CENER NATIONAL RENEWABLE ENERGY CENTRE

The National Renewable Energy Centre of Spain (CENER)

Solar Thermal Energy Department - 2014

GOBIERNO DE ESPAÑA MINISTERIO DE INDUSTRIA, ENERGÍA Y TURISMO MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Gobierno de Navarra

CENER | NATIONAL RENEWABLE ENERGY CENTRE

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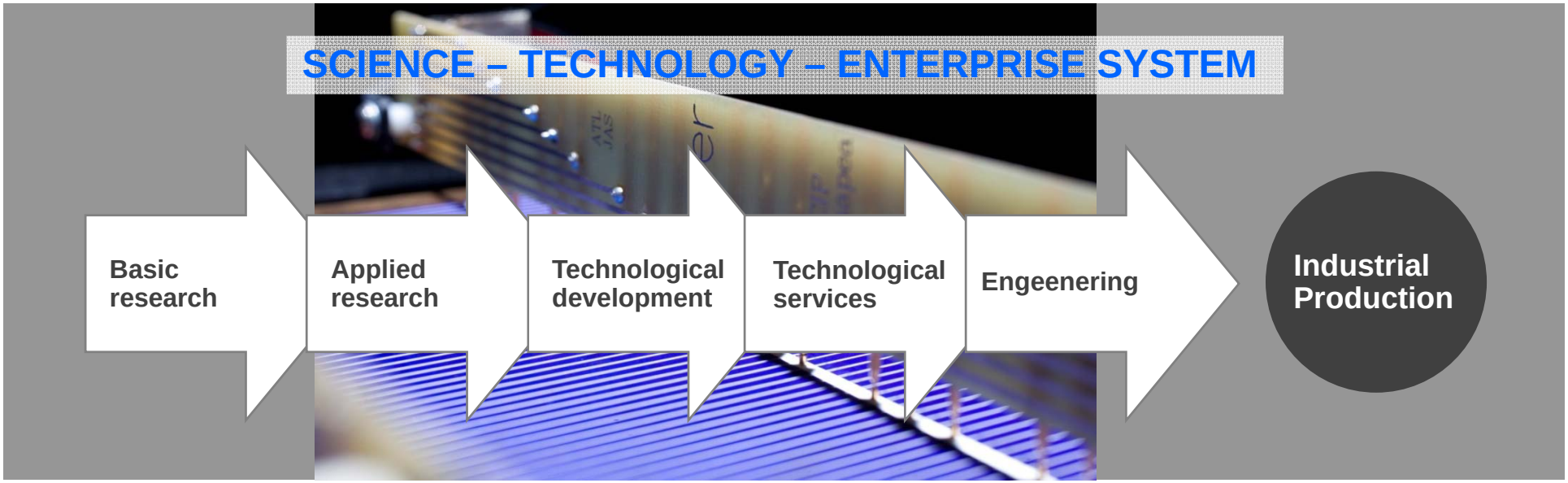
1 Presentation of the National Renewable Energy Centre

Vision	To be a research centre of excellence in the renewable energies field with international outreach.
Mission	To generate knowledge in the renewable energy field and to transfer it to the industry in order to boost sustainable energy development.

1 Presentation of the National Renewable Energy Centre



R&D Projects
Certification
Tests

ACTIVITIES AND RESEARCH AREAS

Activities	Applied research, technology transfer….
	Assessment, approval, accreditation and certification services.
Areas	Wind
	Biomass
	Solar Photovoltaic
	Solar Thermal
	Energy Grid Integration
	Energy in buildings

CENER IN NUMBERS

21,2 M€	The annual 2012 budget is € 21,2 million. 60% self-financing
200	200 employees researchers, technical staff and support personnel
100 M€	Total investments (2002-2011): >€100 million
	More than 200 customers in all five continents

INFRASTRUCTURES

Headquarters
Sarriguren

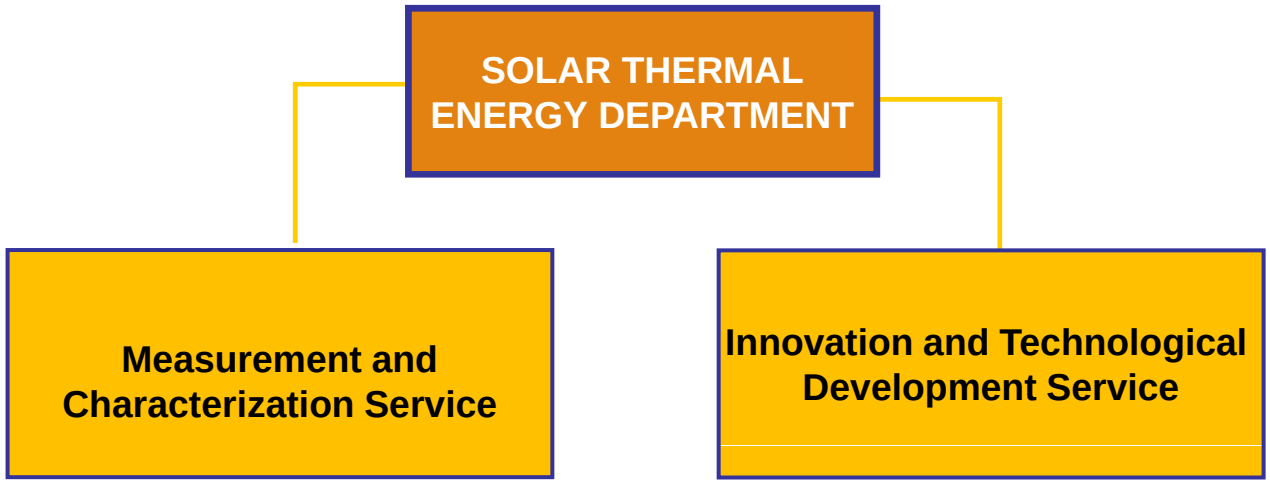
Wind Test Laboratory
Sangüesa

Biofuels plant
Aoiz

Offices
Madrid & Sevilla

2 CENER´s
Solar Thermal
Energy
Department

SOLAR THERMAL ENERGY DEPARTMENT STRUCTURE



Multidisciplinary Team: Engineers, physicists, mathematicians, meteorologists, computer scientists, etc

BACKGROUND

With a technical team of more than 20 highly qualified professionals, the Solar Thermal Energy Department of CENER is an international reference in the Concentrating Solar Power field. Among the key personnel within this technical team, is the former R&D Director of Abengoa Solar New Technologies.

CENER senior solar researchers are well known CSP technical advisors. Within the last 5 years, they delivered assignment from the World Bank in India, and from other institutions in America, Europe, and Africa. They were technical advisors to the A.T. Kearney CSP cost reduction potential study for ESTELA and to MASEN in the definition of the Ouarzazate complex. They also reviewed CSP-related programs for the US Government and the European Commission, and carried out a very detailed study for the Spanish Institute for Energy Saving and Diversification (IDAE).about the potential of the different CSP technologies in Spain.

Since its inception, the Solar Thermal Energy Department of CENER has dedicated a large part of its activities to support the Concentrating Solar Thermal Power (CSTP) industry in Spain and elsewhere. These activities can be classified into three groups:

1. **Technical assistance**: Technical assistance and advice to companies to ensure the success of commercial solar power plants projects.

2. **R&D Projects**: Collaborations with companies in defining and developing R&D projects for development and improvement of solar thermal power technologies.

3. **Strategic Assessments**: Strategic advice to institutions and companies in relation to technology and solar thermal power industry.

EXPERTISE

The CENER team has participated, with different degree of involvement, in more than 50 concentrating solar thermal power (CSTP) plant projects in Europe and elsewhere, many of them in the fields of solar radiation and solar thermal concentrating systems and supported through private and public funding. The reports and lessons learned from these activities have resulted in more than 170 publications, including books, technical reports, papers in reviewed journals and conference proceedings.

The CENER team is currently working in the development of more than twenty five commercial CSP plant projects in Spain and abroad. The activities of the CENER team in these projects range from site monitoring and solar resource characterization to modeling of plants and estimates of annual electricity generation. These projects have CSTP plant configurations that differ in capacity, choice of technology and options regarding storage. The experience acquired in these projects and the very sophisticated methodology developed by CENER for their development will place the team in a unique position to make a successful project of the one that is the subject of this proposal.

The members of the CENER team have also been actively involved in the development of CSTP technologies for many years and especially in the development of tower technology. They also have been actively involved in many of the activities of SolarPACES, the implementing agreement of the International Energy Agency (IEA) for Concentrating Solar Power Technologies and Solar Chemistry Applications, which bringing together teams of national experts from around the world to focus on the development and marketing of concentrating solar power systems.

TECHNICAL TEAM OF THE SOLAR THERMAL ENERGY DEPARTMENT

The team of Concentrating Solar Power (CSP) experts that CENER, has put together ranks among the best in the world. Its senior members are a selected group of seasoned and skilled researchers and engineers with long term international experience in both of solar thermal and conventional power plants. They have participated in the most relevant research, demonstration, and commercial CSP projects that have been planned and implemented in Europe within the last decades.

OUR KEY TEAM MEMBERS

Marcelino Sánchez

Director, Solar Thermal Energy Department

- **Dr. Marcelino Sanchez, has Ph.D. in Physical Chemistry.**
- 24 years of international research experience in R&D projects, in the area of solar thermal energy, especially in projects related to the electricity production from solar thermal energy. He has also participated in hydrogen generation and desalination projects from solar thermal energy, and in solar CPV projects. During these years he has worked for both public institutions and private enterprises, in Spain and abroad, leading research groups in different work environments with remarkable success. This experience covers a wide range of technical and professional skills, working from research laboratory scale to the design, construction and evaluation of commercial demonstration plants, unique in its kind, and including the development of experimental prototypes.
- He has held, among others, the following positions: R&D Director at Abengoa Solar New Technologies; Responsible of the High Concentration Working Group at CIEMAT; Solar thermal expert at Solargen Europe Ltd; Technical consultant for Energy for Sustainable Development Ltd.
- Author of numerous scientific publications, has leaded and participated in a large number of national and international projects, funded by public calls, which a large majority of them have been in international calls. He has also participated and participates in numerous expert groups, and committees, having been selected by the European Union in several times to do assistance to the Commission as International Expert. Author of seven patents, six of which are related to innovative solar energy concepts. Frequent reviewer of scientific journals as "Applied Energy", "Journal of Solar Energy Engineering" and of "Solar Energy".

Alberto García de Jalón

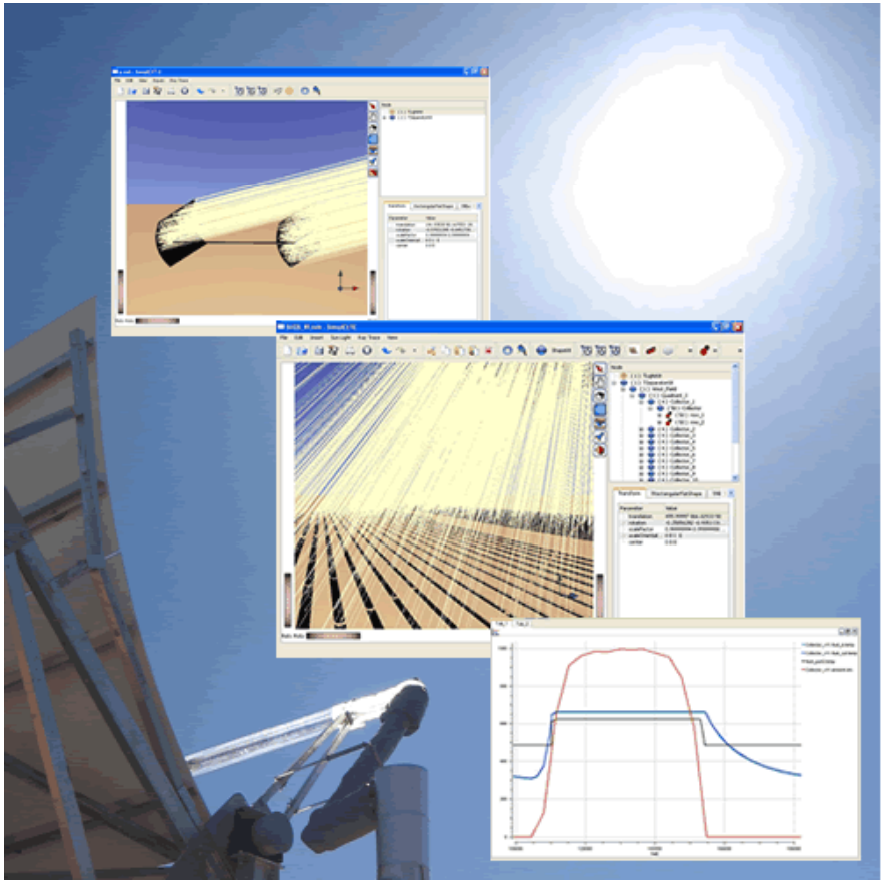
Head of Service, Solar Thermal Energy Department

- **Mr. Alberto García de Jalón, has M.Sc. in Mechanical Engineering.**
- 18 years of experience in engineering works related to the development and implementation of accredited calibration and testing laboratories. the last three as Head of the Measurement and Characterization Service at the Solar Thermal Energy Department of CENER.. Participation in several projects for accreditation thermal and solar radiation applications as solar collectors, solar domestic systems and temperature, pressure and solar radiation measurement sensors. He is too, the Responsible of the Solar Thermal Test Laboratory This laboratory primarily realizes solar components approval tests according to the UNE-EN 12975 and UNE-EN 12976.
- The main important achievements during these years are: 10/2011: ENAC accreditation for calibrating pyrheliometers according to the standard ISO 9059; 06/2010: ENAC accreditation for calibrating pyranometers according to the standard ISO 9847; 10/2009: ENAC accreditation for testing solar collectors according to the standard ISO 9806; ISO 9806. 10/2008: ENAC accreditation for testing solar collectors under outdoor steady state method according to the standard UNE-EN 12975;12/2008: ENAC accreditation for testing solar systems according to the standard UNE-EN 12976; 11/2007: ENAC accreditation for testing solar collectors under quasi dynamic method according to the standard UNE-EN 12975; 04/2004 ENAC accreditation for testing solar collectors under indoor steady state method according to the standard UNE-EN 12975; 04/2003: ENAC accreditation for calibrating relative and absolute pressure sensors.

