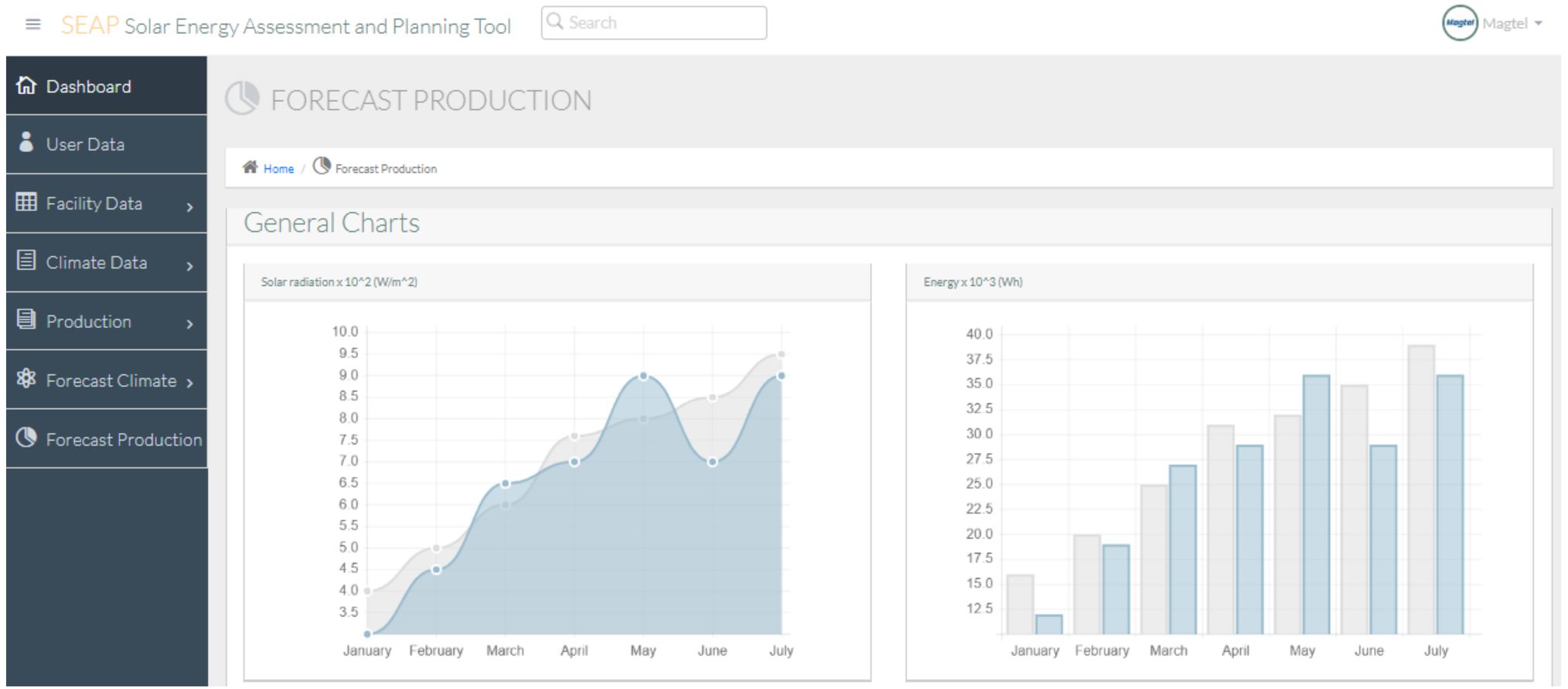



```
cr> select * from mtsmarttrebol.etsimio order by time_index;
+------+------+------+--------------------+-------------+--------------------+------+---------------+------+
| c10u | c10v |  c2t | entity_id          | entity_type | fiware_servicepath | ssrd |    time_index |   tp |
+------+------+------+--------------------+-------------+--------------------+------+---------------+------+
|  2.2 |  3.3 |  4.4 | cliente:simio:0000 | Simio       | /rabanales         |  5.5 | 1555945273000 |  6.6 |
| 12.2 | 13.3 | 14.4 | cliente:simio:0000 | Simio       | /rabanales         | 15.5 | 1555945539000 | 16.6 |
| 12.2 | 13.3 | 14.4 | cliente:simio:0000 | Simio       | /rabanales         | 15.5 | 1555946122000 | 16.6 |
+------+------+------+--------------------+-------------+--------------------+------+---------------+------+
SELECT 3 rows in set (0.041 sec)
```

```
def fraccionradiacion(latitud, dia_jul, vhora, GLOBALMEDIDA):
    #Rem "Esta subrutina permite la descomposici¢n de la radiaci¢n diaria"
    #Rem "medida en un lugar(J) en sus componentes directa y difusa(J), as¡ como"
    #Rem "en los valores instantáneos (W/m2) de directa y difusa"
    #Rem "M<0x90>TODO COLLARES-PEREIRA, Solar Energy,Vol 22,n§2,1979"
    Pi = 3.141592
    lista= GEOSOLTIERRA(latitud, dia_jul, vhora)
    RADTEO=lista[2]
    KH = GLOBALMEDIDA / RADTEO
    if KH <= 0.17:
        difusaestimada = 0.99 * GLOBALMEDIDA
    if (KH < 0.8) and (KH > 0.17):
        difusaestimada = (1.188 - 2.272 * KH + 9.473 * KH ** 2 - 21.856 * KH ** 3 + 14.648 * KH ** 4)
    if (KH < 1) and (KH >= 0.8):
        difusaestimada = 0.18 * GLOBALMEDIDA
    if (KH >= 1):
        difusaestimada = 0.18 * GLOBALMEDIDA
        print ("Errorrrr")
    directaestimada = GLOBALMEDIDA - difusaestimada
    durdia=lista[1]
    ws = Pi / 24 * durdia
    WH = vhora / 24 * 2 * Pi
    difusainst = Pi / 24 * (math.cos(WH) - math.cos(ws)) / (math.sin(ws) - ws * math.cos(ws)) * difusae
    aa = 0.409 + 0.5016 * math.sin(ws - 1.047)
    bb = 0.6609 - 0.4767 * math.sin(ws - 1.047)
    globalinst = (aa + bb * math.cos(vhora * 2 * Pi / 24)) * Pi / 24 * (math.cos(vhora / 24 * 2 * Pi)
    directainst = globalinst - difusainst
    return directaestimada, difusaestimada, directainst, difusainst
```

