

# PROJECT FINAL REPORT

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**Coordinator:**

Prof. Gabriel Sala Pano

Director of the R&D Program "Instruments and System Integration"

Instituto de Energía Solar- Universidad Politécnica de Madrid

**Tel:** +34) 91 336 7231

**Fax:** +34 91 544 6341

**E-mail:** sala@ies-def.upm.es

**Project website address:**

[www.ies.upm.es/nacir](http://www.ies.upm.es/nacir)

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## 4.1 Final publishable summary report

### 4.1.1 Executive summary

The European Commission has subsidized project NACIR for concentrated photovoltaic (CPV) from January 2009 to December 2012. The main goal is to bring together the owners of the most advanced European CPV technology in order to research new applications for CPV systems. This research has unveiled possible sources of failure in new environments outside Europe, in order to assure component reliability. The main objectives are:

- a) Installation of a stand- alone CPV system in Egypt
- b) Installation of a grid connected CPV system in Morocco
- c) Implementation of normative and a worldwide database on CPV systems, and
- d) Improvements of CPV components technology and development of a new CPV system.

#### **Installation of a stand-alone CPV system in Egypt**

The design and installation of the off-grid CPV water pumping, desalination and irrigation system has been carried out. The definition of strategies for operation and energy management and its inclusion into the Energy Management System (EMS), under the responsibility of Fraunhofer plus the deployment of CPV Soitec Solar (formerly Concentrix-Solar) arrays in the Egyptian desert are a set of technical and scientific highlights of the whole project. The standardize protocol (CANopen) helps optimizing the electrical generation and allows the inclusion of other generation sources such as wind and diesel. The plant has combined the scientific and technical implementation with the social and economic output of the irrigation leaded by NWRC

#### **Installation of a grid connected CPV system in Morocco.**

The power plant has been deployed at Ifrane, (1600 m. altitude over sea level) in the campus of the prestigious Anglophone University Al Akhawayn, which reached an agreement with Office National d'Electricité (ONE), for participating with professors and researchers in the project.

The deployed HCPV 30MM modules from Isofoton have passed the IEC 62108 qualification standard. The Spanish regulations for PV grid connection are the ones adopted in the connection and the whole installation, which do not collide with the early normative at ONE. Each half-array is associated to a single phase inverter. Fabrication of the entire module, from the MJ cells production to the final CPV module assembly including test, has been carried out at Isofoton. The rating of the installed power has been carried out by ISFOC, who, according with the project and in absence of any international standard, has defined and promoted the method for this test.

The system is operative since January 2011 providing the scheduled power and energy.

#### **Worldwide database and normative**

The creation of a database of Worldwide CPV experience has been initiated at ISFOC using their powerful software tools. This database include the results and characteristics of the seven power plants owned by ISFOC, all larger than 200 kW, as well as those of NACIR's in Egypt and Morocco plants and other well reported experiences around the world.

The task devoted to create a network for recording overall and spectral DNI data with components cells has finished. The need for simplest spectrum recording devices has pushed UPM to develop a Tri-band Spectral Heliometer equipped with 3 isotype cells. The Project NACIR has contributes to a draft for a standard for CPV module rating.

The task devoted to link indoor rating with outdoor performance is underway in UPM, ISOFOTON and ISFOC research centres which are developing models for translation of IV curves from one testing condition to nominal test conditions or any else operating condition.

#### **Technological improvement of CPV components**

The aim is to improve the efficiency of the CPV systems specially increasing the acceptance angle of the optics. Several activities has been carried out. Fraunhofer and Soitec have initiated the path to use refractive secondary optics to increase the acceptance angle of Soitec modules. Isofoton in cooperation with UPM has analyzed the performance of suitable materials for refractive secondary optics. Isofoton have redesigned the RESET module to solve the weakness of several components uncovered in the IEC62108 testing. UPM has developed the new concentrator Fluidreflex, which uses a fluid as optical index material, as heat exchanger, and as insulator.

#### 4.1.2 Summary description of project context and objectives

The European Commission subsidized **Project NACIR** for Concentrated Photovoltaics (CPV) from January 2009 to December 2012. The main goal of this project was to bring together the owners of the most advanced European CPV technology, with respect to the state of the art, in order to research from their leading position **new applications for CPV systems**. In addition to opening up new markets, this research should **unveil possible sources of failure** in new environments outside Europe, in order to **assure component reliability**. The main objectives of the project were: a) Installation of a **Stand Alone CPV system in Egypt**, b) Installation of a **Grid connected CPV system in Morocco**, c) Implementation of **normative and a worldwide database** on CPV systems, and d) Improvements of CPV **components technology, manufacturing and development of a new CPV system**. Although it was not emphasized at the beginning of the project the implementations in the Mediterranean countries will really contribute to a **socioeconomic** development, in **education** on renewable energies in Morocco and to the progress of **irrigation** in Egypt and other desert areas.

#### Description of work performed and main results

##### Installation of a Stand-alone CPV System in Egypt

The provided steps, from design to full installation, of the first off-grid CPV water pumping, desalination and irrigation system in Egypt has carried out with the collaborative work of the 4 partners involved. The definition of strategies for operation and energy management and its inclusion into the Energy Management System (EMS), under the responsibility of Fraunhofer plus the deployment of CPV Soitec Solar (formerly Concentrix-Solar) arrays in the Egyptian desert are a set of technical and scientific highlights of the whole project. The standardize protocol (CANopen) helps optimizing the electrical generation and allows the inclusion of other generation sources such as wind and diesel.



*Fig. 1. Setup of the NACIR system at the test site of the water research centre in Wadi El Natrum in Egypt.*

Fig. 1 shows the installation which is generating the expected energy and pumping water from a 92 m. deep well. In consequence, the Egyptian hybrid station has combined the scientific and technical implementation of the generation and energy managing with the social and economic output of irrigation led by NWRC

The key parameters of the system are: 28 kW<sub>p</sub> CPV nominal power provided by 5 CPV Soitec-Solar arrays; a 903 A.h. lead acid battery which allows measurement and control of the power plant overnight and allows the system to remain operational for approximately two days without direct sun. A 1 kW<sub>p</sub> flat panel PV system is a backup in case of empty energy storage.

Three stand alone inverters create, along with the battery, an island AC mini-grid, providing the voltage and frequency references. Finally, the CPV generators are connected in AC. This contributes to generalization of operating methodology for stand alone and grid connected systems.

The significant operating system parameters as well as the meteorological data are continuously submitted via internet to ISFOC who is disseminating these data to the other partners. This is the first CPV station devoted to a stand alone application.

Installation of a Grid Connected CPV system in Morocco.

The power plant has been deployed at Ifrane, (1.600 m. altitude over sea level) in the campus of the prestigious Anglophone University Al Akhawayn, which reached an agreement with Office National d'Electricité (ONE), for participating with professors and researchers in the project.

The deployed HCPV 30MM modules from Isofoton have passed the IEC 62108 qualification standard.

The Spanish regulations for PV grid connection are the ones adopted in the connection and the whole installation, which do not collide with the early normative at ONE. Each half-array is associated to a single phase inverter.

The system is operative since January 2011 providing the scheduled power and energy.

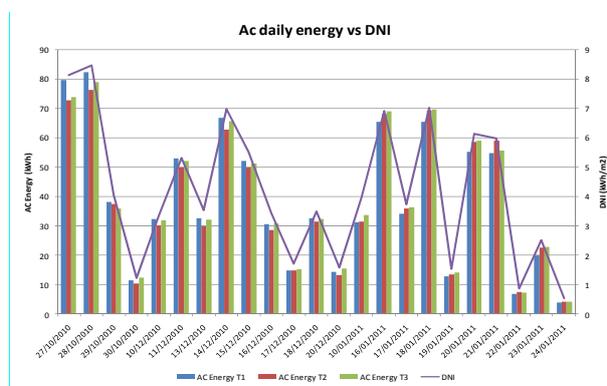


Fig. 2 The Isofoton’s CPV arrays at IFRANE .Generation records during December 2010 and January 2011.

Fabrication of the entire module, from the MJ cells production to the final CPV module assembly including test, has been carried out at Isofoton. The rating of the installed power has been carried out by ISFOC, who, according with the project and in absence of any international standard, has defined and promoted the method for this test.

Members of the Morocco research team have spent several days at ISFOC to learn, in the Puertollano CPV plants, about the field testing methods. Two members of Isofoton trained the local operators on the characteristics of the systems for maintenance and exploitation. The connection at the end of a grid, the high altitude climate of the site and the frequent lightning has provided valuable experience for the protection and maintenance of CPV systems.

Worldwide Database and Normative

The creation of a database of Worldwide CPV experience has been initiated at ISFOC using their powerful software tools. This database include the results and characteristics of the seven power plants owned by ISFOC, all larger than 200 kW, as well as those of NACIR’s in Egypt and Morocco plants and other well reported experiences around the world.

The task devoted to create a network for recording overall and spectral DNI data with components cells started in 2012. The need for simplest spectrum recording devices has pushed UPM to develop a Tri-band Spectral Helimeter equipped with 3 isotype cells. Several laboratories in the world have acquired these devices which will favours a wider network. UPM, Fraunhofer and ISFOC are recording such data.

The preparation of a standard for CPV module rating is the most urgent activity in the concentrator field. The Project NACIR has contributes to a draft with the unique expertise of Fraunhofer and UPM in the indoor measurement of large area CPV modules.

The task devoted to link indoor rating with outdoor performance is underway in these two research centres which are developing models for translation of IV curves from one testing condition to nominal test conditions or any else operating condition.

Technological improvement of CPV components

The aim of this activity is to improve the efficiency of the CPV systems specially increasing the acceptance angle of the optics.

Fraunhofer and Soitec-Solar make several module prototypes carried out using refractive secondary optics, which theoretically promised to increase the acceptance angle of CPV modules. Currently the efficiency of pilot production module is preserved and the module acceptance angle has been increased. The use of a very low cost moulded secondary ensures the economic viability. Fig 3a Also, the durability of the secondary material under high irradiance levels has been demonstrated. Fig 3b

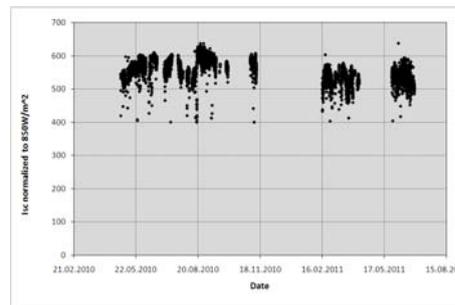
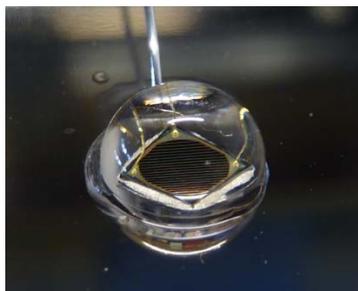


Fig. 3. a) Secondary optics moulded on a 3x3 mm receiving cell. b) The plot shows no degradation after 16 exposure months.

Isofoton in cooperation with UPM has analysed the performance of suitable materials for refractive secondary optics. Transparent silicones have been the materials checked. The samples (domes shaped coupled to cells) have been measured indoors and are currently aged in real operation under 500X for 1cm<sup>2</sup> cells..

The RESET Technology, developed by Isofoton within the FULLSPECTRUM Project has been tested under the IEC62108 Qualification Standard, as scheduled, before going to manufacturing. While prototypes of this technology demonstrated high efficiency, these tests uncovered weaknesses in several components. Therefore Isofoton, according the scheduled plan in NACIR, has re-designed the module in order to preserve efficiency, gain, acceptance angle and performance with a more reliable technology.

New CPV Module

UPM is developing the new concentrator FLUIDREFLEX, which uses a fluid as optical index material, as heat exchanger, as insulator, and finally for preventing water condensation inside the module. Fig. 4a. It allows a significant reduction of module subcomponents and eases the options of reflectors for making simpler and very compact CPV modules

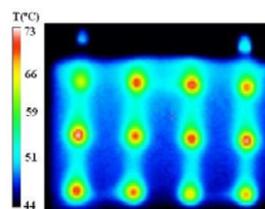
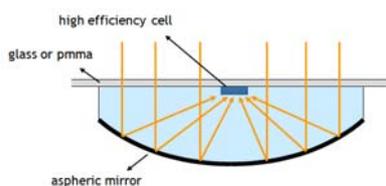


Fig. 4a) The FLUID REFLEX concept

Fig. 4b) Measured temperatures inside the module



*Fig. 4c) Several laboratory assembled FLUIDREFLEX module prototypes*

The properties of the optical materials have been characterised in order to know how they will perform under the double duty of optical transmission and thermal transport. These data have fed into a 3D finite elements thermal model which may be used to predict operational temperatures. Fig. 3b.

Direct diamond turning cut prototype mirrors and later injected plastic mirrors have been fabricated.

The initial measurements yielded 78% optical efficiency, and  $\pm 1.2^\circ$  acceptance angle at 800X. Currently 83% has been measured, which overpasses the 80% objective. Three journal papers and 7 presentations in Conferences on this topic have been generated, always receiving remarkable interest. Several module prototypes have been fabricated and tested. Laboratory made ones demonstrate that the upper limit for manual assembly procedures yields an overall 27% efficiency. The automation will surely increase that value allowing to reach 31.5% with the commercial cells 40% efficient. Soitec is collaborating to these developments by providing cells for the prototypes.

The pictures of Fig 4b and 4c show the thermal behaviour of a 12 cell module and the aspect of the made prototype modules. The first pre-industrial module prototype consists of the assembly of 6 blocks for 9 cell each.

### **Final results and potential impacts**

Along the project, Soitec has improved its module and system technologies. From Generation 2 available at the beginning of the project they are currently industrialising Gen5. The Soitec arrays have demonstrated more than 25% energy efficiency due to the efficient modules and to highly reliable tracking system mainly in the Egyptian hard environment. The stand alone application of CPV's has been demonstrated and a potential market has been opened in the Middle East. From other side, Soitec has developed and checked a two optical stages module at pilot line level, which could be put in manufacturing if it becomes economically suitable. These facts will assure a leading position to Soitec in this field. In a different ambit, the impact of the Egyptian CPV installation is outstanding, both due to the high performance of the systems and the social-economic impact of the application. In addition the great diffusion of that work by TV broadcasting (Euronews) is also creating interest in Africa's developing countries for similar applications.

The other Company in the project, Isofoton, has renewed its module technology and adapted its automated manufacturing capability to the new one which has passed the IEC62108 qualification. The vertical integration of many components in the new module will relocate the company in its pioneering position in CPV.

The impact of the Morocco installation will come from the operation of CPV systems at very high altitude and the interferences from the grid. Still political and economic impacts are foreseen thanks to the project and the relationship with the national utility ONE. for this project along next year.

ISFOC is contributing to improve the difficult task for recording and exploiting real data in CPV power plants located in the associated countries. They are becoming the most powerful institution exploiting CPV data and their results will impact the understanding of the CPV power plant production, operation and rating. The software for performance analysis of CPV generators and

developed applications at ISFOC, called GOCPV, will allow understanding of CPV operation and provide effective maintenance control.

Finally the development of the very innovative Fluidreflex CPV module is achieving the expected results. In principal, 83% optical efficiency has been achieved and several prototype modules have been completed and tested. The promise of very low cost, lower than the best CPV's is still credible because no problems have arisen yet.

#### **4.1.3 Description of the main Scientific and Technical Results/foregrounds.<sup>1</sup>**

##### **4.1.3.1 Scope of the Project**

Project NACIR intended answering one of the objectives of the European Commission expressed in the FP7 Call for Proposals on Energy by 2008. It was oriented to reinforce a.s.a.p. the reliability of Concentrator Photovoltaic Systems (CPV) by means on experiences and developments for new applications. The second aim, linked to the previous one, was to spread and disseminate the European CPV technology en the Mediterranean associated countries. The combination of these two objectives suggested identifying valuable applications for these countries which were suitable for stressing the operation of CPV systems in the hard natural conditions of that region. The experiment should, probably, accelerate the analysis and improvement of CPV systems reliability.

In addition, the call did not forget to stimulate the technological progress of current CPV thorough inventions and novelties as well as promoting the improvement of manufacturing efficiency of state of the art concentrator modules.

This assembly of objectives determined the composition of the consortium. The two principal European Companies in CPV (Soitec Solar and Isofotón) both with commercial products and manufacturing capacity assured the execution of real applications. Their staffs were prepared for learning and improving their products and competitiveness through the project experiments,

In parallel to the companies two research centres Fraunhofer and Universidad Politecnica de Madrid, with long experience in CPV will participate supporting the invention and evaluation of new products and the fundamentals of the new applications.

The most advanced Mediterranean countries, Morocco and Egypt were the Associated Countries selected because their previous activities and interest on CPV were known by the Coordinator and partners. They are the Organisation National d'Electricité and National Water Research Centre respectively.

A project like this should generate a large amount of information which is necessary to record and exploit for reaching conclusions about reliability in short time: the ISFOC was viewed as the best partner thanks to its experience on field rating of many CPV technologies and because the possibility for adding the value of the Spanish administration investment in this centre to favour the knowledge at European level. A summary of the objectives, activities and results follows.

##### **4.1.3.2. The new applications of CPV in Mediterranean countries.**

###### **4.1.3.2 A Stand alone CPV plant for water pumping and irrigation at Wadi el Natroon (Egypt)**

The life in Egypt has been linked to the water availability from millennia. Their engineers have the highest know how and experience for managing that scarce resource: In their interest for widening the cultivable area, transforming the desert into productive land, they tried every possible method for extracting the water from the deep aquifers under the sands. They are acquainted how expensive,

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<sup>1</sup> Main technical results/and foreground are heightened in bold in the text

tiring, noising and requiring are the diesel generators which usually power the electrical well pumps. The National Water Research Centre installed photovoltaics under their initiative twenty years ago looking for a noiseless and reliable source of electricity.

With the NACIR project the opportunity for updating their old PV field with the most effective PV technology, and joining a set centres and companies experts on PV systems, become an exciting option for every partner. It would allow modernising the experimental irrigation station at Wadi-el-Natroun, renewing the PV generators and reinforcing the socially interesting project for cropping in the desert.

In consequence, the **worldwide first concentrating photovoltaic (CPV) stand-alone system** with 30 kWp was installed by **Soitec Solar** at the test site of the **National Water Research Center (NWRC)** in the desert at Wadi-el-Natroun in Egypt within the NACIR project. The CPV system provides **electric power for water pumping, desalination and irrigation applications**.

