PROJECT FINAL REPORT

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[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

Executive summary

Although being a relatively old and proven technology, concentrating solar is not yet widespread, with a global cumulative capacity of less than 5 GW at the end of 2016, about 0.6% of global cumulative non-hydro renewable electricity capacity. Reaching a higher penetration requires a mix of technological progress, policy support and industrial capacity. One important aspect is related to the accurate forecast of the incident irradiance, as this increases the efficiency of power plants and allows a better management of the electricity generated and connected to the grid. Before DNICast, several techniques were applied but the uncertainty was still too large. There was a lack of best practices on how to optimally merge forecasts from different providers with their different uncertainty characteristics. Furthermore, there was a lack of knowledge on how to quantify the uncertainty and how to deal with the existing uncertainty. In particular, there was nearly no peer-reviewed or grey literature on the accuracy obtained by DNI forecasting methods at various locations and for the time range up to 6 hours, the so-called "nowcasting."

To address this research gap, in October 2013 a multidisciplinary consortium of 12 partners initiated the FP7 "DNICast" project. The aim of DNICast ("Direct Normal Irradiance Nowcasting methods for optimized operation of concentrating solar technologies") was to establish a portfolio of innovative methods for the nowcast of DNI. The resulting information on how to optimally combine various nowcasting methods will help advance current state-of-the-art.

The DNICast project brought a series of innovative components, which can be clustered in terms of methodological progress, geographical extension and a participatory approach through the involvement of stakeholders and potential end-users.

In DNICast, methods based on information from several different sources such as ground based, all sky imagers, satellites and Numerical Weather Prediction (NWP) models have been used in an integrated way to offer more reliable DNI estimates that fulfil the requirements for the application in the field of CST. These mentioned methods have different time and spatial resolutions, and there is no single approach valid at all desired scales. Therefore a combination is needed. The project aim was to provide an approach on how to merge different sources depending on the user needs and the plant characteristics. This helps make practical use of several forecasts provided operationally by various institutions and companies, each own having its strengths and weaknesses.

To validate several methods against references, accurate ground measurements of DNI and aerosol and cloud properties have been collected for sites located in the geographical areas of interest for the implementation of CST. Metrics proposed by EU-funded and other international research projects have been used. Overall, the accuracy of 10 different methods, provided by 4 institutes, has been tested against quality controlled ground measurements of DNI for nowcast lead times ranging from 0 to 360 minutes and at various locations. The reference data set used for validation is made of ground measurements of DNI collected at 15 stations in Western Europe, as well as the Middle East and North African (MENA) region, which are currently of interest for CSP plants.

Throughout the 4 years of the project implementation, the DNICast consortium has followed an integrative approach by bringing together specialists of different working fields. The direct contact with potential users of the nowcasting tools (e.g.: plant operators) as well as with companies providing measurement and data services for the solar industry was also part of the consortium's approach. Key research and industrial actors have been involved as members of the Advisory Board.

A comprehensive dissemination package has been prepared to promote project activities via several communication tools, including the project website, newsletters, webinars and informative papers. DNICast consortium members have provided almost 60 oral presentations and more than 18 poster presentations at some 30 conferences, submitted 16 papers to scientific journals, organised three end-user workshops and 3 dissemination events, including the final project workshop.

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Summary description of project context and objectives

The FP7 DNICast project aims to advance current state-of-the-art of concentrating solar technologies by reducing uncertainty and providing guidelines on how to deal with the remaining uncertainty of short-term DNI forecasts and thereby contributing to increase the overall plant efficiency. Since October 2013, a multidisciplinary consortium of meteorological scientists, solar engineers and energy analysts, has investigated different methods for DNI nowcasting, with the aim to identify main advantages and drawbacks and suggest possible combinations depending on the user requirements. The project aimed to provide a portfolio of complementary methods for the nowcasting of the DNI and their combinations in order to cover the complete nowcasting horizon from now to 6 hours. A full market readiness of all methods was beyond the scope of the project. All DNICast nowcast methods were evaluated individually for several years and geographical locations. But furthermore, they were used in an integrated way to offer more reliable DNI estimates for application in the field of CST. Methods to merge nowcasts from various methods giving different results for the individual nowcast, and dealing with the jumpiness between one nowcast and the next nowcast were in the focus. Therefore, DNICast provides knowledge on an improved industrial usage of nowcasts as offered routinely by various providers today or in future. Project results have been extensively discussed with a large number of experts, including the members of the Advisory Board, recipients of the project newsletter and several other experts gathered through end-user workshops, bilateral consultations and other DNICast events.

Context

Concentrating solar technologies (CST) have proven to be very efficient sources of "clean" power for the electrical grid. They include both concentrating solar power (CSP), and concentrating photovoltaics (CPV). The direct component of the solar radiation which is received on a surface normal to the sun rays is powering the CST. It is called direct normal irradiance and abbreviated in DNI. The DNI is very sensitive to aerosol (suspended particulate matter) load in the atmosphere. The greater the load, the less the DNI. The various types of aerosols (coarse particle sand/dust and sea salt or, fine particle sulphates, nitrates, black carbon and organics) do not exhibit the same optical properties: some offer greater forward scattering than the others and therefore, reduce DNI less than others. The DNI is strongly attenuated by water clouds. Cirrus ice clouds have more complex interactions with the DNI: they usually deplete the DNI but at times may enforce it by increased forward scattering. DNI exhibits more variability in space and time than the global radiation.

The efficient operation of CST requires reliable forecasts of the incident irradiance for two main reasons. First, forecasts offer the possibility for better management of the thermodynamic cycle because it becomes possible to dynamically fine tune some of its parameters such as the flow rate of the working fluid or the defocusing mirrors. Second, electricity production can be better connected to the grid if forecasts are more accurate.

Plant and grid operators have defined two forecast windows of interest: very short term: 1 – 45 min, and short term: 45 – 360 min. For such short forecasting windows the term 'nowcast' is used.

Currently, several nowcasting techniques are used. One way is to use the output from numerical weather prediction (NWP) models. Such mathematical models predict the weather based on the current weather condition as an initial state. The process of entering observations into the model to estimate the initial state is called data assimilation. However, small changes in the initial conditions can cause large deviations in the resulting prediction. Hence, ensemble forecasting methods are used to try to forecast the probability distribution of the weather. This is done by producing a number of ensemble members representative of the possible future states of the atmosphere. These ensemble members are generated by running the model using slightly different initial conditions and/or model formulations.

Depending on the coverage, NWP models can be divided in global and limited-area models. Due to the high computational costs, resolutions of a few kilometres and explicit modelling of convection can only be obtained with limited-area models.

Satellite data also enable DNI forecasting since images from geostationary satellites clearly depict clouds which can be identified at a high time frequency, one image every 15 min over Europe and Africa, or every 5 min if limited to Europe. Cloud movements can be deduced from a series of such images by the means of optical flow techniques. Further movements are predicted using e.g., persistence, or wind fields from NWPs yielding a forecast field of clouds or any parameter related to cloud optical properties, which enters a model for the extinction of the direct component of the solar radiation. The technique may be calibrated on past events if ground-based measurements of the DNI are available for this location in real time.

Other techniques use instruments as All-Sky Imagers which are cameras equipped with a fish-eye lens looking upwards. They can acquire information of the cloud conditions directly from the ground with a high sampling rate and local resolution. By using various cameras and additional ceilometers the cloud position and the resulting DNI can be determined more accurately. The movement of the clouds in the last minutes can be used to forecast their position and the corresponding DNI.

Other approaches deal with statistical analysis of ground-based measurements of the DNI or energy yield in order to derive a statistical predictor of the DNI or yield. The statistical forecast of DNI can be well suited for a single location but cannot represent the spatial heterogeneity that can be found in the DNI field over a few square kilometers. Figure 1 gives a schematic representation of the various time-space scales that are involved in the afore-mentioned nowcasting methods.

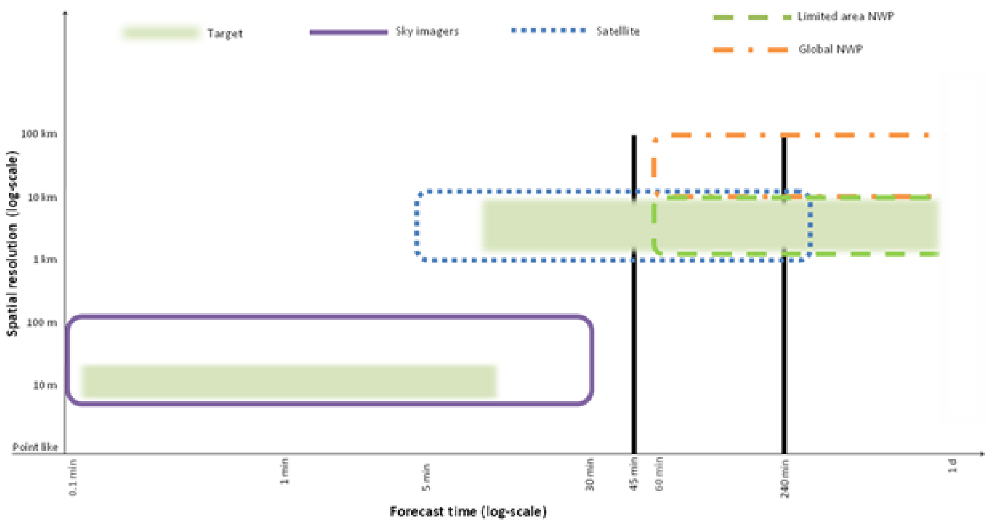


Figure 1: Schematic representation of the various time-space scales involved in the revised nowcasting methods

Concept of DNICast

The concept of the DNICast project is that the various approaches tested up to now have their merit and deserve consideration in an improved approach to DNI forecast. Situations of CST plants are diverse, and a unified approach is not the most appropriate answer to all cases. A “one fit all” forecast system may be too complicated in many cases and may not be accepted by potential users from the energy sector. Therefore, DNICast proposes a concept of a portfolio of innovative or improved methods that can be assembled by company experts to answer the specific needs of a given plant. DNICast also provides innovative knowledge on optimally combining nowcasts from different sources and how to deal with deviations between nowcasts from different providers and the jumpiness in nowcasts from one nowcast to the next in time. These are important strategies to deal with the imperfectness of any nowcast. The accuracy of nowcasts was improved, but there is a fundamental restriction in nowcasting cloud systems due to their chaotic nature. Therefore, DNICast goes beyond the strategy to improve the single nowcast. DNICast suggested several approaches to deal with the still remaining, significant nowcasting errors. The portfolio of validated methods and their combinations are the central result of DNICast. The DNICast approach is summarised in Figure 2.

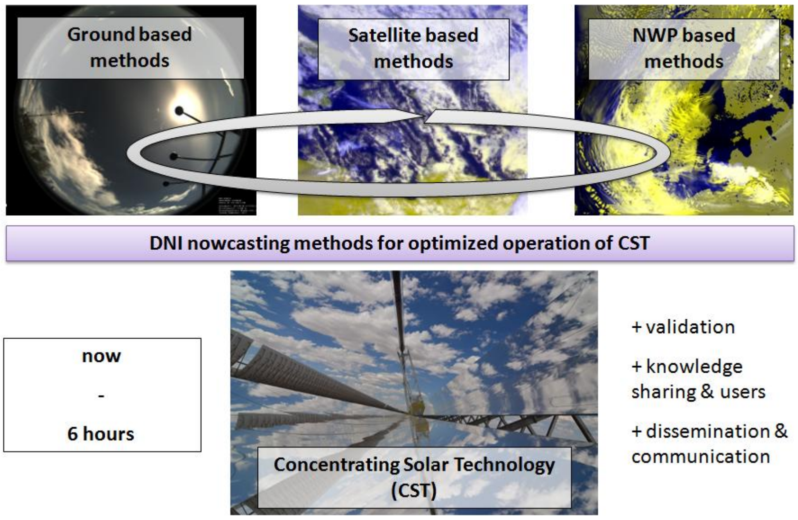


Figure 2: The DNICast approach

The DNICast consortium follows an integrative approach by bringing together specialists of different working fields. The direct contact with potential users of the nowcasting tools is also part of the consortium's approach. Such potential users are e.g. plant and grid operators, which have expressed their interest in applying the project results in their forecasting systems. Also, companies providing data/measurement services have been largely involved, as the development of nowcasting methods is of interest to them. In this way, the project looks at fostering dialogue between researchers and practitioners, and favour potential new partnerships.

Objectives

The main objectives of DNICast are:

i) to establish a portfolio of innovative methods for the nowcasting of the DNI, valid for a portion of the space defined by "time horizon – space resolution – space coverage",

ii) to validate the nowcasts, and to assess the influence of improvement in DNI nowcasting on nowcasting of CST and CPV plant output, and

iii) to involve potential users of the nowcasting methods. Proper dissemination and exploitation of project activities and results is a key component of DNICast, also through the involvement of the wider community in a constant interaction and consultation mode.

The project developments build upon various advanced, state-of-the-art technologies, methodologies, models and measurements from the field of energy meteorology, with the aim to achieve higher accuracy and reliability. The combination of all methods will fulfil the requirements for nowcasts for CST. Within these overarching objectives, several sub-objectives are derived. These are summarised in Table 5 in the Annex section (page 60).

Progress beyond the state-of-the-art

The DNICast project brings a series of innovative components, which can be clustered in terms of methodological progress, geographical extension and participatory approach. In terms of methodological progress, the following achievements are listed by topic.

- Requirements for DNI nowcasting

A report was prepared on DNI nowcasting requirements, which collects the inputs from power plant operators, solar system designers and electricity grid operators. The requirements strongly depend on the specific application and therefore cover a wide range of values. A distinction is made between nowcasting of plant-area averaged DNI values (with no information on the spatial resolution of direct normal irradiance across the solar field) and a nowcast of a spatially resolved DNI map over the plant area. The compilation of nowcasting applications reveals that typically, a spatially averaged DNI value is sufficient for one plant. However, applications with high accuracy demands need for spatial resolution. Such nowcastings can be used to improve operation of the plant on a basis of seconds to 60 minutes. Inaccuracies in the nowcasting can lead to severe penalties thus accuracy has to be high in order to be at a conventional control approach.

With regards to the aerosol optical properties, one task that is selected here as an example, demonstrated the effectiveness of sky cameras in estimating the AOD. A novelty of the proposed method is the use of the saturated area around the sun for the calculation of AOD. Both the RGB intensities at the zenith point and the percentage (%) area of saturation are taken into account in a multi-linear approach to estimate the AOD values at 440, 500 and 675nm and compared with the measurements of the CIMEL radiometer at the same wavelengths. It is found that small-scale dust outbreaks influence AOD locally. Coarse resolution forecasting systems based on satellite observations or large scale modelling may not be sufficient to capture these events. Also the uncertainty of lower resolution aerosol data has been assessed. Finally, concerning circumsolar radiation, a module for the calculation of circumsolar ratios has been developed from different nowcasting data.

- Nowcasting methods

DNICast contributed to improve the accuracy of CST nowcasting methods. An innovative configuration of 4 All-Sky Imagers was combined with a network of pyranometric stations and a ceilometer. This setup allowed deriving new products: 3D-map of clouds and AOD, cloud height and cloud type segmentation, shadow maps, real-time DNI mapping and short-term DNI forecasts. For satellite-based nowcasting a number of new methods were investigated and advanced with respect to cloud position and movement as well as DNI calculations. A new variability classification for both station and satellite data was introduced.

For NWP, progress was achieved using both 3D and 4D-Var experiments with SEVIRI assimilation, cloud initialisation and ensemble-based data assimilation. Utilisation of raw radiances from the SEVIRI instrument was demonstrated to improve the humidity, cloud and precipitation short-range forecasts. For all methods, an important aspect is that considering spatial and temporal aggregation effects melts down errors; these relations should not be ignored as they are very relevant for industry. Overall, method proved to be more effective than the others, as results are strongly site-dependent. Also, nowcasts are highly variable, therefore a merger of consecutive nowcasts is recommended in the industrial practice, together with the use of an ensemble nowcast or a variability interval estimate. Indeed, the combination of several nowcasting methods leads to more accurate results. Also, another methodological contribution is related to post-processing, which proves to correct systematic errors in the NWP- and satellite-based forecasts.

- Method validation

A strong dependence of the models performances is found with the station, both in terms of error magnitude and evolution of this error with lead time. It was therefore necessary to choose a validation approach dealing with this issue. The first step consisted in preparing a “performance summary sheet” for each pair of model and stations; then, a qualitative comparison model was developed in order to link the performances of each model with the structure and input data used. This interpretation can be valuable for forecast providers to improve their nowcasting model. Finally, an attempt has been made to identify critical issues in forecasting the DNI, by identifying and quantifying the different sources of uncertainty of the different models. This can indicate which module of the forecast system can be improved and quantify such improvement. However, an important message to industry is that under current state-of-the art even with the best measurement techniques, a 1-2% uncertainty is unavoidable. Finally, the potential revenue increase of CST plants due to the application of different forecasting information was calculated.