Web application

On-line monitoring application for SEAP service



Conclusion

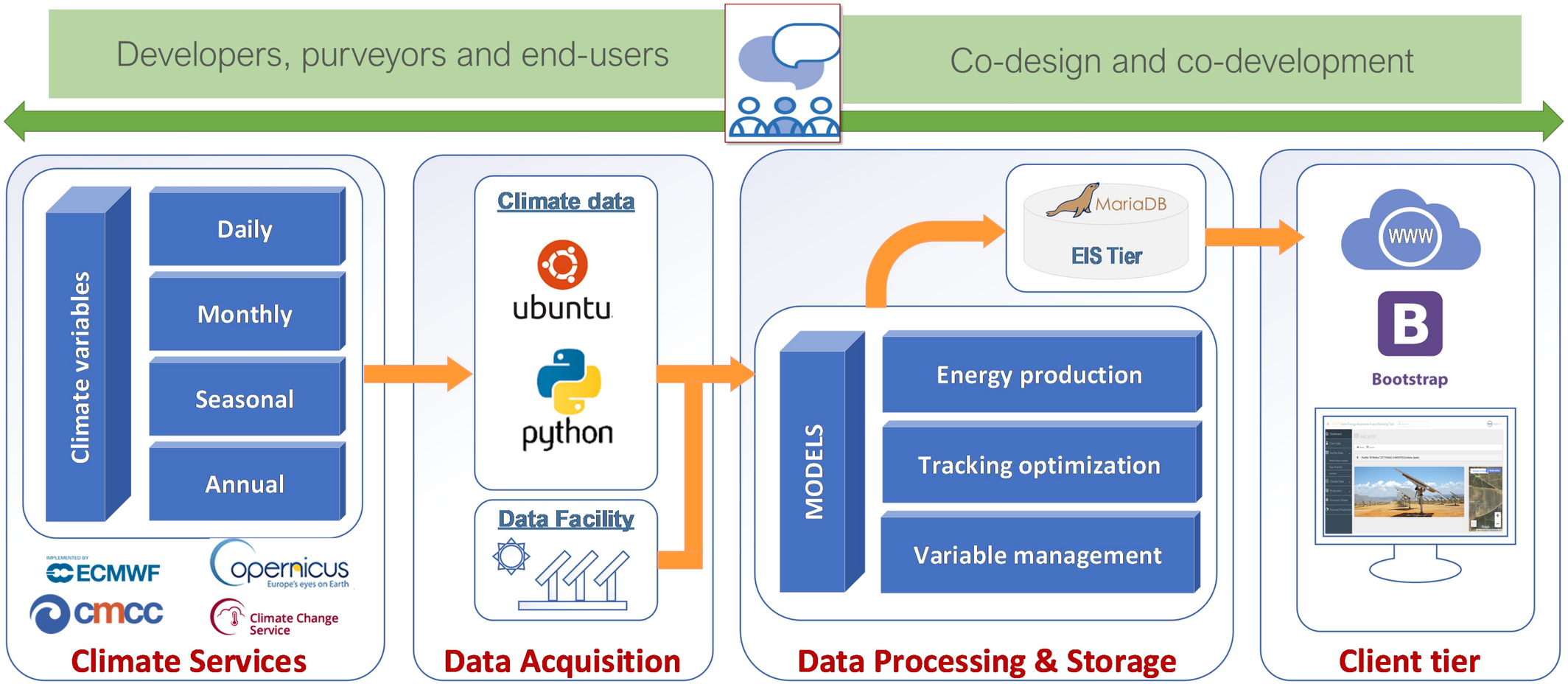
- The SEAP service is enabled to give a global simulation to determine energy produced, providing forecasts from short-term to long-term to climate change conditions.
- This service offers alternatives for PV plants the user can act on, either managing the priority of consumption in autonomous installations or determining the most appropriate tracking for each day.

Thank you for your attention.

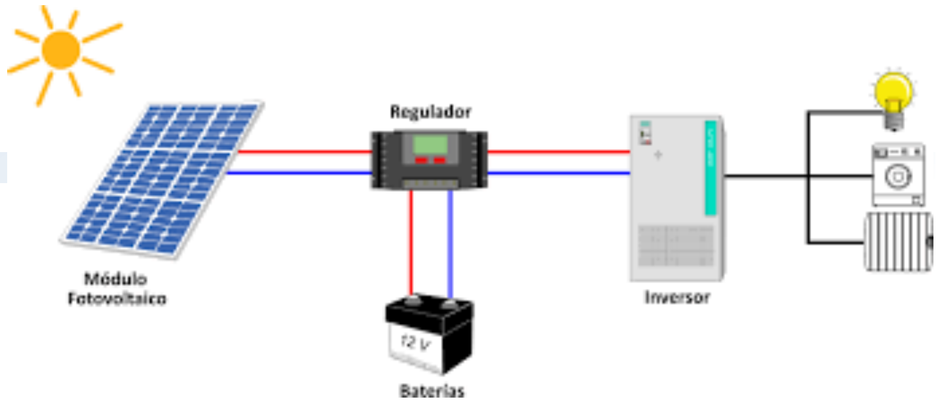
isabel.moreno@uco.es

The CLARA project has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement No 730482.