At **Fraunhofer** an energy management system (**EMS**) was developed for monitoring all energy flows and calculating an **optimized load management** to support the direct use of solar energy by the loads. Thus the system requires only small sized battery storage to secure power supply only for measurement and control equipment. Fig. 1

Another highlight of the NACIR project is the development of the **standardized CANopen communication protocol** (application profile CiA 454) to realize the control algorithm and to enable an easy expansion of the system. This all helped to successfully install **the first CPV island system** worldwide.

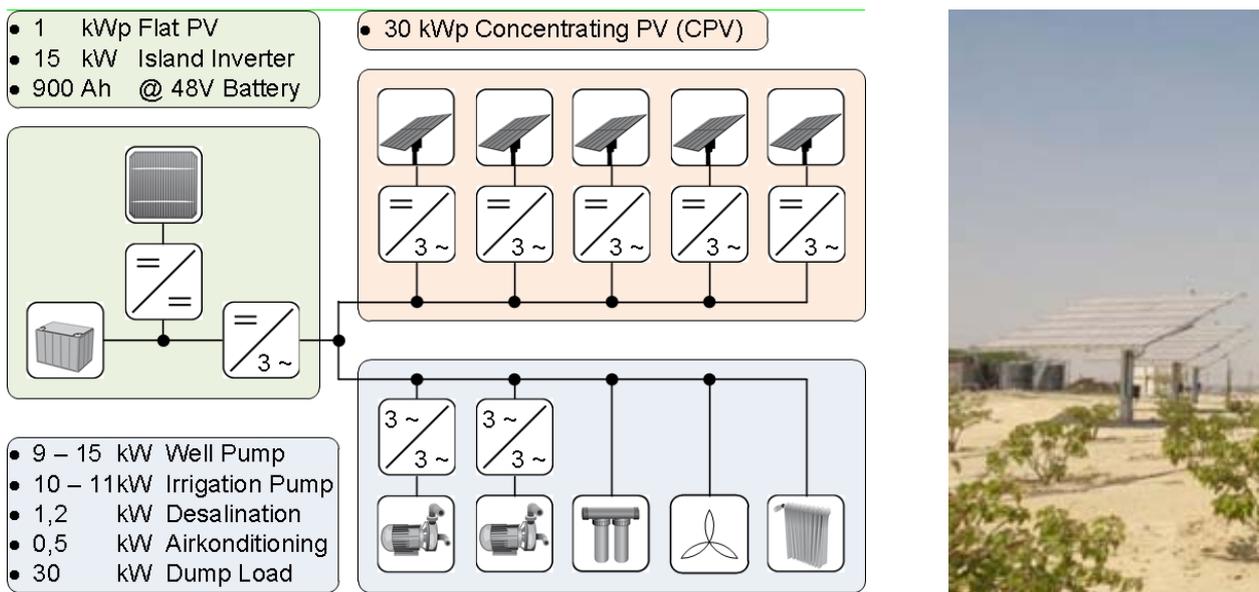


Fig. 1: Left: System design of CPV stand alone installation for water pumping, irrigation and desalination. The loads and the CPV trackers are AC coupled, the battery and the flat plate PV are DC coupled. Right: CPV off-grid system with irrigation system.

All components of an energy supply system like PV chargers, battery management systems, loads etc. are able to communicate in a standardized way if they comply with this profile specification. Thus a communication infrastructure is available allowing a seamless integration of new components and communicability of different manufacturers' components. Furthermore, the **goal is to achieve plug and play options** so that new system components are automatically configured and integrated into the energy management system. This **new invented application profile** is now working reliably in the field.

The EMS allows the operation of controllable loads like water pumps, desalination units or air conditioners with direct use of solar energy. The EMS consists of three modules one prognosis module, one optimization module and a system control module.

We were searching for a general optimization algorithm which can manage many loads to support the future plug and play ability of the CANopen infrastructure. The Field operation of the NACIR system shows: direct use of PV power for saving expensive battery storage capacity is possible. **Storing water instead of energy** is a good way to reduce off-grid system costs. Fig. 2 shows the operation of the energy management system for two days in December. If there is enough power the well pump brings water up to the reservoir, depending on the irrigation timetable the irrigation pump starts and stops, taking the water out of the reservoir. To solve this optimization problem a generic algorithm was developed. The solution of the known “**packing-problem**” was transferred to off-grid systems. The system in Wadi El Natroon proves that there are **no technical barriers for using CPV in Island grids**.

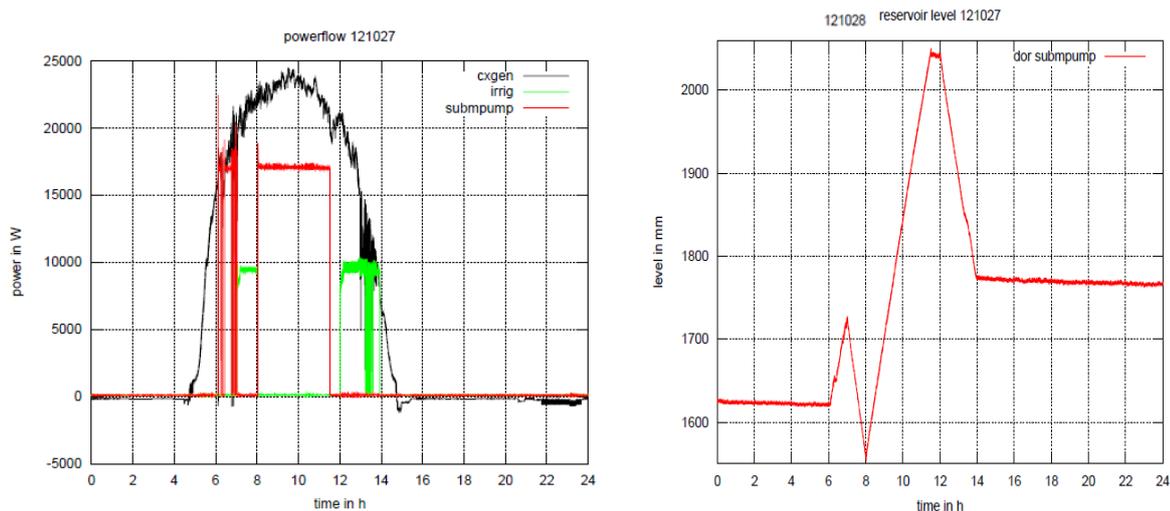


Fig. 2. Field measurements of the CPV power flow and the reservoir level. Left figure: Daily power flow of the CPV field, and the well- and irrigation pump on the 27th October 2012. Right figure: Reservoir level on the 27th October.

Paying now more attention to the CPV generator components of the Egypt site it is important to point out several highlights achieved in the project execution. The **CPV power plant consisted of 5 two axis tracking arrays each 5kW** nominal power equipped with FLATCON 2nd generation CPV Modules.

One key achievement was the **successful integration of the CPV systems into a harsh desert environment**. With a distinguish preparation of the system components of the CPV System, e.g. tracking structure, inverters, cabinets, the complete system was shown to be **desert proof**. No single environment related hardware issue during the complete project period can be seen as good measure to distinguish these result. Another result, also showing the good preparation for harsh environments, was the **uptime record on the complete installation**. This showed similar results compared to the uptime results of all our other installations e.g. in Spain or USA,

The power plant has really served the objective of feeding, in stand alone mode, the **needs of the irrigation plant, cropping and fresh water supply**, and generate data for the **improvement of the reliability** and better knowledge of CPV power plant operating characteristics. ISFOC contributed recording data and presenting them in a comprehensive way. The summary of the targets and the real and verified achievements are listed in Table B1.1

TABLE B1.1

Project targets	Verified results
System Design of a off-grid CPV System	The adapted “desert proof” CPV system was designed and all hardware modifications were successfully performed.
Production and testing of up to 25 kW peak CPV modules for demonstration	All modules were successfully produced and tested in Freiburg. In addition the max. AC power was later measured with 28.7 kW.
Installation of the off-grid System in Egypt	The successful installation and operation of the CPV solar generator, water storage and irrigation system was achieved in time.
DC test of the CPV System	The system performance was tested by a DC acceptance test performed by ISFOC on site.
Setup communications for maintenance and remote diagnostic failure detection	A DSL line with a 3G backup line was established and access provided to the partners.

#### 4.1.3.2 B The grid connected CPV power station at Ifrane (Morocco)

The NACIR installation at Al Akhawayn University (AUI) was completed by ISOFOTON by October 26<sup>th</sup>, 2010 and connected to the grid of ONE by the end of the same year. The power plant consist of **3 two axis tracking arrays**, equipped with “TIR ISOFOTON CPV modules”. Fig. 3.

The electrical configuration of the power plant consist of 6 subarrays, two per tracker. Each sub array is conecteed to one single phase inverters. The power is distributed to the three phases of the grid 220/380V.

The connection to the grid of the partner ONE has been carried out following the **current Spanish normative for grid connection**. Also the connection follows the local security protocols. This subject has promoted a significant interchange of information in this field with the Morocco partner.



Fig. 3. Left: The CPV power station at IFRANE (AUI site) connectd to the utility grid of the partner ONE. Right: The cabin and house where the 6 inverters are installed. The site infrastructure has been provided by the associated partner AUI.

Isofoton has learnt about **exportation and transportation of CPV plant components** material to the site, as well as identifying local providers which will serve to future busines. The majority of actions of relevance in the station have been covered by Isofoton staff moving from Malaga to Ifrane. This allowed **acumulative formation of the local staff**.

The monitoring of the plant operation and the testing of local meteo parameters were already active in 2011, provided by ISFOC and allowed for access by the implied project members.

The localisation of the plant at the English speaking International Al Akhawayn University (AUI), contributes to the project thanks to the **cooperation of its scientific staff**. This College level education centre is the best suited for knowing and understanding the European CPV expertise and also the most adequate for **irradiate and disseminate this technology to the Morocco society and decision makers**. This effect has been widely reached as it will be presented later in Dissemination achievements paragraph.

The environmental conditions at Ifrane, located at 1700 m. above sea level, plus the hards winter and summers conditions, allowed to **accelerate the experience on reliability and performance analysis for CPV industry**. The site has been used for observing **effects of soiling, abrasion, and discoloration** of components by placing several samples outdoor which are periodically analysed by local researches at AUI, in cooperation with UPM.

### Maintenance incidences

Several incidences occurred along 2011 due to meteorological, grid effects and wrong operator actions during 2011 which forced to replace mechanical elements and several inverters. The protection against over voltage was interfied.

During the second semester 2012 the only problem registered at DC level (this is: modules and grid overvoltage protection) was a failure of electrical insualtion of a module: it was substituted. The most frequent problem was due to WIFI communication connection.

Fig. 4 shows the **percentage of incidences recorded** in the second semester of 2012 (not all type of incidences has the same significance respect to power production). Again, the largest share is held by tracker failures. The corrective actions to solve the tracker incidences will be discussed later. Fig. 5 shows the **analysis of tracker incidences** caused by any reason.

The hard contitions of the site and the instability of the grid at ifrane required several visits of Al Akhawayn University researchers from the department of information technology systems and from the ground and maintenace services. They solved the data transfer communication and electrical connection problems, respectively.

One overall cleaning operation was performed by AUI personnel in mid July 2012.

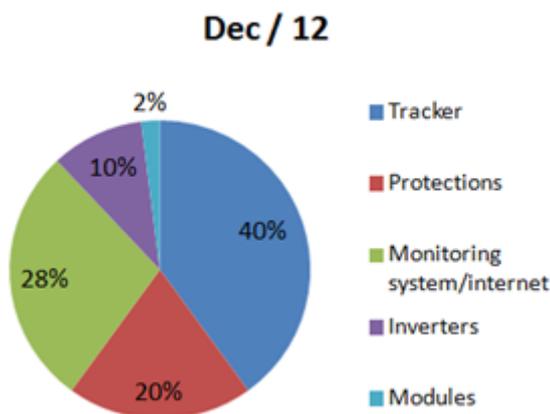


Fig. 4: Total incidences in 2<sup>nd</sup> H 2012

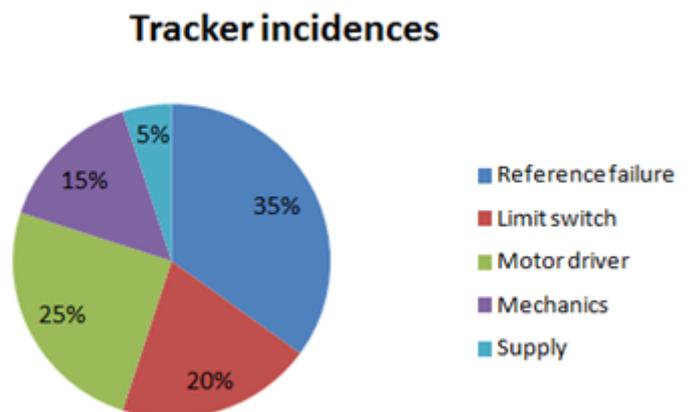


Fig. 5: Tracker incidences in 2<sup>nd</sup> H 2012

The evolution of the incidences along four semesters is shown in Fig. 6.

The **tracker is the element with more relative (percent) incidences**. Most of them are simply solved resetting the system. On the other hand, some mechanical problems were observed in the

elevation drive of the tracker. The **hard winds recorded, over 100 km/hour**, were, probably, the cause of this mechanical failure.

The rule is that the tracker problem remains as the most significant when the assembly of all failures are reduced. The last incidence breakdown plot is similar to the one found in other power plants.

The CPV modules, as happened with flat plate modules, were the most reliable elements of the plant.

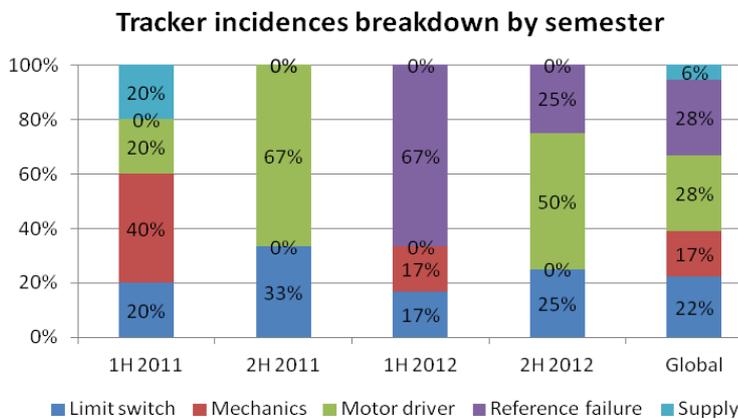


Fig. 6: Tracker incidences in 2H 2012

### Lessons learnt and principal actions carried out after the system installation

Much valuable information has been collected with respect to system incidences. The analysis of these incidences has led, on one hand, to some **improvements in the tracker**, and on the other, to apply the experience in the **design of the new Isofoton's tracker**. This company **will continue** carrying out experiments in the NACIR site after the end of the project. This is an excellent perspective for the project partners that will continue taking value from the CPV realization.

#### i) Improvements in the current system

Some **improvements have already been implemented** while others are scheduled for implementation in 2013: Elevation drive and mechanical reference sensor are changed: Position of limiting sensor for elevation modified; better encoder fixture.

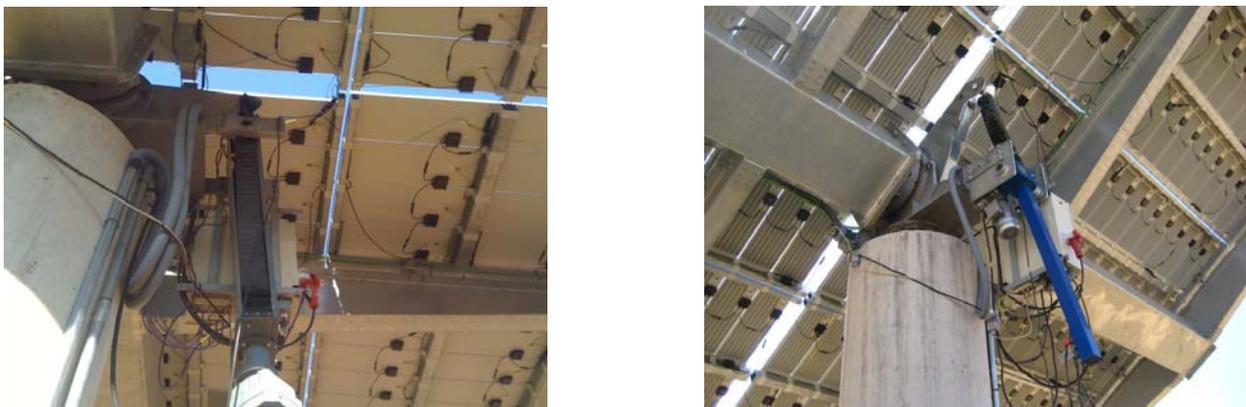


Fig. 7: Old (left) and new (right) elevation drives.

#### ii) Solutions adopted in the new system

In the **new tracker**, all these aspects have been addressed since the conception phase. It has been designed to focus on reliability and minimum maintenance. The concept is completely different, with hydraulic drives replacing electromechanical ones and a **dramatic reduction in the number of sensors**:

- To control de motion, there is only one absolute sensor with no moving part. No limit switches, no reference sensors (4 limit switches + 2 reference sensors + 2 incremental encoders are replaced by 1 sensor).

- There is only 1 motor driver and no electromechanical drives (2 AC motors + 2 AC drivers + 2 electromechanical drives replaced by 1 hydraulic motor + 1 AC driver + 2 hydraulic linear actuators).

This way, many of the potential incidences are not possible any longer. The fact that there are many less sensors also decreases the probability of failure. In addition, it has much smaller area and also smaller weight density. This decreases the drives load and hence the possibility of overloads in the drive electronics.

The experience has shown that **Ifrane is an excellent site for testing CPV system** and components, reliability due to its rather aggressive weather conditions. The occurred incidences in the site have led to new solutions aimed to improve the system reliability.

As a result, **Isofotón will continue using the site** as a test installation of its new technology.

#### 4.1.3.3. CPV Database Experiences, materials, technology and operation

ISFOC is the biggest laboratory in the world for performing field testing of CPV Power Plants (Fig. 8) in order to support the industrialization of CPV. Currently ISFOC has installed in its facilities up to 1.1 MW of 3 different technologies, with different versions of their products, connected to the grid since 2008. Recently have put into operation additional 1.2MW from other four technologies.