Main S&T results/foregrounds

The rationale for the DNICast project builds upon the need for more accurate DNI short-term forecasts. In this respect, the first step was to define the requirements for the nowcasting methods, covering both CSP and CPV technologies. As well, the requirements for the cloud descriptions and the aerosol properties are an important component of this task. Based on this preliminary work, a variety of complementary methods for the nowcasting of DNI that cover different parts of the window from 1-360 min has been developed and combined together. This will allow end-users to assemble them based on the specific needs of the plant. These methods have then been validated. For this, a measurement grid with several stations was used in order to achieve the same spatial resolution than the nowcasted model output. Ground measurement data were collected for validation. Furthermore, in order to assess the influence of the improvement in the DNICast nowcasting on the nowcasting of CSP and CPV plant output, CST plant simulations were performed. As the aim of the project was not only to contribute to methodological progress but also to provide exploitable results for the industry, constant dialogue with potential end-users has been ensured. In particular, three end-user workshops were organised. Also, a web demonstrator has been set up at the end of the project. The project produced about of 400-thousand files of point forecast data from the various methods used within the project. The idea of the web-demonstrator is to set up an interface to browse through the various forecast data sets in an interactive way and to develop illustrations which help to visualize the forecasting results. Below a description of the results achieved by WP is given.

WP2: Prerequisites for nowcasting method development

WP2 main objectives were to define the requirements for a CST nowcasting system, and to provide the necessary information on aerosol and circumsolar radiation for the nowcasting method development. To fulfil these objectives, the WP was structured into 3 main tasks:

- WP2.1 Definition of the requirements of the nowcasting methods for CST
- WP2.2 Near-real-time aerosol monitoring and very short term forecasting
- WP2.3 Forecasting of circumsolar radiation

- Summary of activities conducted

The first step was the definition of requirements of nowcasting methods for concentrating solar technologies which shall serve as a basis for the development of the nowcasting methods. The focus was both on concentrating solar thermal and concentrating photovoltaic plants. Also requirements for the cloud description (e.g. cloud classification, extinction, velocity, height) and aerosol properties had to be defined. A comprehensive report on the requirements of nowcasting systems has been compiled by DLR and CIEMAT. The report (D2.1) was completed in March 2014 and presented at the First End User Workshop held in Madrid on May 7th, 2014 and at the DNICast project meeting held in Paris on July 10th and 11th, 2014. After a chapter on the fundamentals, the question "*How does nowcasting help to operate the plant?*" and the corresponding requirements are presented.

The second chapter provides a description of concepts for nowcasting in different technical configurations. Based on these applications, characteristic numbers are defined and used to derive requirements for the nowcasting systems. The specifications are derived from transient simulation studies carried out during this project and by referring to experience gained from studies in the past. A unique approach applicable to all kinds of CSP/CST systems and for different sizes has been developed. The last chapter compiles these results in compact form.

The main parameters used to describe the specifications are:

- Nowcast horizon split into a nowcast horizon 1 and nowcast horizon 2
- Temporal resolution
- Spatial resolution defining the size of the pixels of a DNI map
- Accuracy in terms of an ideal and minimum accuracy providing an estimate of the required accuracy of the forecast.
- Volatility index as additional information apart from the DNI time series itself.

The compilation of nowcasting applications reveals that we can roughly distinguish between three categories:

1. Applications with moderate accuracy demands usually dealing with electricity production scheduling over a horizon of one or several days. Typically, a spatially averaged DNI value is sufficient for one plant.
2. Applications with high accuracy demands and need for spatial resolution. Such nowcastings can be used to improve operation of the plant on a basis of seconds to 60 minutes. Inaccuracies in the nowcasting can lead to severe penalties thus accuracy has to be high in order to be at a conventional control approach.
3. Compared to type 2, the forecast is a vital part of the control concept. Thus, any inaccuracy will not only lead to less (economic) output but may also lead to possible damage of critical plant components.

Nowcasting system development should focus on the first and second application since systems fulfilling the requirements of type 3 are considered far away from today. Even type 2 applications have to be considered as quite challenging for the nowcasting method development

Once the requirements defined, second step was to prepare cloud camera-based AOD fields and a one year IASI/MODIS dataset. A software to convert Aeronet AOD to clear sky DNI was developed. A list of input parameters for the calculation of circumsolar radiation was prepared. A report was delivered with the recent efforts to derive the aerosol optical properties from the analysis of the spectral characteristics of all-sky images (D2.5). According to the relevant literature, the synergetic use of Red, Green, Blue intensities from the sky images, results from radiative transfer models and training methods are able to provide quite accurate results (error ~ 15-20%). The uncertainties in the retrieval of AOD are site specific and related to the sky camera type not only because of different CCD sensors but also because of using entrance optics of different quality. We focused only on physically derived parameters from the all-sky images and simple approaches to convert them to AOD values. We were based only on the RGB intensities/radiances from the zenith point. We proved that the variability of the zenith point radiances with solar zenith angle and Angstrom beta is adequate in order to use this point for the estimation of the AOD and we checked the effect of changing precipitable water and single scattering albedo. According to results, the expected changes of precipitable water and single scattering albedo at the PSA site affect RGB radiances from the zenith point by ~0.1 and 5% respectively. Furthermore, a novelty of the proposed method is the use of the saturated area around the Sun for the calculation of AOD since the size of this area is related to the circumsolar radiations and, so, with the AOD. Both the RGB intensities at the zenith point and the percentage (%) area of saturation are taken into account in a multi-linear approach to estimate the AOD values at 440, 500 and 675nm and compared with the measurements of the CIMEL radiometer at the same wavelengths (Figure 3). The mean/median difference and the standard deviation are less than 0.01 and 0.03 for all wavelengths. The results are comparable with those from similar methods and satellite-derived methodologies and show that also simple surveillance camera based all sky imagers can be efficiently used for the estimation of AOD.

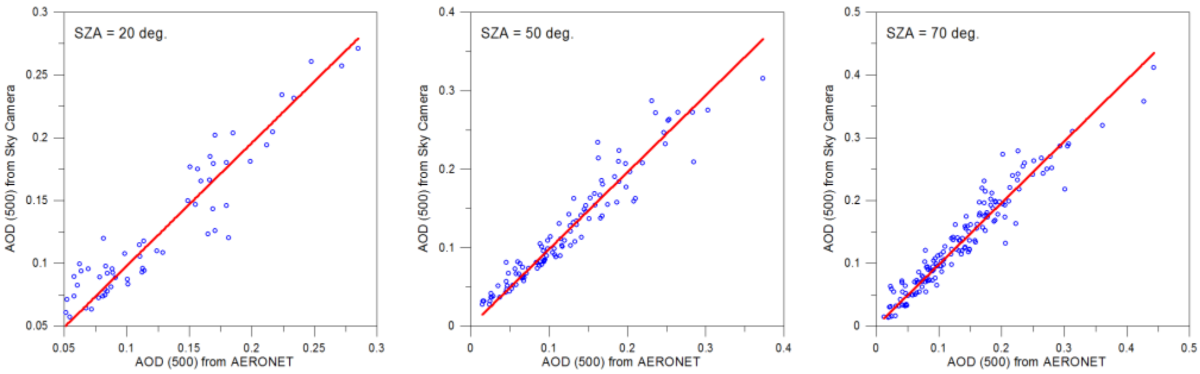


Figure 3: Comparison of the AOD values at 500nm from the sky camera with those from the AERONET measurements for solar zenith angles of 20o (left panel), 50o (middle panel) and 70o (right panel).

The estimated AOD from the sky camera are based on the RGB intensities at the zenith point and the percentage (%) area of saturation around the Sun.

A study report on short-term aerosol forecasting at source-dominated aerosol sites (D2.4) was prepared in September 2015. In the report, assimilation results for dust events at PSA are presented. Small-scale dust outbreaks influence aerosol optical depth (AOD) locally. This is important for concentrating solar power plants (CSP) since aerosols strongly impact direct normal irradiance (DNI). CSP are often located in desert regions, thus close to dust sources where mineral dust outbreaks are likely to occur. Coarse resolution forecasting systems based on satellite observations or large-scale modelling may not be sufficient to capture those small-scale dust events. In the study highly resolved modelling is performed with the chemical transport model EURopean Air pollution Dispersion-Inverse Model extension (EURAD-IM). This model includes sophisticated aerosol dynamics and aerosol chemistry schemes, and a variational data assimilation scheme. The system is embedded in the European Earth observation system MACC (Copernicus) and benefits from near-real time in situ and space borne measurements. This study investigates the performance of this model set-up to forecast AOD as a basis for DNI forecasts at CSP locations in southern Spain. Additionally, a new observation operator for AOD measurements from remote sensing instruments is presented.

In many cases, the EURAD-IM model is able to represent local mineral dust events at the reference station Plataforma Solar Almeria (PSA). The effect of assimilating in-situ PM10 and PM2.5 measurements is limited, since data coverage is found to be sparse. For some events, where the model is not able to capture local events, data assimilation of additional local measurements would be beneficial. Beyond the original project tasks, first results are presented with assimilated AOD information from MODIS satellite observations. Figure 4 presents a typical example of AOD distributions from the forecast, the analysis based on ground-based in-situ PM measurements, and the analysis based on MODIS satellite AOD measurements. Figure 4 shows that the assimilation of MODIS satellite observations help to improve the simulation of large-scale Saharan dust events.

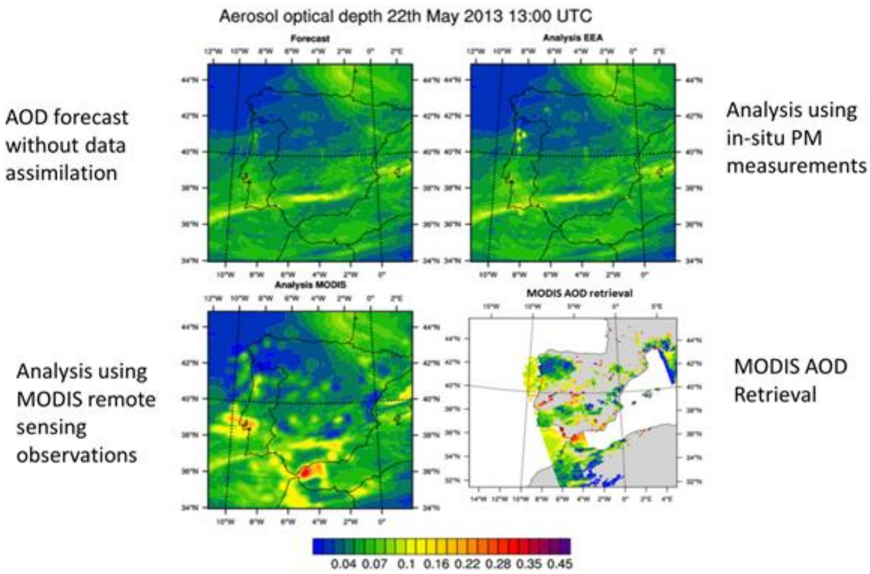


Figure 4: AOD distribution at 22nd May, 2013, 13:00UTC for different simulation configurations: forecast without data assimilation (top left panel), analysis based on EEA ground-based PM10 and PM2.5 observations (top right panel), and analysis based on MODIS satellite measurements (bottom left panel). Additionally, MODIS AOD measurements for the same time are shown (bottom right panel).

In connection to milestone 5 ("Tool for AERONET AOD to DNI conversion ready for partners") a program called Aerosmarts has been developed. Aerosmarts is a software with a graphical user interface (GUI, Figure 5), that allows using SMARTS (Simple Model of the Atmospheric Radiative Transfer of Sunshine, Gueymard, 2001) to create time series of broadband and spectral irradiance data with varying atmospheric input data. Aerosol input data files from the AERONET (Aerosol robotic network) can be used. Relative humidity, pressure and temperature can be imported in the ASCII format defined in the MESOR project.

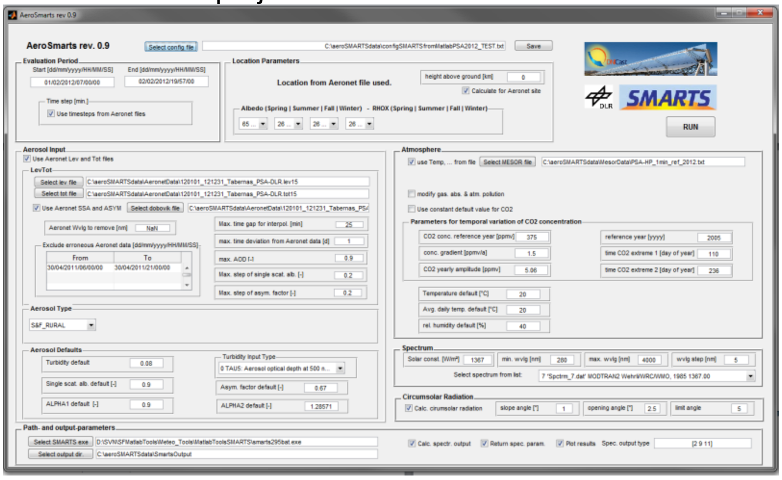


Figure 5: Main window of the Aerosmarts GUI

A review and evaluation report of products available from the WMO Sand and Dust Storm Warning Assessment and Advisory System's (SDS-WAS; D2.2) was published. The report is stressing the importance of aerosol with respect to DNI (and climate in general) focusing on mineral dust and aerosol optical depth (AOD). The report assumes no, a priori, knowledge of aerosol technology or atmospheric numerical modelling covering fundamental aspects of both topics. The scope of SDS-WAS is mentioned and the related portal's capabilities with respect to DNI are analyzed. Each of the numerical model participating in SDS-WAS is also analyzed, without going into too many details, followed by a review concerning each model's capabilities based on available literature. Links to numerical products related to DNI from either the SDS-WAS portal or the website operated by the developer of the models reviewed, are provided along with guidelines.

The COSMO MUSCAT Model was used to assess the uncertainty of lower resolution aerosol data. In this framework and in connection with task 2.2.B, estimates of spatial and temporal correlation lengths have been determined from satellite dust observations (twice-daily observations with the IASI instrument on Metop-A satellite for the year 2009) as well from numerical modelling (COSMO-MUSCAT model). The correlation lengths indicate the scales of variability for airborne desert dust and thus the required resolution of observational systems for assessment of the atmospheric dust load. The resolution of a given aerosol data set was then compared to the correlation length to assess its uncertainty. Satellite and model data at a spatial resolution of 0.25° have been used for the analysis. The general patterns look reasonably similar between satellite observations and model output. From the satellite observations (Figure 6) spatial correlations of 40-60km prevail over wide parts of the domain. That means that spatial representativeness of satellite observations is much higher than the 12km ground resolutions itself and thus that observations on this spatial resolution suffice for dust nowcasting over the domain (i.e. no high-resolution data at 500m-1km are needed). This is the first key finding from task 2.2.E. Temporal correlation lengths in the order of magnitude of 24hrs to 36hrs over the Mediterranean indicate that once daily observations may suffice to assess the dust load in wide parts of the analysis region. Nevertheless, especially over the South European margins, i.e. over Southern Spain, correlation lengths also drop below 24hrs and thus once daily observations become insufficient to resample the temporal dust variability. This is the second key finding from task 2.2.E.

The third component of WP2 was the forecasting of circumsolar radiation. The method developed within the EU FP7 project SFERA to derive circumsolar radiation from satellite cloud measurements and modeled aerosol data[3] has been adapted in a way that the contribution of circumsolar radiation to DNI can be derived from the output of the observations and nowcasting products developed in other work packages (WP3.1-3.3). In the following, we will refer to the direct normal irradiance DNI =

[3] Reinhardt, B., Buras, R., Bugliaro, L., Wilbert, S., and Mayer, B.: Determination of circumsolar radiation from Meteosat Second Generation, Atmos. Meas. Tech., 7, 823-838, doi:10.5194/amt-7-823-2014, 2014.

DNI(α_{cir}) and the circumsolar ratio CSR = CSR(α_{cir}). DNI is used here as the normal irradiance coming from an annular region around the Sun with half opening angle α_{cir} = 2.5° corresponding to the WMO recommendation for pyrheliometers. This comprises direct radiation, which has not been scattered and therefore stems only from the Sun, and diffuse radiation coming from both the sun disk region and the circumsolar region. CSR is defined as the normal irradiance coming from an annular region around the Sun divided by the normal irradiance from this circumsolar region and the sun disk. The forecasted CSR was validated against surface measurements at PSA which have been carried out, and evaluated for two years in this project. The sunshape measurement system was also developed in the SFERA project and consists of the Sun and Aureole Measurement (SAM) instrument, a sun photometer and post-processing software[4]. The software module for the correction of DNI nowcasts with respect to circumsolar radiation was documented and provided to the partners (M16). The method has been applied to various data sets (see also D2.8).