Planning tool workflow



Historial investigador TEP-215



Grupo TEP 215. Física para las Energías Renovables

Tesis Doctoral –Caracterización del balance energético en instalaciones fotovoltaicas autónomas en la España peninsular. 1993

Aproximación a la caracterización matemática del balance energético diario:

Ecuaciones consideradas para el balance energético:

$$B'_i = B_{i-1} + \eta_G A_G H_{g\beta i} - L_i$$

$$B'_i = B_{i-1} + E_i$$

$$B_i = \begin{cases} C_U & \text{si } B'_i \geq C_U \\ B'_i & \text{si } 0 < B'_i < C_U \\ 0 & \text{si } B'_i \leq 0 \end{cases}$$

$$m(y_i/K_S, E, \delta, \eta_B) = a_1(E, \delta\eta_B) \left[\frac{K_S}{\delta}\right]^{b_1(E,\delta\eta_B)} + c_1(E, \delta\eta_B)$$

$$s(y_i/K_S, E, \delta, \eta_B) = a_2(E, \delta\eta_B) \left[\frac{K_S}{\delta}\right]^{b_2(E,\delta\eta_B)} + c_2(E, \delta\eta_B)$$

Caracterización estocástica: Se considera B'_i suma de dos variables estocásticas con interdependencia temporal

Historial investigador

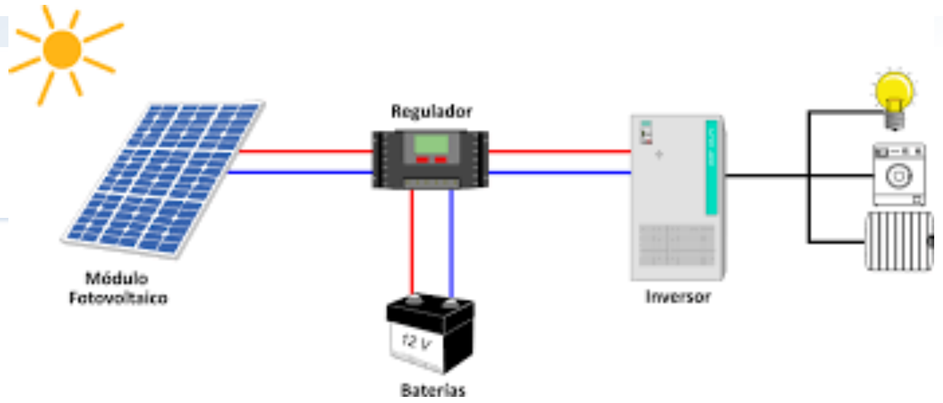
1. Historial académico

2. Actividad investigadora

3. Actividad docente

4. Experiencia en gestión

Dimensionado óptimo y caracterización de plantas solares fotovoltaicas



Tesis doctoral Rosario Posadillo Sánchez de Puerta, *Estudio del Abastecimiento de Demandas Energéticas Variables mediante Energía Solar Fotovoltaica*. 2003

Historial investigador TEP-215

$$LLP = \frac{\int_{time} \text{Energy deficit}}{\int_{time} \text{Energy demand}}$$

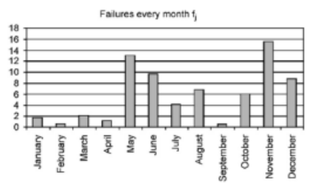


Fig. 3. Monthly distribution of expected failures for systems with twenty 80 Wp modules and 30 accumulator cells.

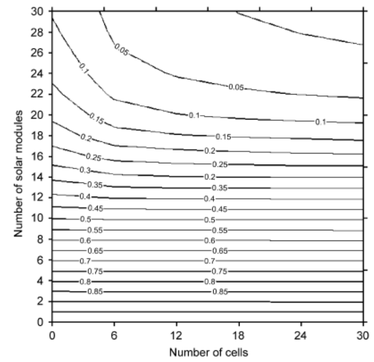


Fig. 4. Distribution of annual LLP according to the number of accumulator Cells and number of 80 Wp modules in the installation.

Tesis doctoral Francisco Casares De La Torre, *Herramientas mejoradas para la caracterización de sistemas fotovoltaicos autónomos*. 2015