Ana Bernardos

Head of Service, Solar Thermal Energy Department

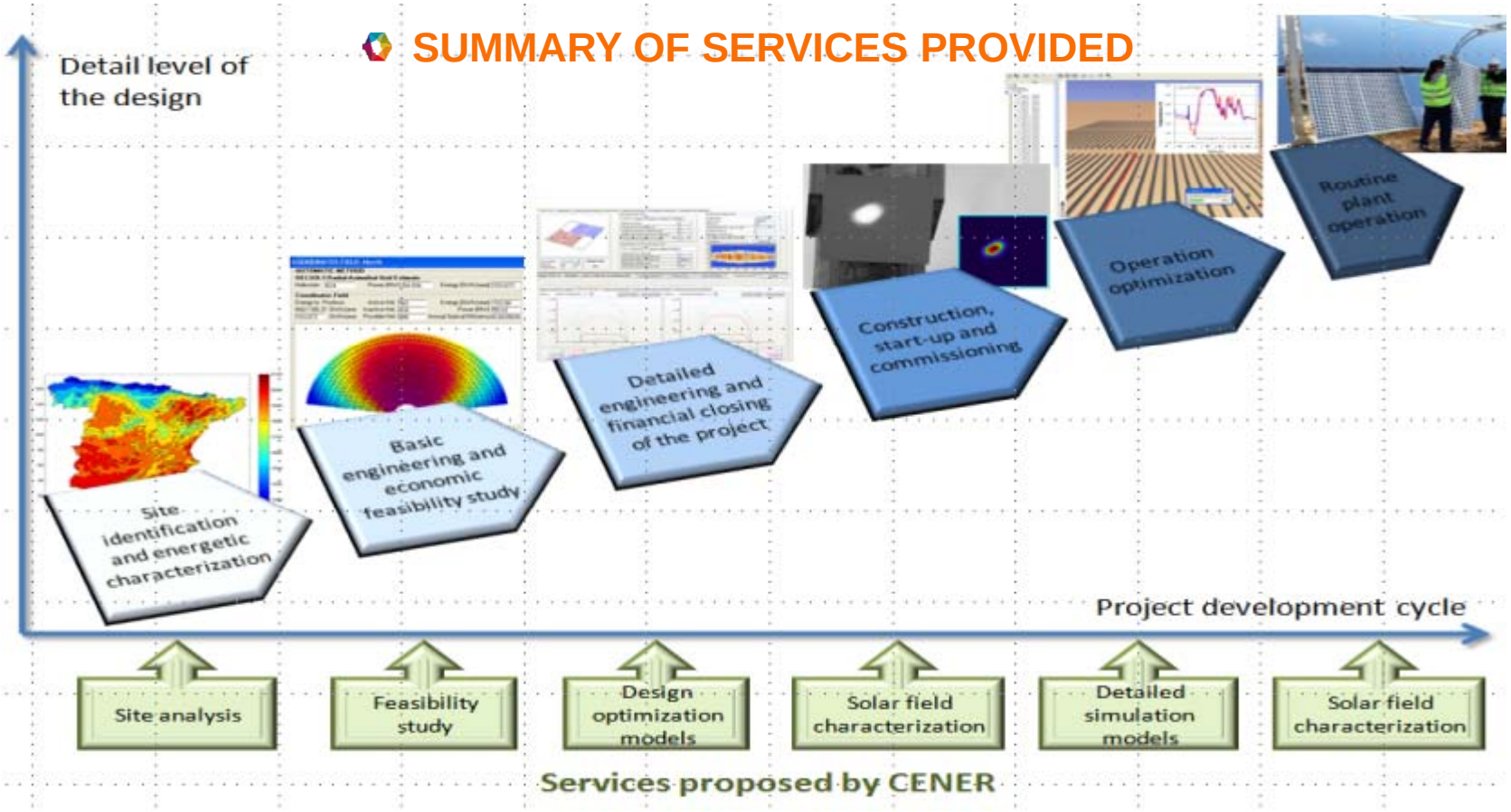
- **Ana Bernardos, has Degree in Physics.**
- 20 years of experience in the field of renewable energy and conventional power plants. This experience covers all the phase of commercial projects, from feasibility studies, development of technical projects for licenses, development of proposals, engineering, procurement, construction and start-up. This experience also covers different renewable and conventional power plants: biomass, biodiesel, bio-ethanol, combined cycles, co-generation and solar plants.
- Five years of experience in the field of solar energy in the solar resource area, long-term measurement and estimates and feasibility studies, market analysis.
- The main works has been developed under the specialty of process, including auxiliary systems for the plants, like make up, waste water treatment, cooling circuits and evaporators and main equipments, like boilers and turbines. Also remark the experience as Technical Manager for biodiesel plant and the participation in the PS10 Solar Power Plant as responsible of steam turbine and auxiliary equipments.



SUMMARY OF SERVICES PROVIDED

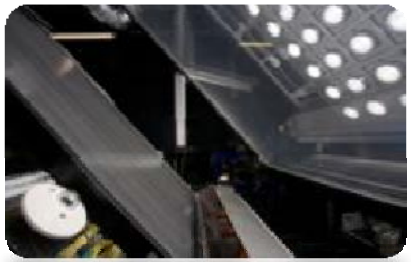
- Site selection and characterization
- Meteorological Design Years
- Design of CSP plants
- Design of CSP components
- Evaluation of plant performance
- Characterization of CSP components
- Analysis of Energy Production
- Guidance on selection of offers
- Feasibility Studies
- Technical Due Diligence
- Technical assistance
- R&D projects
- Strategic advising

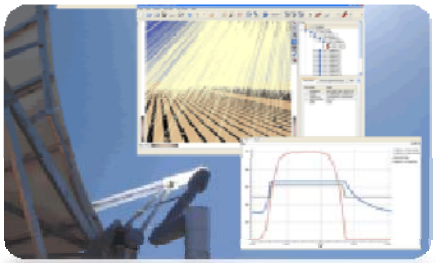
2 CENER s Solar Thermal Energy Department



INTERNACIONALIZATION

MAIN CLIENTS





A.T. Kearney
Abener
Abengoa Solar
Acciona Energía
Alatec
Alucoil
Aries Ingeniería
Botswana Power Corporation
ECOWAS Regional Centre for Renewable Energy and Energy Efficiency (ECREEE)

Électricité de France (EDF)
Energias de Portugal (EDP)
Elecnor
Endesa
Enel Unión Fenosa
ESBI Contracting
Fagor
Flúor
Fotowatio
Garrigues
Gas Natural

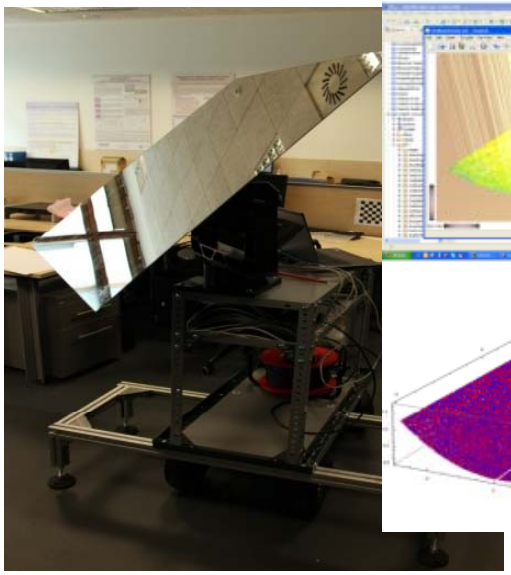
Grupo Enhol
Grupo Samca
Hyperion Energy
Iberdrola
Institute for Diversification and Saving of Energy of Spain (IDAE)
IDOM
Infinia
Ingeteam
Magtel
Martifer

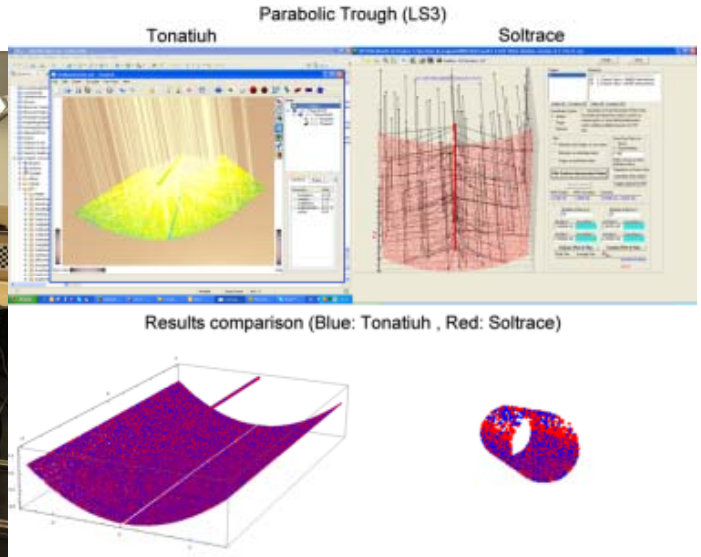
Marguerite Fund
Milenio Solar
Natural Electric
Neo-Energia
Parsons Brinckerhoff
PricewaterhouseCoopers (PWC)
Rio Glass
Sener
Tekniker
Torresol Energy
World Bank

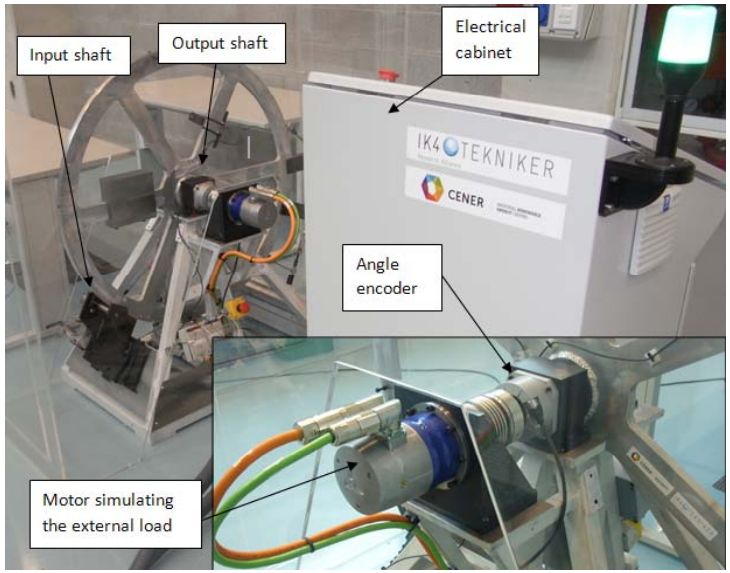
3 Innovation and Technological Development

MODELING AND DESIGN OF COMPONENTS AND SYSTEMS

- ✓ EASY Project. CENER and IK4-TEKNIKER have joined efforts to design a small single facet heliostat with a significant cost reduction with simple tracking systems.