Fig. 8. CPV Plants of 7 different technologies at ISFOC

One responsibility of ISFOC in NACIR project has been the **creation of a database of worldwide CPV experiences** and results of its own tests. Currently, the information contained in the database is covering more than **4 years of operation** in the field of power plants from different manufacturers as well as **long term measurements of solar resource**. The actions at ISFOC allow early detection of failure or degradation modes in any technology and is used as feedback by

all CPV community. In the framework of this project ISFOC has developed a management and **information system, called GOCPV** is focused in the analysis and dissemination of results obtained from the long term operation of CPV plants.

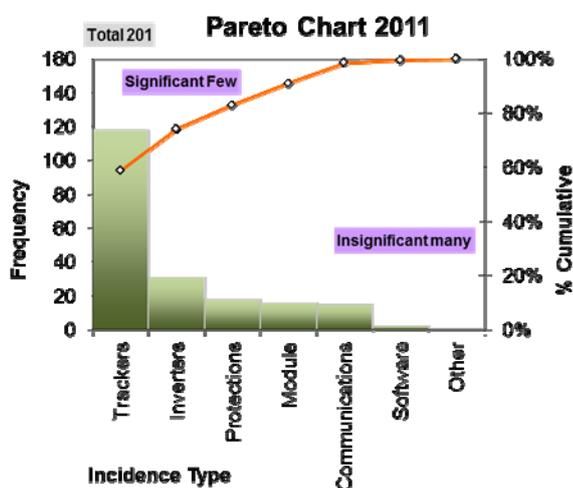


Fig. 9 is a **Pareto chart representing the incidences** occurred during 2011. The main cause is the tracker, with near 70%. The next cause of malfunction is the inverter with a 20%, protections and modules are only causing a 10% of incidences each one.

Fig. 9. Pareto Chart, type of incidences during 2011

Furthermore, it is important to keep in mind that the ISFOC CPV Plants were installed during 2007 and 2008, becoming the first field for demonstration in the world, using early technology.

The next analysis shows the evolution in time of the

averaged **energy generated by one CPV Plant** (100kW) under averaged irradiance level. This important plot can be also used for unveil a change o degradation of performance.

Fig. 10 is a representation of this analysis for 2009 (blue diamonds), 2010 (red squares), 2011 (green triangles) and 2012 (purple dots).

The difference in the slopes of the regression lines, which better fit the data of each year, should represent the **difference or evolution in performance**. Comparing the slopes of years 2009 and 2012, it is obtained that the energy generation of the plant has been reduced by a 2% during the four years of operation.

So small variation suggests that there was **not any significant lose of power nor degradation** with the mature technology available after 2009. The diminution observed in the energy generation during three years is quite small, similar to the one found in conventional PV modules.

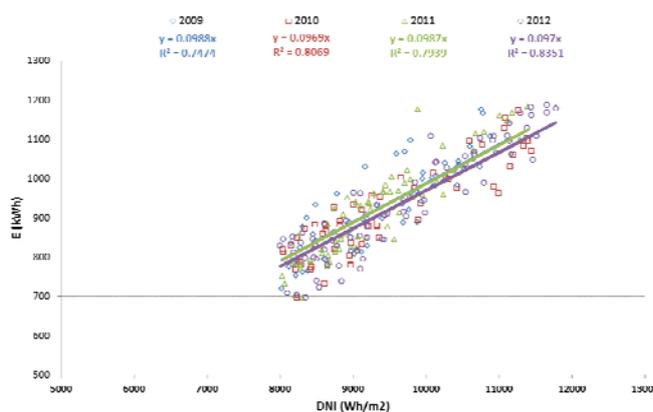


Fig. 10. 100kW CPV plant daily energy generation vs. DNI (2009-2012) for DNI>8 kWh/m<sup>2</sup>

Moreover, <sup>2</sup>some conclusions relating the **usefulness of the IEC qualification normative** to prevent the commercialization of not reliable CPV modules have been obtained along the project. The degradation of a power plant which modules did not adopted the corrections suggested by the IEC 62108 tests showed 13% degradation in 4 years with respect to the same technology with modifications adopted to pass the qualification tests.

ISFOC has been in charge of monitoring the operation of the NACIR stations in Morocco and Egypt. The data have been the first registered in especial location, new for CPVs. The leasons learnt indicates that remote monitoring must rely on the **cooperation of the local operators**, this is the partner ONE and his associated University (AUI) at lfrane.

Five partners of the project are active members of the IEC-TC82, the international organization responsible of the PV standardization. In this frame the experience and results obtained in the project are crucial for the development of CPV standards. The Power Rating, indoor and outdoor, of CPV modules and the rating of large CPV plants at STC are **contributions of NACIR to creation of CPV normative**. UPM is also responsible for the **definition of solar simulator** characteristics for CPV modules.

The forecast of the energy production expected from CPV power plant has required the thermal characterization of the modules arrays including simpler methods for defining the module temperature (CNOCT: Concentrator Normal Operating Cell Temperature) and monitoring the performance with respect to the spectral distribution of the light (using Tri-band Heliometers). It has been shown that **reliable results are obtained if the valid testing** conditions are limited to high irradiation levels and mild ambient temperatures. These research activities have been covered by the **long term thermal characterization of CPV modules** and systems and the **solar spectrum recording network** carried both under this project in collaboration between ISFOC, IES-UPM and Fhg-ISE. Fig. 11 shows module temperatures measurements taken with DNI levels between 800 and 900W/m<sup>2</sup>. It is observed that the values obtained present a linear trend, with some exceptions related to wind influence.

<sup>2</sup> E. D. Dunlop. *Lifetime performance of crystalline silicon PV modules*. Proceedings of the 3rd World Conference on Photovoltaic Energy Conversion, Osaka Japan, 2003;2927–2930

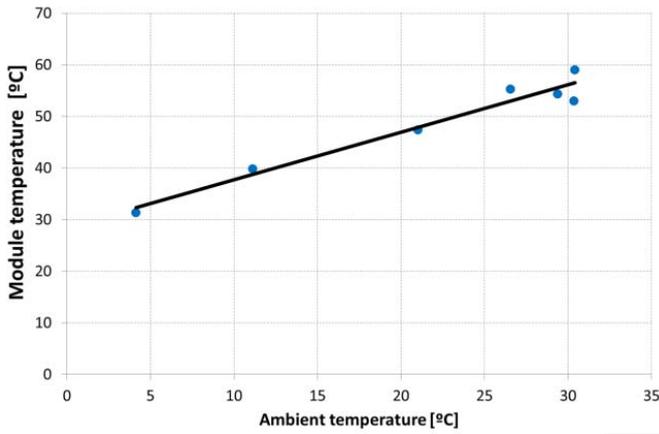


Fig. 11. Module temperature dependence with ambient temperature. Calculation of CNOCT

From that plot the module temperature at “Concentrator standard Operating Conditions” can be calculated. The error in the determination of the module temperature is 2.5°C, what results in an uncertainty in the power determination of ±0.4%. Both, IES-UPM and Fhg-ISE have developed Tri-band Spectro-heliometer. Fig. 12.

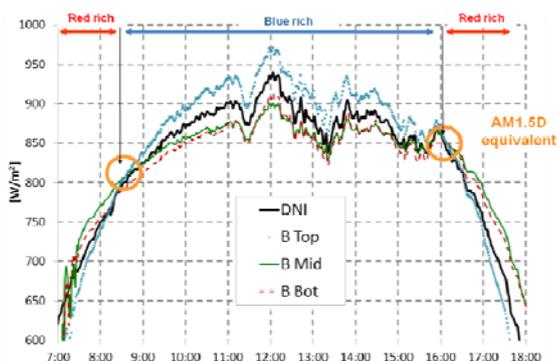


Fig. 12. Tri-band Spectro-heliometer sensors; Fraunhofer (left) IES-UPM (right)

This equipment measures the equivalent direct normal irradiance for each component cell. The IES-UPM Tri-Band Spectro-Heliometers are installed at ISFOC and IES-UPM in Spain and also at the locations of the project, Ifrane in Morocco and Wadi el Natrun Egypt. Fig. 13. The Fraunhofer Tri-Band Spectro-Heliometers are installed at Fraunhofer in Germany and ISFOC in Spain.



Fig. 13. IES-UPM Tri-band Spectro-heliometer in Morocco (left) and Egypt (right)



A daily irradiance measurement carried out with a Tri-band Spectro-heliometer and a classic pyrheliometer is shown in Fig 14.

Fig. 14 DNI measurement with a pyrheliometer and Tri-band Spectro-heliometer in Madrid,

It can be observed a big period around midday with blue rich spectrum where the middle component cell is limiting the current generation, and two red rich periods at the morning and at the evening where the current is limited by the top component cell. The

matching points of both component cells are where the spectral distribution of the direct normal irradiance is equivalent to the reference spectrum AM1.5D. The effective irradiance for the CPV system at every moment is the minimum of the four curves found in the plot of Fig. 14.

In the table C.1 is presented the **error range for Rated CPV Power at CSOC** (standard operating conditions), which confirms the convenience of the spectral tri-band recording.

Table C.1. Comparison of the error in the test of CSOC Power using the Tri-Band Spectro-heliometer and the Pyrheliometer

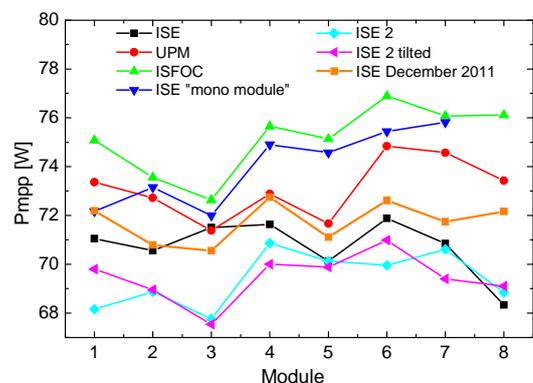
Date	3j-DNI	DNI
06/08/2011	-0.51%	-5.25%
20/09/2011	2.98%	3.43%
13/10/2011	-0.52%	3.08%
09/01/2012	-0.47%	2.25%
13/02/2012	OUT OF THE STUDY	
14/03/2012	-1.76%	-3.52%

These results are being **shared with the WG7 of the IEC-TC82** committee looking for the standardization of the rating methods for CPV technologies.

One significant task included in the NACIR project is the **indoor round robin test performed with Soitec modules, a highlight without precedent in CPV**. Eight modules have been measured at FhG ISE, were sent to Spain to IES UPM and ISFOC and sent back to FhG ISE. Measurements with indoor sun simulators for CPV modules were performed at each location. Comparatively large deviations were found, especially when different sensors were used for the determination of the irradiance level – see Fig. 15.

Fig. 15. Summary graph of the indoor CPV module round robin test within NACIR. Large deviations up to 10 % in power measurements were observed. The determination of irradiance and the choice of irradiance sensor were identified as one main error source

It could be also be demonstrated that deviations can be **minimized when the same irradiance sensors are being used** (see upside down triangle “ISE mono module”). In summary the main outcome of the round robin activities within NACIR are lessons learnt and recommendations for future CPV module round robins, which rules are currently under preparation. The main recommendations are:



- define the irradiance sensor – if possible also **include a mono-module as part of the shipment**
- take temperature of the primary optics into account
- include isotype/component cells in the activity for monitoring the spectrum

#### 4.1.3.4: Technology development: improvement of modules, manufacturing, new products and testing requirements.

##### 4.1.3.4.A Technological development for improving current performance of FLATCON module at Fraunhofer and SOITEC SOLAR.

Further work topic at FhG ISE was the support in the development of silicone on glass CPV modules with secondary optical elements (SOE). The work within NACIR was focussing on refractive secondary optics and there especially on manufacturing issues. Typically SOEs are positioned on the solar cell assembly, i.e. a CPV cell bonded to a carrier. The positioning of refractive SOEs however can correspond to a challenge especially for vision systems that are used for identifying optimum positioning of the SOE and also for the positioning of the solar cell assembly with SOE on the bottom plate. Hence an alternative approach was investigated within the NACIR project. Here the idea was to **directly cast the SOE onto the solar cell assembly**. At FhG ISE a **prototype for the proof of concept** has been realized where a single SOE can be casted directly onto one solar cell assembly – see Fig. 16.

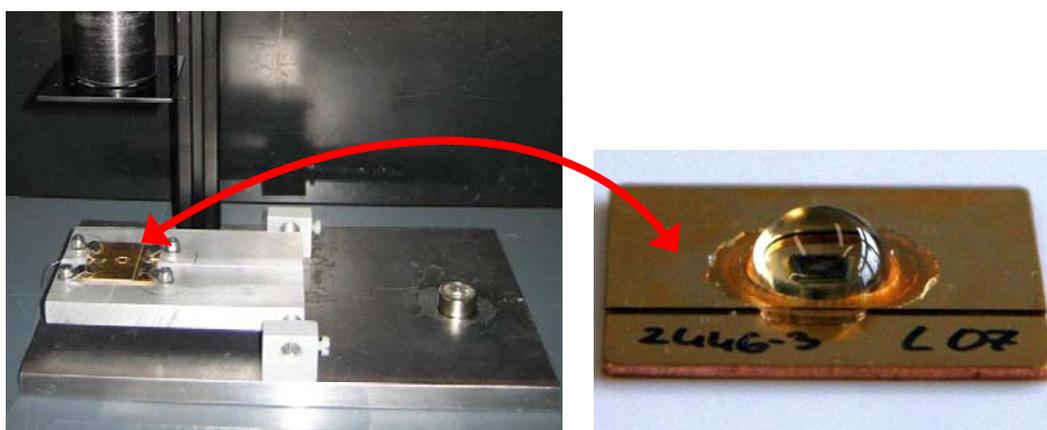


Fig. 16. Left: Test set-up for direct casting of silicone secondaries onto solar cell assemblies. The cell is positioned with the help of a laser. After positioning of the cell, the holder together with the cell is turned by 180° onto the mould filled with silicone. Right: Solar cell assembly after successful direct casting of spherical silicone secondary optic.

After successful demonstration of direct casting of silicone SOEs onto solar cell assemblies and analysis of test modules the technology has **been transferred to full size Soitec modules**. The working principle of the prototype from Fig. 16 were not directly transferred to Soitec in order to avoid the necessity of positioning of solar cell assemblies with SOEs. Thus a method for **direct casting of SOEs** on fully assembled bottom plates was developed. The principle idea is to have metal plate with the same number of moulds as solar cells on the bottom plate. The moulds are filled with silicone and the bottom plate – with mounted solar cell assemblies is put upside down onto this metal plate. The method has been **demonstrated successfully at Soitec**.

**Soitec** was involved in two key aspects of the project. The first one was the development of a **new module generation with a secondary optics**. The second one was the setup of the **first stand alone CPV system in the desert**.

#### Module development at Soitec

The well proven CPV modules of Soitec Solar, was originated from the FLATCON module technology, very simple and compact, made at Fraunhofer-ISE. It consists of two rectangular parallel glass sheets closed by stainless steel perimeter walls. Fig. 17. The top side glass, facing the sunrays, is a Fresnel lens made with the called Silicone on Glass (SoG) moulding process.

The lenses concentrate the light on small MJ solar cells, each mounted on an individual square metallic spreader, which is glued on the bottom glass.

The thermal conductivity of glass and the small size of cells are sufficient for reaching a convenient dissipation of heat.

The chromatic aberration associated to refractive concentrators limits the available concentration level of this module solution. Soitec has reached a good compromise between sufficient light concentration, moderate acceptance angle and excellent tracking accuracy. The SOITEC power plants have **demonstrated yearly top energy efficiency in the field**.

However the possibility for improving the module characteristics, this is more concentration and wider acceptance angle, is a significant target to investigate at SOITEC. The research on this subject became one Work Package in NACIR project.

From the beginning of the project a new CPV module design using a secondary optics has been developed. The following goals were defined in the project layout (Table C1.1).

TABLE C1.1

Target	Result achieved
Geometrical concentration of 1000x	With the new module design, with secondary, optics a geometrical <b>concentration of 820x was achieved</b>
Acceptance angle $\pm 0.9^\circ$	With the additional optical concentration an <b>acceptance angle of <math>\pm 0.53^\circ</math> was achieved</b>

In order to cost effectively integrate the secondary optic an overall cost-optimized redesign of the module was necessary in order to reduce the part count per watt. There following improvements have been additionally included:

- **Primary lens area increased by factor of 2**
- **Increase of concentration level of the primary optic to 460X**
- **Better utilization of solar cell wafers**
- **Change of heat sink and module frame bulk metal for cost reduction**

This module design has **been certified and put into production**.



Fig. 17. Redesign of the Soitec module for the incorporation of secondaries: The part count has been significantly reduced for cost optimization

Another important foreground is the progress made in **understanding of the silicone-on-glass Fresnel lens**. A new **Fresnel lens design has been developed**, that reduces the dependence of optical efficiency on lens temperature (see Gen IV in Fig. 18) and the **performance peak has been moved to the desired value of 35-40°C**.

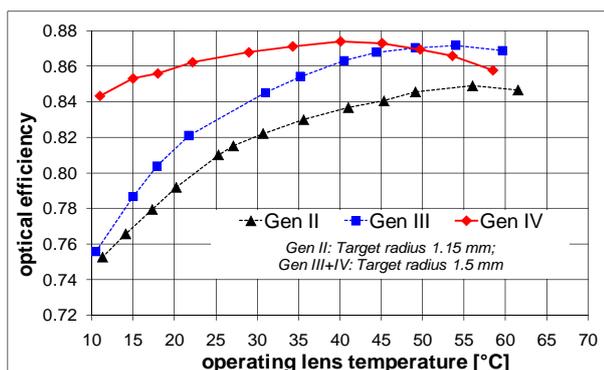


Fig. 18. Optical efficiency versus the lens operating temperature for different Fresnel lens designs

The new module design was used as basis for the secondary integration. Silicone optics are used and directly molded on bottom plate, allowing for very

low cost (see Fig.19).