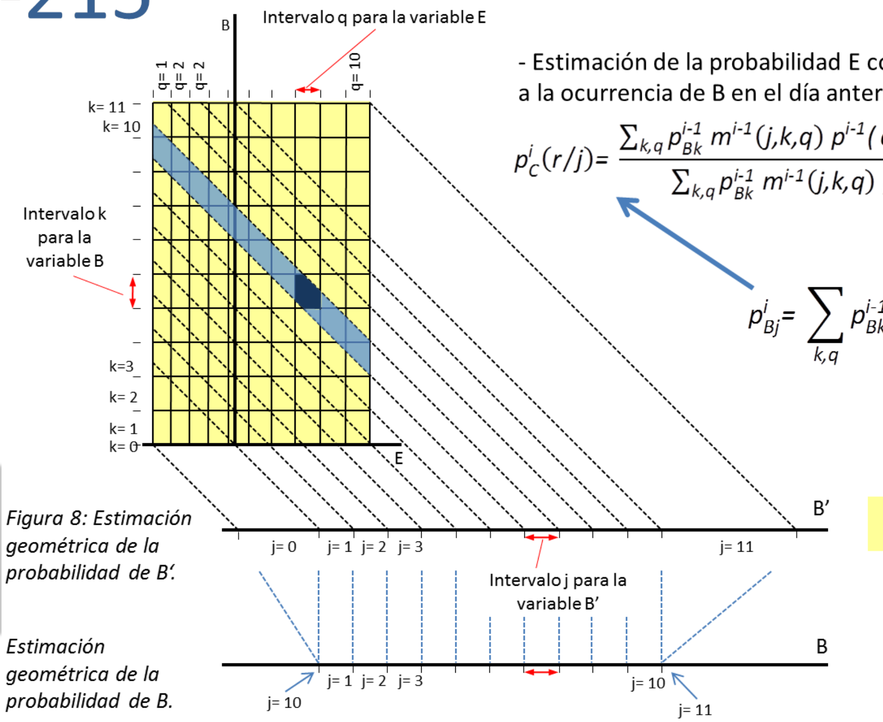


Figura 8: Estimación geométrica de la probabilidad de B'.

Estimación geométrica de la probabilidad de B.

- Estimación de la probabilidad E condicionada a la ocurrencia de B en el día anterior:

$$p_C^i(r/j) = \frac{\sum_{k,q} p_{Bk}^{i-1}\, m^{i-1}(j,k,q)\, p^{i-1}(q/k)\, p_A(q \to r)}{\sum_{k,q} p_{Bk}^{i-1}\, m^{i-1}(j,k,q)\, p^{i-1}(q/k)}$$

$$p_{Bj}^i = \sum_{k,q} p_{Bk}^{i-1}\, m^i(j,k,q)\, p^i(q/k)$$

$$B'_i = B_{i-1} + E_i$$

$$B_i = \begin{cases} C_U & \text{si } B'_i \geq C_U \\ B'_i & \text{si } 0 < B'_i < C_U \\ 0 & \text{si } B'_i \leq 0 \end{cases}$$

Historial investigador

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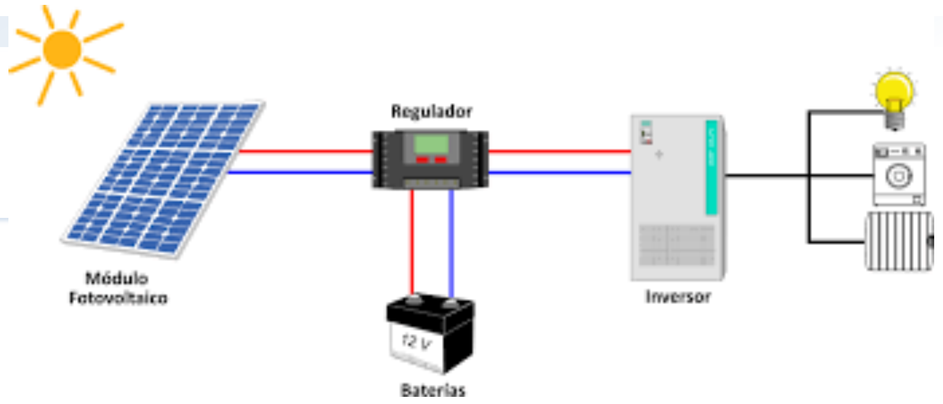
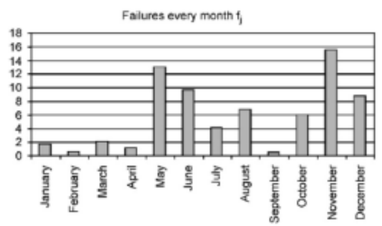


Tesis doctoral Rosario Posadillo Sánchez de Puerta, *Estudio del Abastecimiento de Demandas Energéticas Variables mediante Energía Solar Fotovoltaica*. 2003

$$LLP = \frac{\int_{time} \text{Energy deficit}}{\int_{time} \text{Energy demand}}$$



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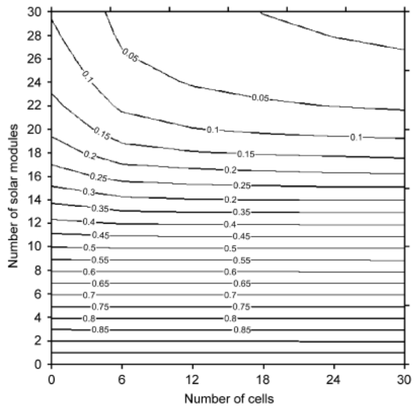