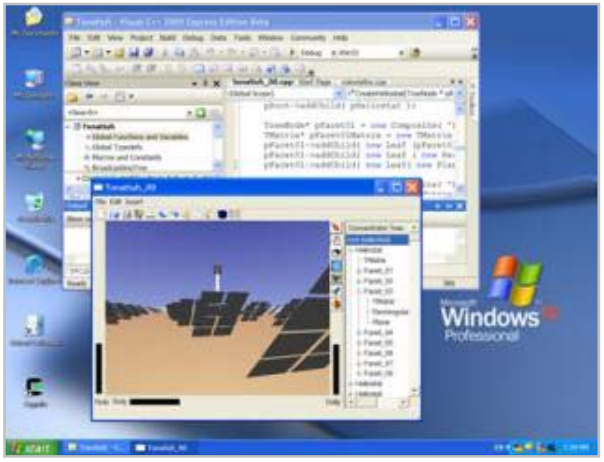


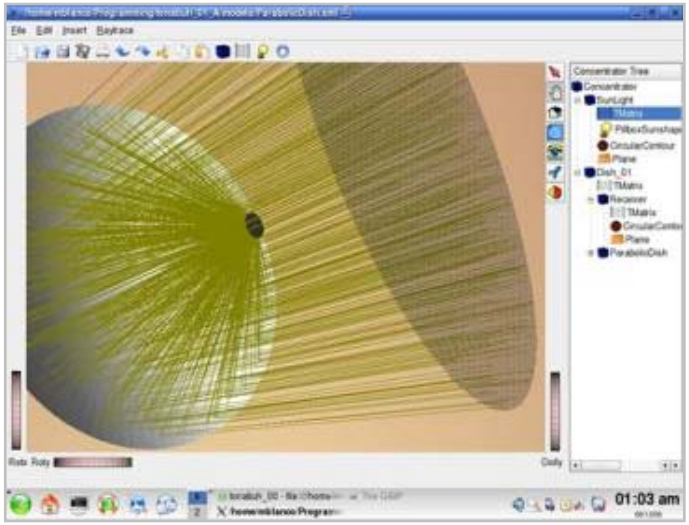
R&D PROJECTS

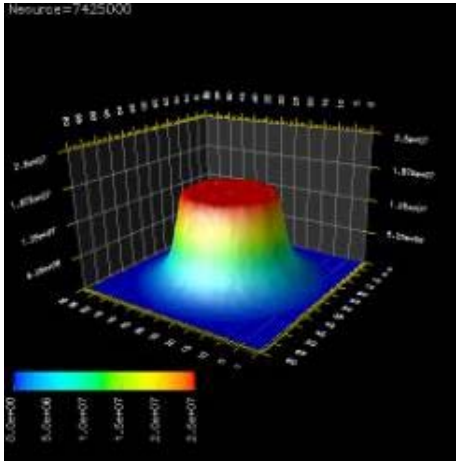
- ✓ **MIRASOL (National Research Plan):** Development of new materials for its use in high temperature central receivers.
- ✓ **EUROSUNMED (7FP):** Cooperation program of Mediterranean countries. CENER has a significant participation in the CSP technology, focused on the development of Brayton and Rankine decoupled combined cycle CSP plant, and on design, manufacturing and test of reduced size and low cost heliostats.
- ✓ **IRP – STAGE (7 FP):** International Cooperation Program, whose specific objectives of the technology development include the improvement of point focus STE technologies. CENER leaders this tasks that includes the development of low cost heliostats fields and the development of high concentration optical systems and new receiver concepts for next generation solar towers.
- ✓ **DNICast (7 FP):** Improvement of tools for solar resource now-casting

DEVELOPMENT AND ADAPTATION OF COMPUTER TOOLS

- ✓ Simulation, analysis and optimization of CSP plants
- ✓ Optical-energy design of solar thermal concentrating systems
- ✓ Energy simulation of low and medium temperature systems



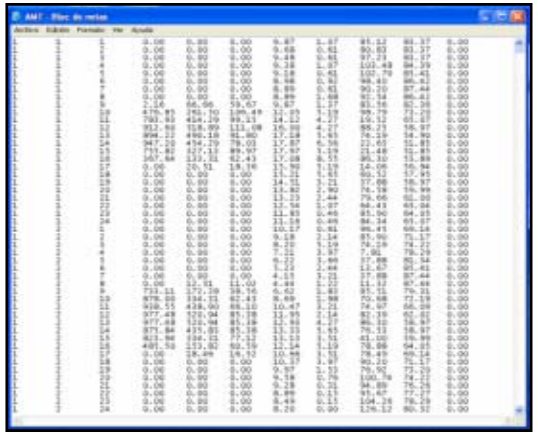


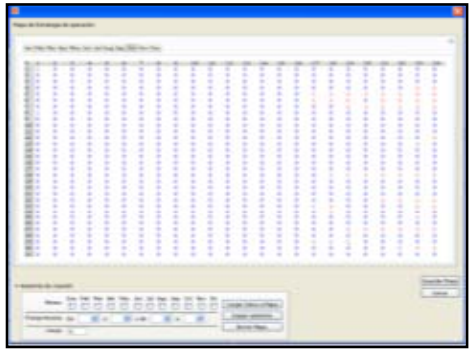


DEVELOPMENT AND ADAPTATION OF COMPUTER TOOLS

- ✓ Program 1: Quasi-steady state model

- ❑ Energy Fluxes Based Model
- ❑ Fast quasi-steady state model
- ❑ Operational Sensibility Studies
- ❑ Friendly Graphics User Interface

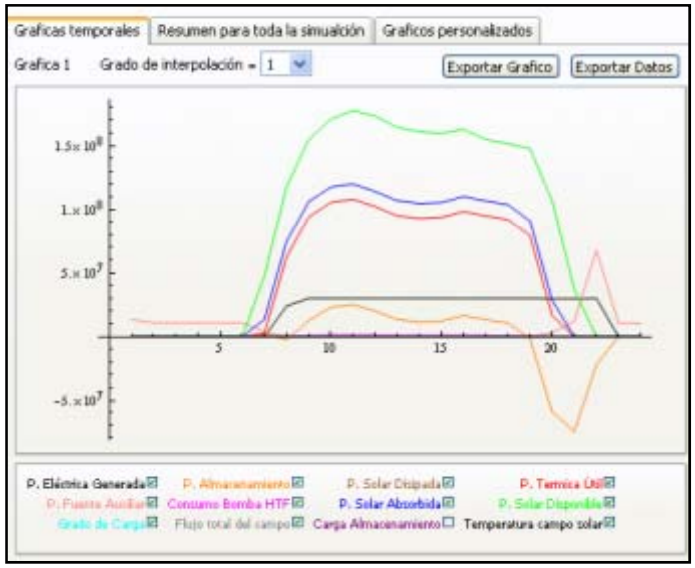


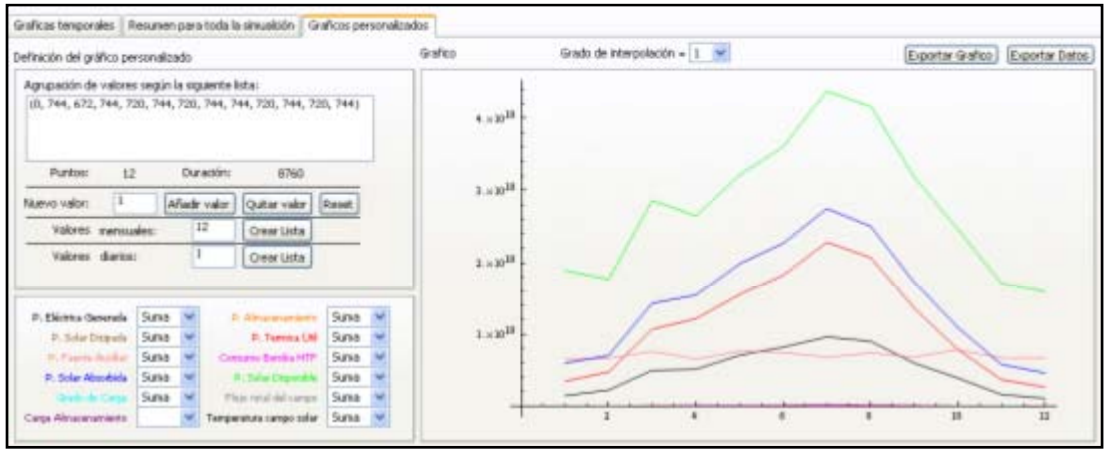


DEVELOPMENT AND ADAPTATION OF COMPUTER TOOLS

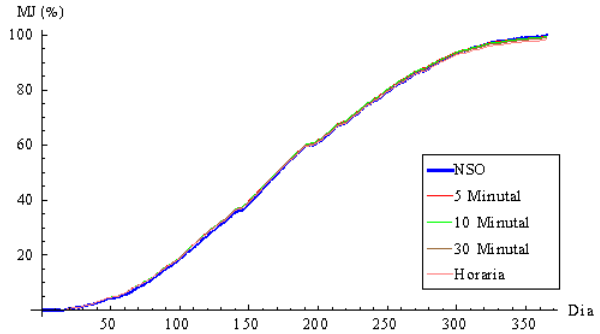
- ✓ **Program 1: Quasi-steady state model**

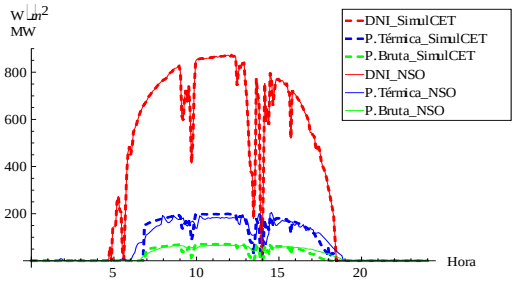
- ❑ **Several post-processing options**
- ❑ **Exportable data to external tools**

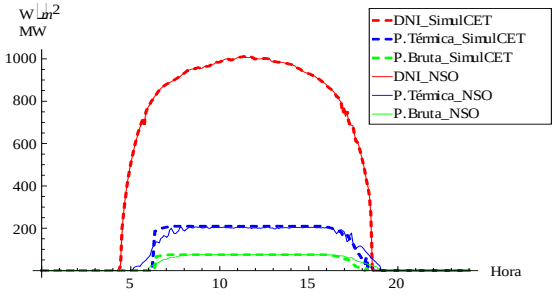


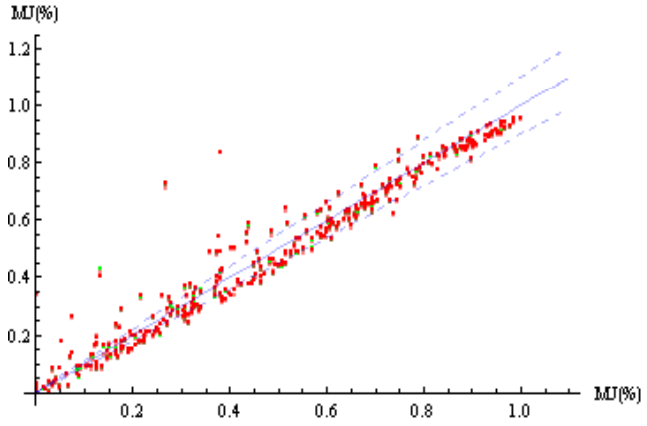


- **Quasi-steady state model continuous improvement process:**
  - ✓ Validation with Nevada Solar One (NSO) measured data
  - ✓ +3 years development.
- **<2% deviation year gross electric energy**
- **Daily simulations (12 reference days)**
  - ✓ Clear Sky Days: <5% deviation
  - ✓ Overcast Days : <8% deviation





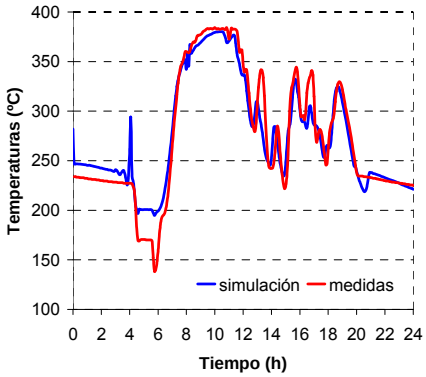


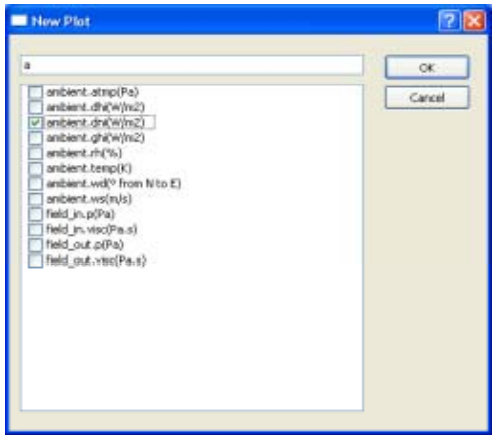


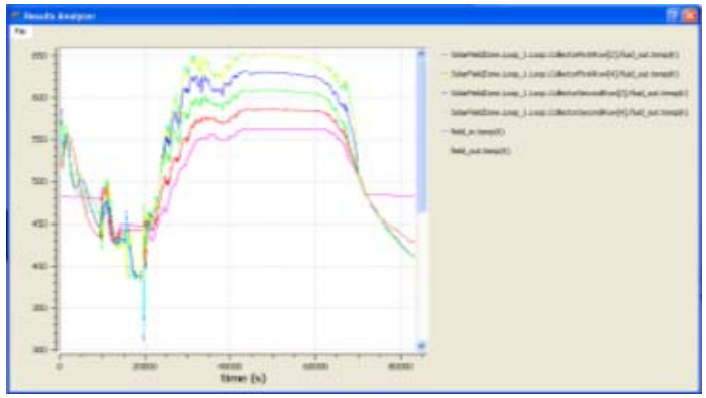
DEVELOPMENT AND ADAPTATION OF COMPUTER TOOLS