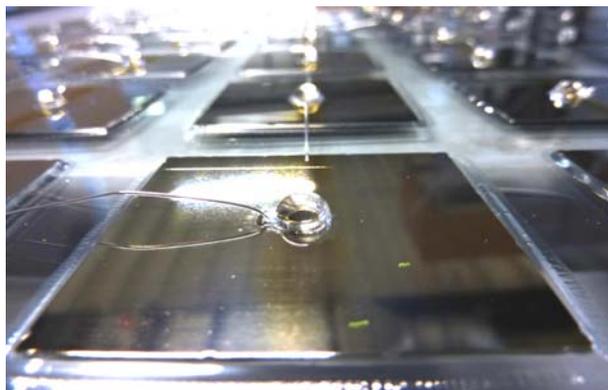


Fig. 19: Bottom plate with silicone secondary optics

The concentration ratio has been increased to **820X at an acceptance angle of +/- 0.53°**. It was shown that this design is **UV proof** by exposing one prototype to sun for 1.5 years. All other climate chamber tests according to the **IEC certification have been successfully passed**. The process has been transferred to pilot production. The efficiency of the module with **secondary optics has reached 28.4%** compared to a module efficiency of 25% at the beginning of the project.

The progress made during this project has led to a production capacity **increase from 25 to 70 MWp/a for the Freiburg production site**. Soitec has secured its position in the CPV sector and has **become the world-leading company**. **New markets** in the Mediterranean region, South Africa and the US have been entered. This success has led to **expanding the production to the US** with the build of a 280 MWp/a factory.

#### **4.1.3.4.B. Technological development at Isofoton**

The technological work at ISOFOFOTON has been focused in the **design of a new generation module**, its qualification and to prepare/modify the manufacturing line for reaching quality and high throughput with this new CPV module. The tests carried out at UPM have helped to optimize the design and provide accurate specifications in STC and SOC.

##### **New module**

A new design of RESET module has been carried out in order to upgrade the former RESET\_Ver01 module in power efficiency, less water and humidity penetration and reduced UV degradation: The reduction of the number of components per unit of energy was the target orienting the new design.

Six highly efficient MJ triple junction solar cells, shunted each by a Schottky diode, are used in these concentration modules. Concentration module RESET\_Ver02 is based on two step optics: Primary element is an acrylic square Fresnel lens which focuses light directly to the entry surface of the SOE, consisting of a glass prism.

##### **Production line and Improved throughput**

Isofoton is a pioneer company producing CPV modules. In consequence, it owns a large variety of manufacturing machines, like die bonder, pick and place, fluid dispenser or rack storing for manufacturing the first generation of Isofotón CPV module (RESET\_Ver01). All this equipment **needed to be modified** for being adapted to the new RESET\_Ver02 technology. The efforts for carrying out this plan and reach high throughput is the aim of Isofoton in this section of NACIR.

The mentioned and many others machines need such adaptation for using them with the new module version. The drastic variation of cell area, from 1,32mm<sup>2</sup> in Ver01 to 1cm<sup>2</sup>, affects many steps of the production line: the modifications affect the following equipment:

Cell bonding- New curing oven

This oven model is able to maintain vacuum while controlling temperature and nitrogen concentration in order to obtain an optimum soldering.

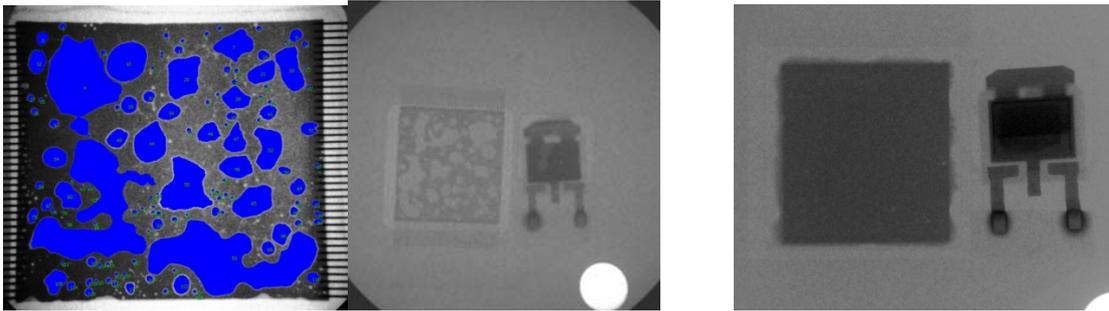


Fig. 20. To the left and middle solder without vacuum. To the right, solder using the new oven

In Fig. 20 blue areas are voids (25% for this case) corresponding to a bond in atmospheric ambient, while in the right side image a **solder made with vacuum (less than 1% voids)** shows how significant the change is. This machine is essential for our quality and reliability product and it's in our process since more than a year.

- Pick & Place machine: It was adapted to new size and shape of receivers.

- Die bonder: It is a two steps machine. The first step consist picking the solar cells chip from the wafer expensor, Then dispense a solder paste over the substrate and place each solar cell onto the corresponding pcb that will be assembled to the module. The second stage is used to make the wire bonding between the solar cells and the PCB.

- Receivers sorter: It makes possible to test each receiver before sealing the module housing. The modifications have been significant because the large variation of the cell output power, from mA range to 5 A.

- Silicone dispenser for module sealing and top glass placing

This machine automatically covers the final steps of the assembling process increasing the production rate The main steps performed here are: back plate alignment, silicone dispensing for frontal and back covers of the housing and frontal lens parquet.

Fig. 21. Robotic arm for SoG lens parquet placing

This machine has been **recently installed in** our facilities and is working properly after the corresponding set up and configuration.

- Module tester and sorter: The automatic system for module measurements

“SAMMOD” consists of an electronic rack with the corresponding voltage source, electronic charge, control PC, a double face module-holding system and a flashing light system consisting in a controlled **flash light and a parabolic mirror to collimate the light onto the modules.**

Fig. 22. SAMMOD module tester and sorter



Throughput and production results:

The current production capability of our factory **has achieved the 2000 modules per month**, and it could be improved as to achieve maximum of 4000 units' month by just adding replicas of some of the available machines. These values are equivalent to a production 2-4 MW/year. Two installations based on the new modules have been recently installed: **One in Golmud (China) and the other one in Sicily (Italy)**. Fig. 23. These are result of the development inside NACIR and an evidence of the degree of confidence reached which the new generation of modules. The Chinese installation is **located in the desert Tibetan plateau**, characterized by high radiation and low temperatures consist of 8 trackers.



Fig. 23a. 100kW installation in Golmud (China)

The installation of Italy is also a 100kW one but requires **only 7 trackers of a new type**. The radiation and temperature conditions of this location are less extreme but assure 1800kWh/m<sup>2</sup>. per year

Fig. 23b. 100kW installation in Sicily (Italy)



### Modules Characterization at UPM

The Partner UPM, at IES has developed a deep study on our RESET\_Ver02 module looking for its optimization and characterization. The analysis was developed not only with complete modules of our production line but also with individual elements as a necessary step towards optimization of the optical subsystem.

#### *Experimental setup*

The measurements were performed indoors and outdoors. For the indoor measures the CPV solar simulator UPM-Helios 3198 was employed. Collimation and spectrum are well controlled: in addition the UPM can operate this test locating a single **optical element inside a thermal cabinet** which allows testing at any temperature. **The optimization of a CPV module** was carried checking out experimentally the variation of the focal distance with temperature, the maximum power vs. with the focal length, the short circuit current vs. the spectrum across the optics and finally the efficiency with the DNI level. The **outdoor measurements of modules** were carried out continuously on a tracking system with 0.1 degree accuracy. The result of the optimization and measurements yield the following specifications at 850 W/m<sup>2</sup>, AM1.5D, 25°C. (Table C2.1).

Table C2.1 RESET\_Ver02 module specifications: Optical and electrical main characteristics at 850 W/m<sup>2</sup>, AM1.5D, 25°C

Focal distance	253 mm	Cell active area	1 cm <sup>2</sup>
Primary lens side	240 mm	Peak power (Pm) @	85 W
Geometric concentration	570 X	Open circuit voltage (Voc)	17 V
Nº of receivers	6	Short circuit current (Isc)	5,5 A

### Optimization techniques based on indoor tests.

The results of extensive and intensive measurements at UPM has allowed to generate the plot of Fig. 24 which **defines the optimal focal distance at each lens operating temperature**, which is a key for the efficient use of the SoG primary optics. This technique is a must for the optimization of the CPV modules based on SOG lens concentrators.

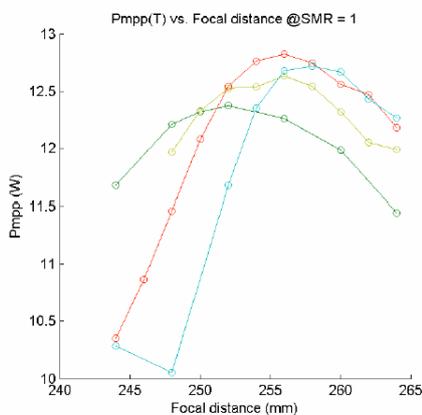


Fig. 24. Maximum power vs Focal distance at different operating Temperatures

The other key dependence of this concentration technology is related to the radiation spectrum. The triple junction solar cells are designed for a standard spectrum AM1.5 D. But the optics and the meteorology modifies that spectrum during normal operation of CPV systems. The **definition of Equivalent Spectrum and the parameter SMR** have been improved and consolidated during NACIR at UPM, ISOFOTON and Fraunhofer. SMR becomes higher than 1 for bluish spectrum and less than

1 for reddish ones.

### Outdoor measurements

**Outdoor tests along a large period provide** the best information about the expected energy generation. The results from the work done in the Project are summarized in Fig. 25.

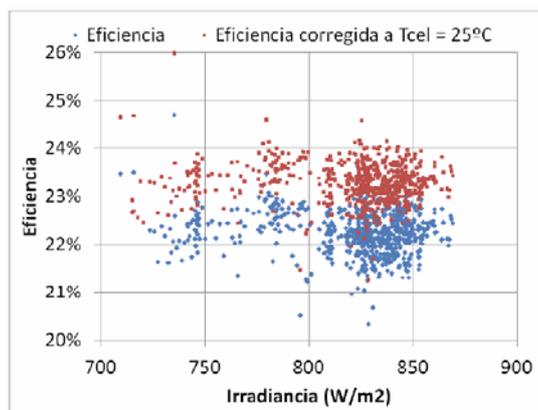


Fig. 25: Measured (blue dots) and corrected (25°C) Efficiencies of a module analyzed outdoors

The data were collected at 5 minutes interval without filtering with respect to ambient temperature nor spectrum. However, the results are not too disperse, just +/- 4%. From other side the objective of efficiency proposed in the project has been reached as 24% at STC. **The goal is satisfied and demonstrated moreover** when this is a randomly chosen module of

our production, not the best we have manufactured.

In addition to this result, the continuous testing outdoor has provided the **variation of Voc with the ambient temperature**, which is an useful parameter for refining any energy forecast. The obtained value is  $V_{oc}(T) = -0,0235 \text{ mV/}^\circ\text{C}$  for the module which corresponds to 4mV/°C per cell.

#### 4.1.3.4.C. Development of a new Concept for CPV modules – Fluidreflex- at UPM.

##### Introduction and Scope

The technological activity of UPM in NACIR has been devoted to the development up to pre-industrial module level of a new PV concentrator concept. This novel concentrator concept consists of a single reflective stage immersed in an optical fluid. The presence of the fluid entails significant advantages. Not only it allows a high system optical efficiency and increases the attainable concentration but it also enhances the heat dissipation from the cell. In addition, the electrical insulation is improved and simplified and the problem of water vapour condensation inside the module is avoided. Among the experimental results, it stands out a measured optical efficiency of 83.5% for a concentration of 1035X. The full development and verification of the initial premises and the development of a pre-industrial prototype are the tasks carried out in the project.

##### Description of the new concept and its advantages

**The new concentrator, named FluidReflex**, is based on a single optical stage immersed in a dielectric fluid. Previous experiences at low concentration ratios using optical fluids were carried out at the IES-UPM with successful results but, to the knowledge of the authors, this is the first attempt to use fluids benefits in a high concentration module. The FluidReflex elementary unit consists of a parabolic mirror which acts also as the rear face of the module, a high efficiency MJ solar cell placed in its focus at the inner side of a transparent front face and the dielectric fluid filling the volume between the mirror and the front face (Fig. 26). Square elementary units are placed in a grid, composing an array of elements that constitute the module.

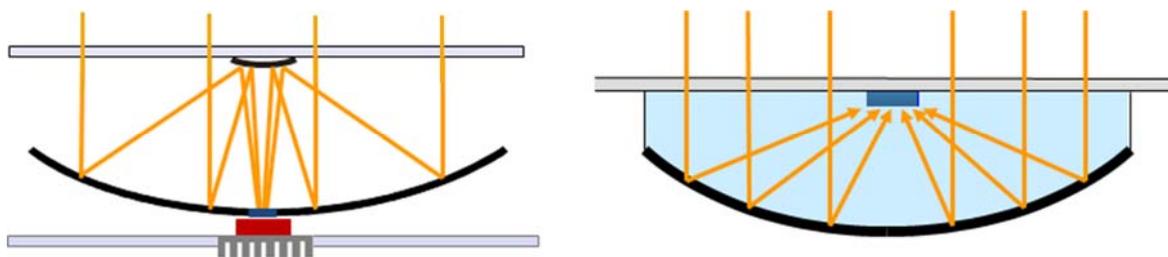


Fig.26. Left: Conventional reflexive CPV where two reflectors are used for good heat dissipation. Right: The Fluidreflex concept which simplifies the fabrication and the operation by means of a fluid which performs simultaneously optical, thermal and insulation functions.

FluidReflex uses only reflective optics to concentrate light, **avoiding the limit in concentration caused by chromatic aberration** in refractive systems. When using a single mirror the solar cell must be placed between the sun and the optics, so if a cooling element were added next to the cell it would cast shadow reducing the system efficiency. A common solution to this problem is to add a secondary mirror to redirect light through a hole in the primary mirror to a solar cell on the back surface of the module (Fig. 1). The drawback of this configuration, known as Cassegrain, arises from the fact that the light is now reflected twice and, as reflection is not ideal, light losses become more significant and optical efficiency decreases. On the contrary, in FluidReflex concept, the fluid presence improves the thermal management within the module **avoiding the need of external cooling fins** and enabling the use of a single reflective stage. Moreover, the fluid enhances the optical efficiency by **reducing Fresnel losses in several interfaces** and it **increases the concentration-acceptance angle product** as it is explained in detail later.

The heat concentrated in the solar cell is transported to the module walls by convection (natural or forced) and conduction in the fluid.

From other side the **water condensation inside the module is impossible** because the Fluid fills the internal space. In addition, once the fluid has been proven to be harmless to the cell and the rest

of the module components it acts as an encapsulate **protecting the components inside the module** from degradation.

### Verification of the Fluidreflex suitability for reaching the objectives

#### Optical characterization of the elementary unit

Several elementary unit prototypes were built to measure FluidReflex optical performance. They were composed of the same circular parabolic mirror (58 mm in diameter) manufactured by diamond turning and cells with different sizes obtaining different concentration ratios. Fig. 27.

For the best-performing elementary-unit prototype an optical efficiency of **83.5% at 1035X** was measured. Furthermore, efficiencies **higher than 80%** were measured for concentration ratios up to **1500X**. According to that and the cell state of the art a total CPV system conversion efficiency of **higher than 31.5% is predicted**.

Angular transmission curves at different concentrations were measured illuminating the concentrator with collimated light using the Helios 3198 solar simulator which allows the accurate deviation of the concentrator from the incident light beam. Fig. 28.

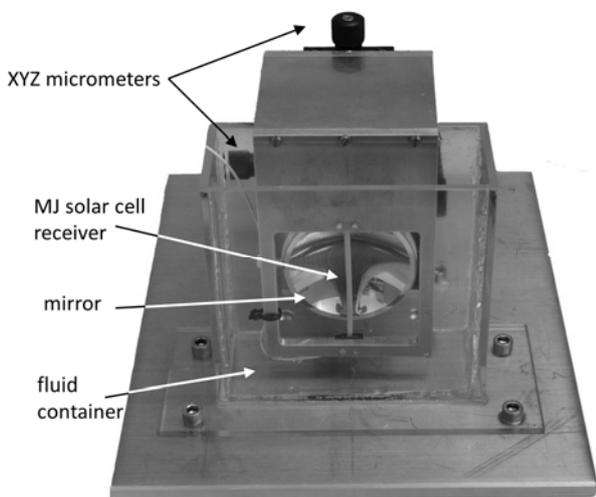


Fig. 27. FluidReflex early elementary unit prototype.

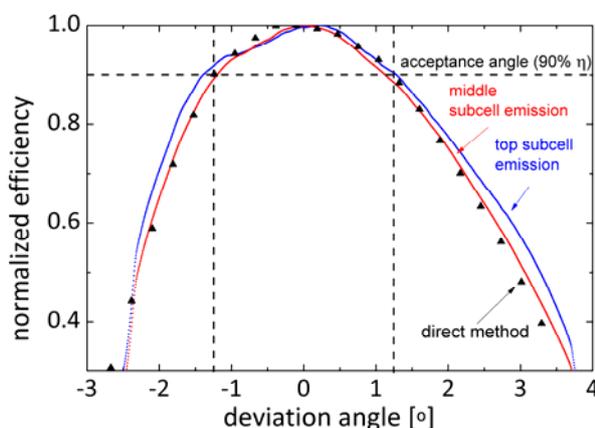
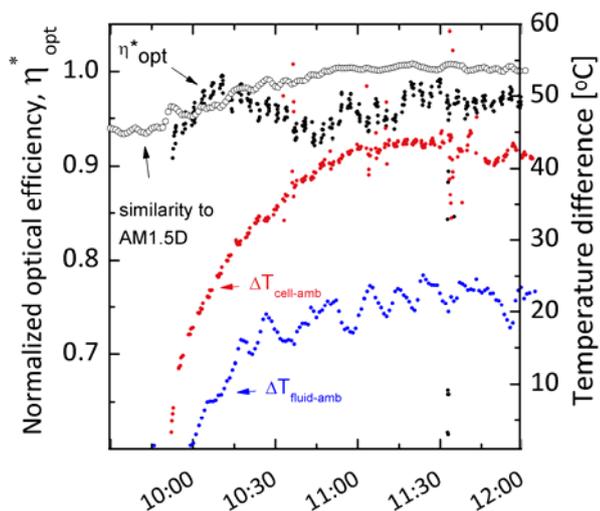


Fig. 28. Normalized efficiency vs. incidence angle. Acceptance angle is +/-1.2 degrees.