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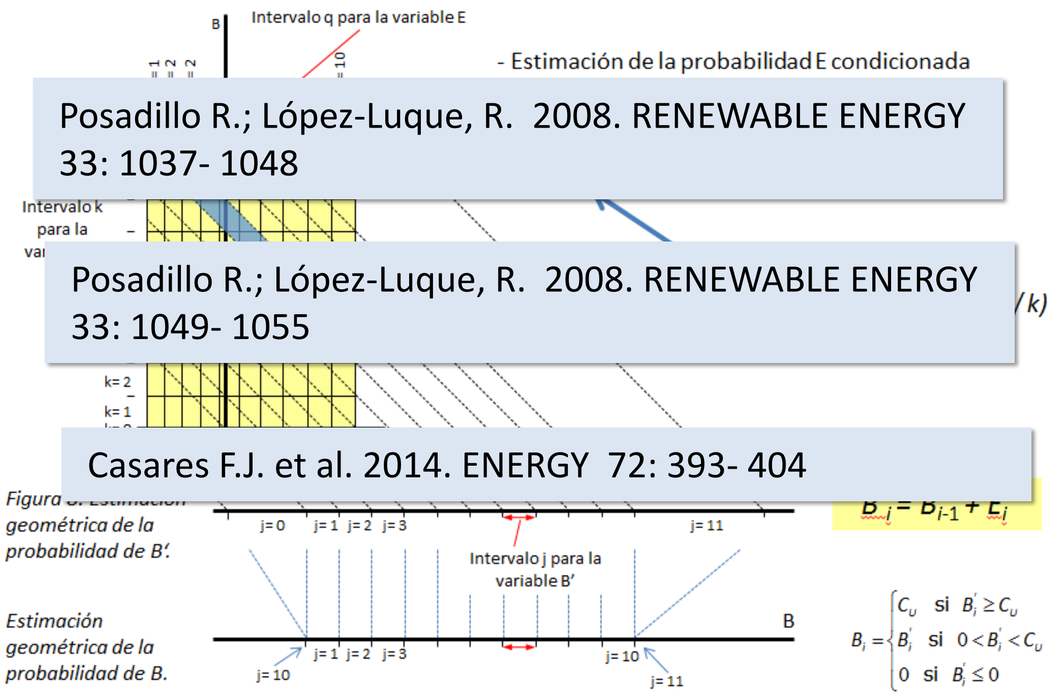


Figura 3. Estimación geométrica de la probabilidad de B'.

Estimación geométrica de la probabilidad de B.

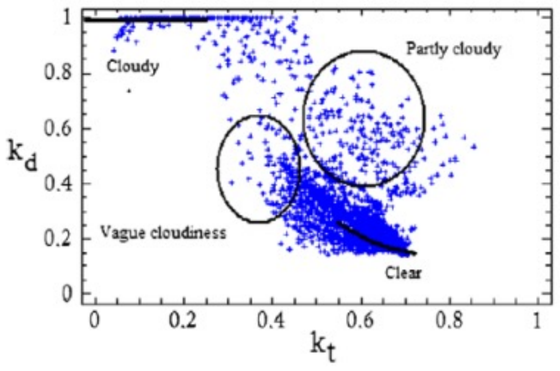
Historial investigador

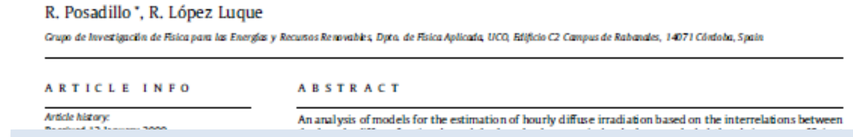
Medida y Caracterización de la radiación solar

Tesis doctoral Gerardo Pedrós Pérez. Caracterización de la Radiación Global Ultravioleta Solar (290-385nm). Universidad: de Córdoba. 1998.

Posadillo R.; López-Luque, R. 2010. ENERGY CONVERSION AND MANAGEMENT 51: 627- 635

Posadillo R.; López-Luque, R. 2009. ENERGY CONVERSION AND MANAGEMENT 50: 223- 231





Posadillo R.; López-Luque, R. 2009. ENERGY CONVERSION AND MANAGEMENT 50: 2324- 2330

Historial investigador

Modelado y simulación de instalaciones fotovoltaicas autónomas

Medida y Caracterización de la radiación solar

Creación del Grupo PAIDI:
TEP215: FISICA PARA LAS ENERGIAS Y RECURSOS RENOVABLES

Disponibilidad de recurso solar en fachadas de edificios

Desarrollo de prototipos y mejora de dispositivos de aprovechamiento solar

Historial investigador

1. Historial académico

2. Actividad investiga-dora

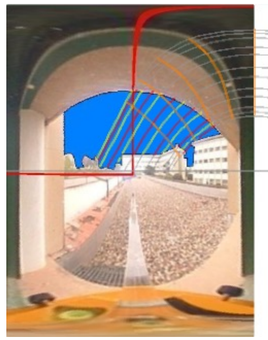
3. Actividad docente

4. Experiencia en gestión

Disponibilidad de recurso solar en fachadas de edificios

Tesis doctoral José C. Ramírez Faz, *Desarrollo de una metodología basada en el análisis de imagen y desarrollo de un prototipo para la evaluación y cuantificación de variables asociadas a la radiación solar*. 2012

Ramírez-Faz, J.; López-Luque, R. 2012. RENEWABLE ENERGY 37: 426- 433



Casares, F.J. et al. 2014. ENERGY AND BUILDINGS 82: 696- 702

$$r = r(\varphi, \theta) \qquad \xi = \xi(\varphi, \theta)$$

$$\frac{\delta r^2}{\delta \varphi}\frac{\delta \xi}{\delta \theta} - \frac{\delta r^2}{\delta \theta}\frac{\delta \xi}{\delta \varphi} = 2\rho\left(\varphi, \theta\right)$$

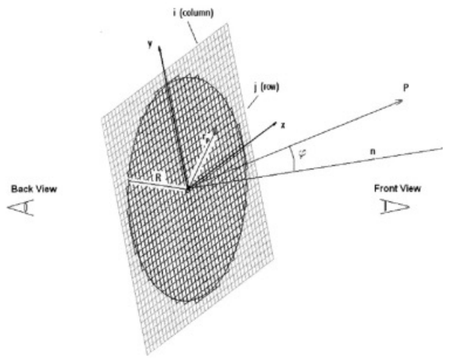
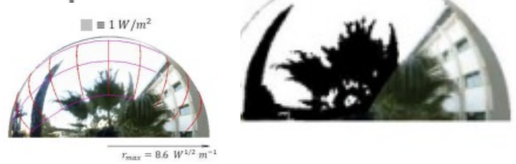


Fig. 6. Transformed image.