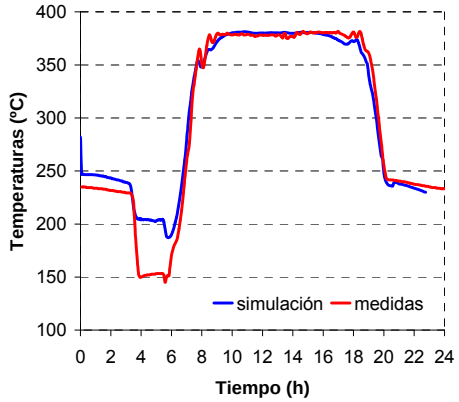
- ✓ **Program 2: Transient model**

- ❑ **Allows:**
  - ✓ Accurate simulations in temperatures, even for cloudy day
  - ✓ Temperature control system







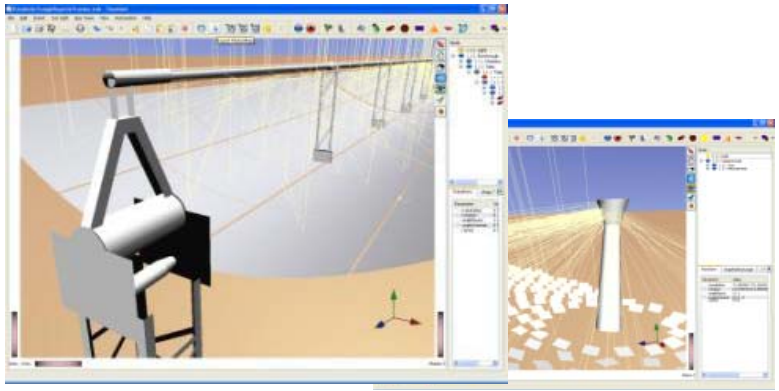


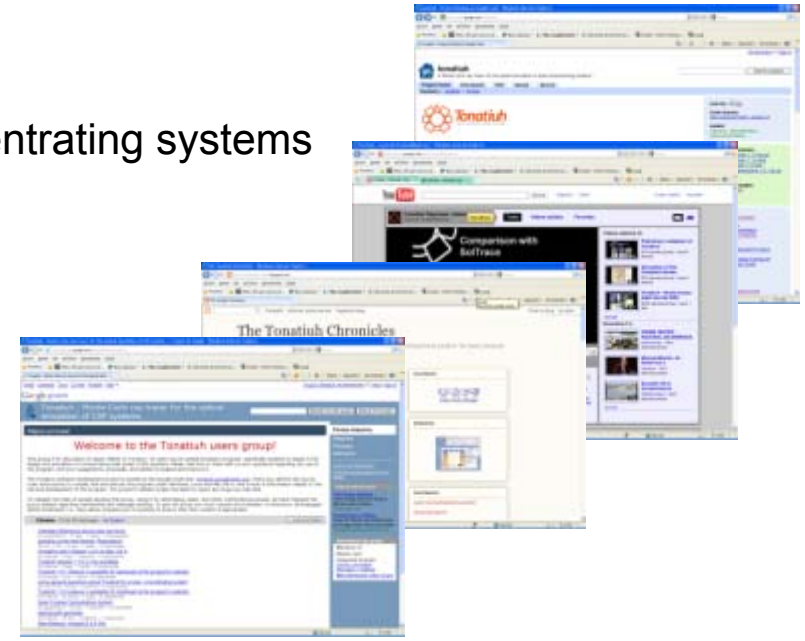
DEVELOPMENT AND ADAPTATION OF COMPUTER TOOLS

- ✓ **Program 3: Tonatiuh**

❑ **Allows:**

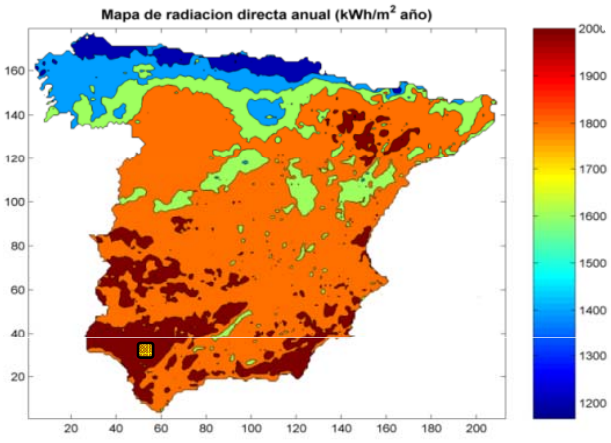
- ✓ Open source Monte Carlo ray tracer
- ✓ Simulate the optical behavior of solar concentrating systems

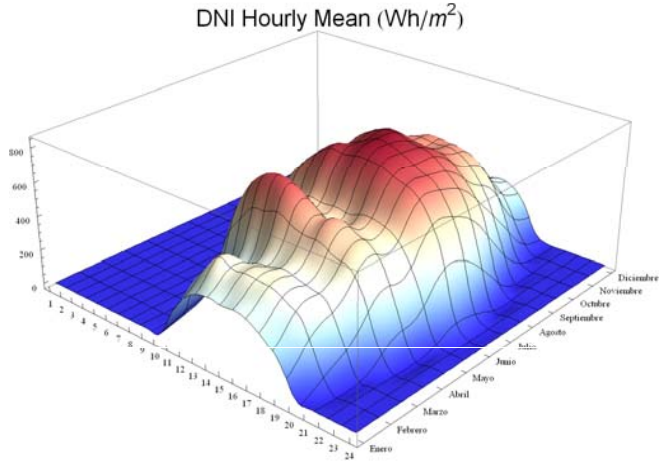




SOLAR RESOURCE CHARACTERIZATION

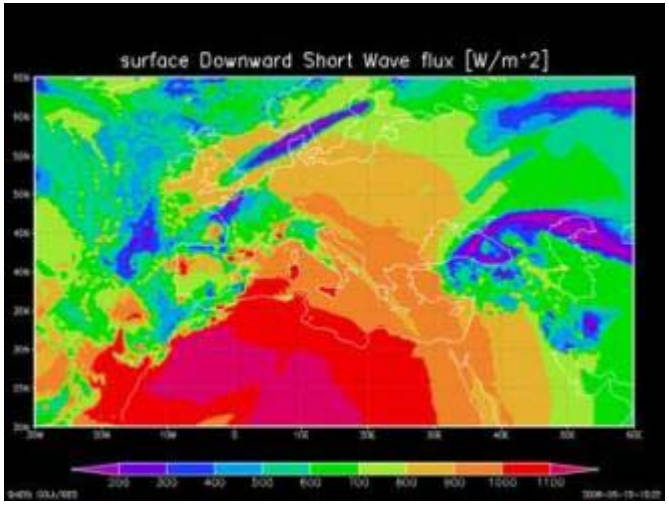
- ✓ Generation of solar resource maps and integration in geographic information system (GIS).
- ✓ Generation of Typical Meteorological Years (TMY) using satellite databases ((Meteosat...) and NWPM (Skiron,WRF)
- ✓ Remote monitorization of measurement campaigns (WEB tool to access to processed data)

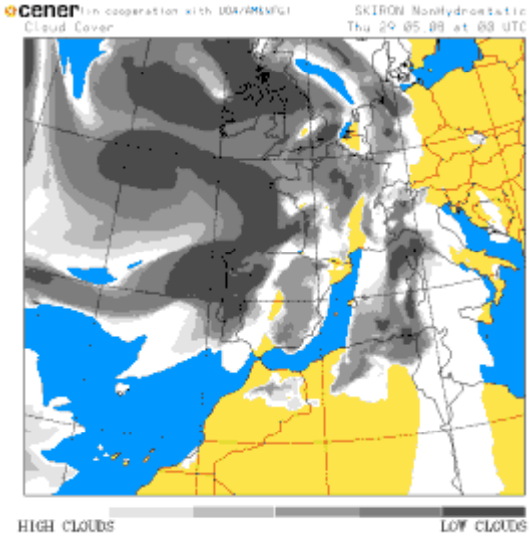




SOLAR RADIATION FORECASTING

- ✓ Solar radiation forecasting
- ✓ Daily solar radiation forecasting (2/3 days)
- ✓ Hourly solar radiation forecasting 24/36 hours
- ✓ Intraday solar radiation forecasting

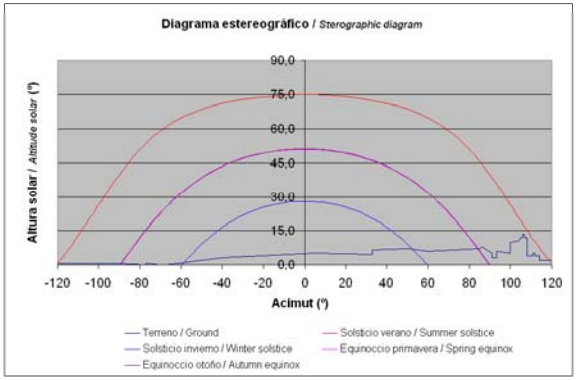




4 Measurement and Characterization

MEASUREMENT OF SOLAR RADIATION

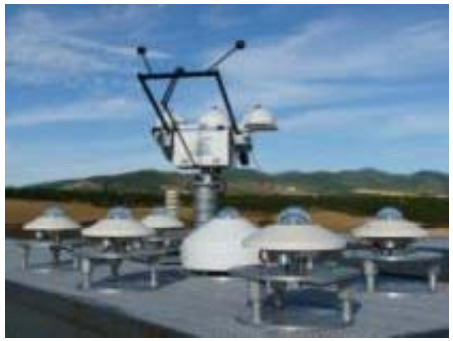
- ✓ Baseline Surface Radiation Network (BSRN) station at CENER
- ✓ Portable station for in situ measurement validation as well as:
  - Checking the station (configuration, installation, maintenance)
  - Validation of site (horizon line, obstacle analysis)
  - Validation of radiation measurements
    - o Comparison with CENER portable station, traceable to World Radiation Center (PMOD-WRC, Davos-Suiza) World Radiometric Reference(WRR)



CALIBRATION SERVICE

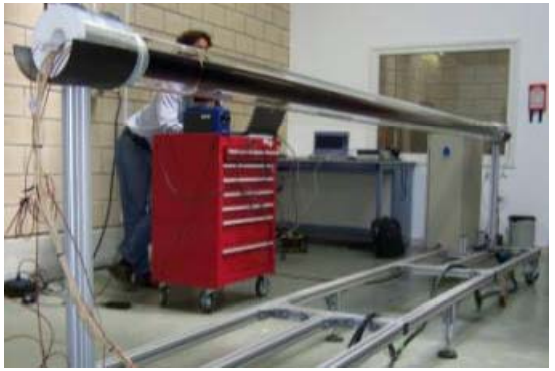
- ✓ CENER Solar Thermal testing laboratory is accredited by ENAC for the calibration of:
  - Field Pyrheliometers: based on the International Standard ISO 9059 – “Solar energy - Calibration of field pyrheliometers by comparison to a reference pyrheliometer”
  - Pyranometers: based on the International Standard ISO 9847 – “Solar Energy- Calibration of field pyranometers by comparison to a reference pyranometer”

ENAC
Entidad Nacional de Acreditación



CONCENTRATING SOLAR POWER COMPONENT TESTING

- ✓ Optical and thermal characterization of solar receiver
  - Thermal characterization test: Determination of the PTC receiver tube's characteristic thermal loss curve by unit of length at different temperatures
  - Optical characterization test: determine the optical properties of a PTC receiver tube during nondestructive testing. spectral measurements of solar transmittance of glass and solar reflectance of the absorber in the 300 nm to 2500 nm wavelength range at different absorber tube temperatures
- ✓ Accelerated ageing tests
- ✓ IR temperature analysis