Additionally, cell positioning tolerances have been determined as part of this optical analysis because the required assembly accuracy will have a large influence on the trade-off between module performance and assembly costs. The system lose 10% power output when the cell is displaced  $\pm 0.6$  mm from ideal XY position or  $\pm 0.4$  mm in X Z direction, at 584X. It is clear from these results that the FluidReflex concept **will require relatively high assembly accuracy**, though well within the level achievable with robotic placement tools



Evolution of normalized optical efficiency and temperature drop between the cell, the fluid and the ambient during the initial thermal transient of the FluidReflex elementary unit prototype. DNI varies within 800-900 W/m<sup>2</sup> and temperature range is 15-19 °C during the measurements.

Fig. 29: Evolution of normalized optical efficiency and temperature drop between the cell, the fluid and the ambient during the initial thermal transient of the FluidReflex elementary unit prototype. DNI varies within 800-900 W/m<sup>2</sup> and temperature range is 15-19 °C during the measurements.

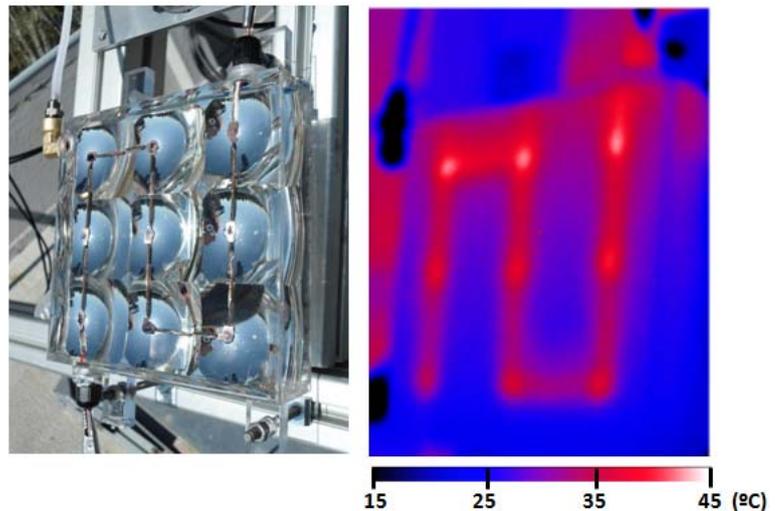
#### About the fluid

The presence of a **dielectric fluid is the major novelty of the new concentrator** so its optical

performance was studied. Transmittances of many fluid candidates were measured from 350-1700 nm for a 5 nm interval. Due to its low cost, reliability and high transmittance, **paraffin oil seems one of the best candidates**. A consideration when designing a fluid-filled concentrator is related to **the refractive index variation** across the fluid when temperature is not uniform. A non-homogeneous refractive index bends rays from their original design paths and enlarges the spot size reducing attainable concentration. The results of modelling were experimentally confirmed by observing the evolution of the normalized optical efficiency  $\eta_{opt}^* = \eta_{opt} / \eta_{opt\ max}$ , and the solar cell temperature  $T$ , when the FluidReflex prototype is measured outdoors Figs. 29 and 30.

The normalized optical efficiency **remains almost constant** during the time period in which the cell and the fluid temperature significantly vary, as we see in Fig. 29 for the 9:45-11:15 time interval.

Fig. 30. Left: The “9 cells module” prototype in real sun operation. Right: Thermometric image of the module (the electrical connectors contribute to heat spreading from the cell)



### About AR Coating optimization

When designing the ARC over the solar cell several important aspects were considered. First, the **angular distribution of light over the MJ solar cell** was taken into account. In this case, FluidReflex compact design illuminates the cell with a wide-angle ( $\pm 65^\circ$ ) cone of light.

### Manufacturing of concentrating optics

Prototype mirrors for FluidReflex concentrator were **manufactured by plastic injection** as this is a promising low cost technology that may, in a future, enable the fabrication of the complete module rear wall (including the array of parabolas) **in a single injection**. Later, the injected pieces were mirrored by evaporating aluminium or silver. Silver is preferred for its major reflectivity but is unstable in contact with air. Fig. 31.

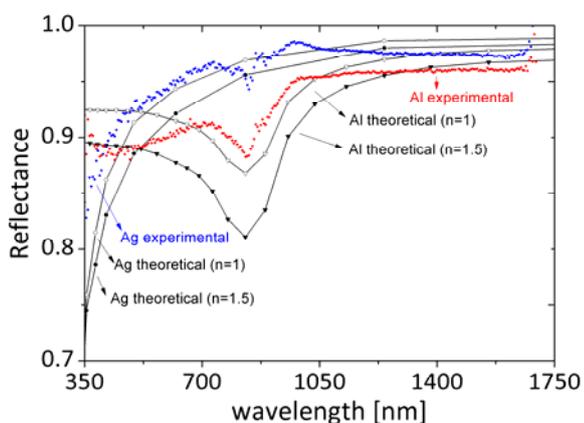


Fig. 31. Reflectance for the evaporated aluminium and silver mirrors. For comparison, theoretical reflectance of aluminium and silver surrounded by a medium with refractive index.

In FluidReflex modules silver mirrors are immersed in a fluid so, once **it has been proven to be innocuous**, the fluid may avoid the mirror corrosion showing an extra benefit from its presence. The long term reliability is currently under study. Regarding adherence both materials showed a good behaviour

when evaporated over PMMA.

The reflectance measurements shown in Fig. 7 were made with the samples surrounded by air. However, in FluidReflex concentrator mirrors will be surrounded by a fluid whose refractive index is higher than one. Therefore, a decrease in reflectance of approximately 2 absolute points is expected for both materials when they are immersed in fluid.

### About Plastic injection for Fluidreflex optics

Plastic injection is considered a very promising technological option for CPV manufacturing by several reasons. If sufficient optical quality is attained this process could **translate into a significant cost benefit** compared to, for example, glass mirrors. More importantly, it may be possible to fabricate the FluidReflex whole module rear wall by a single injection in which all the parabolas are simultaneously obtained. Fig. 32 shows the encircled energy (EE) of the light distribution created by the injected mirrors. EE is defined as the amount of total energy contained in a circle of a certain radius. The three injected mirrors samples show a very similar curve to the EE of the spot casted by a diamond turning machined mirror, differences being within the experimental error. The machined mirror can be considered as the highest attainable optical quality so consequently, **the injected mirrors show a high optical quality with a low cost**. For all the injected mirror samples measured, 90% of the energy is contained in a spot with 1.4 mm diameter.

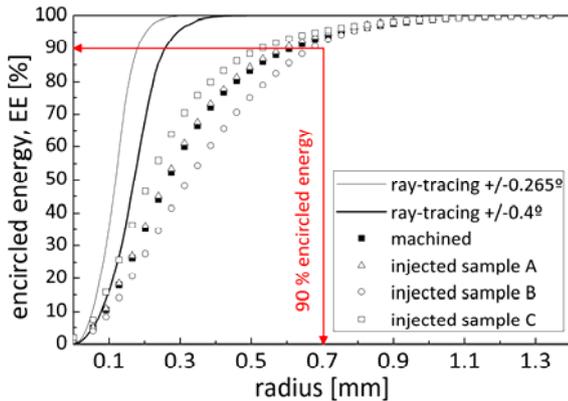


Fig. 32. Encircled energies (EE) of the spot casted by machined and injected mirrors. Superimposed EE predicted by ray-tracing simulation with solar simulator ( $\pm 0.4^\circ$ ) and real sun ( $\pm 0.265^\circ$ ) collimation angles. The differences between the machined mirror and the injected piece which seems to perform better are within the experimental error.

The spot casted by each mirror is photographed using a CCD camera. The light of each mirror is cast inside each cell, although some deviation is observed. Fig. 33.

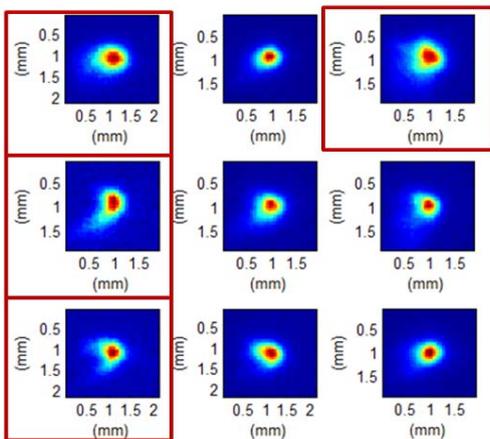


Fig. 33. The light distribution on each cell of a 9 mirror module made by a single injection shot.

The parabolic mirror casts a non-uniform irradiance profile over the cell, which worsens the cell performance as compared to uniform illumination. Unlike refractive concentrators, reflective ones produce the same spectral distribution throughout the cell, thus **avoiding additional losses due to spectral non-uniformities**. The masks method described in detail in previous works by UPM has been applied to estimate cell-efficiency worsening due to non-uniform illumination. The measurements indicate that, for two out of the three manufacturers analyzed, MJ solar cell technology **losses due to non-uniformity are in the range of the experimental error**

( $\pm 2$ ) for uniformity factors as low as  $U = 0.4$ .

### Prototype modules

**Many prototypes have been made and tested.** Figs. 34 and 35. The alignment of the mirrors and the cells has been a very difficult task while made by manual procedures. However we have **reached 26.6 % efficiency modules with cells 35-36% efficient** using just some aids to manual mounting. The precession with robots for cell positioning and the use of 40% cells **assures 30-31 % module efficiency**.



Fig. 44. Left: Cell receiver manufactured by bending a copper sheet and using a plastic material to insulate both contacts (left) and nine cell receivers mounted on the module front wall. Right: Module filled with fluid and sealed.

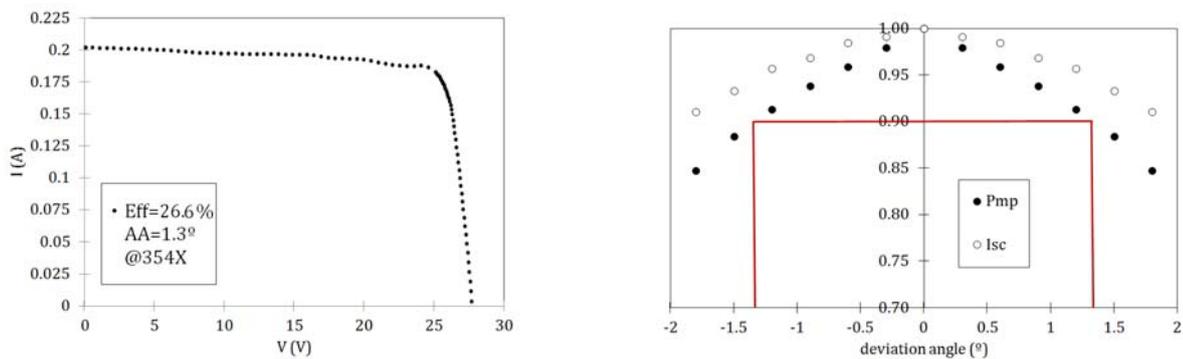


Fig. 35. IV curve (left) and angular transmission curve measured indoors ] for the best performing industrial prototype (named F). The optical mismatch is less than 7 % including electrical dispersion among cells, for manually mounted receivers.

### Conclusions and future research lines

An extensive set of experimental results prove that there is **no fundamental reason that prevents the practical realization of the concept**. The high optical performances predicted by theory were shown to be attainable in practice. In particular a high **optical efficiency of 83.5% at 1035X was measured simultaneously to a  $\pm 0.92^\circ$  acceptance angle**. Since this new concept seems very promising as a means to obtain cheap photovoltaic electricity, future work will be directed towards translating the concept into an entire module. In addition, accelerated degradation experiments must be carried out to guarantee the long term reliability of the materials, or their combinations, that have never being used in photovoltaics before.

parts that will be treated as such by the Commission. Information under Section B that is not marked as confidential will be made available in the public domain thus demonstrating the added-value and positive impact of the project on the European Union.

#### 4.1.4. Potential impact, dissemination activities and exploitation of results.

##### 4.1.4 1. About potential impact (actual or potential impacts have been highlighted in bold)

The Project has already demonstrated an evident impact in the areas of new applications of CPV, development of testing methods for concentrators, creation of normative and technological development, according to the objectives stated in the EU call and in the Grant Agreement.

The work developed in Egypt is the one with clearer socio-economic impact. From one side it is the first stand-alone CPV power plant, which in addition has the double aim of checking the performance in desert areas and simultaneously to develop an irrigation plant absolutely based on PV solar energy.

The experience of the Egypt partner, the NWRC in capture of underground water wells, pumping from deep water level, desalination storage and irrigation has allow to achieve demonstration level results just with the execution of a pure R&D work.

The new application has required more dedicated work than provided from Fraunhofer in order to optimize an ambitious management of CPV energy at the irrigation and fresh water supply station.

The Wadi El Natroon stand-alone power plant is operating as an island AC grid. This allows operating the site with conventional AC loads combining simultaneously Diesel generators, windmills, etc. in the same grid. The station is an example not only for CPV but also for PV in the region. The professional execution of the whole system and the good orientation of the project was documented and spread, at worldwide level, with the documentary "The Photovoltaic Oasis" produced by Euronews channel.

#### **IMPACTS from**

##### **Stand-alone application in desert areas**

- Stand-alone island AC grid managing PV, diesel generator, windmills, etc.
- Confirmed reliability of Soitec CPV in desert areas.
- Opening markets for the CPV application.
- Opening markets in the region.
- Management protocol ready.
- Irrigation and fresh water supply from CPV.
- Operation continuity of station after NACIR termination for R&D and .Demo
- Consolidation of partnership with NWRC (Egypt).

With the results obtained here, Soitec has verified and confirmed the high reliability of this system and unveil the sources of failure in desert areas. Now Soitec is ready for the occupation of the niche of activity related with the crop irrigation and fresh water supply.

The interchange of information with local partner has been significant and very positive for all parts. The keys for operating in the Middle East markets are currently better known thank to the cooperation with NWRC.

Along the four years of the project, Soitec Solar (formerly Concentrix Solar) has

passed technically from modules Gen 2 to Gen 5. From the commercial and industrial points of view, passed from producing few MW to hundreds of MW per year, becoming the number one CPV company.

The cooperation between NWRC (Egypt), Fraunhofer and Soitec has been so satisfactory that the company will continue developing work at the station of Wadi el Natroon after the end of the project. Such decision should increase the opportunities for the spreading of the NACIR results in the region.

In conclusion, we can say that the new application has found solid base and is going to solve real needs. The technology is ready for electricity generation (Soitec), energy management (Fraunhofer) and water supply engineering (NWRC).

Isofoton, the other manufacturing company involved in NACIR is a pioneer in CPV. The company was born manufacturing bifacial cells, previously developed for concentrators. Its research and development activities in concentration have been continuous form the 90's.

A Call for Proposals aiming to promote the CPV technology at worldwide level was opened by ISFOC funded by Central Spanish Administration, Isofoton and Soitec applied and were awarded with the compulsory and stimulating conditions for starting a real production of more than 300kW. Isofoton started a real production for installing a 400kW Power plant in Puertollano (Spain).

Isofotón has been exporting up to 60 countries from its foundation in 1981.

The opportunity for exploring the performance and reliability of its CPV system in remote areas defined its role in NACIR.

A combination of circumstances suggested Morocco as the ideal partner due to the stability of this Country and because the Kingdom is planning and executing large PV electrification as well as expensive experiments in renewable (solar thermal electricity) and wind.

The partnership was established necessarily with the only utility in Morocco; ONE (Organisation National d'Electricite) who become ready for share the CPV experience and rules for grid connection. Although the grid connection is not a "new application", the particularities of the grid, the remote site, the climate, the need for remote control under week communications became the task a true challenge and novelty.

**IMPACTS from  
New CPV application in Morocco:**

- First grid connection of CPV in remote site.
- Operation in weak utility grids.
- Extreme winter conditions (1.700 m) strong wind, lightning, UV radiation.
- Logistics in Magreb.
- Improving high level education: New Master on Renewable Energies at AUI.
- Impact of PV in Morocco administration during RETEM 2012 Conference (Ifrane).
- Regulation for grid connection adopted in ONE.
- Implementation of maintenance routines in CPV by Isofotón

In addition, for compensating the experiment in the sands and glazy sky of Egypt, in Morocco was selected a high altitude site (1.700 m. altitude), with extreme low temperature, wind and high radiation (+high UV)

In addition to the lessons learnt about exportation and logistics in North Africa the continuity of power injection in the grid has been a challenge due to grid instability and lack of protection for the long power line in a region with frequent lightning.

The continuity of communications has been also difficult to maintain resulting in response slower than expected.

The ONE invited the International Al Akhawayn University (AUI) for contributing to the project providing location, support

and infrastructure as well as researching attitude and capacity.

The presence of the University in NACIR opened educational and disseminating opportunities. With respect to education, the course about CPV management to the researcher and engineer technical staff given by Isofotón paved the way for improving the cooperation and the resolution of small problems during operation.

The UPM has the opportunity for presenting a short course to the AVI students and professors.

In addition the influence of NACIR has induced the creation of a MASTER in "management and economics of new energies" which will be directed, in principal, to future decision makers in Morocco and other African countries, because the high prestige of this Anglophone University.

And last, but not the least, the proposal of NACIR management board for organizing a Workshop at AUI (Ifrane) with occasion of the semester meeting on January 2012 become a reality exceeding all imagined,. It became an open Conference called RETEM 2012, which joined very relevant Morocco authorities, from the National Research centers, from Ministries of Industry and Science, and the Director of MASEM, which is the center contracting and installing renewable energies at multi-megawatt levels, etc.

In addition, scientist of Morocco Universities presented their works sharing the sessions with the NACIR partner leaders and other invited speakers.

Isofotón has learned about the tracker defects early unveiled in the conditions of Ifrane, where it has withstood snowing, lighting and winds over 100 Km/h. The feedback from the extreme conditions of the two sites in North Africa (Mediterranean) was one objective of the project

The power plant of 30 KW peak, as rated by the partner ISFOC, after the grid problems and internal failures were identified the system is injecting regularly the grid.

Additional education and scientific contribution of the AUI consisted of the analysis of the CPV module materials evolution under the high UV content of the irradiance at 1700 m. and about the freezing conditions found in winter.

The lessons learn by Isofotón with the installation at Ifrane have decided, as did Soitec in Egypt, to continue using the site installing new generation modules in order to take advantage of the “accelerating” conditions of operation in the ONE-AUI site.

The need for normative and techniques for rating the CPV power, testing components, defining standards and forecasting energy production determined the second block of activity in the project.

The commercial activity requires standards for the mutual protection of manufacturers and customers in economic, business, safety, financial risks, etc.

Conventional PV took 25 years for creating a quasi complete normative around IEC-TC82 Committees.