- Aerosol optical depth (AOD) (Figure 7, left).
- MSG/SEVIRI satellite forecast derived cloud optical properties[5] or Cloud Index.
- Cloud and aerosol IASI instrument aboard Metop-A (Figure 7, right)
- Data from COSMO-MUSCAT was used to derive a dust optical thickness

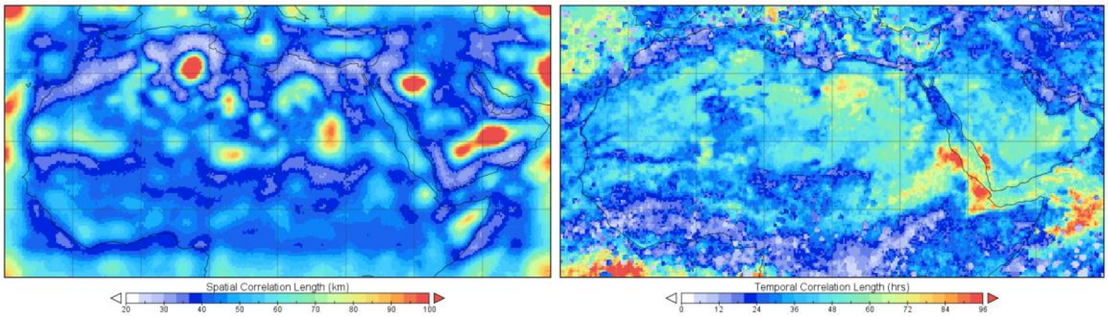


Figure 6: Spatial (left) and temporal (right) dust AOD correlation lengths from twice-daily IASI observations over the year 2009.

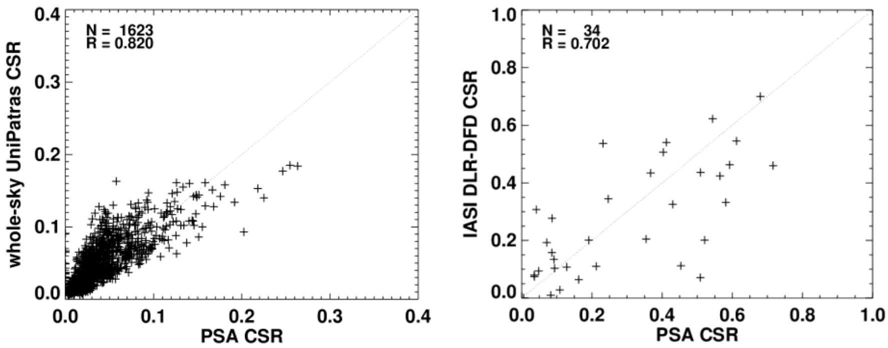


Figure 7: Scatter plot of measured CSR for PSA and whole-sky camera derived CSR for clear measurements (left). Scatter plot of measured CSR for PSA and CSR from MetOp/IASI for cloudy samples.

Furthermore, an alternative to this physical model based CSR forecasting was created using an empirical approach. The empirical model of all-sky CSR was derived from ground-based measurements of DNI and measured probability distributions of the CSRs for many different

[4] Wilbert, S., Reinhardt, B. et al.: Measurement of Solar Radiance Profiles With the Sun and Aureole Measurement System, Journal of Solar Energy Engineering 135(4), 041002-041002, 2013.
[5] Bugliaro, L., Zinner, T., Keil, C., Mayer, B., Hollmann, R., Reuter, M., and Thomas, W.: Validation of cloud property retrievals with simulated satellite radiances: a case study for SEVIRI, Atmos. Chem. Phys., 11, 5603-5624, doi:10.5194/acp-11-5603-2011, 2011, and Kox, S., Bugliaro, L., and Ostler, A.: Retrieval of cirrus cloud optical thickness and top altitude from geostationary remote sensing, Atmos. Meas. Tech., 7, 3233-3246, doi:10.5194/amt-7-3233-2014, 2014.

intervals of the slant path particulate optical thickness at 550 nm. To apply the model a set of probability distributions has to be selected. Such a set can come from PSA or another site with CSR measurements and slant path particulate optical thickness at 550 nm have to be selected. Then, DNI, air pressure temperature and humidity for a given forecasted timestamp are used to derive the slant path particulate optical depth at 550 nm. Finally, a CSR for this timestamp is selected based on the probability distribution. If the probability distributions at a site of interest are similar to that from PSA realistic CSR data can be derived.

- Main achievements

The WP fulfilled its goal as regards the definition of requirements for a nowcasting system for Concentrating Solar Technology (CST). In fact a detailed, frequently cited requirements report was produced, together with a publication presented at SolarPACES. With regard to providing the required aerosol input & information concerning circumsolar radiation for the nowcasting methods, it was identified where aerosol nowcasting is required. This helps answering the question: “*Do we need aerosol nowcasts at the site of interest*?”. A map for Western Europe and North Africa of temporal correlation lengths was provided. Also, products from SDSWAS were identified for aerosol nowcasting, which are helpful for the users. The nowcasting of aerosol for cases with dominant local sources was improved. A software called Aerosmarts with graphical user interface was used to create solar irradiance spectra with Aeronet data and the SMARTS model.

Circumsolar radiation can be forecasted with two of the tested solutions, for example ASI and satellite forecasts. A module for the calculation of circumsolar ratios from different nowcasting data (ASI, satellites, chemical transportation model) is available.

- Lessons learnt and priorities for future research

Many potential applications for nowcasts in CST plants were identified. The potential of the pertinence of the nowcasts for these applications should be quantified in detail. We expect a high potential for the nowcasting applications in CST, but the economic benefit must be evaluated precisely to speed up the utilisation of DNI nowcasting in power plants.

Even simple all sky imagers can be used to estimate AOD. This capability can be explored and exploited further. Also the capability of modelling circumsolar radiation based on ASI images was shown. At some sites in the MENA region dust nowcasts are of interest. SDSWAS or CAMS products or cheap sensors in the surroundings of the plant should be tested and enhanced if necessary to allow their implementation in nowcasting systems.

WP3: Nowcasting method development

WP3 objectives were the development and combination of the different nowcasting methods, for the complete nowcasting horizon and according to the requirements identified in WP2.

- Summary of activities conducted

The first step was to set up and exploit ground-based nowcasting systems at the Plataforma Solar de Almeria. In this respect, innovative configuration of 4 fish-eye cameras was set up, along with a network of pyranometric stations, and a ceilometer (see Figure 8).

Figure 8: Locations of the four all-sky cameras and the ceilometer at PSA.

Algorithms for cloud height and type were developed. Furthermore, based on 3D-maps of clouds an algorithm to derive real-time DNI maps combined with cloud motion was developed for DNI forecasts. Here, it is important to consider spatial and temporal aggregation effects that considerably melt down nowcasting error. It was demonstrated that the newly developed system reaches state-of-the-art accuracy and better.

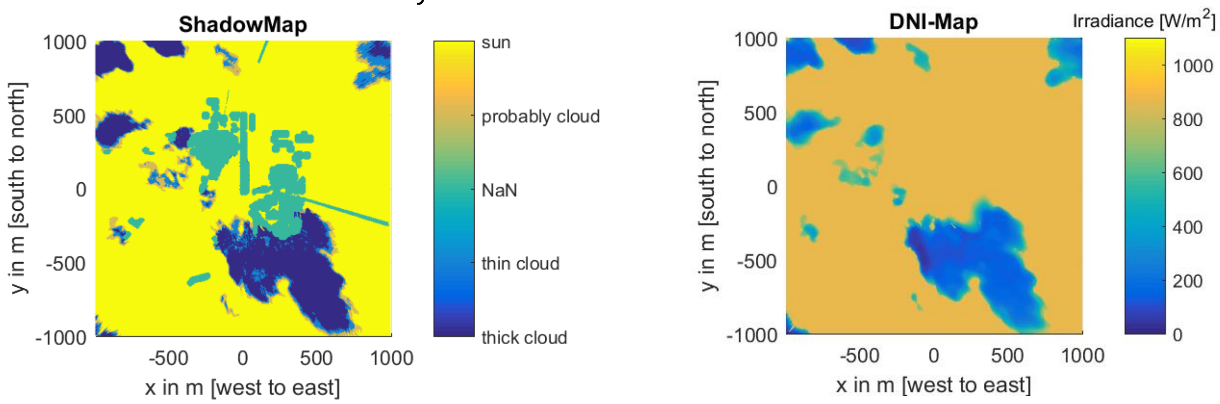


Figure 9: Example of derived shadow map (left) and DNI-map (right) from all-sky camera configuration at PSA.

Regarding satellite-based methods, nowcasting development was based on Meteosat Second Generation satellite, with identification of clouds by cloud index and physical retrieval. Heliosat-2, APOLLO/APOLLO_NG or COCS and APICS methods were applied. To simulate cloud forward movement two approaches were used (motion vectors from optical flow, starting from pyramidal matcher, and a sectoral approach). External wind fields were modeled from WRF. To calculate DNI, cloud index was transformed to irradiances with Heliosat-2 (Meteotest). Cloud optical depth was transformed to irradiances with Heliosat-4/broadband Lambert-Beer law (DLR). In the DLR-DFD method the cloud optical depth coming from a sector was used to generate an ensemble of DNI values.

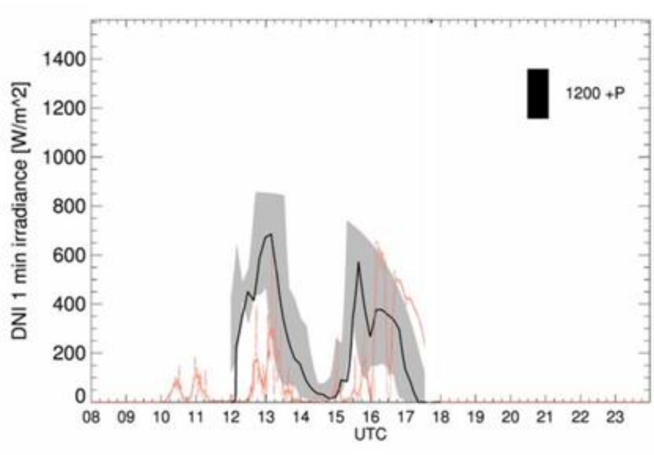


Figure 10: Nowcast as released from 3rd March 2013, 12 UTC satellite imagery and WRF wind field ensembles. Nowcasted DNI is given in black with the 1 sigma range in grey. Observations are given in red – with 10 min moving averages in bold and the 1 min resolved data in a thin line.

An example from the DLR-DFD method for the PSA location is given in Figure 10. In this case the structure of DNI is well met – there is a peak around 1300 UTC and after 15 UTC, and a drop to zero values in between. This structure is correctly nowcasted. However, the DNI around the 13 PM peak is estimated too high compared to the observation while the ramp towards higher DNI at the 15 UTC peak is nowcasted too early.

Often, the observations are inside the 1 sigma range. The 1 sigma range can be interpreted both as an uncertainty of the nowcast due to spatial variability of the cloud field but also as a measure of the expected DNI range due to the cloud field internal variability and therefore as an estimate how much unrepresentative the point measurement may be for the plant area. The exact differentiation between both effects is not possible, but it is recommended to take the 1 sigma range into account – not only as an uncertainty of the nowcast, but also as a meaningful range of expected DNI values.

Another example from 23rd March 2013 is given in Figure 11. It illustrates the decrease of the 1 sigma range from nowcast to nowcast, while the most likely DNI is coming closer to the observations. The ramp between 12 and 14 UTC is better and better nowcasted in consecutive nowcasts. The observations are always within the 1 sigma range marked as grey area. On the other hand the increase of DNI after 1500 UTC is not seen at the early time of the day. This peak appears in the nowcasts only after 1330 UTC (not shown here). Another feature observed very frequently can be illustrated with this case: The clear sky values are too small compared to the maximum values reached by the observations. So, even if the nowcast provides a clear sky DNI value, this can be too low or too high as the maximum DNI values defined by the used clear sky model. This can be corrected by correcting the nowcast using recent DNI measurements which are available at CST plants. It is highly recommended in an operational use of such a nowcasting scheme to continuously correct the clear sky model output.

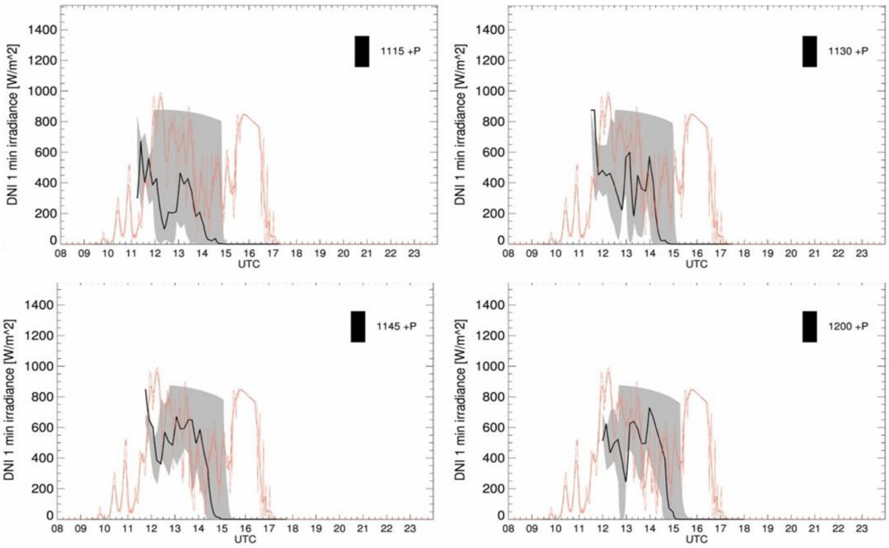


Figure 11: Nowcasts as released from 23rd March 2013, 1115, 1130, 1145, and 1200 UTC satellite imagery and WRF wind field ensembles. Nowcasted DNI is given in black with the 1 sigma range in grey. Observations are given in red – with 10 min moving averages in bold and the 1 min resolved data in a thin line.

As for numerical weather prediction models, the DNI forecasts were with two different prediction systems: HARMONIE-AROME and WRF. The following procedure was applied for the different systems:

- Set up of state-of-the-art quasi-operational mesoscale NWP system HARMONIE-AROME
    - Use of frequent satellite data to initialize model's cloud and wind fields
    - Tested 4D-VAR for mesoscale NWP
- Development of a new ensemble-based method with WRF based on particle filter idea
- Post-processing using machine learning in order to improve the NWP output (#hashtdim)

In Figure 12 the bias and RMSE for BHI forecasts from IFS and the several HARMONIE-AROME experiments are shown for the Almeria site. At Almeria there is a clear negative bias in the BHI for the forecasts initialised with MSG cloud data (both the one started at 00 and 06).
Looking at the RMSE scores IFS performs best during the midday hours (10-12 UTC) while HARMONIE-AROME shows lower RMSE during morning and afternoon hours. The HARMONIE-AROME run with MSG cloud initialisation performs worse throughout the day, as the initialized clouds are too dense. The impact of assimilation of SEVIRI radiances in 4D-Var seems to be neutral. HARMONIE-AROME forecasts issued at 06 UTC seem to perform better than the ones issued at 00 UTC, at least after some spin-up time of about three hours. This indicates that the more frequent update cycles used for limited area NWP can be beneficial for short DNI forecasts.

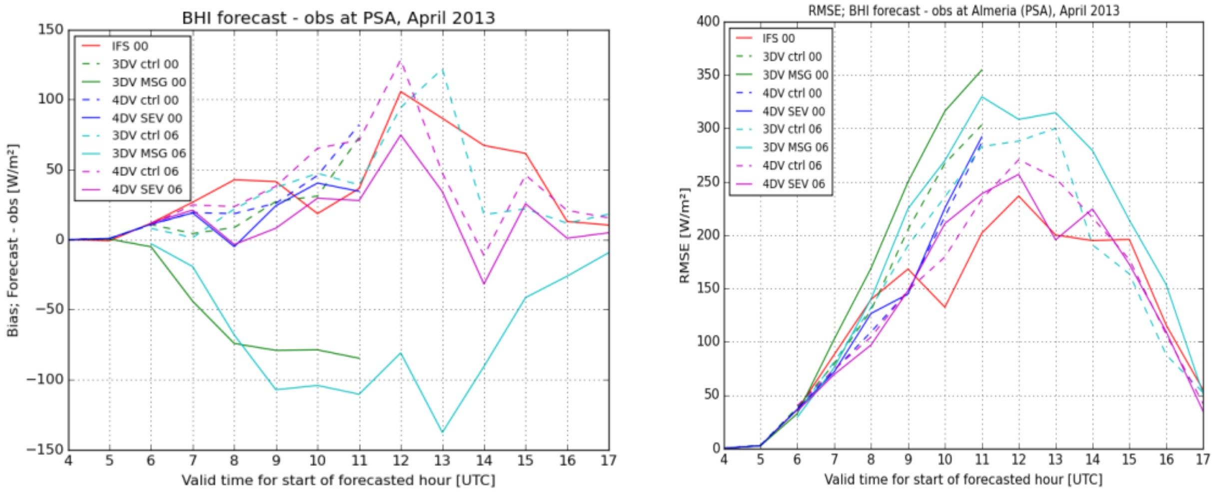


Figure 12: Left: Bias for BHI forecasts from IFS and a number of different HARMONIE-AROME model runs when validated against observations from Almeria (PSA). Right: RMSE for the same forecasts. Experiments include 3D-VAR control (3DV ctrl), 3D-VAR with cloud initialization (3DV MSG), 4D-VAR control (4DV ctrl), 4D-VAR with SEVIRI assimilation (4DV SEV). The numbers in the end gives the initial time in UTC.