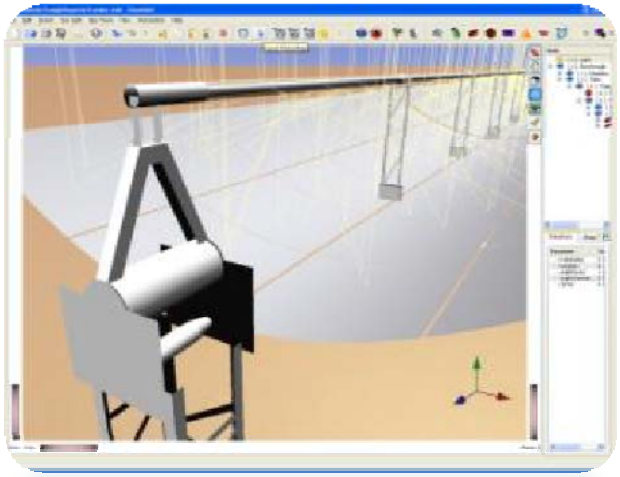


CONCENTRATING SOLAR POWER COMPONENT TESTING

- ✓ Concentrating reflectors:
  - Reflectance measurements
  - Accelerated ageing tests:
    - o UV
    - o humid heat
    - o salt mist corrosion
    - o thermal cycles
  - Hail impact resistance tests

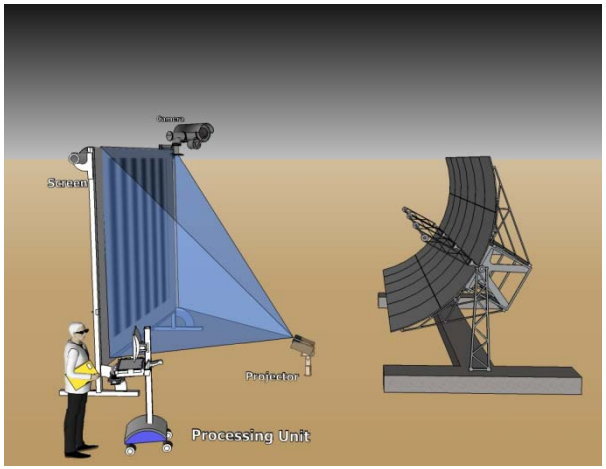
CONCENTRATING COLLECTOR AND FIELD OPTICAL PERFORMANCE

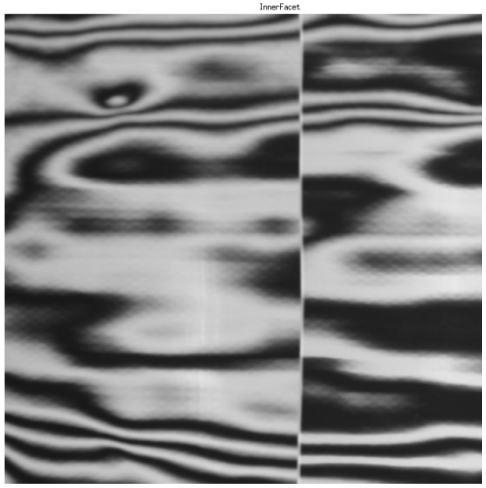
- ✓ Photogrammetry
  - The optical characterization determines the amount of energy that will reach the solar receiver tube, and compares it with the amount of energy that will reach and ideal solar receiver tube from and ideal mirror collector under similar circumstances

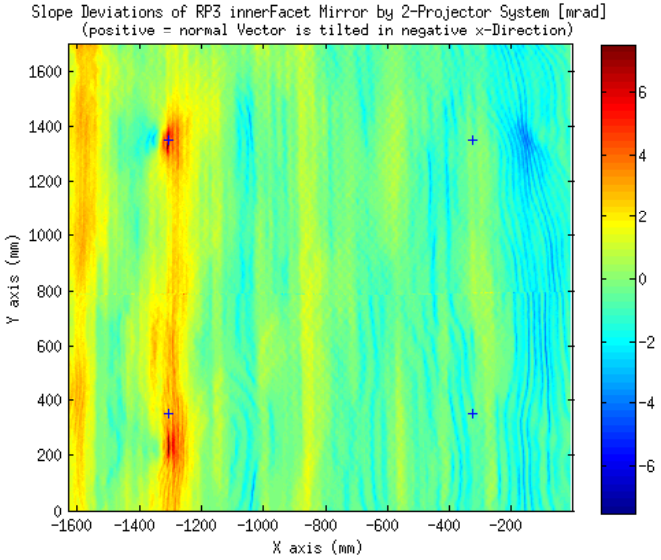


CONCENTRATING COLLECTOR AND FIELD OPTICAL PERFORMANCE

- ✓ Deflectometry
  - A quick optical method to characterize mirror defects with highest resolution.
  - A test indoor/outdoor bench is in development at the laboratory.

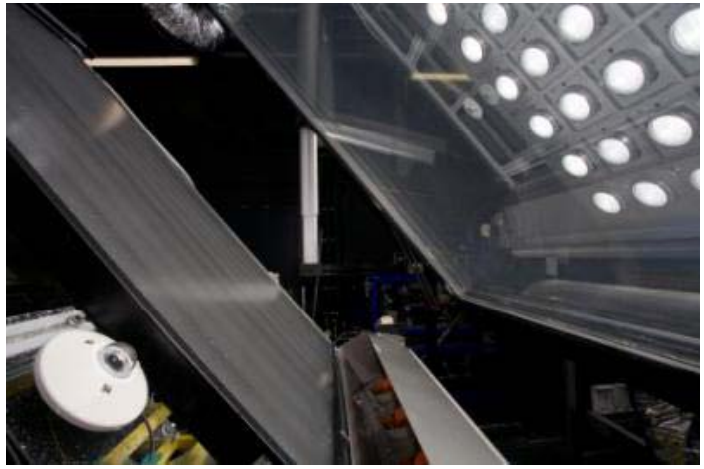






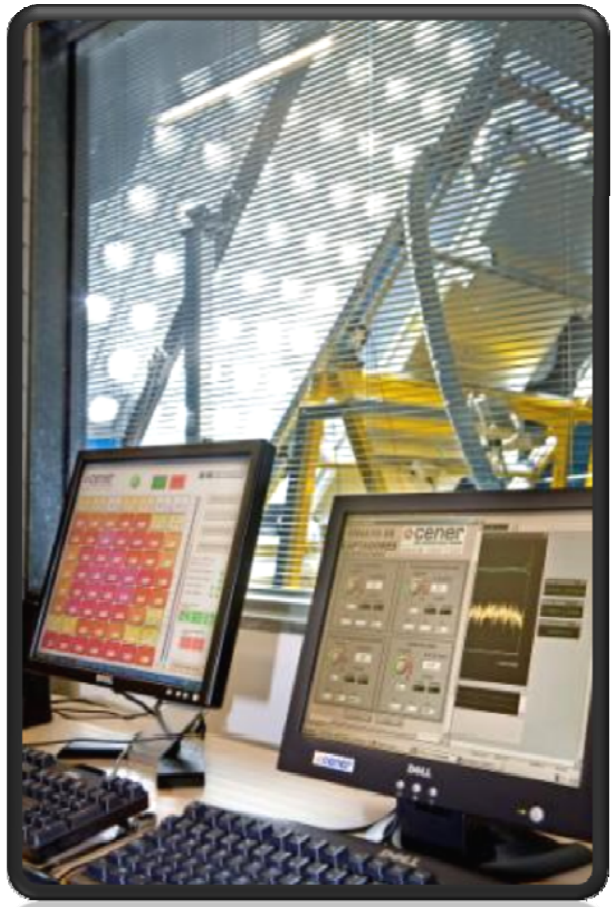
EVALUATION AND CHARACTERIZATION OF SYSTEMS AND COMPONENTS

- ✓ Laboratory accredited by ENAC (Spanish National Accreditation Laboratory) to perform solar thermal collector test in accordance with the standards:
  - UNE-EN 12975 and ISO 9806 (Collectors)
  - UNE-EN 12976 (Solar systems)
- ✓ Solar KEYMARK and SRCC laboratory (sampling, audit and testing)



EVALUATION AND CHARACTERIZATION OF SYSTEMS AND COMPONENTS

- ✓ Additional capacities:
  - Special testing and evaluation of prototypes
  - Testing of optical characteristics of materials
  - Testing of durability of materials and components
  - Testing of solar thermal storages (EN 12977).



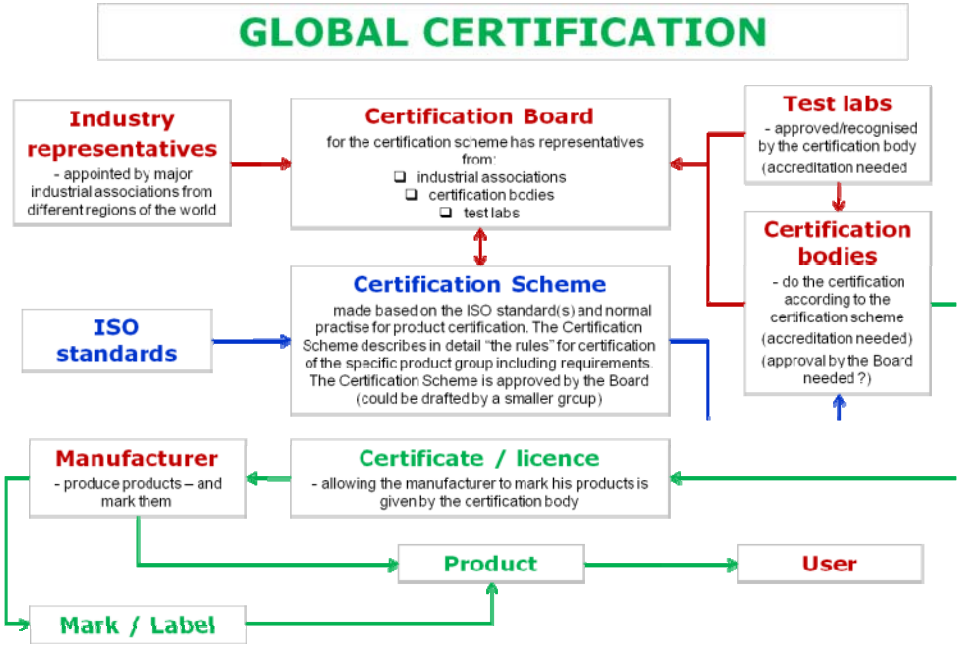
5 Technical Committees and International Organizations

COMMITTEES (INTERNATIONAL ENERGY AGENCY (IEA) SOLAR HEATING & COOLING PROGRAMME (SHC)

- ✓ **Task 43: Solar Rating and certification procedure**
  - Goal: Global certification and solar thermal standards harmonization / revision
  - CENER: Subtask leader for solar thermal collectors
- ✓ **Task 36: Solar resource Knowledge Management**
  - Goal: Provide the most suitable and accurate information of the solar radiation resources at the Earth's surface
- ✓ **Task 46: Solar Resource Assessment and Forecasting**
  - Goal:1st order and 2nd order methods for benchmarking of solar resource products with quality data sets were established; a prototype design of a web portal for accessing both public and private data sets was developed following basic protocols of GEOSS, and improved methods for developing data sets, including short-term and long term solar resource forecasting techniques, were developed.

TECHNICAL COMMITTEES

- ✓ CEN/TC312 Thermal Solar systems and components
- ✓ ISO/TC 180 Solar Energy
- ✓ EU Solar Keymark Network
- ✓ AENOR CTN94, Spanish national technical committee for solar thermal energy
- ✓ AENOR CTC78, Spanish national technical subcommittee for solar thermal energy
- ✓ AENOR CTN206, Spanish national technical subcommittee for thermoelectric solar energy systems



INTERNATIONAL ORGANIZATIONS

- ✓ SolarPACES (Solar Power And Chemical Energy Systems). A Implementing Agreement of the International Energy Agency

  - Participation in Work Package 9 – Benchmarking
  - Leader of the Work Package 5 - Transient Effects guiSmo (Guidelines for CSP Performance Modeling) into theTask I - SOLAR THERMAL ELECTRIC SYSTEMS.