Ramírez et. al. ENERGY AND BUILDINGS, 6: 391- 397



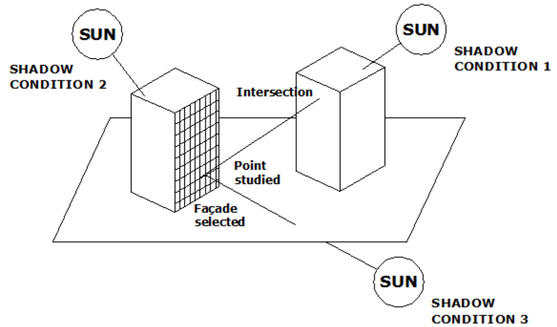
Ramírez-Faz, J.C. et al. 2015. RENEWABLE ENERGY 74: 279- 286

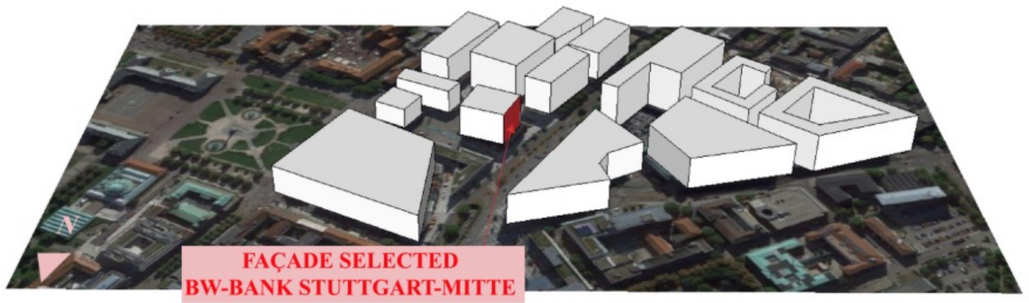
Historial académico, docente e investigador

Disponibilidad de recurso solar en fachadas de edificios

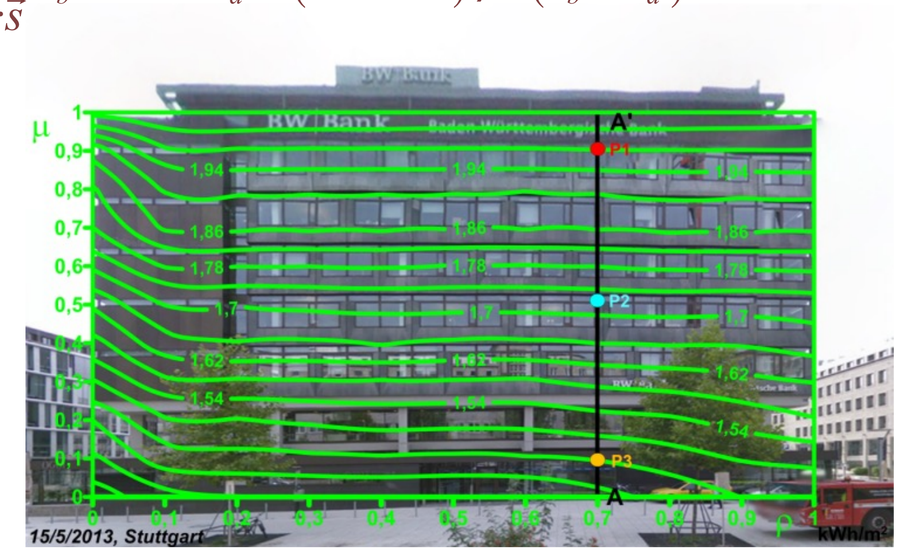
Márquez-García, A. et al. 2016. INTERNATIONAL JOURNAL OF LOW-CARBON TECHNOLOGIES 11(1): 61-65

Márquez-García,A.; Varo-Martínez,M.; López-Luque, R. 2013. Solar energy in urban environments: a new solar radiation model for the analysis of energy on façades. LAP Lambert Academic Publishing. Saarbrucken, Germany





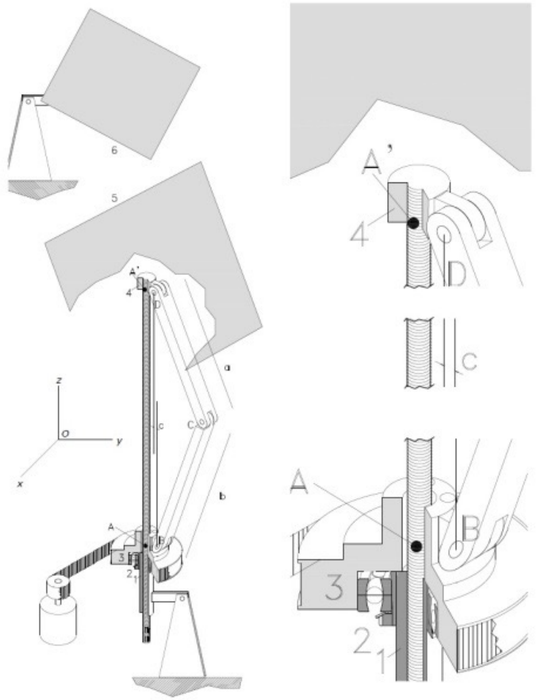
$$I = SS \cdot \frac{\vec{n}\cdot\vec{s}}{\vec{k}\cdot\vec{s}} I_b + SVF \cdot I_d + (1 - SVF)\cdot\rho'\cdot(I_b + I_d)$$