Applying statistical post-processing on the NWP data, Table 1 compares the relative MAE present in case of clear sky situations against the whole data results for three forecast data sets including the post-processed results from #hashtdim. We can observe how the level of error is very low for #hashtdim when clear sky situations are analyzed, achieving 10 to 13% of relative error in the first five refresh and increasing up to 20% in the last three runs. The post-process is able of improve the initial results of HARMONIE-AROME.

Table 1: rMAE obtained by the three approaches for all data and for clear sky conditions.

	Clear sky data			**All data**		
Refresh	**Persistence**	**Harmonie**	**#hashtdim**	**Persistence**	**Harmonie**	**#hashtdim**
00	0.78	0.17	0.11	0.9	0.67	0.46
03	0.68	0.16	0.13	0.61	0.41	0.35
06	0.54	0.13	0.10	0.58	0.37	0.34
09	0.12	0.13	0.11	0.52	0.34	0.32
12	0.15	0.13	0.13	0.43	0.36	0.31
15	0.31	0.20	0.20	0.42	0.42	0.31
18	0.28	0.20	0.17	0.36	0.62	0.24
21	0.29	0.21	0.18	4.13	3.50	1.02

For the particle filter method with WRF, the MAE and RMSE are increasing continuously with forecast lead time (Figure 13 upper panel). The lower panel of Figure 13 illustrates how the MAE is not dependent on the forecast horizon for highly variable hours for the variability classes 4, 6, and 7. This is interpreted as the impact of the full modeling the cloud movement without any assumption of linear cloud motion vectors.

Effects like turning clouds or divergence/convergence of the wind field are used and they do have a positive impact of the MAE in variable conditions.

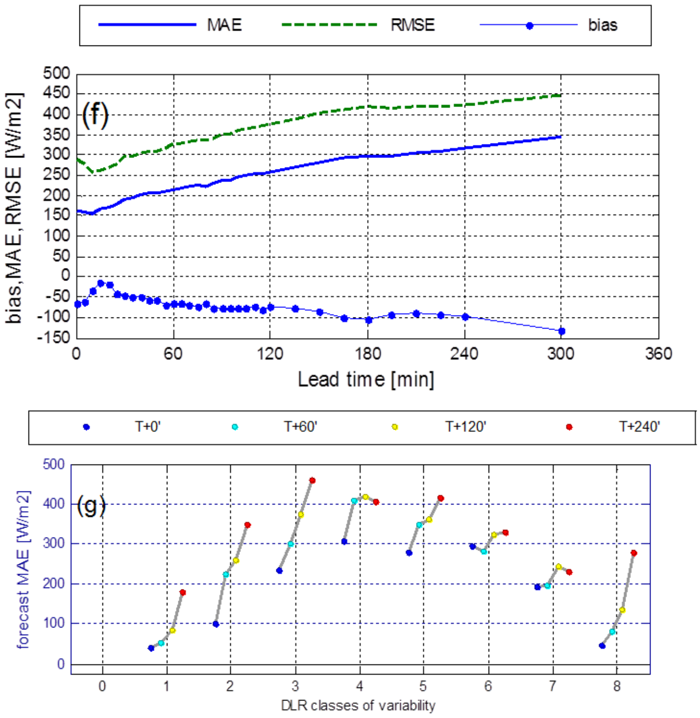


Figure 13: Biases, MAE and RMSE over lead time together with MAE as a function of variability class and forecast lead time for the results from the particle filter method with WRF.

The final step was to improve current DNI forecast by combining the different nowcasting models. Three different approaches were implemented for the combination:

- Uncertainty weighted combination method (UWA)
- Multi-regressive approach
- Distance weighted combination method

Figure 14 shows the selected sites for method combination as well as those with available observational data.

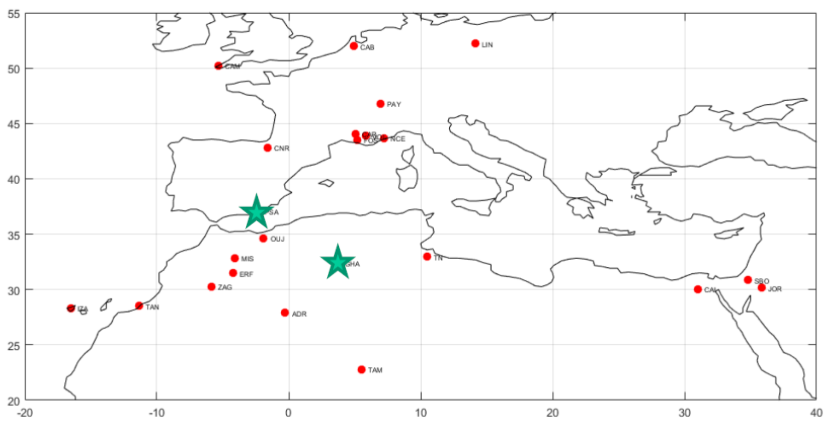


Figure 14: Selection of sites with available observational data (red points) and selected sites for combining method (green stars).

Figure 15 shows the Root Mean Square Error at PSA for the different nowcasting methods, each one identified by a different colour in the legend. The error calculation includes the selected periods of 2010, 2013, 2014 and 2015. The combined method is the red curve. The combined nowcast in almost all cases displays lower errors than single forecasts. Summer months show better results due to less clouds and better coincidence of persistence with measurements. The UWA model seems to be the most simple and effective method for combination of nowcasts.

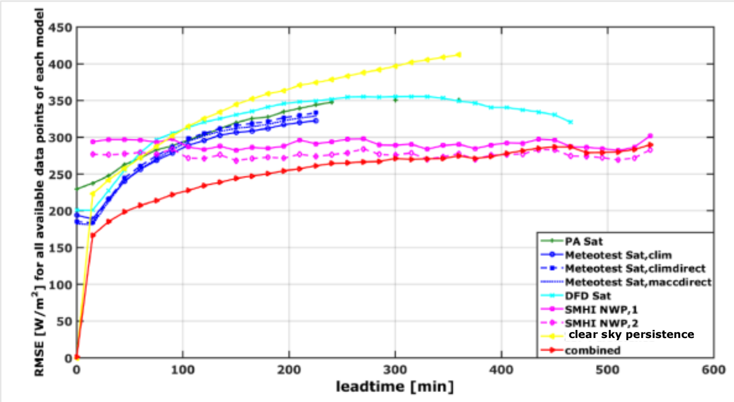


Figure 15: Root Mean Square Error at PSA for the different nowcasting methods (different colours in legend. The error calculation includes the selected periods of 2010, 2013, 2014 and 2015. The combined method is the red curve.

- Main achievements

Several achievements can be listed in the implementation of WP3. Firstly, it was demonstrated the capability of a configuration with multiple all-sky cameras for DNI nowcasting. Also, new products on basis of the all-sky cameras were derived: 3D-map of clouds, cloud height and cloud type segmentation, shadow maps, real-time DNI mapping and short-term DNI forecasts. An important lesson is that considering spatial and temporal aggregation effects melts down errors also in camera-based nowcasts. As mostly such aggregated figures are of interest in industry, these relations should not be ignored. Regarding satellite-based methods, five different satellite-based nowcasting methods were improved. A new receptor-based approach was developed. The work demonstrated that the frequent update for the DNI nowcasting with Rapid-Scan from MSG yields better forecasts. Finally, a new variability classification for both station and satellite data was introduced. Further main results are:

- First implementation of cloud initialization using SAF NWC products in Harmonie 3D-Var.
- First implementation of assimilation of MSG clear sky radiances in Harmonie 4D-Var.
- Data assimilation of SEVIRI data allow improving forecasts by providing a better starting state; Cloud mask yields promising results, as cloud information from satellite remains also in the model forecast. However, more care is needed how the satellite information is included in the model.
- Innovative particle filter was implemented in WRF ensemble.
- The post-process #hashtdim corrects systematic errors in the NWP forecasts. In general the post-processing improves the initial results of numerical weather predictions. The impact of post-process is greater in the first horizons and in the evening ones. It is observed a high level of error decrease in summer months. In some months the improvement after post-process is low principally in Winter situations which could imply that random errors are of the NWP models.

- Lessons learnt and priorities for future research

As regards modelling based on all sky imagers, the first lesson learnt is that very common cloud detection approaches do not work properly. Cloud classification can be improved by using segments of sky vault to detect more than one cloud type. A system of 3D-cloud reconstruction (by a multi camera system) improves calculations of height and velocity. Also, cloud detection can be challenging in the circumsolar region (due to saturation, flare effects). Cloud base height errors may increase significantly the uncertainty of cloud shadow localization for high solar zenith angles. Furthermore, temporal and spatial variability of solar irradiance across a CSP plant can be studied with camera systems. In these cases, the inclusion of temporal and spatial aggregation effects reduces significantly the differences on results when compared with single-point ground-based instruments.

Using observations for post-processing is pre-requisite for any nowcasting method to avoid clear-sky errors and therefore obviously wrong nowcasts which disturb any trust of users in the nowcasting scheme. Using only a single deterministic forecast is still subject to strong errors in the nowcasting methods – this may be a very fundamental restriction due to natural variability of clouds and the temporal/spatial observation frequency/resolution of the space segment.

After testing several satellite-based approaches, no single ‘winner’ could be found among optical flow, sectoral or NWP-based cloud movement methods, as results depend heavily on the location of interest. Also, nowcasts are highly variable and tend to jump from nowcast to nowcast as they are still affected by many errors. So one important resulting lesson is that making a merger of consecutive nowcasts is recommended in the industrial practice; the use of an ensemble nowcast or a variability interval estimate is recommended, too. As well, giving a range of DNI instead of a single time series in the visualization and further decision support is recommended. The combination of several nowcasting methods as ‘multi-method’ ensemble was successful to overcome some of the afore-mentioned limitations. For future work, it is recommended to focus on ensemble-based data assimilation methods.

Data assimilation improves the DNI forecast even in high-resolution models. More work is ongoing on how to best initialize clouds in the NWP model on basis of satellite observations. Post processing of NWP output is needed for DNI nowcasting.

As for the statistical post-processing, summer months show better results due to less clouds and better coincidence of persistence with measurements. The uncertainty weighted combination model seems to be the most simple and effective method for combination among the tested. Combination methods that are good for minimizing errors sometimes change the variable range and distribution which might be important for the user. Thus the nowcasting application has to be considered in order to select a combination method not only assessing the errors results.
In the case of nowcasting for CST plant operation, the range and variability of the forecasts are in fact more important than the right time forecast.

WP4: Validation of the nowcasting methods and plant output nowcasting

The three objectives of WP4 are: i) to collect datasets of known and high quality; ii) to validate nowcasted DNI provided by WP3; iii) and to assess the influence of improvement in DNI nowcasting on nowcasting of CST plant output.

- **Summary of activities conducted**

The first step was the setup of a database of quality checked ground measurements of DNI collected at 15 stations in the Western Europe, Middle East and North African (MENA) region (Figure 16). This exercise is summarised in D4.3. The periods selected for validation are January to March 2010, March to May 2013, June to August 2014 and September to November 2015. These periods have been selected to have a large diversity of meteorological conditions in the dataset. All the measurements have been performed using 3 independent sensors, except for stations ERF and ZAG, where DNI is measured with a Reichert RSP sensor. The measurements are performed every 10 minute and every minute for enerMENA and BSRN stations respectively.

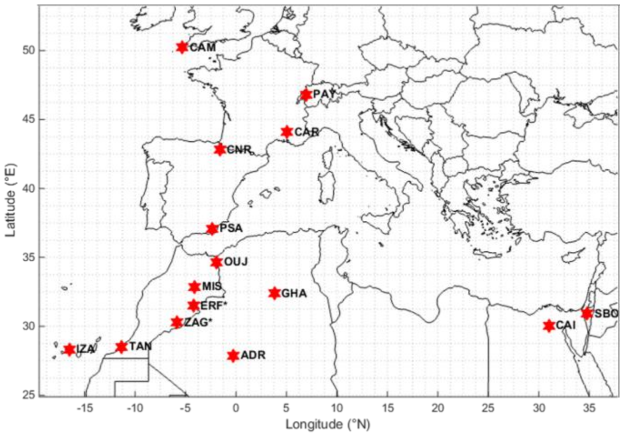


Figure 16: Location of the stations used in the DNICast project.

The quality control (QC) of the measurements retrieved needs to ensure that the references against which the forecasts results are compared have the highest quality. The QC is performed in 2 steps. First step consists in a visual control of the time series in order to assess their overall quality, identify gaps, time shifts, shading/orographic effects, etc. The second step performs 4 tests on each measurement: the physically possible limit (PPL), the extremely rare limit (ERL) test, the consistency test with 2 components (T2C), the consistency test with 3 components (T3C). T2C and T3C are assessing the consistency between the simultaneous measurements of the different sensors, essentially targeting possible sensor failures for each acquisition. The aim of the visual check is to control the quality of the data before and after implementation of the four quality control routines.

The accuracy of 10 different methods, provided by 4 institutes, has been tested against quality controlled ground measurements of DNI for nowcast lead times ranging from 0 to 360 minutes. Eight of them are based on satellite models, one on numerical weather prediction models, the last one is referred to as a smart persistence model. The reference data set used for validation is made of ground measurements of DNI described in the previous section.

A strong dependence of the models' performances is found with the station, both in terms of amplitude of the error and evolution of this error with lead time, as represented in Figure 17. Considering this dependence, any performance analysis of the models made regardless of the station can show strong differences resulting from a different data availability among stations. Having nowcasting data on different stations for the model made it difficult to conclude on the respective performances of the models since their global performances strongly depend on the set of stations where data is available. It was therefore necessary to choose a validation approach that deals with this issue.

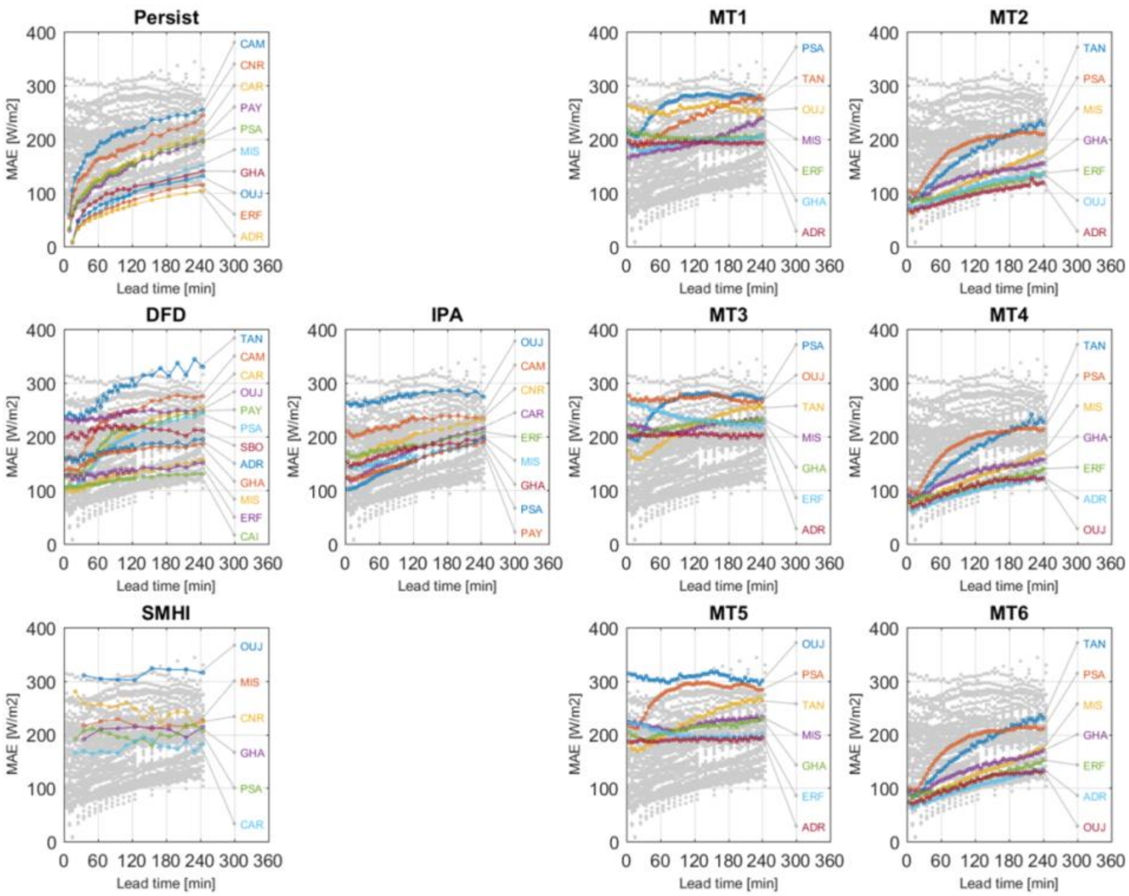


Figure 17: MAE as a function of lead time and station. The MAE values of the stations considered are represented in colour. The MAE values of the other stations are in grey.