- ✓ Member of ESTELA (European Solar Thermal Electricity Association)

- ✓ Member of SOLARCONCENTRA (Spanish Technologic Platform of Solar Thermal Energy)

5 Technical Committees and International Organizations

- **World Meteorological Organization**
  - ✓ Baseline Surface Radiation Network
- **GMES. European Commission.**
  - ✓ Atmosphere Implementation Group

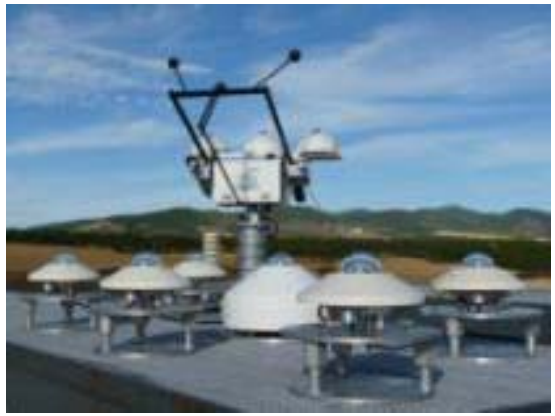
6 Conclusions: What services can be offered by CENER

6 Conclusions: What services can be offered by CENER

DESIGN AND EVALUATION OF CSP COMPONENTS

a. Measurement of solar radiation

- ✓ **Baseline Surface Radiation Network (BSRN)** station at CENER
- ✓ **Portable station for in situ measurement validation**

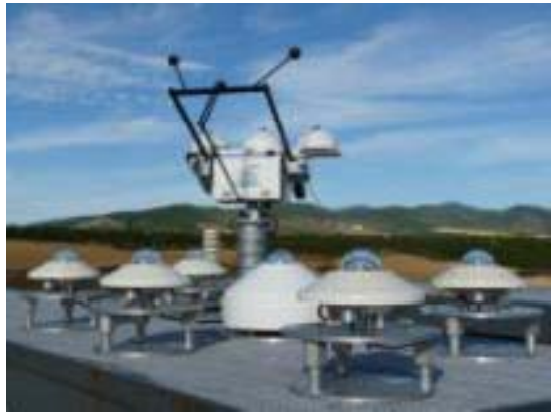


DESIGN AND EVALUATION OF CSP COMPONENTS

b. Calibration Service

- ✓ **CENER Solar Thermal testing laboratory** is accredited by ENAC for the calibration of Field Pyrheliometers under international standard ISO 9059 and Pyranometers under international standard ISO 9847.

ENAC
Entidad Nacional de Acreditación



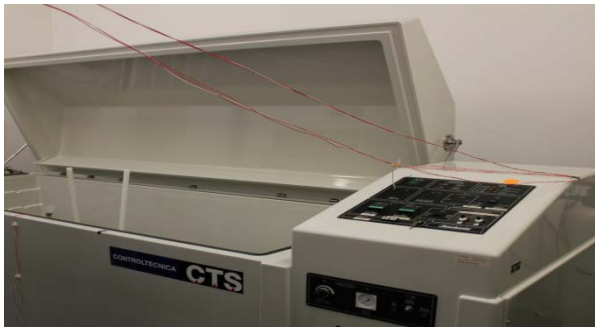
6 Conclusions: What services can be offered by CENER

DESIGN AND EVALUATION OF CSP COMPONENTS

c. Optical and thermal characterization of solar receiver tubes
d. Accelerated ageing tests
e. IR temperature analysis

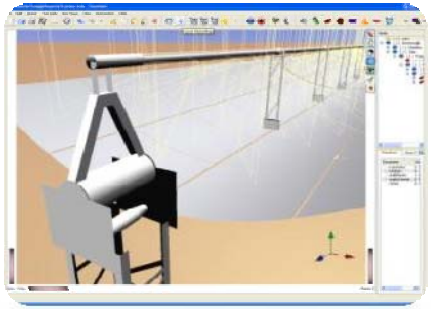
DESIGN AND EVALUATION OF CSP COMPONENTS

f. Concentrating reflectors

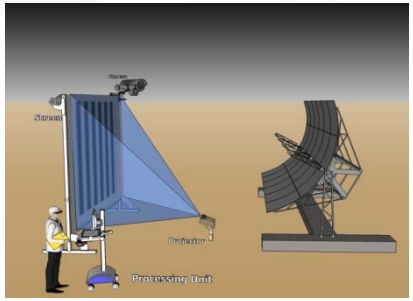


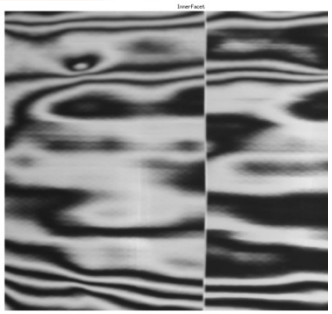
DESIGN AND EVALUATION OF CSP COMPONENTS

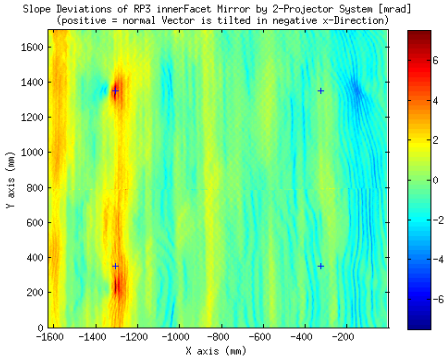
g. Photogrammetry



h. Deflectometry



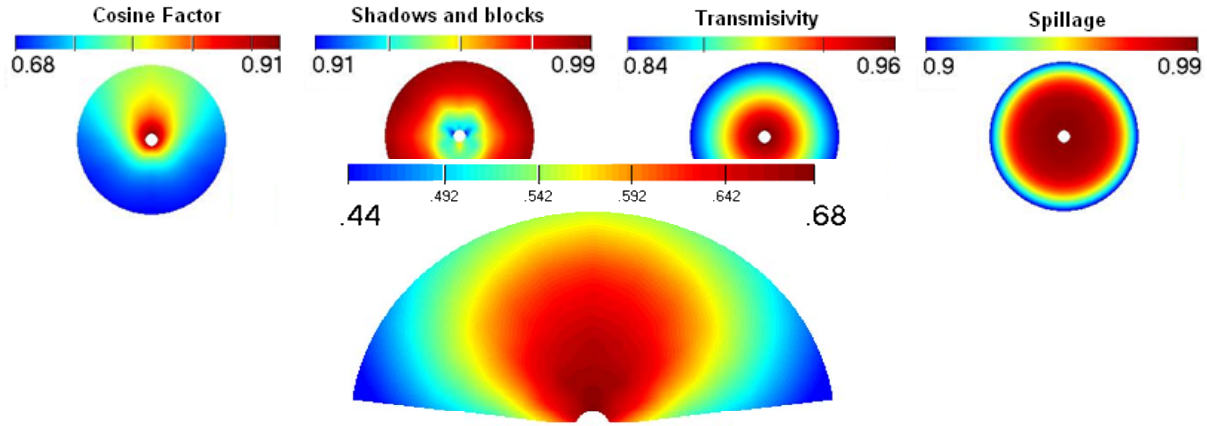




6 Conclusions: what services can be offered by CENER

TECHNICAL ASSISTANCE TO CSP POWER PLANT DEVELOPERS

a. Due Diligence
b. Solar resource assessment , TMY and percentiles
c. Yield analysis
d. Site selection: solar map and GIS systems
e. Feasibility study
f. Assistance to develop performance test and performance models



7 Relevant credentials

2014 – Ongoing projects

7 Relevant credentials

Development of the first solar testing and certification site in the Kingdom of Saudi Arabia (Phase 1) for K.A. CARE

Objective

The main purpose of this K.A.CARE initiative is to develop a testing and certification facility for different types of solar power technologies, in order to support the development of these technologies in the Kingdom of Saudi Arabia.

Main activities

✓**Stage 1**: Project definition and preparation

✓**Stage 2**: Testing concept

✓**Stage 3**: Site master plan and design

✓**Stage 4:** Definition of O&M and business plan and budget needs

Dates

November 2013 – May 2014

Client

مدينة الملك عبد الله للطاقة الذرية والمتجددة K·A·CARE

King Abdullah City for Atomic and Renewable Energy (K.A.CARE)

Country

Saudi Arabia

Partners

This project has been carried out in partnership with TYPSA

TYPSA CONSULTING ENGINEERS & ARCHITECTS

7 Relevant credentials

1 GW UPINGTON SOLAR PARK FOR THE PHASE 2 OF THE SOLAR CORRIDOR PROGRAMME

Objective

The main purpose of this project is to carry out a high level feasibility study structure into three main project phases:

- ✓ **Phase 1 Status Quo Review**: Initial project inception work incl. existing market review and identification of technical constraints.
- ✓ **Phase 2 Feasibility Analysis Statement**: Evaluation of the different technical/economic options including PV and CSP projects and Socio-Economics impact.
- ✓ **Phase 3 Output**: full feasibility study report, including technical description of option selected

.

Main activities

1. High Level Technology Review
2. Technology Options Assessment
3. Solar Resource Assessment
4. Review in detailed de the measurements at site
5. Estimation of long term irradiance at monthly frequency.
6. Generation of TMY from the previous steps, based on site measurements.
7. Elaboration of Final Report

Dates

September 2013 – February 2014

Client

ARUP (final client CEF)

ARUP

Country

South Africa

7 Relevant credentials

STAGE – STE : Scientific and technological alliance for guaranteeing the European excellence in concentrating solar thermal energy

Objective

The main objective of this project is to promote coordination and support actions between institutions in the field of solar thermal energy. In parallel, the promotion of the realization of coordinated projects covering the full spectrum of current research topics concentrating solar energy to provide the highest EU added value and filling gaps between national programs.

Main activities

CENER leads WP12: Solar thermal as CSP Experts. Development of low cost heliostat fields and high concentration optical systems and new receiver concepts for next generation solar towers.

Budget

Total budget: 9.997.207 €

CENER´s budget: 643.917 €

Dates

2014 – 2017

Client

European Commission FP7 – ENERGY – 2013 IRP

Countries

Switzerland, Cyprus, Portugal, United Kingdom, Spain, France, Turkey, Germany, Italy, Belgium, Saudi Arabia, Qatar, Mexico, South Africa, Lybia, Australia, Brazil, China, Chile, Morocco

Partners

CIEMAT, DLR, Paul Scherrer Institut, CNRS, Fraunhofer, ENEA, ETH Zurich, CEA, CYI, LNEG, CTAER, CNR, TECNALIA, University of Evora, IMDEA Energía, Cranfield University, IK4 – Tekniker, Torresol Energy, AREVA, Hitit Solar, Acciona Energía, Schott Solar, Archimede Solar, ESTELA, KSU, QEERI, UNAM, SU, CSERS, CSIRO, FUSP, Institute of Electricity, Universidad de Chile, UCAM, UNIPA, CRS4, INESC – ID, IST – ID

7 Relevant credentials

DNICast : Direct normal irradiance nowcasting methods for optimized operation of concentrating solar technologies

Objective

The main objective of this project is to develop a number of novel methods for the prediction of DNI and combining them in order to cover all the requirements and need that present solar concentration Plants.

Main activities

CENER will lead WP5 “Knowledge sharing and Users' workshops” to establish a dialogue and cooperation between the consortium and external stakeholders, via workshops and bilateral consultations. Furthermore, it will contribute to DNI nowcasting developments using machine learning and in the validation processes.

Budget

Total budget: 2.994.761€

CENER´s budget: 121.264€

Dates

2013 – 2017

Client

European Commission, FP7 ENERGY-2013-1

Countries

France, Spain, Greece, Switzerland, Germany, Sweden, Cyprus

Partners

Observatoire Mediterraneen de l´energie, Deutsches Zentrum fuer luft – und Raumfahrt EV, Genossenschaft Meteotest, Association pour la recherché et le development des methods et processus industriels...and others.

7 Relevant credentials

EUROSUNMED: Euro-Mediterranean Cooperation On Research & Training In Sun Based Renewable Energies (more information www.eurosunmed.eu)

Objective

To develop new technologies in 3 energy fields area, namely photovoltaic, concentrated solar power and grid integration 2) To establish strong networking between EU and MPCs through exchange of students, senior researchers/engineers who will the vehicles for transferring knowledge and technologies.3) To disseminate the results of the projects.

Main activities

The Solar Thermal Energy Department of CENER will lead and participate in the WP2: Concentrated Solar Power (CSP) which encompasses the definition and analysis of complete solar tower power plants based in the use of a decoupled Brayton and Rankine combined cycles, in which the Brayton cycle is decoupled from the Rankine cycle by means of the thermal storage

Budget

Total budget: 5.291.631 €

CENER´s budget: 826.378€

Dates

2013 – 2017

Client

European Commission FP7 – ENERGY – 2013-1

Countries

Spain, Italy, France, Norway, Belgium, Morocco, Egypt

Partners

Centre National de la recherché scientifique, Stiftelsen Sintef, Sintef Energías, Tekniker, EEIG, European materials research society, CNESTEN, Centre National pour la recherché scientifique et technique, Moroccan Foundation for Advanced Science, Innovation and Research, University Mohammed V-Agdal, Université All Akhawayin d´Ifrane, Moroccan Agency for Solar Energy, Helwan University, Alexandria University, Turboden, Office National de l´Électricité

7 Relevant credentials

MIRASOL: Materials and innovative design Research for Advanced Solar Receivers

Objective

The main objective of this project is fundamental research of high performance materials that allow the later development of high temperature and high efficiency solar receivers, that guarantee their reliability and durability under working demanding conditions which high concentrating technology require.

Main activities

- ✓ Requirements definition
- ✓ Developments Tools
- ✓ Experimental Validation Tool
- ✓ Durability Tests
- ✓ Analysis of development of receptor based on analyzed materials

Budget

Total budget: 340.800€

CENER´s budget: 154.440€

Dates

2013 – 2017

Client

Spanish Ministry of Economy and Competitiveness, non-oriented fundamental research National R&D Plan (2008-2011).