The CPV technology, in some aspects more complicated than conventional PV, must demonstrate to the market its reliability based on consistent standard assuring energy generation for reaching the necessary bankability.

In such task, several partners of the project are fully and directly involved writing and developing testing programs on module power rating, field testing, solar simulators for CPV and energy production forecast.

For contributing to this line of activity, the first round robin of CPV modules has been carried out in the project.

Secondly, it has been demonstrated the consistence for relating the output power of modules and systems to the available irradiance separated into spectral bands coincident with the absorption of the used MJ cells.

UPM and Fraunhofer developed separately tri-band spectral heliometers. A network registering spectral irradiance in Freiburg, Madrid, Puertollano, Ifrane and Egypt are registered.

After the Tri-band technology developed in NACIR has been transferred to a company; there are 10 additional sensor around the world (included NREL), which suggest a possible increase of the spectral network in near future.

ISFOC has prepared the data management system called GOCPV, which generates reports from the data obtained from the NACIR sites, recorded by different

#### **IMPACTS due to work on Normative, testing and standardization**

- Fast and consolidated method for field rating of CPV plants
- Results from testing at ISFOC, Fraunhofer and UPM are adopted in IEC normative standards.
- Manuscript of standards for module power rating, (indoor and outdoor).
- new CPV solar simulator standard.
- New equipment (hybrid heliometers) for current rating of CPV with MJ cells.
- Helio-meter technology transferred to company for industrialization and commercialization.
- Database and software for exploitation of recorded CPV field data.
- First round robin of CPV modules.
- Determination of the degradation rate of CPV power plants.

equipment (from Soitec, NWRC, Fraunhofer, Isofotón, UPM) in any site. The harmonization of data system and recording rate has been solved at ISFOC.

The CPV database stored in ISFOC is the world most valuable because includes data from seven different technologies in power fields of significant size.

Among such series is important to point out that the degradation CPV systems installed in Puertollano, all made with early generation of modules and trackers is practically negligible, similar to conventional PV plants. This is a conclusion of principal socio-economic information for the progress of CPV, which has become a technology led by Europeans.

The third block of activity in NACIR is devoted to technological progress of the principal components of CPV industry, the modules and de BOS, which is a key for cost reduction and assured performance.

Soitec has industrialized the FLATCOM technology defined by Fraunhofer. They have work together in NACIR for exploring several ways for improving the efficiency and optical performance of current (by 2008) modules.

**IMPACTS due to  
Technological development at Soitec Solar,  
Fraunhofer and UPM:**

- Development of CPV module prototype with new secondary optics
- Increased CAP (gain x acceptance angle) of FLATCON technology on SOE Fresnel lenses.
- Substantial reduction of temperature effect on SoG Fresnel lenses
- Manufacturing y capability passed from 25 to 74 MW/y.
- Company becoming first worldwide.

The FLATCON module technology is one on the most simple, both in number of elements and materials. It uses Silicone on Glass Fresnel lens technology and Multi-Junction cells mounted on simple metallic substrates, which are glued to a back module substrate, also made of glass.

The use of just one refractive optical step provides a low CAP (concentration x acceptance angle product) and consequently a very accurate tracker array and to trim the parallelism of modules mounted in a tracker platform.

Although this one significant difficult

Soitec has solved reasonably the problems derived from the low CAP.

The immediate technical solution is to use two-stage optics, but the preserving reliability simplicity and low cost of the module is not immediate. The efficiency cannot be degraded and the new modules must pass the hard IEC62108 qualification test to assume credible reliability.

Fraunhofer and Soitec have solved the inclusion of a secondary in a brilliant way with a solution which did not reduce efficiency and passed the IECG2108.

A pilot manufacturing has been developed conforming that Soitec has already an alternative module with higher CAP. The evolution of the MJ cell prices will recommend adopting the two-stage optics module of just to increase the size of cells looking for better acceptance angle at constant CAP.

Also after the inclusion of the secondary optics (SOE) the Soitec module is the most simple all CPV market.

In parallel to the adoption of a secondary optics, the appreciable problems associated with the dependence of the SoG Fresnel lens with temperature have become negligible modifying the manufacturing process for better adaptation to module operating temperature in the field.

Soitec was using modules of Generation 2 at the beginning of the project but commercializing today Generation 5. This is a demonstration of the fast learning curve promised by CPV technology in its beginning.

Soitec has been celebrated and received several prizes for its innovation and industrial developments. SOITEC took the opportunity offered by the ISFOC call for consolidating its manufacturing technology and field deployment expertise. It continued with NACIR.

Isofotón was a world pioneer using GaAs solar cells into high gain concentrators using the ultra compact TIR technology. Later TIR optics has been used with MJ cells of very small size.

The NACIR project has contributed directly to the continuity of the CPV line in Isofotón, due to the opportunity of the grant negotiation with the change of company owners in 2008: TIR technology needed to be substituted because it was not the best suited for the new MJ cells and the new prices of module components.

Isofotón has carried out in NACIR the development of a new module with larger cells (100 cm<sup>2</sup>) and consequently larger focal distance.

The principal effort has been devoted, not only on the module design, but also to adaptation of manufacturing capability and instruments to the new size and two-stage optics architecture. This was already provided in the proposal and included as main tasks in the Grant Agreement.

The new module uses the state of the art cells and Fresnel lenses made of SoG with a pyramid glass secondary.

This classic configuration has achieved 24-25% efficiency in the first prototypes while the manufacturing line is ready for 2-4 MW throughputs.

NACIR has restored the confidence of Isofotón headquarters on CPV and the deployment of two demonstration installations, in China and Italy, are positive pre-commercial steps based on the new module developed within the NACIR project.

The adoption of a new tracker, with less expensive components and true reduced cost is reinforcing the return of Isofotón to the CPV world market again.

The visibility obtained with NACIR has contributed to gain such confidence. As stated in the project proposal in 2007, Soitec and Isofotón are still the two leading CPV European companies.

Finally, the technological activity in NACIR has supported the development of a new concentrator module based on reflexive optics at UPM.

The mirrors, which operate with the simplest optical principle, reflection, combine the highest concentration level within compact focal distances. In addition, reflectors do not cause chromatic aberration, which still improves their comparison with lenses.

However the practical solutions adopted classically, present in the current market are made of two mirrors, with a glass sheet in the top, with secondary, insulating cell on carrier and supporting water condensation inside.

UPM decided to eliminate all problems affecting the reflexive CPV modules, using an old experience of the Instituto de Energía Solar who used a fluid as optical element and heat remover.

The called Fluidreflex technology was proposed promising to give 1000X, 1.2° acceptance angle, less than 80°C cell operating temperature and module efficiency at the state of the art using MJ cells.

**IMPACTS from**  
**Technological development at Isofotón and UPM:**

- Design of new module with larger reduced number of components.
- NACIR has inspired the continuity of Isofotón on CPV.
- New tracker development combined with module GEN2 demonstration plants in Italy and China.
- NACIR drove modifications in the module production line adapting for new module (cell area from 2 to 100 mm<sup>2</sup>).
- Production throughput reaches 2-4 MW/y range after NACIR.

The space between the mirror and the cell must be filled with a transparent insulating, stable head conductive and low cost liquid which will carry the heat from the cell to the front and back module surfaces.

Although on the paper the proposal looks excellent, the task scheduled in NACIR was to prove that achieving all required characteristics is possible and compatible with long-term operation, reliability, high efficiency and cost.

As can be seen in previous reports all steps have been demonstrated and the technical solutions achieved, with several Fluidreflex prototypes assembled and tested indoor and outdoor.

Prototypes are passing the IEC 62108 qualification test.

Two patents have been issued. High level of dissemination has been carried out on Fluidreflex with five conferences and three papers in SCI journals.

Conversations with companies are already in course in order to start a pilot line and deploy a demonstration.

This work has contributed to high-level education of young scientists with the preparation of their thesis.

It is a case of success from the theoretical “revolutionary” proposal of a CPV structure to a real operating module.

### IMPACTS due to

#### Development of a new reflexive CPV module technology “Fluidreflex” at UPM

- New reflexive CPV module using fluid as optical and thermal element (patent pending).
- Reflexive CPV module minimizing number of components.
- Maximizing CAP and module thickness with only POE.
- Characterization of suitable liquids for PV applications investigated (published).
- Electrical Interconnection method inside the module (patent pending).
- No longer problems with water condensation.
- All original statements of the invention are demonstrated on prototypes (optical, thermal, UV stability, efficiency, etc).

#### 4.1.4 2. About dissemination of NACIR Project activities and achievements

The dissemination of the whole project has been above average, and circumstantially had the opportunity to be presented to more than 80 press agents at the Shanghai Expo 2011 as the “only” European PV project included in the “Europe-China Technical Week”. We can combine the satisfaction for the high dissemination with the pride of representing world leading PV European science and industry.

#### Dissemination Activities of NACIR Project

- Articles published in scientific journals with peer review: published **8**; to be published **1**.
- Publications in Conferences with revised Proceedings: **34**
- Invited Conferences : **12**
- Workshops : **1**
- Press releases: **5**
- TV documentaries: **1** “**The Photovoltaic Oasis**” by Euronews.
- Videos on FP7 Projects: **NACIR** (by Tipik, EU, May 2013)
- Conferences promoted by NACIR: **1 RETEM12**

The Documentary “The Photovoltaic Oasis” a very professional piece of work produced by Euronews, sound in ten languages has obtained a worldwide diffusion in TV and the web.

The NACIR project has reached a great diffusion in the Maghreb through the conference RETEM 2012 (Jan 2012) organized by the local partner ONE-AUI at Ifrane (Morocco): In this case the diffusion reached regional decision makers on renewable energy planning

The dissemination will continue presenting results at the PV conferences and writing articles not only in scientific journals but also in industrial magazines. The patents issued will be also object of publicity.

#### 4.1.4.3. About Exploitation plans.

The new generation of Soitec modules is already in commercial exploitation at MW level.

##### Number of exploitable items classified by type of

- Current commercial exploitation: 4
- New Product/ Product certified: 10
- Improvement of existing equipment o process: 8
- New methods, new normative, new services; 13

Isofoton is commercializing its new module and tracker.

ISFOC is offering consulting on field-testing and software for Data exploitation.

UPM has transferred the technology of the Tri-band heliometers to a company for industrialization and commercialization (seven equipments are already sold).

The Fluidreflex technology and achievements are currently offered to a couple of companies for starting a demo program.

#### 4.1.5. Address of the project website.

A website has been established on a Server located at the UPM Server. It has a public part used for dissemination of the Project results and a private part used for the partners communication.

The website URL is:

<http://www.ies.upm.es/nacir>

## 4.2 Use and dissemination of foreground

### 4.2.1 Section A

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers <sup>3</sup> (if available)	Is/Will open access <sup>4</sup> provided to this publication?
1	<i>Multijunction Solar Cell Model for Translating I-V Characteristics as a Function of Irradiance, Spectrum and Cell Temperature</i>	<i>César Domínguez</i>	<i>Progress in Photovoltaics Research and Application</i>	<i>Vol 18, N° 4, June 2010</i>	<i>Jhon Wiley &amp; Sons, Ltd</i>	<i>Printed in Singapore by Ho printing Pte Ltd</i>	<i>2010</i>	<i>pp. 272-284</i>	<a href="http://onlinelibrary.wiley.com/doi/10.1002/pip.1145/abstract">http://onlinelibrary.wiley.com/doi/10.1002/pip.1145/abstract</a>	<i>no</i>
2	<i>Energy harvesting efficiency of III-V triple-junction concentrator solar cells under realistic spectral conditions</i>	<i>S.H. Philipps</i>	<i>Solar Energy Materials and Solar Cells</i>	<i>Vol 94, Issue 5, May 2010</i>	<i>Elsevier B.V.</i>		<i>2010</i>	<i>pp 869-877</i>	<a href="http://dx.doi.org/10.1016/j.solmat.2010.01.010">http://dx.doi.org/10.1016/j.solmat.2010.01.010</a>	<i>no</i>
3	<i>Investigations on the temperature dependence on CPV modules equipped with triple-junction solar cells</i>	<i>P. Peharz</i>	<i>Progress in Photovoltaics Research and Application</i>	<i>Vol 19, N° 1, January 2011</i>	<i>Jhon Wiley &amp; Sons, Ltd</i>	<i>Printed in Singapore by Ho printing Pte Ltd</i>	<i>2011</i>	<i>Pp 54-60</i>	<a href="http://onlinelibrary.wiley.com/doi/10.1002/pip.987/abstract">http://onlinelibrary.wiley.com/doi/10.1002/pip.987/abstract</a>	<i>no</i>
4	<i>Two dimensional angular transmission characterization of CPV modules</i>	<i>Rebeca Herrero</i>	<i>Optics Express</i>	<i>Vol 18, Issue 4, Sep. 2010</i>	<i>Optical Society of America</i>		<i>2010</i>	<i>pp.A499-A505</i>	<a href="http://www.opticsinfobase.org/search/2.cfm?reissue=J&amp;journalList=&amp;fullre">http://www.opticsinfobase.org/search/2.cfm?reissue=J&amp;journalList=&amp;fullre</a>	<i>yes</i>

<sup>3</sup> A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

<sup>4</sup> Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

									<a href="#">cord=Two+dimensional+angular+transmission+characterization+of+CPV+modules&amp;basicsearch=Go</a>	
5	<i>Antireflecting coatings for multijunction solar cells under wide-range ray byndles</i>	Marta Victoria	<i>Optics Express</i>	<i>Vol 20 Issue 7 March 2012</i>	<i>Optical Society of America</i>		2012	Pp8136-8147	<a href="http://www.opticsinfobase.org/view/article.cfm?gotourl=http%3A%2F%2Fwww%2Eopticsinfobase%2Eorg%2FDirectPDFAccess%2F14CB9E75%2D9B3F%2DBC33%2D86BFE7EBA%2D7%2D8136%2Epdf%3D%2D1%26id%3D231254%26seq%3D0%26mobile%3Dno&amp;org=">http://www.opticsinfobase.org/view/article.cfm?gotourl=http%3A%2F%2Fwww%2Eopticsinfobase%2Eorg%2FDirectPDFAccess%2F14CB9E75%2D9B3F%2DBC33%2D86BFE7EBA%2D7%2D8136%2Epdf%3D%2D1%26id%3D231254%26seq%3D0%26mobile%3Dno&amp;org=</a>	yes
6	<i>Characterization of the spatial distribution of irradiance and spectrum in cconcentrating photovoltaic systems and their effect on multi-junction solar cells</i>	Marta Victoria	<i>Progress in Photovoltaics Research and Application</i>	<i>Published on line</i>	<i>Jhon Wiley &amp; Sons Ltd</i>	<i>Printed in Singapore by Ho printing Pte Ltd</i>	2011 (Published on line)		<a href="http://onlinelibrary.wiley.com/doi/10.1002/pip.1183/full">http://onlinelibrary.wiley.com/doi/10.1002/pip.1183/full</a>	no
7	<i>Characterization Fluid Reflex Optical Transfer Function</i>	Marta Victoria	<i>Japanese Jopurnal of Applied Physics</i>	<i>Vol 51, n° 10 Issue 2</i>			2012	10ND06	<a href="http://jjap.jsap.jp/journal/JJAP-51-10S.html">http://jjap.jsap.jp/journal/JJAP-51-10S.html</a>  10ND06	yes
8	<i>High concentrator CPV module based on a single stage immersed in an optical fluid</i>	Marta Victoria	<i>Progress in Photovoltaics Research and Application</i>	<i>To be published</i>	<i>Jhon Wiley &amp; Sons Ltd</i>		2012			No
9	<i>Durability of dielectric fluids for concentration photovoltaic systems</i>	Marta Victoria	<i>Solar Energy Materials and Solar Cells</i>	<i>Published on-line</i>	<i>Elsevier B.V.</i>		2013		<a href="http://dx.doi.org/10.1016/j.solmat.2013.01.039">http://dx.doi.org/10.1016/j.solmat.2013.01.039</a>	No

**TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES**

NO.	Type of activities <sup>5</sup>	Main leader	Title	Date/Period	Place	Type of audience <sup>6</sup>	Size of audience	Countries addressed
1	<i>Publication in Congress: 34 th IEEE PVSEC</i>	<i>UPM</i>	<i>A new project on CPV's funded by the European Commission under 7<sup>th</sup> FP's</i>	<i>Jun 7-12, 2009</i>	<i>Philadelphia</i>	<i>Scientific Community, Industry, Policy makers</i>	<i>➤ 1000</i>	<i>All</i>
2	<i>Publication in Congress: 24 th PVSEC</i>	<i>UPM</i>	<i>An European Initiative Dedicated to Cooperation with Mediterranean Partner countries in the Philed of Photovoltaic Concentrators</i>	<i>September 2009</i>	<i>Hamburg</i>	<i>Scientific Community, Industry, Policy makers</i>	<i>➤ 1000</i>	<i>All</i>
3	<i>Publication in Congress: 24 th PVSEC</i>	<i>ISFOC</i>	<i>ISFOC demonstration plants: Rating and production data analysis</i>	<i>September 2009</i>	<i>Hamburg</i>	<i>Scientific Community, Industry, Policy makers</i>	<i>➤ 1000</i>	<i>All</i>
4	<i>Publication in Congress: 24 th PVSEC</i>	<i>Fraunhofer</i>	<i>A theoretical analysis on the energy production of III-V multijunction solar cells under realistic spectral conditions</i>	<i>September 2009</i>	<i>Hamburg</i>	<i>Scientific Community, Industry, Policy makers</i>	<i>➤ 1000</i>	<i>All</i>