The first step of the validation consisted in preparing a “performance summary sheet” for each pair of model and stations, where the main characteristics of the model performance are outlined and the dependence of the model error on some parameters such as e.g. the solar elevation angle, the variability or forecast issue time are highlighted. The aim of the “performance summary sheet” is to give forecast provider a feedback on the performance of their model at different stations in a common format. With this information, they can compare the behaviour of their model among stations but also with other models. A set of 86 performance summary sheets have been generated and disseminated among the project partners.

Though a direct comparison and ranking of the models is made difficult by the heterogeneous data availability, some trends could be visually identified in the performance summary sheets or in plots. To exploit these trends while mitigating artefacts due to the data issue, a qualitative model comparison was adopted. In this qualitative model comparison, it is tried to link the respective model performances to the structure and input data used by the different models. This interpretation can be valuable for forecast provider for improving their nowcasting model.

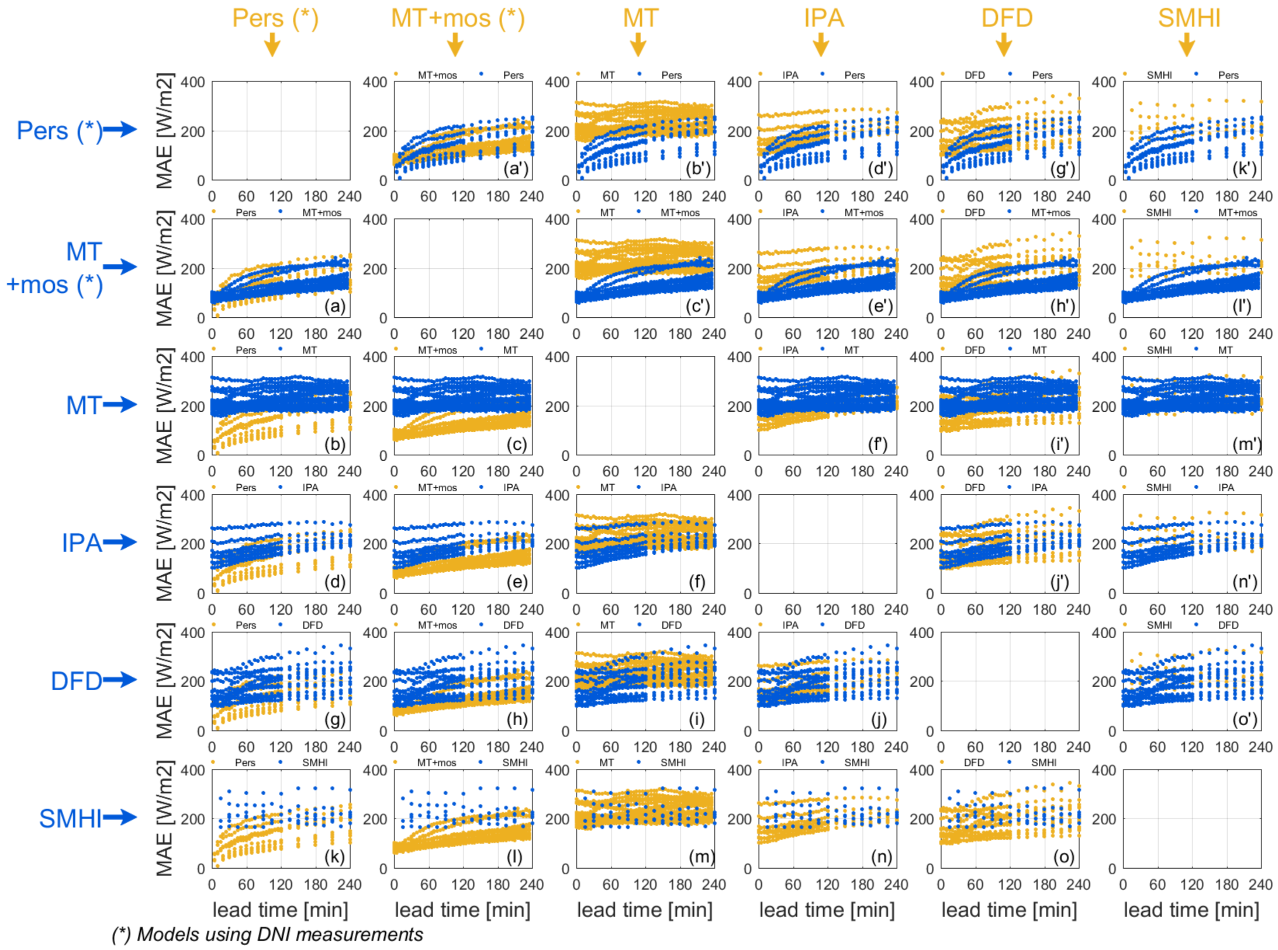


Figure 18: Matrix of figures showing MAE of each pair of model group as a function of lead time.

Finally, an attempt has been made to try identifying critical issues in forecasting the DNI. The motivation of this last part of the validation was to identify and quantify the different sources of uncertainty of the different models. This can indeed be a very valuable piece of information for a forecast provider since it can indicate which part of a forecast system can be improved and to quantify the expected improvement. For this purpose a conditional verification considering different variability classes was used. This approach allows getting some insight into the sources of error of a nowcasting system but it also shows some limitation.

Concentrating Solar Power plants with thermal storage offer the benefit of dispatched power generation even after sunset or during cloudy time periods. Nowcasting information can be used to optimize the storage utilization and increase the revenues of CSP plants when the tariff structure supports this scheme. The goal of this study (summarised in D4.4) was to examine the possible benefit and to calculate the actual numbers for some examples. A software tool for annual yield calculation of CSP plants (http://freegreenius.dlr.de) has been modified and used to calculate the revenues using different forecast information. 110 MWe power plants with 5 hours of thermal storage and time of delivery feed-in tariff were investigated (see Figure 20). The plant's operation time and output power is optimized to produce as much electricity as possible during the high tariff hours and utilize the remaining heat production during the normal tariff hours as far as possible. Heuristic methods are used instead of a full optimization scheme.

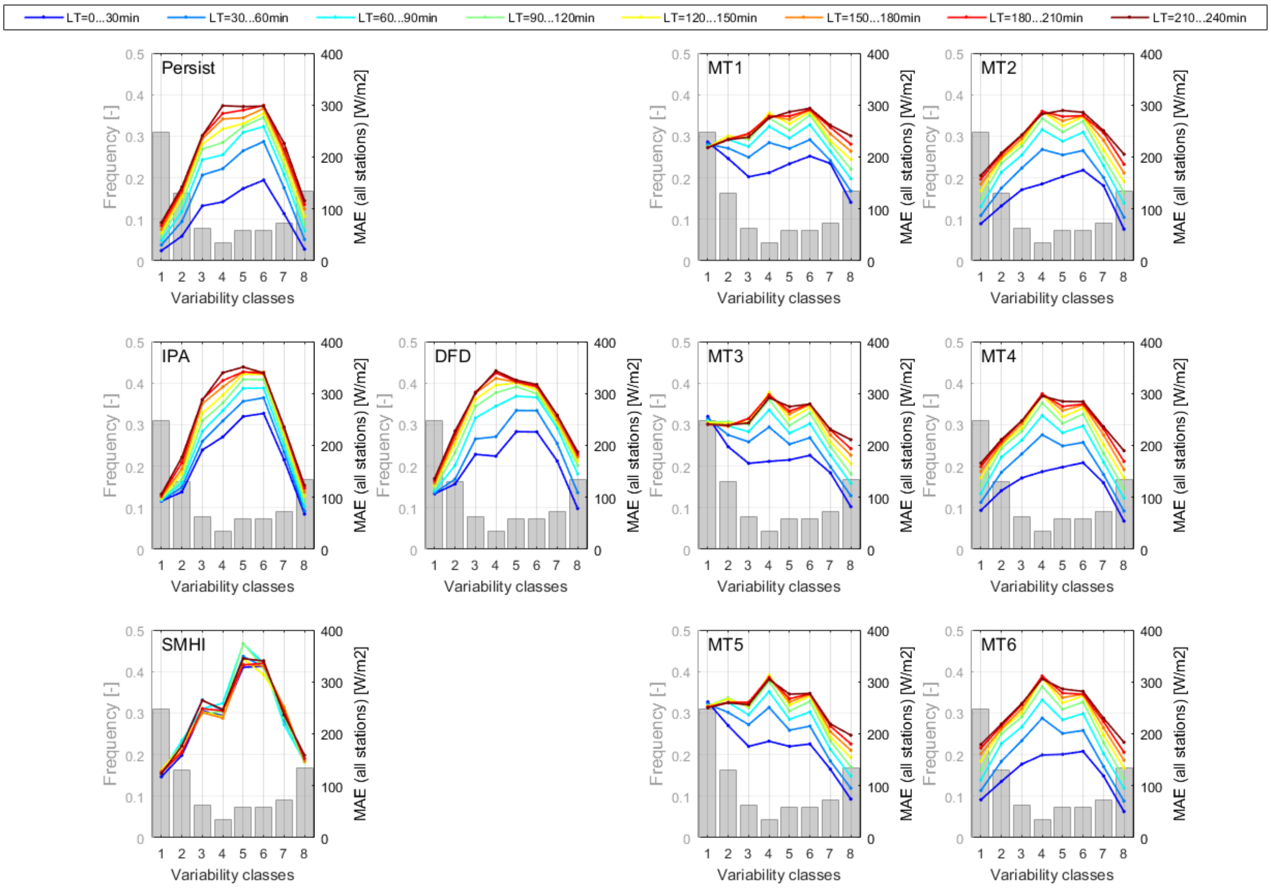


Figure 19: Figures of MAE values as a function of the 8 variability classes (x-axis) and lead time (solid lines) for the 10 models considered

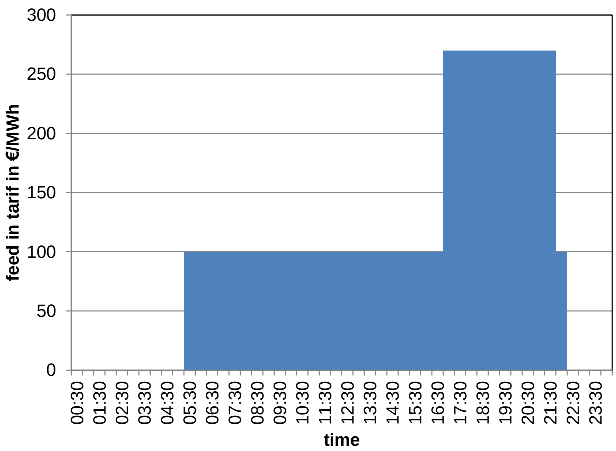


Figure 20: Daily variation of the considered relative feed in tariff.

Two technologies are considered: Parabolic trough reference plant and Solar tower reference plant.[6] Revenues obtained with an ideal forecast, forecast developed in the DNI project and a day 0 and day 1 forecasts are presented in Figure 33-34. Comparing the results from the DNICast combined forecast with those from the ECMWF day 0 forecast, one should keep in mind that these forecast datasets only differ for 3 months in each year. The remaining 9 months are identical. Therefore one

[6] The characteristics of the two reference plants are described in detail in the Annex section, page 64.

can expect a larger benefit if the DNICast combined forecasts for the full year had been available. The benefit with a 12 month data set can only be estimated roughly from the available data. However, we indicated this estimation in the bar plot using the error bars for the column belonging to the DNICast data sets for PSA. The errors bars have been generated by adding the differences between ECMWF day 0 and DNICast forecast of the other 3 years to the actual one. This is of course just a rough extrapolation but may be used as first indicative value for a full year. This exercise showed that:

- The utilization of nowcasting for CSP plants to maximize revenues under a ToD tariff scheme is appropriate
- The actual benefit depends on the base line which is used as benchmark
- Using the day ahead forecast as benchmark, nowcasting may increase the revenues by up to 5 %
- Even when a single forecast of the current day is used as benchmark the annual revenues may be increased by up 2 %
- This may be up to additional 600,000 to 900,000 Euros per year for a 100 MW CSP plant depending on the actual tariff
- With a perfect forecast the annual revenues may be increased by up to 10% compared to the day ahead forecast as benchmark

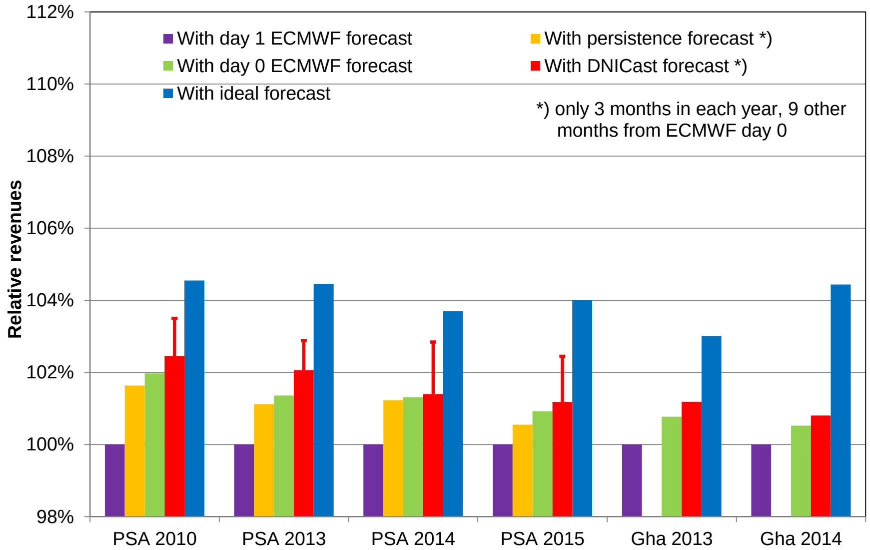


Figure 21: Results overview parabolic trough plant. The columns for DNICast only contain 3 months from the DNICast data set and 9 months from ECMWF day 0 data. The error bars indicate a rough estimation of the revenues with 12 months DNICast data.

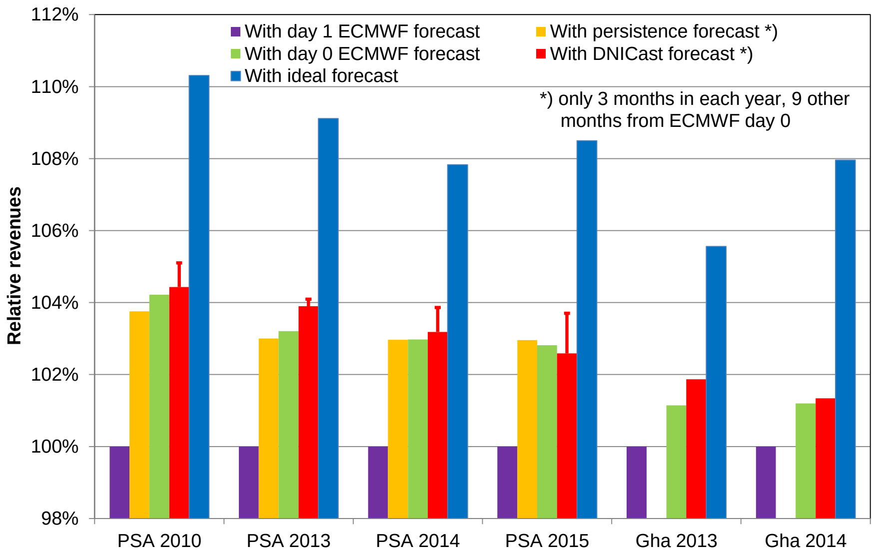


Figure 22: Result overview for solar tower plant. The columns for DNICast only contain 3 months from the DNICast data set and 9 months from ECMWF day 0 data. The error bars indicate a rough estimation of the revenues with 12 months DNICast data.

- Main achievements

The methodology to validate and benchmark nowcasting systems providing DNI maps with high temporal and spatial resolutions has been developed, significantly enhanced and presented using an example data set. The nowcasts deviate from the reference system similarly to previous findings reported in the literature. Previous nowcasting systems were only evaluated using ground measurement stations. Nevertheless, comparing nowcasts to singular radiometers is not relevant for operational use without taking the spatio-temporal aggregation effects into account.