Countries

Spain

Partners

✓PRODINTEC

http://www.prodintec.es/prodintec/en/presentation

✓ICV (Institute of Ceramics and Glass (ICV)

http://www.icv.csic.es/en/about

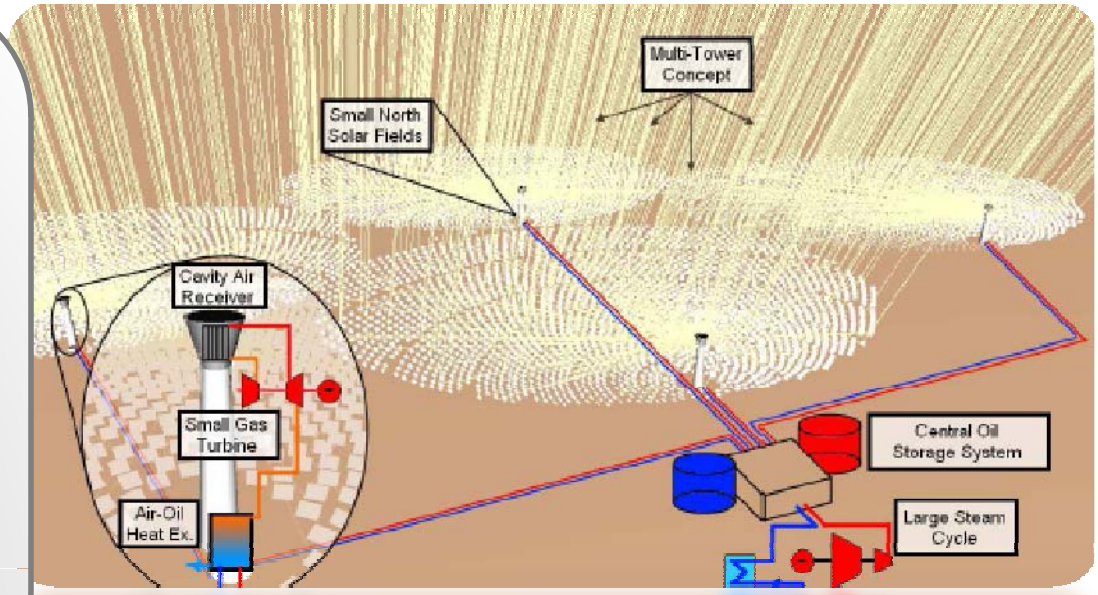
7 Relevant credentials

New concept of innovative tower plant (2012 – 2016)

Objective

The main objectives of this project are the following:

- ✓ To develop a tower system with the aim of reducing substantially the cost of electricity from solar thermal energy.
- ✓ To carry out this project in a maximum period of five years. At the end of that period all the necessary technology will be developed and demonstrated experimentally
- ✓ To develop all technological knowledge and tools needed to be at the forefront in the provision of technical assistance services and high value-added industry to solar thermal tower technology, whatever technology



7 Relevant credentials

EASY : hEliostats for eAsy and Smart deployment - Development of an optimized heliostat concept (2012 – 2015)

IK4 TEKNIKER
Research Alliance

The EASY concept

Among all the available Concentrated Solar Power (CSP) technologies, Power Tower has been predicted to be the most cost-effective for producing solar generated electricity on a large scale. Current investment costs are still high (just the solar field can involve up to 50% of the plant capital cost), but their cost reduction potential for the following years is wide. CENER and IK4-TEKNIKER have joined together to develop the EASY project, where the analysis and design of an innovative and cost effective small size heliostat is being carried out. This cost effective solution offers clear advantages: use of standard components, no need of canting, easy installation, minimal on-site labor, low wind loads, automatic heliostat calibration system and cheaper testing equipment needed.

Main activities

Driving mechanism

The use of a simpler tracking mechanism strongly red. the cost of the heliostat. A test bench has been designe. and created, which allows to test many different driving mechanisms (i.e. belts, chains, wire…) from the point of view of many key factors (i.e. stiffness, accuracy…). Limits, benefits and drawbacks of several mechanisms have been already analyzed.

Calibration system

Frequent calibration of the heliostats make it possible to relax the requirements on the mechanical construction of the heliostat, allowing cheaper solutions. An innovative calibration system based on computer vision has been designed. A first prototype has been prepared in parallel to the development of specific software. Performance tests for the fine adjustment to ensure proper orientation of heliostats are currently underway.

Wind load tests

Wind load effects are a key factor to establish the optimum heliostat mechanical design. A testing prototype has been designed for the monitoring of bending moments and torques caused by the wind in real conditions. This prototype has been anchored to the ground with a ground screw system foundation at a location with rich wind resources, carefully chosen for this activity.

CENER | NATIONAL RENEWABLE ENERGY CENTRE

GOBIERNO DE ESPAÑA | MINISTERIO DE INDUSTRIA, ENERGÍA Y TURISMO | MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Ciemat

Gobierno de Navarra

7 Relevant credentials

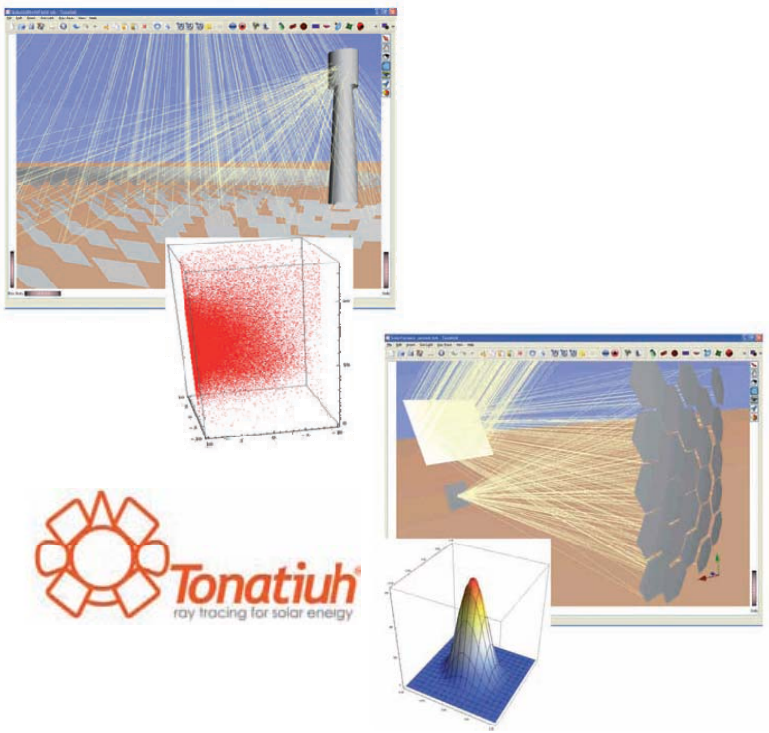
TONATIUH – Ray tracing for solar energy (more information http://secure.cener.com/documentos/F_Tonatiuh.pdf) 2006 - Ongoing

Objective

The Tonatiuh project aims to create an open source, cutting-edge, accurate, and easy to use Monte Carlo ray tracer for the optical simulation of solar concentrating systems. It intends to advance the state-of-the-art of the simulation tools available for the design and analysis of solar concentrating systems, and to make those tools freely available to anyone interested in using and improving them.

Main activities

- ✓ To develop a robust theoretical foundation that will facilitate the optical simulation of almost any type of solar concentrating systems.
- ✓ To exhibit a clean and flexible software architecture, that will allow the user to adapt, expand, increase, and modify its functionalities with ease.
- ✓ To achieve operating system independence at source level, and run on all major platforms with none, or minor, modifications to its source code.
- ✓ To provide the users with an advanced and easy-of-use Graphic User Interface (GUI).



8 Relevant credentials

Impulse to the development of the renewable energy based on the Spanish experience

Objective

The main outcome of the project is the elaboration of a solar radiation map and a potential assessment of solar energy in Vietnam.

Main activities

- ✓ To provide several ground stations to be placed in different parts of the country
- ✓ To provide accurate information on monthly mean values of GHI and DNI
- ✓ To provide information related to solar energy potentials.

Dates

2012 – Ongoing

Client

The General Department of Energy- Ministry of Industry and Trade of Vietnam (MoiT)

Countries

Vietnam

MINISTRY OF INDUSTRY AND TRADE
OF THE SOCIAL REPUBLIC OF VIETNAM

Calibration of field pyrheliometer according ISO 9059:1990 and calibration of field pyranometers according ISO 9847:1992

Objective

Calibration of field pyrheliometers according to the International Standard ISO 9059:1990 (CENER has the ENAC accreditation Nº198/LC518).

Calibration of field pyranometers according to the International Standard ISO 9847:1992 (CENER has ENAC accreditation).

Main activities

- ✓ Calibration of field pyrheliometers according to the International Standard ISO 9059:1990 (CENER has the ENAC accreditation Nº198/LC518).
- ✓ Calibration of field pyranometers according to the International Standard ISO 9847:1992 (CENER has ENAC accreditation).

Dates

2010/2011 – Ongoing

Client

Manufacturers, laboratories, universities, CSP and PV plant promoters.

Countries

Spain

7 Relevant credentials

STEPHANIE: Development of an open source computer tool for the energy and economic analysis of solar thermal concentrating systems for electricity production

Objective

The main objective of this project is the development of an open source computer tool for the energy and economic analysis of solar thermal concentrating systems for electricity production.

Main activities

- ✓ The computer program should be able to analyze in detail the yearly performance of the above CSTP plants, based on technical inputs such

Dates

2010– Ongoing

Client

Confidential (French Electricity company)

Countries

Spain

7 Relevant credentials

Solar radiation measurement stations. Station audits and quality control of recorded data according BSRN operation manual and ISO TR 9901

Objective

The main objective of this project is to check and to validate f the equipment layout of the measurement station, as well as the validity of the recorded data at the station.

Main activities

- ✓ Checking the station (configuration, installation, maintenance.
- ✓ Validation of site (horizon line, obstacle analysis.
- ✓ 3) Validation of radiation measurements (comparison with CENER portable station, traceable to World Radiation Center (PMOD-WRC, Davos-Suiza) World Radiometric Reference (WRR).

Dates

2010– Ongoing

Client

CSP plant promoters as ACCIONA ENERGIA, ABENGOA SOLAR, TORRESOL ENERGY...

Countries

Spain

Durability and performance tests for solar collectors according to UNE-EN 12975 and SRCC OG-100 and for factory made solar systems according to UNE-EN 12976

Objective

Durability and performance tests for solar collectors according to the standards UNE-EN 12975 and SRCC OG-100.

Durability and performance tests for factory made solar systems according to the standard UNE-EN 12976

Main activities

- ✓ Durability and performance tests for solar collectors according to the standards UNE-EN 12975 and SRCC OG-100.
- ✓ Durability and performance tests for factory made solar systems according to the standard UNE-EN 12976

Dates

2008 / 2009 – Ongoing

Client

Several manufactures from Spain, Poland and Portugal

Countries

Spain, Poland and Portugal

7 Relevant credentials

Analysis of the energy production of more than 50 CSP plant projects

Objective

The main objective of this project was to conduct a detailde analysis of the annual energy production for more than 50 CSP projects in Spain.

Main activities

Study of the annual energy production. The main data provided by the client: Site location, longitude, latitude and altitude, Typical Meteorological Year, Definition of solar field, collectors , Power block, operating strategy.

Upon CENER will deliver a report explaining the results obtained for the simulation of the plant, on an annual basis with monthly breakdown of data.

Dates

2008 – Ongoing

Client

Natural Electric, Martifer Renewable, AMDA Energía , Magtel, Renovables SAMCA; Iberdrola Energías Renovables, Ingeteam Power Plants, Cobra Energía.

Countries

Spain

Meteorological monitoring of more than 50 potential CSP plant sites

Objective

Meteorological monitoring of more than 50 potential CSP plant sites, to estimate the solar radiation potential of the sites, and to generate Meteorological Reference Years as input to determine for each site the CSP plant annual energy production, and other energy related information in order to provide appropriate input to feasibility studies, and technical due diligence analysis.

Main activities

Technical assistance to the clients during the configuration and installation of the meteorological station; monitoring and quality control of data provided by the station; and long term solar resource assessment based on measured data and other information available

Dates

2007 – Ongoing

Client

Grupo Enhol, Acciona Energía, ENEL, Natural Electric, Aries, Torresol, ELECNOR, Gas Natural, , EONA, Innovación Verde, Energía Termosolar; Iberdrola , Fundación Chile.

Countries

Spain

7 Relevant credentials

Solar resource assessment for more than 80 potential CSP and PV plant sites

Objective

The main objective of these project is the solar radiation characterization for a specific location.