<sup>5</sup> A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

<sup>6</sup> A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

5	Publication in Congress: 24 th PVSEC	Fraunhofer	<i>Shaping the angular divergence at sun simulators for concentrator modules</i>	September 2009	Hamburg	Scientific Community, Industry, Policy makers	➤ 1000	All
6	Publication in Congress: 24 th PVSEC	UPM	<i>Comparative analysis of different secondary optical elements: Effective concentration, acceptance angle and light distribution</i>	September 2009	Hamburg	Scientific Community, Industry, Policy makers	➤ 1000	All
7	Publication in Congress CPV-6	Fraunhofer	<i>Temperature coefficient of FLATCON Modules</i>	April 2010	Freiburg	Scientific Community, Industry, Policy makers	➤ 1000	All
8	Publication in Congress CPV-6	Fraunhofer	<i>Evaluation of satellite Cirrus data for Performance models of CPV Modules</i>	April 2010	Freiburg	Scientific Community, Industry, Policy makers	➤ 1000	All
9	Publication in Congress CPV-6	Fraunhofer	<i>Energy harvesting efficiency of III-V Multi-Junction Concentrator Solar Cells under Realistic Spectral Conditions</i>	April 2010	Freiburg	Scientific Community, Industry, Policy makers	➤ 1000	All
10	Publication in Congress CPV-6	UPM	<i>Spectral Solar Radiation Measurement and Models for CPV Module production</i>	April 2010	Freiburg	Scientific Community, Industry, Policy makers	➤ 1000	All
11	Publication in Congress CPV-6	UPM	<i>Optical characterization of Fluid Reflex concentrator</i>	April 2010	Freiburg	Scientific Community, Industry, Policy makers	➤ 1000	All
12	Publication in Congress CPV-6	UPM	<i>Angular transmission characterization of CPV modules based on CCD measurements</i>	April 2010	Freiburg	Scientific Community, Industry, Policy	➤ 1000	All

						makers		
13	Publication in Congress CPV-6	UPM	<i>Indoor characterization of Multijunction Solar Cells under non Uniform Light Patterns</i>	April 2010	Freiburg	Scientific Community, Industry, Policy makers	➤ 1000	All
14	Publication in Congress CPV-6	ISFOC	<i>Evaluation parameters for CPV production</i>	April 2010	Freiburg	Scientific Community, Industry, Policy makers	➤ 1000	All
15	Publication in Congress CPV-6	ISFOC	High Resolution Direct Normal Irradiance Data for testing CPV Plants: ISFOC Database	April 2010	Freiburg	Scientific Community, Industry, Policy makers	➤ 1000	All
16	Publication in Congress CPV-6	ISFOC	<i>First Experiences of ISFOC in the maintenance of CPV plants</i>	April 2010	Freiburg	Scientific Community, Industry, Policy makers	➤ 1000	All
17	Publication in Congress CPV-6	ISFOC	<i>Monitoring, Communications and Data Processing of CPV Plants</i>	April 2010	Freiburg	Scientific Community, Industry, Policy makers	➤ 1000	All
18	Publication in Congress CPV-6	ISFOC	<i>Energy Losses estimations for CPV plants</i>	April 2010	Freiburg	Scientific Community, Industry, Policy makers	➤ 1000	All
19	Publication in Congress 35 <sup>th</sup> PVSEC	Fraunhofer	<i>Promises of Advanced Multijunction Solar Cells for the use in CPV Systems</i>	2010	Hawaii	Scientific Community, Industry, Policy makers	➤ 1000	All
20	Publication in Congress 25 <sup>th</sup> EUPVSEC	UPM	<i>Finite elements model for thermal analysis of FLUIDREFLEX CPV system</i>	September 2010	Valencia	Scientific Community, Industry, Policy makers	➤ 1000	All

21	Publication in Congress 25 <sup>th</sup> EUPVSEC	UPM	<i>Indoor characterization of non uniform light distribution due to concentration optics and it effects on solar cell performance</i>	September 2010	Valencia	Scientific Community, Industry, Policy makers	➤ 1000	All
22	Publication in Congress 25 <sup>th</sup> EUPVSEC	UPM	<i>Applying the IEC Draft Standard for indoor CPV module power rating first experiences</i>	September 2010	Valencia	Scientific Community, Industry, Policy makers	➤ 1000	All
23	Publication in Congress 25 <sup>th</sup> EUPVSEC	Fraunhofer	<i>The world's first CPV stand-alone system- Water supply in remote areas of Egypt</i>	September 2010	Valencia	Scientific Community, Industry, Policy makers	➤ 1000	All
24	Publication in Congress 25 <sup>th</sup> EUPVSEC	ISFOC	<i>Status of CPV Technology</i>	September 2010	Valencia	Scientific Community, Industry, Policy makers	➤ 1000	All
25	Publication in Congress 25 <sup>th</sup> EUPVSEC	ISFOC	<i>Field Technical inspection of CPV Power plants</i>	September 2010	Valencia	Scientific Community, Industry, Policy makers	➤ 1000	All
26	Publication in Congress 25 <sup>th</sup> EUPVSEC	ISFOC	<i>Analysis of inverter configuration on CPV plants</i>	September 2010	Valencia	Scientific Community, Industry, Policy makers	➤ 1000	All
27	Publication in Congress CPV-7, Las Vegas	UPM	<i>FLUID REFLEX Concentrator: From Elementary Unit to Module</i>	2011	Las Vegas	Scientific Community, Industry, Policy makers	➤ 1000	All
28	Publication in Congress 26 <sup>th</sup> PVSECc	Fraunhofer	<i>Spectral Measurement Precision</i>	September 2011	Hamburg	Scientific Community, Industry, Policy	➤ 1000	All

						makers		
29	Publication in Congress 26 <sup>th</sup> PVSECC	Fraunhofer	<i>The World's first CPV, Stand-Alone System- Operating control and field results</i>	September 2011	Hamburg	Scientific Community, Industry, Policy makers	➤ 1000	All
30	Publication in Congress 21 <sup>st</sup> International Photovoltaic Science and Engineering Conference	UPM	<i>High Efficiency Photovoltaic Concentrator using a single reflective stage and a fluid dielectric</i>	Nov-Dec 2011	Fukuoka Japan	Scientific Community, Industry, Policy makers	➤ 1000	All
31	Invited Conference RETEM12	Soitec	<i>Concentrator PV technology: Status and outlook</i>	January 2012	Ifrane, Morocco	Scientific Community, Industry, Policy makers	➤ 100	All, specially Morocco
32	Invited Conference RETEM12	ISOFOTON	<i>The global photovoltaic industry and markets</i>	January 2012	Ifrane, Morocco	Scientific Community, Industry, Policy makers	➤ 100	All, specially Morocco
33	Invited Conference RETEM12	NWRC	<i>PV technology for underground water and desalination in MENA region</i>	January 2012	Ifrane, Morocco	Scientific Community, Industry, Policy makers	➤ 100	All, specially Morocco
34	Publication in Congress CPV-8 Toledo	UPM	<i>Outdoor performance on Fluid Dielectric CPV Modules</i>	April 2012	Toledo, España	Scientific Community, Industry, Policy makers	➤ 1000	All
35	Publication in Congress CPV-8 Toledo	ISFOC	<i>CPV Plants Data Analysis. ISFOC and NACIR Projects</i>	April 2012	Toledo, España	Scientific Community, Industry, Policy makers	➤ 1000	All
36	Publication in Congress	ISFOC	<i>Minimizing the uncertainty in the power rating of modules</i>	September 2012	Franfurth, Germany	Scientific Community, Industry, Policy makers	➤ 1000	All

37	Publication in Congress 6 <sup>th</sup> European Conference on PV-Hybrids and Mini-Grids	Fraunhofer	<i>The NACIR Project: CPV Island System for Water Pumping and Irrigation in Egypt- Energy Management Strategy and Field Results</i>	April 2012	Chambers, France	Scientific Community, Industry, Policy makers	➤ 1000	All
38	Invited Conferences Thin film technologies Summit MENA	NWRC	<i>Description of the NACIR project, objectives and expected outcome</i>	June 2009	Abu Dhabi United Arab Emirates	Scientific Community, Industry, Policy makers	➤ 100	All
39	Invited Conference Immosolar	UPM	<i>Sistemas fotovoltaicos de concentración y el proyecto NACIR en el norte de Africa</i>	October 2009	Málaga, Spain	Scientific Community, Industry, Policy makers	➤ 100	All, specially Spain
40	Invited Conference EU-China Science and Technology week	UPM	<i>Clean power for tomorrow's cities: key innovations in photovoltaic technologies (Project NACIR)</i>	June 2010	Shanghai China	Scientific Community, Industry, Policy makers	➤ 100	All
41	Invited Conference American Chamber of Commerce and Association of Moroccan Professionals in America	ONE-AUI	<i>Renewable energies at AUI</i>	June 2010		Scientific Community, Industry, Policy makers	➤ 100	Morocco and USA
42	Workshop Photovoltaics and nanotechnology	UPM	<i>New applications for CPV: A fast way to improve reliability and technology progress</i>	October 2010	Aix Les Bains, France	Scientific Community	>100	Europe
43	Invited Conference 16 <sup>th</sup> Sede Boqer Symposium on Solar Electricity production	ISFOC	<i>ISFOC: The Spanish Test Center for Concentrator Photovoltaic Systems</i>	February 2010	Boqer, Israel	Scientific Community	>100	All
44	Invited Conference Solar TR1 Conference and exhibition	Fraunhofer	<i>Development of III-V based solar Cells and their applications</i>	April 2010	Ankara, Turkey	Scientific Community, Industry, Policy makers	>100	All

45	Invited Conference CIMTEC 5 <sup>th</sup> Forum on New Materials	Fraunhofer	<i>Characterization of III-V Multijunction Cells and Systems</i>	June 2010	Montecatini Italy	Scientific Community, Industry, Policy makers	>100	All
46	Invited Conference 1 <sup>st</sup> EPIA International Conference on CPV	Fraunhofer	<i>CPV technology Overview – Research and Development</i>	November 2010	Munich, Germany	Scientific Community, Industry, Policy makers	>100	All
47	Invited Conference Zukunftforum	Fraunhofer		May 2011	Berlin, Germany	Scientific Community, Industry, Policy makers	>100	All
48	TV documentaries <a href="http://www.euronews.com/2011/02/23/a-photovoltaic-oasis/">http://www.euronews.com/2011/02/23/a-photovoltaic-oasis/</a>	NWRC	<i>A photovoltaic oasis</i>	January 2011	Wadi el Natroon, Egypt	Civil Society	➤ 10000	All
49	Press Releases <a href="http://www.agenciasinc.es/Noticias/Instalacion-en-Africa-sistemas-de-concentracion-de-energia-solar">http://www.agenciasinc.es/Noticias/Instalacion-en-Africa-sistemas-de-concentracion-de-energia-solar</a>	UPM	Instalarán en Africa sistemas de concentración solar	Febrero 2009		Civil society		All (Spanish language)
50	Press Releases <a href="http://www.lacomarcadepuertollano.com/diario/noticia/2010_01_28/06">http://www.lacomarcadepuertollano.com/diario/noticia/2010_01_28/06</a>	ISFOC	Puertollano acoge a representantes del proyecto NACIR	January 2010	Puertollano, Spain	Civil society		All (Spanish language)
51	Press Releases <a href="http://afrol.exxs.net/es/articulos/36871">http://afrol.exxs.net/es/articulos/36871</a>	ISOFOTON	Marruecos crea su primera planta de concentración solar	November 2010		Civil society		All (Spanish language)
52	Press Releases <a href="http://www.energias-renovables.com/article/fotovoltaica-de-concentracion-en-marruecos-de-la">http://www.energias-renovables.com/article/fotovoltaica-de-concentracion-en-marruecos-de-la</a>	ISOFOTON	Fotovoltaica de concentración de Marruecos de la mano de Isofotón	October 2010		Civil society		All (Spanish language)
53	Press Releases Le Soir	ONE-AUI	Un centre experimental à Al Akhawayn	13, Janvier 2012		Civil society		All (French language)

54	Publication	UPM	<i>Energía solar para el Norte de Africa</i>	April 2009	Revista UPM Page 16	Civil Society, Scientific community		Spain
55	Publication	UPM	<i>Energía Solar para el Norte de Africa,</i>	Juky 2009	Solar News, Vol 22, pages 52-53	Civil Society Scientific community		Spain

#### 4.2.2 Section B

<b>TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.</b>					
Type of IP Rights <sup>7</sup> :	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
Patent	NO		PCT/ES2008/000727	High-gain photovoltaic concentrator with reflective stage inserted into a liquid optical dielectric	UPM
Patent	NO		In progress	Invisible interconnection frame for reflective high concentration system	UPM

<sup>7</sup> A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

## Part B2

TEMPLATE B2 : LIST OF EXPLOITABLE FOREGROUND								
Type of Exploitable Foreground <sup>8</sup>	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application <sup>9</sup>	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Commercial exploitation of R&D results	Penetrate new markets and Build new business opportunities	NO		Pipeline of isolated grid projects world wide created, Pipeline of On-Grid projects in north Afrika created, Partner of Desertec Foundation,	A - Agriculture, forestry and fishing B - Mining and quarrying D - Electricity, gas, steam and air conditioning supply E - Water supply; sewerage; waste management and remediation activities	2012 – 2015	-	Soitec Solar
General advancement of knowledge	New work group for Island market formed , developing background knowledge in Isolated Grids and Systems	NO		New Market segment covered, Pipeline of CPV isolated grid projects can be technically designed	D - Electricity, gas, steam and air conditioning supply	2012 -	-	Soitec Solar
Commercial exploitation of R&D results	CPV System Components adjusted and tested to be desert proof	NO		desert proof tracking solution for arid, dusty regions	D - Electricity, gas, steam and air conditioning supply	2012 –	-	Soitec Solar
Commercial exploitation of R&D results	Cost optimized Module design	NO		Cost optimized Module has been certified and put into production	D - Electricity, gas, steam and air conditioning supply	2011-		Soitec Solar

<sup>19</sup> A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

<sup>9</sup> A drop down list allows choosing the type sector (NACE nomenclature) : [http://ec.europa.eu/competition/mergers/cases/index/nace\\_all.html](http://ec.europa.eu/competition/mergers/cases/index/nace_all.html)

<i>Commercial exploitation of R&amp;D results</i>	<i>Database that centralise the CPV Plants data. Monitoring and analysis of long term operation</i>	<i>NO</i>		<i>GOCVP: management and information system</i>	<i>Engineering activities and related technical consultancy</i>	<i>2011-</i>		<i>ISFOC (owner) CPV manufacturers</i>
<i>Exploitation of R&amp;D results via standards</i>	<i>Characterization methods for CPV systems based in CSOC and spectral correction</i>	<i>NO</i>		<i>CSOC rating procedure</i>	<i>Other research and experimental development on natural sciences and engineering</i>	<i>2009 -</i>		<i>ISFOC and IES-UPM (owner) CPV community</i>
<i>General advance of knowledge</i>	<i>Analysis of system failures</i>	<i>NO</i>		<i>System failures analysis</i>	<i>Engineering activities and related technical consultancy</i>	<i>2010</i>		<i>ISFOC (owner) CPV manufacturers</i>
<i>General advance of knowledge</i>	<i>Method for analysing long performance of CPV systems: degradation analysis</i>	<i>NO</i>		<i>Degradation analysis</i>	<i>Engineering activities and related technical consultancy</i>	<i>2010</i>		<i>ISFOC (owner) CPV manufacturers</i>
Commercial exploitation of R&D results	CPV with highest CAP without SOE	NO		CPV market-Any stand alone or grid connected Manufacturing CPV modules or subcomponents application	D - Electricity, gas, steam and air conditioning supply	2014 –	Patent PCT/ES2000/000727	UPM
Commercial exploitation of R&D results	Method for manufacturing CPV module without electrical insulating layers	NO		CPV module without electrical insulating layers	D - Electricity, gas, steam and air conditioning supply	2014 –	Patent in progress	UPM

Commercial exploitation of R&D results	Procedure for CPV module avoiding vapour condensation	NO		CPV module avoiding vapour condensation	D - Electricity, gas, steam and air conditioning supply	2014 –		UPM
Commercial exploitation of R&D results	Procedure for Single metal CPV receiver substrate for electrical and thermal functionality.	NO		Single metal CPV receiver substrate for electrical and thermal functionality.	D - Electricity, gas, steam and air conditioning supply	2014 –		UPM
Commercial exploitation of R&D results	<i>Proven stability of Ag evaporated layer withing parafine oil</i>	NO		Manufacturing CPV modules or subcomponets	D - Electricity, gas, steam and air conditioning supply	2014–		UPM
Commercial exploitation of R&D results	<i>Proven stability of one type of parafine oil under UV light.</i>	NO		Manufacturing CPV modules or subcomponets	D - Electricity, gas, steam and air conditioning supply	2014 –		UPM
Commercial exploitation of R&D results	<i>Techniques for injecting multi-parabolic mirror with centesimal mm. accuracy</i>	NO		Manufacturing CPV modules or subcomponets	D - Electricity, gas, steam and air conditioning supply - <i>plastic Optics</i>	2014 –		UPM
Commercial exploitation of R&D results	<i>New module RESET-Gen 2 with SoG primary Fresnel and Piramid SOE.</i>	NO		Manufacturing CPV modules or subcomponets	D - Electricity, gas, steam and air conditioning supply	2011 –		ISOFOTON

Commercial exploitation of R&D results	<i>New automated manufacturing line for RESET-GEN2 new CPV module</i>	NO		Manufacturing CPV modules or subcomponents	D - Electricity, gas, steam and air conditioning supply	2012 –		ISOFOTON
Commercial exploitation of R&D results	<i>New module with Passed IEC 62108</i>	NO		Manufacturing CPV modules or subcomponents	D - Electricity, gas, steam and air conditioning supply	2012 –		ISOFOTON
Commercial exploitation of R&D results	<i>Sealing of ALL PMMA CPV module</i>	NO		Manufacturing CPV modules or subcomponents	D - Electricity, gas, steam and air conditioning supply	2014–		UPM
Commercial exploitation of R&D results	<i>Triband spectral heliometer sealed for continuous outdoor operation</i>	NO		<i>Manufacturing sensor devices for CPV market.</i>	D - Electricity, gas, steam and air conditioning supply  <i>Meteorology , solar Ambient preservation, Climatic change</i>	2011 –	<i>Manufacturing licence to a Company</i>	UPM
Commercial exploitation of R&D results	<i>New tracking array based on X-Y turning axis</i>	NO		Manufacturing CPV modules or subcomponents	D - Electricity, gas, steam and air conditioning supply	2012 –		ISOFOTON
Commercial exploitation of R&D results	<i>Proven large secondary dome made of SILICONE</i>	NO		Manufacturing CPV modules or subcomponents	D - Electricity, gas, steam and air conditioning supply <i>_optics, illumination</i>	2012 –		UPM SOITEC ISOFOTON
<i>General advance of knowledge</i>	<i>CPV system operating at highest altitude site</i>	NO		<i>CPV system operating at highest altitude site</i>	D - Electricity, gas, steam and air conditioning supply	2012 –		ISOFOTON