To the best of our knowledge, this is the first time that a detailed study of both temporal and spatial aggregation effects on the accuracy of ASI derived nowcasting systems is published. Results show a significant reduction in the deviations for both temporal and spatial aggregations. As in CSP plants and CPV plants with batteries, both temporal and spatial aggregation effects occur, the deviations found for the DNICast nowcasting system relevant for industrial applications are encouragingly low, leading to accurate forecasts. These forecasts can then be used to optimize plant operations, especially for variable (partially cloudy) situations. Therefore, although the results are far from being perfect, the validations of the DNICast nowcasting system revealed promising potential.

Accurate guidelines for DNI measurements were produced, which are a very useful tool for industry. They focus on the daily procedures required to maintain a DNI measurement infrastructure performing with the reliability allowing DNI data acquisition with the required quality and accuracy for solar energy applications. This includes maintenance and control of the sensors and auxiliary equipment at the site. Overall, the minima requirements are 2 fish-eye cameras and 1 pyranometer.

A validation of nowcasting methods taking into account 10 different methods (8 based on satellite models, 1 on numerical weather prediction models, and one referred to as a smart persistence model) was performed. The influence of the input data and model setup on the forecast performances was discussed and assessed, and the main critical issues in DNI forecast were identified.

Finally, the studies conducted for optimizing revenues for parabolic trough and solar tower plants under a ToD tariff scheme by utilizing nowcasting datasets have shown that such an optimizing may increase the revenues. The actual benefit depends on the base line which is used as benchmark (day ahead vs. current day). According to the calculations, this may translate into an additional revenue of 600,000 to 900,000 Euros per year for a 100 MW CSP plant, when an updated forecast is used to adapt the operating strategy to maximize revenues.

- Lessons learnt and priorities for future research

The validation of the ten different forecast approaches was very instructive and allowed identifying interesting trends for end-users as well as possible improvements for future research activities. It was first identified that roughly similar performances can be expected from different systems as soon as similar approaches and input data are used. Large differences were noted among stations indicating that dedicated adaptations of the forecast system for taking into account local effects should be promising. The different approaches considered in the work showed that the different forecasting approaches are complementary, each being especially suited for a given lead time. Lastly, a clear improvement in forecast skill was observed for each system making use of local measurements for adjusting the forecasted DNI. It was also observed that the use of forecasts can generate significant economical assets in the operation of large solar plants.

The detailed validation of the different forecast revealed that each approach has still potential for improvement, whether by improving the method itself but also by combining the different methods or by integrating local measurements. In the course of the work, it was identified that validation work can be very helpful for forecast provider, by for example providing them a feedback on the performance of their system with respect to different meteorological issues. Further work on advanced validation method may thus be pursued for getting a deeper understanding of the strengths and weaknesses of different forecast.

The benefits of forecast were assessed for a given example application but DNI forecast can be a useful information for further application such as e.g. the management of the plant in further economical conditions, the start-up of a large solar plant.

WP5: Knowledge sharing and users' workshops

The rationale for WP5 is to align the methods to be developed within the project with user needs. As such, knowledge exchange with CST plant operators was one of the key components of DNICast. This interaction took different forms. In particular, stakeholders were invited to three end-user workshops. A series of bilateral consultations was conducted as well.

- Summary of activities conducted

Three end user workshops have been organized covering different topics. Bilateral consultations were held to identify relevant information from stakeholders and potential end-users. In addition to the consultations, a questionnaire was sent to a big number of stakeholders. The questions were divided into four clusters:
1. General description of the plants: Collecting the more technical aspects as the technology, size or power of the plant.
2. Available information over the plant: Referring to the ground data recorded in the plant or near it.
3. Current forecasting system in the plant: It is focused in the characteristics related to the predictions that are now available in the plants and the use that the operators make of it.
4. Requirements for a useful forecasting system: The features that each end user hopes to obtain from an operative system of forecast.

The more usual configuration in the operative plants are parabolic trough of 50 MW, however it is important to note that the new developments are also focussed on central tower and different sizes.

In terms of the available information on the plant there are different situations that can be summarised as follows:
1. One ground station sited out of the borders. According to some end users, it is usual that this station was installed to make the feasibility analysis of the emplacement. So, they present long time periods of data being, covering the three solar radiation components. However, often the maintenance of these stations is reduced after the start-up of the plant.
2. One station sited inside the plant. The measurement of the three components of the solar radiation by a complete station installed in the plant is a usual practice.
3. Some stations inside the plant. Often, in larger plants there are a set of complete solar radiation stations with correct maintenance.

4. One (or more) sky cameras sited in the plant. It is less common that the plants present an operative sky camera. However, according to the consultations conducted, the end users think that this kind of sensors could be very useful in the plant operations tasks. They need to observe the impact that the installation of sky cameras can produce (simulations) to decide the installation of them.

Another critical aspect that has been identified is related to the accessibility to the data. It is usual that the stations can be monitored from outside. But in other cases all data in the station has no external access, in this situation the nowcasting system must be installed in the plant.

Regarding the forecasting system, the information collected shows that normally only general meteorological prediction is used in the plant operation. In other cases the local knowledge of the weather is used in the operative decisions taken in the plant. To finish, it is noted that the accuracy of the DNI prediction systems implemented up to now is not enough to be useful in the plant operation and grid integration activities.
According to the consultations, there are different applications of forecasts as priorities of the plant operators:

- Daily market: The possibility to participate in the electricity market. It supposes the forecasts of the DNI 24 hours ahead and with hourly frequency. The last modifications in the Spanish legislation have reduced this interest but it is still taken into account as one of the interesting applications of the forecast.
- Intraday Market. The possibility to participate in the intraday market. The intraday markets of electricity imply new forecasts with each 4 hours producing hourly predictions. However, it is important to note that for this application the horizons of forecast that can be used are, in general, from third to sixth. This fact is due to the time needed by the market to manage the power generation schedules. The market rules force the delivery of the forecast three hours before to the use of this information. Then the predictions covering these three nearest hours are not used.
- Operation. The operation of the plants with storage is probably considered the application with the highest economic impact potential. In this case the requirements depend on the operation system used in the plant. It was noted that a horizon of six hours ahead is needed to cover the needs. Refresh the forecast with at least hourly frequency is also common as expectation of the system and in case of the operation application, higher temporal resolution is demanded.

Another important question that appears in the consultations has been the kind of information expected from the nowcasting system. In addition to the quantitative forecast, it was noted that some qualitative information could be very helpful in the plant operation. This prediction should generate information about daily start up, levels of DNI or other general conditions. Besides, the information about probabilistic occurrence included in the forecasts system is noted as an interesting tool in the decision making, being another common expectation form a nowcasting system.

To finish, end users concur on the importance of providing a reliable simulation tool to analyze the impact of the prediction system in the plant operation. This simulation tool would reproduce exactly the real conditions of the plant and the available information.

The results of bilateral consultations have been used as an input to produce the first draft of the exploitation plan of results, which has been constantly updated throughout the project implementation.

Another relevant activity and output within WP5 has been the best practice guideline for DNI nowcasting. The guideline (produced as D5.5) contains the recommendations that a nowcasting system should present.

As far as the nowcasting of the meteorological parameters is concerned, High spatial resolution in numerical weather prediction is recommended for meteorological parameters such as wind speed, temperature or relative humidity. Regarding aerosols, Aerosol forecasts providing total and dust aerosol optical depths are highly relevant to DNI nowcasting. Forecasts providing only mass concentrations or dust loads are less interesting, since further assumptions on optical properties and the vertical profile of aerosols are required to provide the optical extinction in radiative transfer calculations. Aerosol forecast models making use of data assimilation of satellite-based aerosol observations are more reliable with respect to large-scale dust storm events. Data assimilation is routinely applied by a number of aerosol forecast services. It is recommended to ask for data assimilation experiment results when choosing an aerosol forecast provider.

Depending on the location, the temporal variability of aerosols may be low. In regions with low variabilities in time and space of the aerosols, their amount can be monitored either by an aerosol observation or by the pyrheliometer. Only in regions with high spatial and temporal variabilities, where a larger number of significant dust events is expected, a forecasting and nowcasting scheme is recommended.

For DNI nowcasting system, there is a need for good quality measurements on a regular basis with storage of these measurements. This will enable to the qualification and quantification of uncertainties of the nowcasted values and built improved models for nowcasting.

In regions with low spatial and temporal aerosol variability, the nowcasting of aerosols can be replaced by the monitoring of aerosols. As an example, using the COSMO-MUSCAT model system and IASI-based satellite dust observations, spatial and temporal correlation lengths maps were generated (see deliverable 2.4 and 2.5) showing the way to do it.

Also, the nowcasting of clouds which is an intermediate step towards the nowcasting of the DNI value, has been assessed through different methods: satellite-based, NWP and all sky cameras and several recommendations have been put forward. Furthermore, circumsolar radiation should be taken into account for the plant modelling and the DNI reported from a nowcasting system should include the circumsolar radiation in a way similar to pyrheliometer measurements. Otherwise a nowcasting sytem must specify exactly how circumsolar radiation is included or not in the nowcasted DNI. Ideally the CSR should be forecasted together with the DNI. However, currently the uncertainty of DNI nowcasts is noticeably higher than the error caused by a wrong estimation of the CSR. Hence, nowcasting a time series of the CSR next to the DNI is currently not an obligation. However, the CSR should always be considered to avoid systematic errors of DNI nowcasts that would occur if the circumsolar radiation is neglected completely. Some points are crucial for the actual and future quality of the nowcast that can be produced by any system:

- For the time being, the application of various forecasting methods is recommended (In-situ sensors, All Sky Imager, satellite and NWP).
- Any nowcasting scheme should be validated at various locations and with various meteorological conditions covering the conditions that are relevant for the site of interest.
- Nowcasted data should be reported with uncertainty information.
- In-situ measurements and their real-time integration within any nowcasting scheme will dramatically improve the results notably for the lower time horizons.
- All nowcasts being made in an operational system should be stored in the power plant database. Only this allows any evaluations by the research & development team afterwards.

Some tracks to the future of the work proposed during the DNICast project can be already determined, even if all activities are not yet achieved.

The integration of all measurements and all the nowcastings of the different parameters of interest for being able to nowcast DNI with a good accuracy is the major challenge for obtaining an operational tool. All the work done during this project is focused on this objective. This definition of characteristics of such an integrated system is not straight forward and will need more interactions with operators of the solar farms.

An additional step of the work is represented by the web demonstrator. The demonstrator website is embedded into the project website. One part of the website gives a general introduction into the aim of the demonstrator and some short explanations of the different views. The nowcasted data of the difference DNICast methods can be viewed in the interactive web-demonstrator. Some parts are shown as static results, since the used tools as the simulation software cannot be run in an online environment. Also the sky-cameras are shown as short movies.

The project produced about of 400-thousand files of point forecast data from the various methods used within the project. The idea of the web-demonstrator is to set up an interface to browse through the various forecast data sets in an interactive way and to develop illustrations which help to visualize the forecasting results.

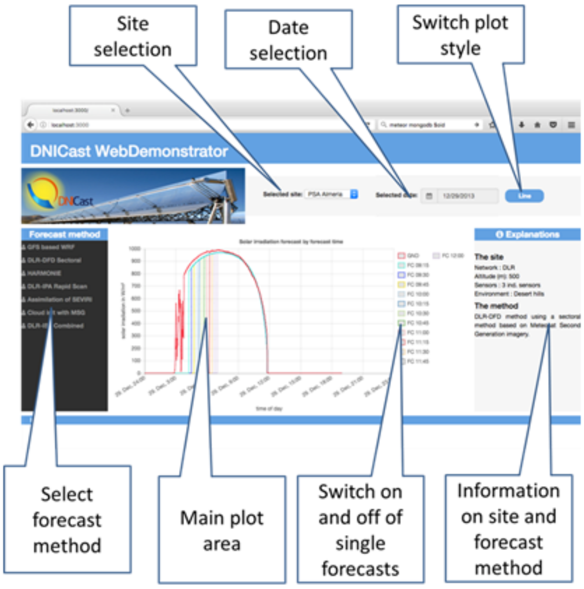


Figure 23: Screenshot of the user interface of the web-demonstrator

The user interface consists of four parts. The left hand block is for the selection of the forecasting method the user is interested in viewing. On the top part, the site, the date and the plotting type can be selected. The right hand block gives information about the selected site and method. It can contain additional information e.g. on the specific day. The central part is the plotting area. It contains a plot of the selected forecasting day.

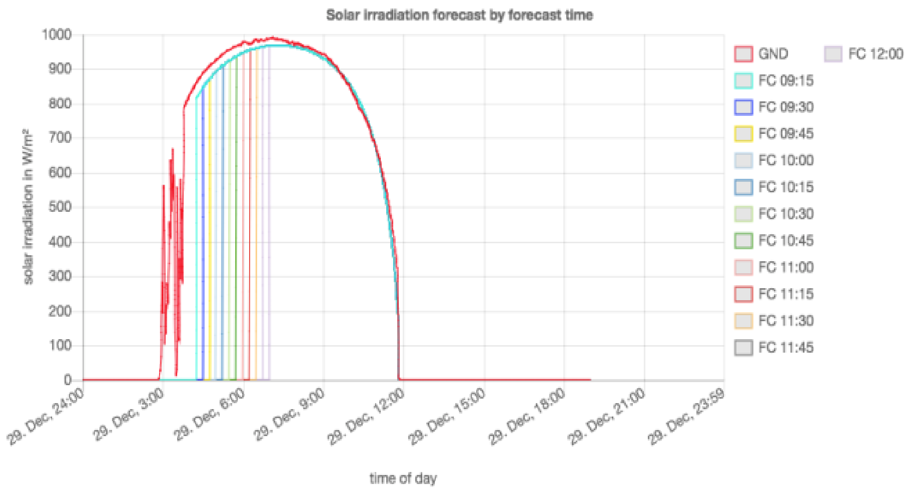


Figure 24: Example Line Plot

The line plot shows the ground measured data (if available) and the single forecasts for one site in one day. The single data plots can be switched on and off by ticking the symbols on the legend on the right hand side. This allows the visualization of the performance of the single forecasts during the day. Switching on and off single forecasts eases viewing the results of single forecasts.

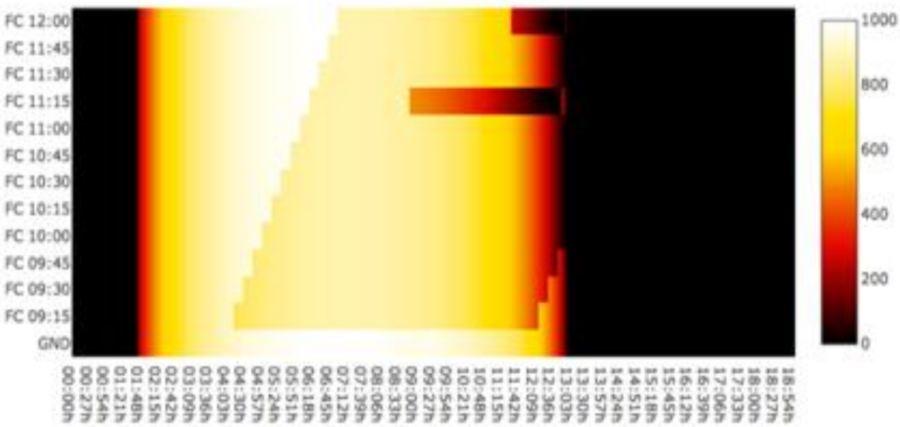


Figure 25: Example Heat map plot

Within the heatmap plot the time of the day is plotted on the x-axis and the forecast time on the y-axis. The measured and forecasted radiation is visible as a colour code. It ranges from dark black for 0 W/m² to a light yellow for 1000 W/m². The measured radiation is of course the same for all forecasts times and appears as a background colour map. The forecasted time series start along a diagonal line which corresponds to the forecast time and the results are plotted towards the right. Differences in measurement and forecasts can be spotted by the different colours. The advantage of the heat map is to show the whole day in one picture. The example in Figure 26 shows a clear day which can be seen by the smooth contours in the background. The forecasts are always lower than the measurement, which can be seen by the darker colours. In the afternoon there is one forecast which expects clouds coming in, shown by the change to much darker colours. The following forecast changes the behaviour again.