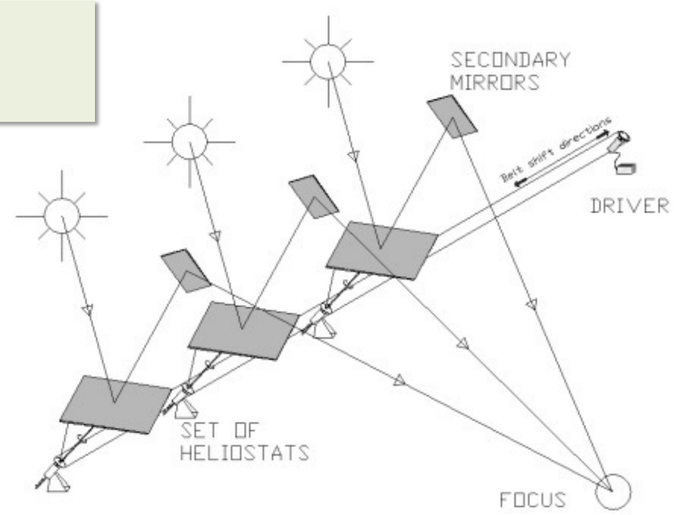


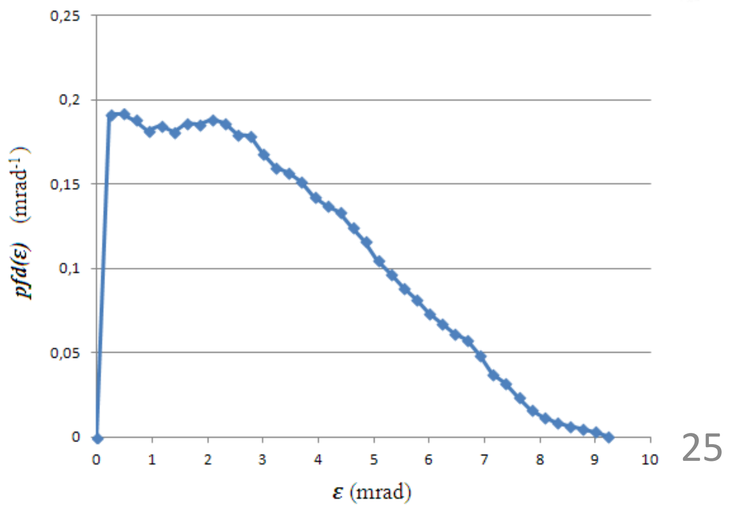
Historial investigador

Desarrollo de prototipos y mejora de dispositivos de aprovechamiento solar

Tesis doctoral Manuel Torres Roldán, *Diseño de un helióstato polar innovador y simplificado para la integración en edificios y entornos urbanos*. 2016







UNIVERSIDAD DE CÓRDOBA

An Approach for the Solar Energy Assessment using Weather Medium-Range Forecasting

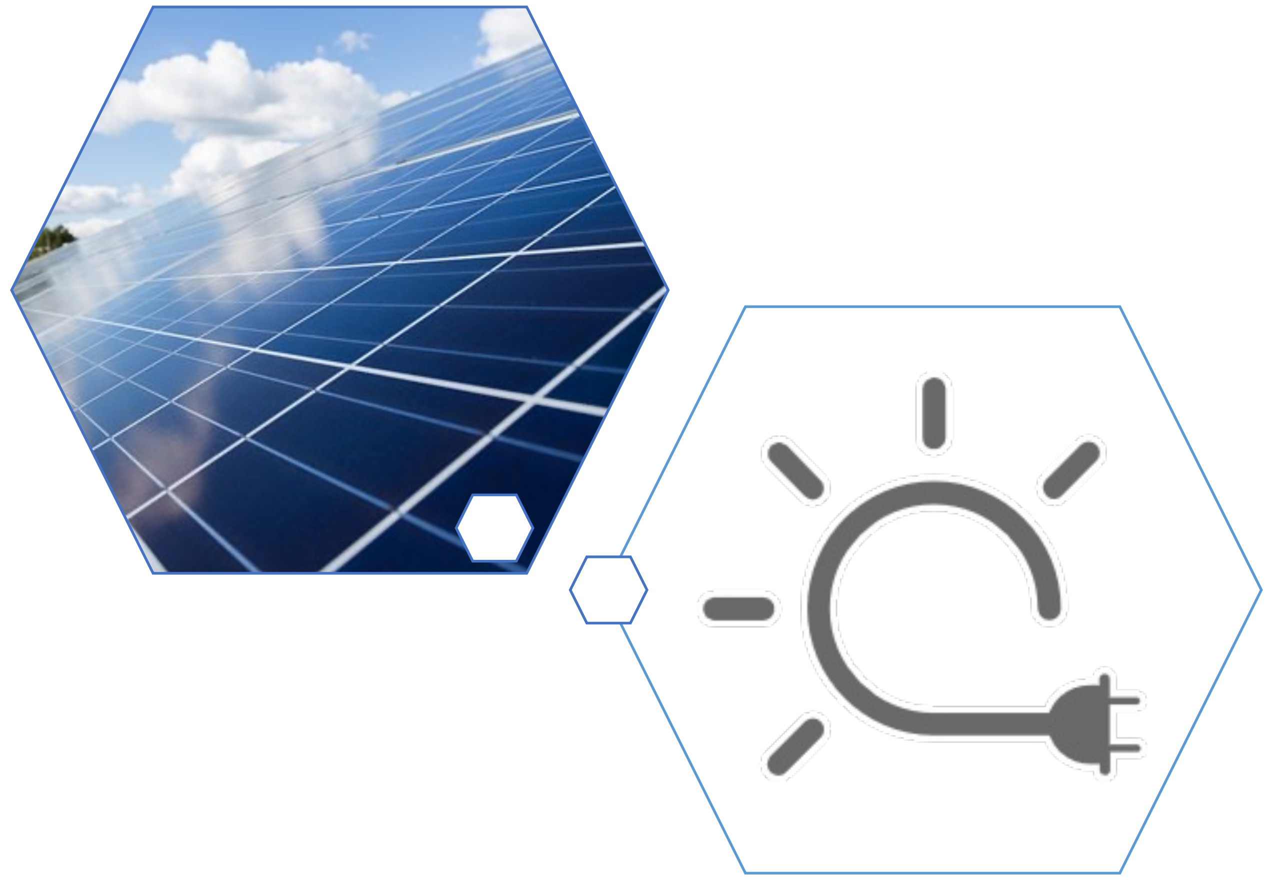
Moreno-Garcia, Isabel M.