Main activities

- ✓ Generation of the Reference Meteorological Year (RMY).
- ✓ Extraction of the global irradiation series using the CENER numerical prediction model.
- ✓ Generation of the Typical Meteorological Year (TMY) with hourly data representative of the long-term behaviour of the GHI and DNI at the specific site.
- ✓ Generation of the design year corresponding to annual percentiles 90 and 95.

Dates

2005 – Ongoing

Client

EONA, Hyperion, Fotowatio, Galileo, Ayesa, Amda, Endesa, Abengoa, Samca, Magtel, Eufer, Innovación Verde, Milenio Solar, Fundación Chile, Grupo Enhol, Acciona Energía, Natural Electric, Aries, Torresol, Iberdrola, Cobra Energía..etc.

Countries

Spain, Australia, GCC, India, South Africa, Chile, Portugal, USA, Italy, Cyprus, Morocco, West Africa, Botswana, United Arab Emirates

Completed projects

7 Relevant credentials

Bankable feasibility study for a 200 MW Concentrating Solar Thermal Power plant in Botswana

Objective

To align the CSTP technology energy output to the Botswana National Energy Policy, which advocates that by 2030, 25% of the electrical energy demand be met from renewable energy sources. To carry out a Bankable Feasibility Study for a 200MW Concentrating Solar Power Plant with a two-fold objective: to perform a techno-economic assessment benchmarking; to develop a financial structure for CSP project and a corresponding financing plan

Main activities

- ✓ **Phase 1**: to benchmark the available solar technologies against site specific conditions, and national considerations
- ✓ **Phase 2** : to determine whether public sector support should be sought for the project, and to propose a financing plan and prepare a complete and comprehensive road map.

Dates

2011 - 2013

Partners

YES; NIXUS Consulting and PB

Client

Botswana Power Corporation (BPC); funded by the World bank and African Development Bank

WORLD BANK

Analysis of CSP potential in ECOWAS region for ECREEE (ECOWAS Regional Centre For Renewable Energy And Energy Efficiency)

Objective

The overall objective of this project is to provide a outstanding knowledge about the potential of CSP technologies in ECOWAS region taking into account the peculiarities of West Africa, and also to build capacities among ECREEE staff and West African Expert regarding CSP. identified.

Main activities

- ✓ **Phase 1:** Context analysis, and review of the state of the art of CSP technologies
- ✓ **Phase 2**: Feasibility study of a CSP plant, in the optimal location of the region.
- ✓ **Training** for ECREEE staff on the methodology to appraise CSP projects.

Dates

2011 - 2013

Client

ECOWAS Regional Centre for Renewable Energy and Energy Efficiency (ECREEE)

Countries

Burkina Faso, Ghana, Mali, Niger, Nigeria...

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7 Relevant credentials

EU-GCC Clean energy network

Objective

The EU – GCC Clean Energy Network aims to respond to the common interests of stakeholders, both in the GCC and the EU, active in the field of clean energy.

Is the practical instrument for development of concrete cooperation activities on clean energy, including the related policy and technology aspects, among various players across the EU and GCC countries.

Main activities

- ✓ The EU-GCC Clean Energy Network provides a wide variety of services and offering to its members. Networking and fostering of partnership between EU and GCC institutions are the key services that are provided.
- ✓ More info http://www.eugcc-cleanenergy.net/Home.aspx

Dates

2010 - 2013

Client

European Commission

Countries

Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates

EU CONSORTIUM

GCC COUNTERPART

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ACTEPARQ: Technical assistance for the construction of a test platform for parabolic trough collectors

Objective

The definition, technical specification development and technical evaluation of proposals for a test platform of parabolic trough collector modules proposed by CTAER as part of the National Call ACTEPARQ 2009.
The main objective of this test platform of parabolic trough collector modules was to contribute to the development and experimental validation of characterization and evaluation standards for the industry of solar thermal collectors.

Main activities

- ✓ **Phase I:** Conceptual definition and preparation of the technical specifications of the test platform and its auxiliaries systems. Assistance to the client in defining and implementing the RFP process to suppliers.
- ✓ **Phase II:** Technical Analysis of received offers and technical assistance in the selection of technology suppliers.

Dates

2009- 2012

Partners

N/A

Client

CTAER (Advanced technology center for renewable energy)

CTAER ANDALUCIA

7 Relevant credentials

QAIST (Quality assurance in solar thermal heating and cooling technology – keeping track with recent developments)

Objective

The long term objective of the QAiST project is to prepare the quality assurance framework so that the European solar thermal heating and cooling industry can sustainably contribute to the targets agreed by the Member states (20% of RES by 2020) and become a technological world leader. technologies, existing or potential. More info in: www.qaist.org

Main activities

- ✓Active participation in the revision of EN 12975
- ✓Development of aspects related to solar thermal systems and adaptation of calculation procedures to Energy Labelling according to Mandate 324
- ✓Give continuity to the Solar Keymark activities and extending Solar Keymark certification activities to new products, actors and countries within Europe
- ✓Strengthening the quality assurance on laboratory tests through inter laboratory comparisons (Round Robin) and development of guidelines and checklists
- ✓Identification of need for standardization for solar thermal systems in association with heat pumps and cooling machines
- ✓Dissemination of project results

Dates

2008- 2012

Partners

ARSENAL,, CSTB, DEMOKRITOS, ESTIF, INETI, IPiEO/EC BREC, ISE, ISFH, ITC, IZES, PlanEnergi, SP, TÜV, USTUTT-ITW

Client

European Commission, CIP-IEE 2008

European Commission

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7 Relevant credentials

Consultancy for a technical expert recruitment to assist the client in CSP solar technology phase at the Solar Complex of Ouarzazate

Objective

The main objective of this project was a technology assessment consultancy services leading to a technically and financially sound recommendation for the configuration of the remaining part of the 500MW Ouarzazate Solar Complex that is expected to be in operation by 2015

Main activities

- ✓ Analysis of CSP technologies adapted to the site of Ouarzazate
- ✓ Recommendations on the development of a Power Tower project

Dates

2011

Client

Moroccan Agency for Solar Energy (MASEN)

Countries

Morocco

masen
Moroccan Agency for Solar Energy

Study of local capabilities to manufacture and supply components for development of Concentrating Solar Thermal Power plants (CSTP) in India

Objective

Consulting services for a study of local capabilities to manufacture and supply components for development of concentrating solar thermal power plants.

The overall objective is to contribute to the successful implementation of the Jawaharlal Nehru National Solar Mission (JNNSM), which envisages a capacity of 20000MW by the year 2022, of which 50% will be CSTP electricity.

Main activities

- ✓ **Phase 1**: First general assessment about the technical and commercial feasibility of installing a CSP plant at the sites proposed shall be made.
- ✓ **Phase 2:** To prepare the project(s) to the extent necessary to take a positive decision for the investment.

Dates

2010

Client

World Bank on behalf of National Thermal Power Corporation (NTPC) de India

Countries

India

एनटीपीसी NTPC
NATIONAL THERMAL POWER CORPN. LTD.

7 Relevant credentials

Analysis of CSP potential in Spain. Elaboration of a solar radiation map.

Objective

Technical assistance for the analysis of CSP potential in Spain for preparation of the PER 2020 (Renewable Energy Plan 2020). This study was conducted at national level, by regions and provinces, and for the main technologies (PT, Power Tower, Stirling and Fresnel) and for other promising emerging solar technologies in order to determine the geographical distribution of the potential for each type.

Main activities

- ✓ As first task in this project a solar radiation map covering the whole Iberian domain have been implemented
- ✓ Technical evolution
- ✓ Evolution of costs,
- ✓ Evolution of installed capacity, among other information, and
- ✓ The results were incorporated into a geographic information system (GIS).

Dates

2010

Client

Institute for Energy Diversification and Saving (IDAE)

Countries

Spain

IDAE
Instituto para la Diversificación y Ahorro de la Energía

7 Relevant credentials

Kalahari solar project: solar radiation assessment and pre-feasibility study review

Objective

The overall objective of this project was that the client and its strategic partners were considering the development of Concentrated Solar Thermal Power (CSTP) plants in the Kalahari region of the Northern Cape. The client´s Sponsors planned to develop, build, own and operate a CSTP facility on the proposed site.

Main activities

- ✓ Review the results of the site assessment study and prepare a report in respect to the suitability of the proposed site for purposes of implementing and operating a CSTP plant.
- ✓ Make recommendations
- ✓ Providing a high level business case for the project
- ✓ Advise on the regulatory environment

Dates

2010

Client

Groupe Five

Countries

Spain

GROUP FIVE
structured ingenuity

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7 Relevant credentials

CSTP Technologies study for ESTELA (European Solar Thermal Electricity Association)

Objective

The client was in charge of carrying out a study about Concentrating Solar Power (CSP) technologies for the European Solar Thermal Electricity Association (ESTELA) and was interested in incorporating to its project team senior consultants from the National Renewable Energy Centre of Spain (CENER).

Main activities

- ✓Analysis of the functionalities and roadmap per individual CSP technology
- ✓Prioritization of contributions and relevance for roadmap targets
- ✓Analysis of technology specific and generic components to develop a product development roadmap per key component for different technologies to meet target costs
- ✓Benchmarking of existing publications for the 4 key CSP technologies.
- ✓Prepare and moderate, together with the client 2 Workshops with ESTELA subject matter experts to validate and agree upon technology and product development roadmap.

Dates

2009 - 2010

Client

AT Kearney funded by ESTELA (European Solar Thermal Electricity Association)

Countries

Spain

ATKearney

Preliminary documental analysis for a CSP project

Objective

The purpose of this technical assistance is to provide an independent and preliminary analysis of the technical characteristics of a CSP Project in Spain.

Main activities

✓Evaluation of the documents supplied by customer, with special relevance in the next points: Location of Site, Size of site, Shape of site, Grid connection, Need to achieve Zero Liquid Discharge, Water supply contract, Dependence on Liquefied Natural Gas for hybridization, Potential requirement to use several companies as contractors (EPC contractor, O&M contractor...). A Meteorological Design Year (MDY) was generated for the project location.

Dates

2009

Client

Confidential (Irish Electricity Company)

Countries

Spain

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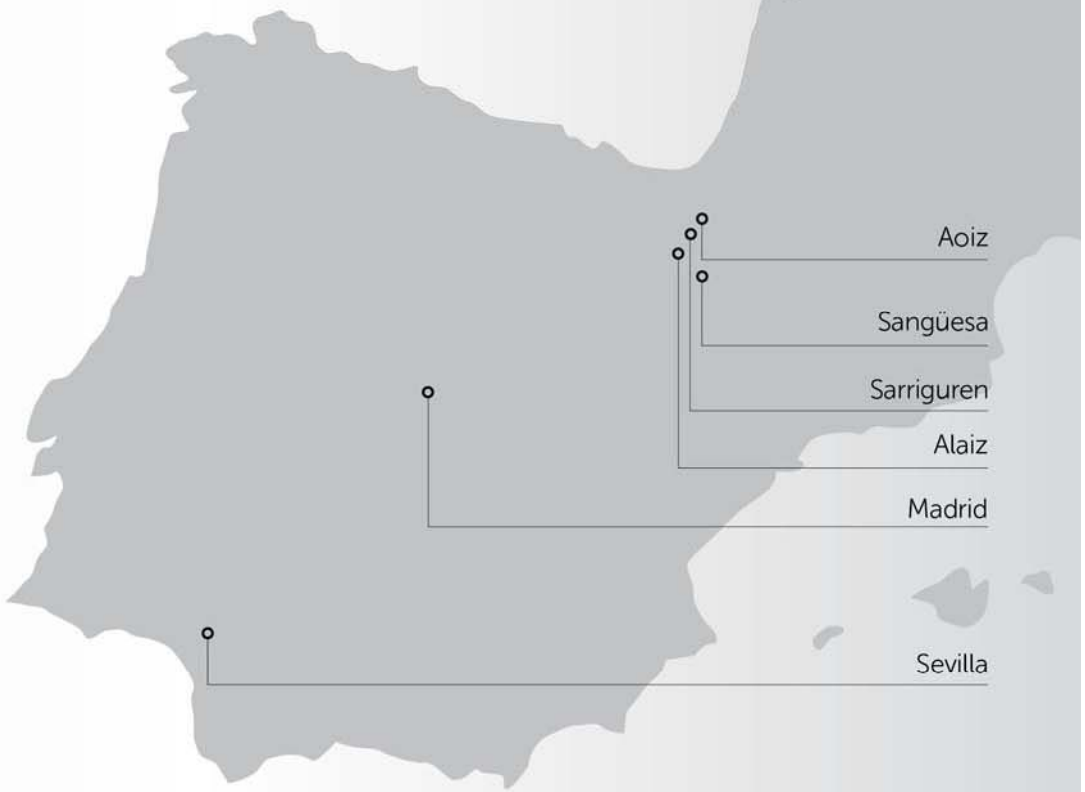

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