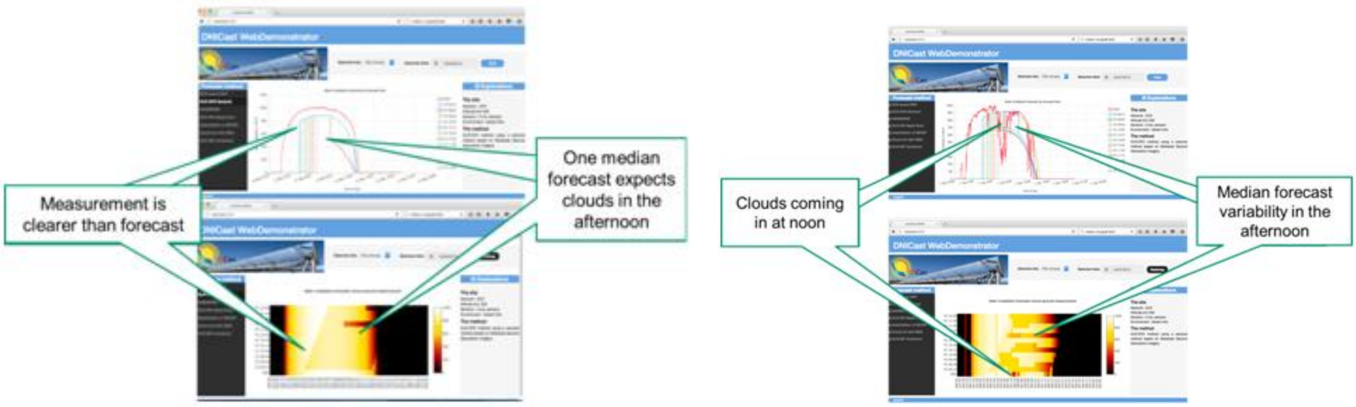


Figure 26: Comparison of forecasts on clear sky day, and on a partly cloudy day.

Finally, a plan for the exploitation of results has been redacted and a market analysis has been conducted. An analysis of the exploitable results of the DNICast project and a guideline to determine the business model for each key topics identified in the project.

The market analysis identifies the current situation of the CSP sector. It shows how the CSP technologies have been extended and have opened new market possibilities. The situation of the CSP projects, technologies and status is analysed in detail.

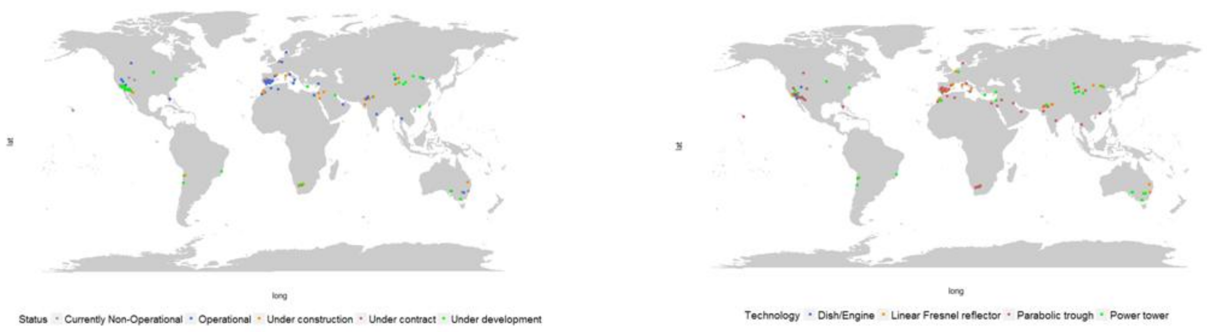


Figure 27: CSP projects at world level by status of development (left) and technology type (right), 2017

Besides, the economic impact of the DNICast results is estimated by using the data of the CSP in the world and the work made in the DNICast project. It shows that, as gross number, the economic benefit of using DNI nowcast in the CSP plants could achieve 171 Mio. €/year.

Table 2: Estimation of annual economic impact by applying DNICast nowcasting on CSP plants with thermal storage.

Technology	Global Capacity[7]	1-day ahead revenue	Nowcasting revenue
Parabolic trough	3360 MW	66 Mio. €/year	99 Mio. €/year
Solar Tower	1767 MW	36 Mio. €/year	72 Mio. €/year
Total	**5127 MW**	**102 Mio. €/year**	**171 Mio. €/year**

The key topics of the project have been analysed under the Canvas model methodology to identify the different business models. It can be a guide for developers of DNICast methods to implement commercial versions of them.

The main actions to make commercial versions and the operative services that the DNICast partners are making have been also compiled. To finish, it should be noted that new technology developments can be used in the models of the DNICast. For example, during the last years high advances in the framework of fish eye cameras have been observed and, therefore, in the all sky images. Other options that can improve the possible commercial versions of DNICast developments are related with the new methods to easy make high amount of calculi like the cloud computing that can make direct impact to extend the RUC to other NWPM.

- Main achievements

A continuous interaction with end users has been achieved. A set of tools to end users has been made to spread the knowledge and disseminate DNICast results:

- End users Workshops
- Nowcasting Guideline
- Web tool to show the DNICast prediction outputs.

Market analysis has been performed and schemes of exploitation have been evaluated.

- Lessons learnt and priorities for future research

The interaction with end-users proved to be very effective and allowed orientating the work in order to achieve exploitable results. However, it has to be noted that the CSP industry community is rather reluctant in sharing information about plant characteristics and behaviour. Additional network and more platforms for knowledge sharing would eventually lower barriers and enable to collect more first-hand data.

The market analysis indicates that the developed methods will have promising economic impact. It should be analyzed different electricity market structures to be able of obtain a more detailed economic impact estimation.

[7] Only CSP plants with thermal storage have been included.

Potential impact and main dissemination activities and exploitation of results

Energy research in the Seventh Framework Programme and the role of DNICast

FP7 Energy's overall objective was to evolve the current energy system toward a more sustainable, competitive and secure one. Renewable energy technologies have an important role to play, in a diversified energy mix which is the less and less dependent on carbon intensive fuels.

The FP7 DNICast project aim was to advance current state-of-the-art of concentrating solar technologies by reducing uncertainty of short-term DNI forecasts and thereby helping to increase the overall plant efficiency. Therefore, its input to the FP7 Energy programme relies on its contribution to the development of concentrating solar technologies, thus increasing energy security, renewable energy supply, climate and environmental protection. Furthermore, through its integrated and participatory approach DNICast focused on enhancing the current industrial and academic cooperation on innovation in energy technology, thus being in line with the approach of the EC Horizon 2020 framework programme. As well, it will support the implementation of the Strategic Energy Technology (SET) plan, in particular by contributing to increasing the performance of CST and encouraging the commercial implementation of these technologies. In this respect, several industrial players have sent letters of support to the project, declaring that the DNICast activities will strengthen the EU position in the field of concentrating technologies. Six industrial operators joined the Advisory Board of the project, thus contributing to advance dialogue between academia and practitioners, and to orientate the research work toward action-oriented results.

Impact on industry development and EU competitiveness

Improved and more reliable DNI estimation nowcasts will increase the efficiency of CST plants, thus accelerating cost reduction and the massive deployment of renewable energy technologies. This will have important effects in terms of job creation, and other socio-economic benefits which are particularly relevant in the current economic situation and increased global competition. In this respect, DNICast is fully in line with the EU strategy to support growth and job creation, thus contributing to meet the overarching objective of the EU research policy to develop an open and competitive European Research Area. This is a core element in the research and innovation agenda of the EC, and is a specific objective of the Innovation Union Flagship Initiative, where research and innovation are seen as key drivers of competitiveness, jobs, sustainable growth and social progress. Furthermore, by fostering the development of low carbon technologies, the project will support the main objectives of the EC directive 2009/28/EC on the promotion of the use of energy from renewable sources, EC Energy Strategy to 2020 and the Energy Roadmap 2050.

Added value of DNICast for the research and industry communities

One of the key aspects of DNICast was the capability to bring together specialists from different fields, in order to exchange knowledge, exploit synergies, and better identify potential innovative solutions. In particular, some of the DNICast outputs are of immediate benefit to both the meteorological and solar communities. Meteorological models can be further improved by taking into account some of the recommendations drawn in the project, such as for example the need for the meteo community to focus on surface solar irradiance measurements. The DNICast project therefore shows relevant inputs that can be useful to e.g. the CIMO guide or other meteorological tools. The work performed on the effect of aerosols links well with the activities of the COST Action on aerosols (e-COST, InDust). SMHI will continue the work through a national project funded by the Swedish Energy Agency to support the expansion of solar energy in Sweden. Furthermore, all model developments are submitted to a joint repository of the HIRLAM NWP community and are also communicated to the ALADIN NWP community encompassing in total 26 European and Northern African National Meteorological Services. Meteotest has an operational product for satellite-based DNI nowcasts, updated every 15 minutes (CloudMove).

These are just few examples of possible contributions and added value brought by the project. In terms of the solar industry community, DNICast methods have already served as the basis for enhanced forecasting systems like for example the WobaS all sky imager based system, developed by DLR and CSP services. Other applications, projects, initiatives (CSP-FoSyS, ESA, La Africana) have benefited from the knowledge acquired in DNICast. Furthermore, CENER is adapting the DNICast developments such as #hashtdim to use WRF model and built the Shortcasting system.

DNICast dissemination activities

A series of dissemination activities have been envisaged during the project preparation, with two work packages specifically addressing such topics. In particular, under WP5, bilateral consultations and end users workshops have been performed. Four deliverables have been produced, which describe the main activities conducted:

- D5.1: First end-user workshop report
- D5.2: Second end-user workshop report
- D5.3: Third end-user workshop report
- D5.4: Report of bilateral consultations with key stakeholders

All of them are publicly available and can be accessed both through the project website and the EC portal. In the following, a short summary of their main contents is provided.

Table 3: The three DNICast end-user workshops

Workshop title	Date	Venue
Energy Sector End-User Requirements for Direct Normal Irradiance Nowcasting and Forecasting	7 May 2014	Madrid
Applications of Observations and Forecasts of Vertical Profiles of Aerosols in the Lowest 200m of the Atmospheric Surface Boundary Layer in Optimizing Concentrated Solar Energy Power Plant Operations	2 December 2015	Oberpfaffenhofen
Presenting the nearly final results of the FP7 project DNICast	1 June 2017	Munich

- **D5.1: First end-user workshop**

The first end-user workshop, titled "Energy Sector End-User Requirements for Direct Normal Irradiance Nowcasting and Forecasting" was held during the first year of the project implementation. Its main aims were to collect expressions of interest for a DNI nowcasting system, to document current practices for forecasting of DNI and to interface to the SDSWAS and the MACC-II community. It was held in the framework of the GENERA congress in May 2014, Madrid (Spain) and attended by over 35 participants, including consortium members, Advisory Board and external experts. The workshop provided valuable inputs to advance progress in WP2, and also identified the topic of forecasting of atmospheric attenuation due to the vertical aerosol profile as an important issue for further discussion.

Figure 28: First end-user workshop at GENERA, Madrid, May 2014

- **D5.2: Second end-user workshop**

The second DNICast end user workshop was held in DLR, at Oberfaffenhofen, Germany on December 2nd, 2015. The workshop attracted speakers with expertise in remote sensing, meteorology, and instrumentation developing along with scientists that model operations related to concentrated solar power (CSP) plants and the atmosphere. The speaker's topics focused on aerosol vertical profiles in the lowest 200 m of the boundary layer, which is of specific interest for the CSP community. During the talks enough time was given so that these experts answer questions of the audience that comprised of CSP end-users, stakeholders, plant operators, and national agencies responsible for research. The general goal was to pinpoint the strengths and weaknesses of available techniques (satellites, numerical models, LIDAR, visibility sensors) able to provide information on aerosol vertical profiles and communicate this information directly to the CSP end-users. The workshop concluded with a round table discussion where it was summarized which type of information/measurement is required to answer specific questions, related to CSP operation. The event was by over 35 participants, including consortium members, Advisory Board and external experts.

Figure 29: Second end-user workshop at DLR, Oberfaffenhofen, December 2015

- **D5.3: Third end-user workshop**

The third end-user workshop was held during on June 1st, 2017 at the occasion of the Intersolar Europe Exhibition in Munich. It had the aim to present and discuss overall results, as well as to collect feedback for streamlining before the end of the project. The focus was to:

- disseminate the results for the benefit of the industry
- present and discuss lessons learnt and areas for further improvement
- move forward to make sure that the results are of use and can be further exploited by the research and industry communities

The agenda included a mix of presentations and discussions and allowed for an extensive exchange and dialogue among participants. It was attended by nearly 40 participants, including consortium members, Advisory Board and external experts.

Figure 30: Third end-user workshop at INTERSOLAR Europe, June 2017

- **D5.4: Bilateral consultations with key stakeholders**

The goal of these consultations is to obtain relevant information about the characteristics and particularities of the CSP plants related to the definition and use of the nowcasting systems.

The information was collected via face-to-face interview and a dedicated questionnaire. The profile of respondents has been kept confidential. Four different priorities have been identified by the interviewed operators: the possibility to participate in the electricity market; the possibility to participate in the intra-day electricity market; and, in terms of operation, an horizon of 6 hours ahead is needed with a hourly frequency forecast refresh. The results of these consultations have been used in the Exploitation plan of results.

In its turn, WP6 focuses on the communication to both the scientific community and the broader audience. Four deliverables have been produced:

- D6.1: Communication and dissemination strategy
- D6.2: Report on the results of the scientific dissemination
- D6.3: Report on the broader dissemination
- D6.4: Final workshop report

- **D6.1: Communication and dissemination strategy**

The dissemination and communication strategy developed in the framework of the DNICAST project outlines the goals of the project, the main messages to be conveyed, the target groups to address, and the main activities to be performed, as well as the tools through which the communication and dissemination activities will be implemented. Along the project's implementation period, the DNICAST partners have disseminated promotional and informative materials related to the DNICAST project. Dissemination has been conducted through correspondence, personal meetings and discussions with interested stakeholders. The deliverable D6.1 Communication and Dissemination strategy describes the implementation strategy to make sure that the project results are widely communicated, and that the consortium reaches the targeted stakeholders in an effective way, using the appropriate language and media tools. It includes also the visual identity of the project (logo, banner, website and other materials).

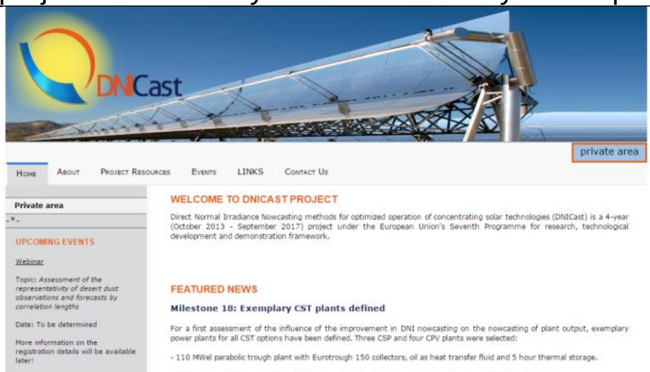
- **D6.2: Report on the results of the scientific dissemination**

During the project's duration, several scientific dissemination activities were carried out such as oral presentations and posters at international conferences, articles in peer-reviewed journals, workshops, a target session dedicated to concentrated solar thermal at SolarPACES 2016 and a side event back-to-back with a large European conference (EMS 2017). Overall, during the four years of project implementation, consortium members have participated in 25 scientific conferences, giving 37 oral presentations and contributing 16 posters. In addition, more focused DNICast events were organised, like for example the “Solar Resource Assessment” session devoted to DNICast, where consortium members provided five oral presentations and 6 posters. Another major DNICast scientific event was the final project workshop, organised during the European Conference for Applied Meteorology and Climatology 2017 (EMS2017) in Dublin, Ireland. EMS2017 took place on 4–8 September 2017 and was attended by 814 participants from 46 countries. One of “Energy Meteorology” Sessions was dedicated to DNICast on Wednesday, September 6th. During these “DNICast talks” seven oral presentations were made by DNICast consortium members, with about 65 attendants. Prior to the DNICast Talks at EMS, another dissemination workshop focusing on end users was organized on September 5th, at the Dublin City University (DCU), Dublin, Ireland, with 8 oral presentations by DNICast members. This means that in four years, almost 60 oral presentations on DNICast were given at some 30 events, in addition to the three end-user workshops organised directly by the DNICast team. Furthermore, 16 peer-reviewed papers were submitted to scientific journals. Deliverable 6.2 summarises the main activities conducted and the outcomes achieved, also in comparison with the fixed objectives.

- **D6.3 Report on the broader dissemination**

This report outlines the main broader dissemination activities performed and the tools through which the activities and results communicated to stakeholders were conducted. Broader dissemination activities are important as they allow the consortium to interact with a larger stakeholder community, thus increasing project visibility and its potential impact.