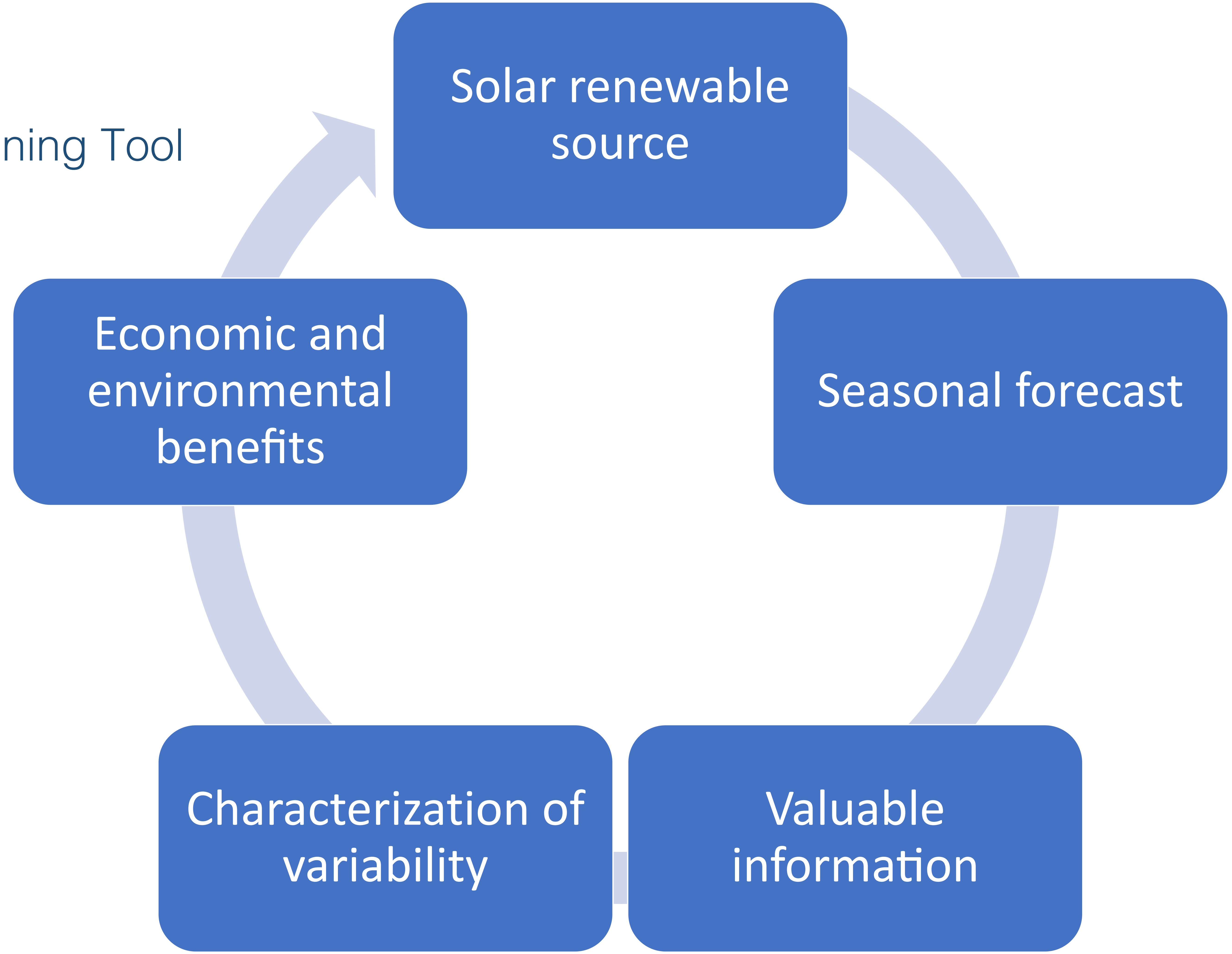
Research Group Physics for Renewable Energies. University of Córdoba

Introduction

SEAP

Solar Energy Assessment and Planning Tool





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