Exploitation of R&D results via standards	<i>Implantation of Spanish Grid connection rules in Moroccan grid</i>	NO		<i>Rules for grid connection in Morocco</i>	D - Electricity, gas, steam and air conditioning supply	2011 –		ISOFOTON
Exploitation of R&D results via standards	<i>Normative for indodor test of CPV modules</i>	NO		<i>Normative for indodor test of CPV modules</i>	<i>Engineering activities and related technical consultancy</i>	2012 –		UPM
Exploitation of R&D results via standards	<i>Normative for power rating of CPV modules</i>	NO		<i>Normative for power rating of CPV modules</i>	<i>Engineering activities and related technical consultancy</i>	2011–		UPM ISFOC
Exploitation of R&D results via standards	<i>Normative for Indoor solar simulators</i>	NO		<i>Normative for Indoor solar simulators</i>	<i>Engineering activities and related technical consultancy</i>	2011 –		UPM ISFOC FRAUNHOFER
Exploitation of R&D results via standards	<i>Methods for fastest rating of CPV arrays on the field.</i>	NO		<i>Methods for fastest rating of CPV arrays on the field.</i>	<i>Engineering activities and related technical consultancy</i>	2011 –		ISFOC UPM
Exploitation of R&D results via standards	<i>Method for calibrating references for a given CPV technology</i>	NO		<i>Method for calibrating references for a given CPV technology</i>	<i>Engineering activities and related technical consultancy</i>	2011 –		UPM
Exploitation of R&D results via standards	<i>Spreading a world network for spectral DNI analysis using Triband Heliometers</i>	NO		<i>world network for spectral DNI analysis using Triband Heliometers</i>	<i>Engineering activities and related technical consultancy</i>	2012 –		ISFOC UPM FRAUNHOFER
Exploitation of R&D results via standards	<i>Definition of a method for thermal characterization of module operating temperature</i>	NO		<i>Method for thermal characterization of module operating temperature</i>	<i>Engineering activities and related technical consultancy</i>	2012 –		UPM ISFOC

<i>General advance of knowledge</i>	<i>First round robin of CPV modules</i>	NO		Rules for round robin of CPV modules	<i>Engineering activities and related technical consultancy</i>	2012 –		<i>ISFOC</i> UPM FRAUNHOFER
<i>General advance of knowledge</i>	<i>Methodology for optimizing the power output trimming the distance from lens to receiver</i>	NO		<i>Methodology for optimizing the power output trimming the distance from lens to receiver</i>	<i>Engineering activities and related technical consultancy</i>	2012 –		UPM
Commercial exploitation of R&D results	<i>Design of three layer AR coating for very wide angular light cones on 3MJ cells</i>	NO		Manufacturing CPV modules or subcomponents	D - Electricity, gas, steam and air conditioning supply	2012 –		UPM
Exploitation of R&D results via standards	<i>Test System for accelerated UV aging at controlled (low) temperature</i>	NO		<i>Test System for accelerated UV aging at controlled (low) temperature</i>	<i>Engineering activities and related technical consultancy</i>	2012 –		UPM

Description of exploitable foreground	Explanation
Penetrate new markets and Build new business opportunities	Purpose: market growth at Soitec Exploit:ation in clasical and new applications of CPV, in all world by Soitec Technology in house, secret Impact: Progress in manufacturing; potential 1Gw/y in 2018
New work group for Island market formed , developing background knowledge in Isolated Grids and Systems	Purpose: market growth at Soitec Exploit:Stand alone applications of CPV, in all world, by Soitec and Fraunhofer Potential: 100Mw/y by 2018
CPV System Components adjusted and tested to be desert proof	Purpose:Reliability of CPV's Exploit: in desertic areas by Soitec Potential: 100Mw/y by 2018
Cost optimized Module design	Purpose:Cost reduction, larger market penetration of CPV Soitec Exploit: world Potential: 1GW/y in 2018
<i>Database that centralise the CPV Plants data. Monitoring and analysis of long term operation</i>	Purpose:Tools for CPV control and maintenance forecast Exploit: Direct services from ISFOC, selling software and equipment Resarch ; convenient continuation Potential: 5 contracts /year after 2014
<i>Characterization methods for CPV systems based in CSOC and spectral correction</i>	Purpose:Tools for CPV control and maintenance forecast Exploit: Certificates for customers Resarch ; convenient continuation Potential: 5 contracts /year after 2014
<i>Analysis of system failures</i>	Purpose:Tools for CPV control and maintenance forecast Exploit: Certificates for customers Resarch ; convenient continuation Potential: 5 contracts /year after 2014
<i>Method for analysing long performance of CPV systems: degradation analysis</i>	Purpose:Tools for CPV control and maintenance forecast Exploit: Certificates for customers Resarch ; convenient continuation Potential: 5 contracts /year after 2014

Description of exploitable foreground	Explanation
CPV with highest CAP without SOE	Purpose: Lower cost CPV module. Easier mounting and transportation. IRP: patented Exploit: Manufacturing after demonstration period of 2 years. Research and Demo required with industrial partner Potential: 100Mw/y in 2020
CPV module without electrical insulating layers	Purpose: Lower cost module Exploit: Increased reliability. Potential: more bankability
CPV module avoiding vapour condensation	Purpose: more reliable CPV modules Exploit: Increased reliability. Potential: better bankability, more energy production
Single metal CPV receiver substrate for electrical and thermal functionality.	Purpose: Simplify CPV receiver, Lower temperature lower costs Lower cost CPV module. IRP: patented Exploit: Manufacturing after demonstration period of 2 years. Research and Demo required with industrial partner Potential: better bankability
<i>Proven stability of Ag evaporated layer withing parafine oil</i>	Purpose: Higher reflectivity .Higher module efficiency lower cost. Research and aging Demo required. Potential: 1: not quantified.00Mw/y in 2020
<i>Proven stability of one type of parafine oil under UV light.</i>	Purpose: Optical and thermal function: Creating new Simplify CPV receiver, Lower temperature lower costs Lower cost CPV module. Exploit: In Fluidreflec fabrication and Hybrid PV. Potential: In luidrefelx 100Mw/y or 10M liters /y
<i>Techniques for injecting multi-parabolic mirror with centesimal mm. accuracy</i>	Purpose: Low cost primary optics for CPV Exploit: Know how on injection molding with optical quality: It is a scarce know how. Research necessary. Potential: technology useful for Fluidreflex and other CPV's.
<i>New module RESET-Gen 2 with SoG primary Fresnel and Piramid SOE.</i>	Purpose: Low cost reliable CPV module Exploit: Manufacturing and commercialization by Isofoton. Potential: capacity 2-4 Mw/y in 2013

Description of exploitable foreground	Explanation
<i>New module with Passed IEC 62108</i>	Purpose: Assuring quality and bankability of Isofoton CPV systems Exploit: Access to market and loans.
<i>Sealing of ALL PMMA CPV module</i>	Purpose: Leakage free monolithic PMMA modules. Exploit: Manufacturing and commercialization confirmed. Potential: Reliability and feasibility of new Fluidreflex modules
<i>Triband spectral heliometer sealed for continuous outdoor operation</i>	Purpose: New Device for correct rating of MJ cells and CPV Systems with MJ cells. Exploit: Technology licensed to a manufacturing company. Calibration at UPM. Research : additional necessary for generation 2.. Potential: 10 Sensors(year in 2014 an successive).
<i>New tracking array based on X-Y turning axis</i>	Purpose: Significant cost reduction of tracker by drastic reduction of components number. Exploit: Exclusive for Isofoton, A use in new commercial plan.Know how on injection moulding with optical quality: It is a scarce know how. Research necessary: reliability checkout. Potential:100 MW/year by 2018
<i>Proven large secondary dome made of SILICONE</i>	Purpose: to increase the Gain factor x acceptance angle (CAP) for Soitece module. Exploit: better module, easier alignment in arrays, more energy generation. Potential: depending of cell price evolution adopted in all production or not.
<i>CPV system operating at highest altitude site</i>	Purpose: demonstration for operation in extreme cold windy weather. Exploit: confidence for business in high altitude sites. Potential: widening CPV market and confirming qualification and bankability.
<i>Implantation of Spanish Grid connection rules in Moroccan grid</i>	Purpose: Harmonization of rules for commercial and cooperation purposes Exploit: Sharing of normative among utilities Potential: Difficult quantification
<i>Normative for indoor test of CPV modules</i>	Purpose: improving technical and commercial CPV development Exploit: Normative and standards are unavoidable for business growth. Used by all everywhere Potential: Necessary for market development.
<i>Normative for power rating of CPV modules</i>	Purpose: improving technical and commercial CPV development Exploit : Normative and standards are unavoidable for business growth. Used by all everywhere Potential: Necessary for market development

Description of exploitable foreground	Explanation
<i>Normative for Indoor solar simulators</i>	Purpose: improving technical and commercial CPV development Exploit: : Normative and standards are unavoidable for business growth. Used by all everywhere Potential: Necessary for market development.
<i>Methods for fastest rating of CPV arrays on the field.</i>	Purpose: improving fair and dynamic commercial activity. Exploit: Service offered by ISFOC to all, international CPV. Potential: Rating 100Mw/year is possible after 2018
<i>Method for calibrating references for a given CPV technology</i>	Purpose: improving technical and commercial CPV development Exploit: : Normative and standards are unavoidable for business growth. Used by all everywhere Potential: Necessary for market development.
<i>Spreading a world network for spectral DNI analysis using Triband Heliometers</i>	Purpose: Facilitate energy forecast for CPV in any climatic region. Exploit: Better and easier business for Soitec and Isofoton. Potential: Contribution to business based on energy supply of CPV's. Envisaging 20% market increase
<i>Definition of a method for thermal characterization of module operating temperature</i>	Purpose: Facilitate energy forecast for CPV in any climatic region. Exploit: Better and easier business for Soitec and Isofoton. Potential: Contribution to business based on energy supply of CPV's. Envisaging 20% market increase
<i>First round robin of CPV modules</i>	Purpose: improving technical and commercial CPV development Exploit: : Normative and standards are unavoidable for business growth. Used by all everywhere Potential: Necessary for market development.
<i>Methodology for optimizing the power output trimming the distance from lens to receiver</i>	Purpose: increase power of modules, lower cost, with methodology during research and demo. Exploit: technology offered to companies by UPM and Fraunhofer to any manufacturer. Potential: allow contracts with new companies or new prototypes: Optimization, certification and consulting. (2 to 4 contracts per year) Necessary for market development.
<i>Design of three layer AR coating for very wide angular light cones on 3MJ cells</i>	Purpose: Optimize efficiency of cells for any CPV module architecture Exploit: : custom design of AR cell layers Potential: Designing service for new comer companies and new prototypes. 1 to 2 design per year at UPM
<i>Test System for accelerated UV aging at controlled (low) temperature</i>	Purpose: Better certification of reliability, very limited up today. Exploit: : Provide service to manufacturers from UPM Potential: Reliability vs. UV radiation better assured: Capacity for 2-3 cycles/year at UPM..

## 4.3 Report on societal implications

### B. Ethics

<b>1. Did your project undergo an Ethics Review (and/or Screening)?</b>	No
<b>If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final reports?</b>	
<b>2. Please indicate whether your project involved any of the following issues :</b>	
<b>RESEARCH ON HUMANS</b>	
<b>Did the project involve children?</b>	No
<b>Did the project involve patients?</b>	No
<b>Did the project involve persons not able to consent?</b>	No
<b>Did the project involve adult healthy volunteers?</b>	No
<b>Did the project involve Human genetic material?</b>	No
<b>Did the project involve Human biological samples?</b>	No
<b>Did the project involve Human data collection?</b>	No
<b>RESEARCH ON HUMAN EMBRYO/FOETUS</b>	
<b>Did the project involve Human Embryos?</b>	No
<b>Did the project involve Human Foetal Tissue / Cells?</b>	No
<b>Did the project involve Human Embryonic Stem Cells (hESCs)?</b>	No
<b>Did the project on human Embryonic Stem Cells involve cells in culture?</b>	No
<b>Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?</b>	No
<b>PRIVACY</b>	
<b>Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?</b>	No
<b>Did the project involve tracking the location or observation of people?</b>	No

### RESEARCH ON ANIMALS

<b>Did the project involve research on animals?</b>	No
<b>Were those animals transgenic small laboratory animals?</b>	No
<b>Were those animals transgenic farm animals?</b>	No
<b>Were those animals cloned farm animals?</b>	No
<b>Were those animals non-human primates?</b>	No
<b>RESEARCH INVOLVING DEVELOPING COUNTRIES</b>	
<b>Did the project involve the use of local resources (genetic, animal, plant etc)?</b>	No
<b>Was the project of benefit to local community (capacity building, access to healthcare, education etc)?</b>	No
<b>DUAL USE</b>	
<b>Research having direct military use</b>	No
<b>Research having potential for terrorist abuse</b>	No

## C. Workforce Statistics

**3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).**

Type of Position	Number of Women	Number of Men
Scientific Coordinator	2	6
Work package leaders	3	6
Experienced researchers (i.e. PhD holders)	1	10
PhD student	4	2
Other	1	18

<b>4. How many additional researchers (in companies and universities) were recruited specifically for this project?</b>	6
<b>Of which, indicate the number of men:</b>	3

## D. Gender Aspects

<b>5. Did you carry out specific Gender Equality Actions under the project ?</b>	Yes
<b>6. Which of the following actions did you carry out and how effective were they?</b>	
<b>Design and implement an equal opportunity policy</b>	Effective
<b>Set targets to achieve a gender balance in the workforce</b>	Effective
<b>Organise conferences and workshops on gender</b>	Not Applicable
<b>Actions to improve work-life balance</b>	Effective
<b>Other:</b>	
<b>7. Was there a gender dimension associated with the research content - i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?</b>	No
<b>If yes, please specify:</b>	

## E. Synergies with Science Education

<b>8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?</b>	Yes
<b>If yes, please specify:</b>	Open days
<b>9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?</b>	Yes

## F. Interdisciplinarity

<b>10. Which disciplines (see list below) are involved in your project?</b>	
<b>Main discipline:</b>	2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]
<b>Associated discipline:</b>	5.3 Educational sciences (education and training and other allied subjects)
<b>Associated discipline:</b>	1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology,

palaeoecology, other allied sciences)

## G. Engaging with Civil society and policy makers

<b>11a. Did your project engage with societal actors beyond the research community? (if 'No', go to Question 14)</b>	Yes
<b>11b. If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?</b>	Yes, in communicating /disseminating / using the results of the project
<b>11c. In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?</b>	No
<b>12. Did you engage with government / public bodies or policy makers (including international organisations)</b>	Yes, in communicating /disseminating / using the results of the project
<b>13a. Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?</b>	Yes - as a secondary objective (please indicate areas below - multiple answer possible)
<b>13b. If Yes, in which fields?</b>	
<b>Agriculture</b>	Yes
<b>Audiovisual and Media</b>	No
<b>Budget</b>	No
<b>Competition</b>	No
<b>Consumers</b>	No
<b>Culture</b>	No
<b>Customs</b>	No
<b>Development Economic and Monetary Affairs</b>	No
<b>Education, Training, Youth</b>	No
<b>Employment and Social Affairs</b>	No
<b>Energy</b>	Yes
<b>Enlargement</b>	No
<b>Enterprise</b>	No
<b>Environment</b>	Yes
<b>External Relations</b>	No
<b>External Trade</b>	No
<b>Fisheries and Maritime Affairs</b>	No
<b>Food Safety</b>	Yes
<b>Foreign and Security Policy</b>	No

<b>Fraud</b>	No
<b>Humanitarian aid</b>	No
<b>Human rights</b>	No
<b>Information Society</b>	No
<b>Institutional affairs</b>	No
<b>Internal Market</b>	No
<b>Justice, freedom and security</b>	No
<b>Public Health</b>	No
<b>Regional Policy</b>	No
<b>Research and Innovation</b>	Yes
<b>Space</b>	No
<b>Taxation</b>	No
<b>Transport</b>	No
<b>13c. If Yes, at which level?</b>	

## H. Use and dissemination

<b>14. How many Articles were published/accepted for publication in peer-reviewed journals?</b>	8
<b>To how many of these is open access provided?</b>	2
<b>How many of these are published in open access journals?</b>	2
<b>How many of these are published in open repositories?</b>	2
<b>To how many of these is open access not provided?</b>	6
<b>Please check all applicable reasons for not providing open access:</b>	
<b>publisher's licensing agreement would not permit publishing in a repository</b>	Yes
<b>no suitable repository available</b>	No
<b>no suitable open access journal available</b>	No
<b>no funds available to publish in an open access journal</b>	No
<b>lack of time and resources</b>	No
<b>lack of information on open access</b>	No
<b>If other - please specify</b>	
<b>15. How many new patent applications ('priority filings') have been made? ("Technologically unique": multiple applications for the same invention in</b>	1

different jurisdictions should be counted as just one application of grant).

16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).

Trademark

0

Registered design

0

Other

0

17. How many spin-off companies were created / are planned as a direct result of the project?

1

Indicate the approximate number of additional jobs in these companies:

3

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

Increase in employment, In small and medium-sized enterprises

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (FTE = one person working fulltime for a year) jobs:

0Difficult to estimate / not possible to quantify

## I. Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

No

22. Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

Press Release

Yes

Media briefing

Yes

TV coverage / report

Yes

Radio coverage / report

No

Brochures /posters / flyers

No

DVD /Film /Multimedia

Yes

Coverage in specialist press

Yes

Coverage in general (non-specialist) press

No

Coverage in national press

No

<b>Coverage in international press</b>	Yes
<b>Website for the general public / internet</b>	Yes
<b>Event targeting general public (festival, conference, exhibition, science café)</b>	Yes
<b>23. In which languages are the information products for the general public produced?</b>	
<b>Language of the coordinator</b>	Yes
<b>Other language(s)</b>	Yes
<b>English</b>	Yes

<b>Attachments</b>	
<b>Grant Agreement number:</b>	226409
<b>Project acronym:</b>	NACIR
<b>Project title:</b>	NEW APPLICATIONS FOR CPV'S: A FAST WAY TO IMPROVE RELIABILITY AND TECHNOLOGY PROGRESS
<b>Funding Scheme:</b>	FP7-CP-SICA
<b>Project starting date:</b>	01/01/2009
<b>Project end date:</b>	31/12/2012
<b>Name of the scientific representative of the project's coordinator and organisation:</b>	Prof. GABRIEL SALA UNIVERSIDAD POLITECNICA DE MADRID
<b>Name</b>	
<b>Date</b>	

This declaration was visaed electronically by Gabriel SALA (ECAS user name nsalasga) on