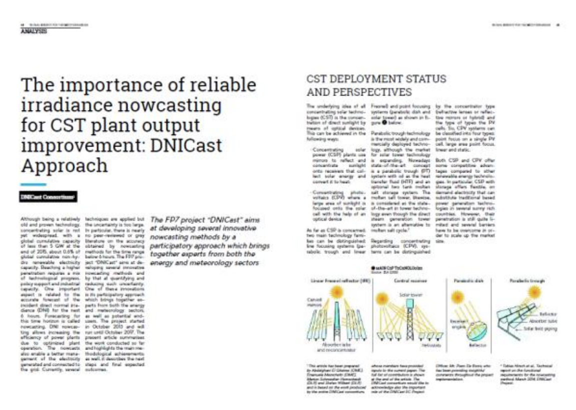
The broader communication activities have been conducted through a variety of channels: the project website, the project leaflet, the project newsletter, informative papers and webinars. Each tool served specific purposes and aimed at increasing project visibility and disseminating the most relevant research results. Targeted audience included a variety of stakeholders, and particularly practitioners. In this respect, efforts were made to use an appropriate language in order to make project results easily understandable by non-expert audience.



Homepage of the DNICast Project

DNICast Project Brochure

Cover Pages of the Newsletters



Extract of DNICast Article in OME’s magazine

Figure 31: DNICast communication product samples.

- **D6.4 Final workshop report**

The final DNICast events constituted the last major dissemination activities within the framework of the DNICast project and aimed at presenting and discussing the overall project results.

The focus was to:

- disseminate the results for the benefit of the industry;
- present and discuss lessons learnt and areas for further improvement; and
- move forward to make sure that the results are of use and can be further exploited by the research and industry communities.

The last dissemination events were organized back-to-back with the 2017 EMS Annual Meeting - European Conference for Applied Meteorology and Climatology that was organized from 4 to 8 September 2017 at the Helix, Dublin City University, Ireland. Two separate events were organised: i) a DNICast Dissemination workshop on Tuesday, September 5th, 2017, and ii) the DNICast talks at the EMS official conference programme on Wednesday, September 6th, 2017. In this way, the project consortium approached both the industry and the research communities.

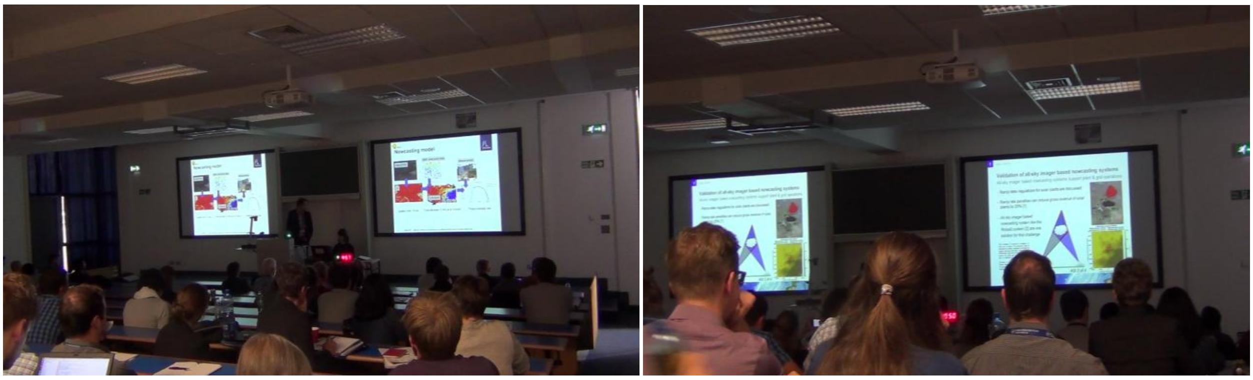


Figure 32: DNICast dissemination event, Dublin

DNICast contribution to knowledge sharing in the scientific and industry communities

It is difficult to get accurate statistics on the number of stakeholders approached throughout the DNICast project implementation. However, some key numbers allow getting an idea of the reach out efforts and –consequently- the potential impact implications. For instance, the project leaflet was printed in 1000 copies, which were entirely distributed at various conferences and events. In total, the DNICast consortium members participated in 24 conferences and workshops (on average 6 per year), contributing with 47 presentations and 18 posters. Several Power Point presentations at the various workshops and conferences were made available through the DNICast project website; it can be then assumed that a much larger group was actually taking advantage of the material prepared. The newsletter was sent to a recipient list of over 100 contacts from research, academia, industry, energy companies, the EC, international organizations, etc. Advisory Board members were also constantly invited to further disseminate the newsletter within their own network. As far as the Advisory Board composition is concerned, the consortium tried to respect a certain balance between the different expertise domains, with experts coming from the solar industry and engineering field, measurement and data service providers, meteorology researchers. In total, the AB was composed of about 15 members, who have regularly attended all AB meetings and contributed to further disseminate the project results beyond the DNICast project network. The Chair of the Advisory Board, Dr. Chris Gueymard, is a worldwide recognised expert based in the US. This has given consortium members additional opportunities to disseminate the work outside the EU borders.

Furthermore, a dialogue has been maintained with other EC projects having a similar scope, such for example the Horizon 2020 project titled “the Energy Oriented Centre of Excellence for computer application (EoCoE)”, started in October 2015, with a three year duration. EoCoE is coordinated by

CEA, the French Alternative Energies and Atomic Energy Commission, with 12 partners from several EU countries.

As far as the informative papers are concerned, the OME GEM magazine is distributed to a list of 2000 contacts, including public and private sector stakeholders. As for the other two articles, they were issued on some of the most reputed portals for analysis on CSP market. CSP Today is the reference point for CSP professionals and a cornerstone for communications within the industry. Similarly, HeliosCSP provides readers with relevant news on CSP technology and market progress, and forecasts.

In terms of scientific publications, 16 papers were submitted to peer-reviewed journals such as Atmospheric Environment, Energy, Renewable Energy, etc. with high impact factors.

Regarding the organised webinars, the first one on nowcasting of high resolution DNI maps with multiple fish-eye cameras in stereoscopic mode, organised in May 2016, was made available on youtube and was seen by over 400 people; the one on data assimilation methods of December 2016 was attended by some 30 people.

Finally, several consortium members participate in international research and industrial networks such as the Technology Collaboration Programme for Solar Power and Chemical Energy Systems (SolarPACES). This creates further opportunities for DNICast consortium members to promote the work within the framework of the IEA technology collaboration programmes and reach out to a broader community.

Project contacts

Project website

A project website was set up in the initial stages of implementation, which contains all relevant information about DNICast activities. It also serves as a platform for information sharing among partners through the restricted area. The address is: http://www.dnicast-project.net.

Contact details

Table 4: Main contact details of the DNICast consortium partners

Organisation	Short name	Country	Role in DNICast	Contact names	E-mail address
Observatoire Méditerranéen de l'Energie	OME	France	General coordinator & WP6 leader	Abdelghani El Gharras	abdelghani.elgharras@ome.org
				Emanuela Menichetti	emanuela.menichetti@ome.org
Deutsches Zentrum für Luft- und Raumfahrt e.V	DLR	Germany	Scientific coordinator & WP2 leader	Stefan Wilbert	stefan.wilbert@dlr.de
			Scientific coordinator & WP2.2, WP3.2 leader	Marion Schroedter Homscheidt	marion.schroedter-homscheidt@dlr.de
			Scientist, WP3	Franziska Schnell	Franziska.Schnell@dlr.de
			Scientist, WP5.4, WP4	Steffen Stoekler	Steffen.Stoekler@dlr.de
			WP5.4 leader	Carsten Hoyer-Klick	Carsten.Hoyer-Klick@dlr.de
			WP2.1 leader	Tobias Hirsch	Tobias.Hirsch@dlr.de
			WP4.3 leader	Jürgen Dersch	Juergen.Dersch@dlr.de
				Tobias Zinner	tobias.zinner@lmu.de
			WP2.3 leader	Luca Bugliaro Goggia	luca.bugliaro@dlr.de
			Scientist, WP3	Niels Killius	niels.killius@dlr.de
			Administration	Miriam Schuster	Miriam.Schuster@dlr.de
			Scientist, WP2	Lars Klueser	Lars.klueser@dlr.de
			Scientist, WP3	Tobias Sirch	Tobias.sirch@dlr.de
			Scientist, WP3, WP4	Christoph Prahl	Christoph.Prahl@dlr.de

			Scientist, WP3, WP4	Bijan Nouri	Bijan.Nouri@dlr.de
			Scientist, WP3, WP4	Natalie Hanrieder	Natalie.Hanrieder@dlr.de
			Scientist, WP3, WP4	Fabian Wolfertstetter	Fabian.Wolfertstetter@dlr.de
			Scientist, WP3, WP4	Wolfgang Reinalter	Wolfgang.Reinalter@dlr.de
			Scientist, WP3, WP4	Pascal Kuhn	Pascal.Kuhn@dlr.de
			Scientist, WP2	Heiko Schenk	Heiko.Schenk@dlr.de
			Scientist, WP2	Abdallah Khenissi	Abdallah.Khenissi@dlr.de
			Scientist, WP3, WP4	Lothar Keller	Lothar.Keller@dlr.de
			Scientist, WP3, WP4	David Schüler	David.Schueler@dlr.de
			Scientist, WP3	Diana Rocio Mancera Guevara	Diana.ManceraGuevara@dlr.de
			Scientist, WP3	Miriam Kosmale	Miriam.Kosmale@dlr.de
			Scientist, WP3	Christoph Bergemann	Christoph.Bergemann@dlr.de
Association pour la recherche et le développement des méthodes et processus industriels	ARMINES	France	WP4 leader, WP3.1.A leader, and contributor to other tasks	Lucien Wald	lucien.wald@mines-paristech.fr
				Philippe Blanc	philippe.blanc@mines-paristech.fr
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Centro de Investigaciones Energéticas, Tecnológicas y Medioambientales	CIEMAT	Spain	WP3.4 leader	Lourdes Ramirez	Lourdes.Ramirez@ciemat.es
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Fundacion CENER-CIEMAT	CENER	Spain	WP5.2 leader WP5.5 leader and WP3.3.D leader	Marcelino Sánchez González	msanchez@cener.com
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				Ana Bernardos	abernardos@cener.com
				María Vicenta Guisado	mguisado@cener.com
				Iñigo Pagola	ipagola@cener.com
Rheinisches Institut für Umweltforschung an der Universität zu Köln E.V.	RIUUK	Germany	WP2.2.C contributor	Hendrik Elbern	he@riu.uni-koeln.de
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University of Patras	UNIPATRAS	Greece	WP3.1 and WP6.2 leader	Andreas Kazantzidis	akaza@upatras.gr
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Sveriges Meteorologiska och Hydrologiska Institut	SMHI	Sweden		Åke Johansson	ake.johansson@smhi.se
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Use and dissemination of foreground

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[8] (if available)*	*Is/Will open access[9] provided to this publication?*
1	*Field validation and benchmarking of a cloud shadow speed sensor*	*Pascal Kuhn*	*Solar Energy*	*Under review*						*No*
2	*Benchmarking three low-cost, low-maintenance cloud height measurement systems and ECMWF cloud heights*	*Pascal Kuhn*	*Solar Energy*	*March 2018*			*2018*	*In press*	*https://doi.org/10.1016/j.solener.2018.02.050*	*No*
3	*Classifying ground-measured 1 minute temporal variability within hourly intervals for direct normal irradiances*	*Marion Schroedter-Homscheidt*	*MetZet*	*January 2018*			*2018*		*https://doi.org/10.1127/metz/2018/0875*	*Yes*
4	*Validation of an all-sky imager based nowcasting system for industrial PV plants*	*Pascal Kuhn*	*Progress in Photovoltaics*	*November 2017*			*2017*	*pp. 1 -14*	*https://doi.org/10.1002/pip.2968*	*Yes*
5	*Shadow camera system for the generation of solar irradiance maps*	*Pascal Kuhn*	*Solar Energy*	*No 157, November 2017*			*2017*	*pp. 157 - 170*	*https://doi.org/10.1016/j.solener.2017.05.074*	*Yes*
6	*Performance Evaluation of Radiation Sensors for the Solar Energy Sector*	*Laurent Vuilleumier*	*Meteorologische Zeitschrift*	*September 2017*			*2017*	*pp. 1 -20*	*https://dx.doi.org/10.1127/metz/2017/0836*	*Yes*
7	*Validation of spatially resolved all sky imager derived DNI nowcasts*	*Pascal Kuhn*	*AIP Conference proceedings*	*1850, 140014, June 2017*			*2017*		*https://doi.org/10.1063/1.4984522*	*Yes*
8	*Short-term forecasting of high resolution local DNI maps with multiple fish-eye cameras in stereoscopic mode*	*Philippe Blanc*	*AIP Conference proceedings*	*1850, 140014, June 2017*			*2017*		https://doi.org/10.1063/1.4984512	*Yes*
9	*Cloud and DNI nowcasting with MSG/SEVIRI for the optimized operation of concentrating solar*	*Tobias Sirch*	*Atmospheric Measurement Techniques*	*No 10, February 2017*			*2017*	*pp. 409-429*	*https://doi.org/10.5194/amt-10-409-2017*	*Yes*

[8] 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).
[9] 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.

	power plants									
10	*New challenges in solar energy resource and forecasting in Greece*	*Andreas Kazantzidis*	*International Journal of Sustainable Energy*	*January 2017*			*2017*	*pp. 1 -8*	*https://dx.doi.org/10.1080/14786451.2017.1280495*	*Yes*
11	*The effect of clouds on surface solar irradiance, based on data from an all-sky imaging system*	*Panagiotis Tzoumanikas*	*Renewable Energy*	*No 95, September 2016*			*2016*	*pp. 314 - 322*	*https://doi.org/10.1016/j.renene.2016.04.026*	*Yes*
12	*Evaluation of WRF shortwave radiation parameterizations in predicting Global Horizontal Irradiance in Greece*	*Melina-MariaZempila*	*Renewable Energy*	*N 86, February 2016*			*2016*	*pp. 831 - 840*	*https://doi.org/10.1016/j.renene.2015.08.057*	*Yes*
13	*Effects of changing spectral radiation distribution on the performance of photodiode pyranometers*	*Frank Vignola (Laurent Vuilleumier)*	*Solar Energy*	*No 129, February 2016*			*2016*	*pp. 224-235*	*https://dx.doi.org/10.1016/j.solener.2016.01.047*	*No*
14	*Spatial and temporal correlation length as a measure for the stationarity of atmospheric dust aerosol distribution*	*Kerstin Schepanski*	*Atmospheric Environment*	*N 122, December 2015*			*2015*	*pp. 10 - 21*	*https://doi.org/10.1016/j.atmosenv.2015.09.034*	*No*
15	*Retrieval of surface solar irradiance, based on satellite-derived cloud information, in Greece*	*Andreas Kazantzidis*	*Energy*	*N 90, October 2015*			*2015*	*pp. 776 - 783*	*https://doi.org/10.1016/j.energy.2015.07.103*	*Yes*
16	*Cloud observations in Switzerland using hemispherical sky cameras*	*Stefan Wacker (Laurent Vuilleumier)*	*Journal of Geophysical Research*	*N 120, Issue 2, January 2015*			*2015*	*pp. 695 - 707*	*https://doi:10.1002/2014JD022643*	*Yes*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[10]	Main leader	Title	Date/Period	Place	Type of audience[11]	Size of audience	Countries addressed
1	*Organization of a DNICast Dissemination workshop*	*Abdelghani El Gharras and Emanuela Menichetti*	*DNICast Dissemination Workshop – Presenting the Final Results of the FP7 Project*	*5 September 2017*	*DCU Campus in Glasnevin, EMS 2017, Dublin, Ireland*	*Scientific Community, Industry, policy makers*	*30*	*World-wide*
2	*Organization of 3rd End-User DNICast workshop*	*Abdelghani El Gharras, Emanuela Menichetti and Michael Pikridas*	*DNICast – Presenting the nearly final results of the FP7 project*	*1 June 2017*	*Intersolar Europe Exhibition, ICM Munich, Germany*	*Scientific Community, Industry*	*38*	*World-wide*
3	*Organization of 2nd End-User DNICast workshop*	*Michael Pikridas Abdelghani El Gharras*	*Applications of Observations and Forecasts of Vertical Profiles of Aerosols in the Lowest 200m of the Atmospheric Surface Boundary Layer in Optimizing Concentrated Solar Energy Power Plant Operations*	*2 December 2015*	*DLR, Oberpfaffenhofen, Germany*	*Scientific Community, Industry*	*36*	*World-wide*
4	*Organization of 1st End-User DNICast workshop*	*Mihalis Vrekoussis, Leonard Barrie*	*Energy Sector End-User Requirements for Direct Normal Irradiance Nowcasting and Forecasting*	*7 May 2014*	*GENERA 2014, Madrid, Spain*	*Scientific Community, Industry*	*37*	*World-wide*
5	*Oral presentation*	*Marion Schroedter-Homscheidt*	*Satellite-based DNI nowcasting based on a sectoral atmospheric motion approach*	*26 – 29 September 2017*	*SolarPACES 2017, Santiago , Chile*	*Scientific Community, Industry, policy makers*	*40*	*World-wide*

[10] 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.

[11] 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).

6	Poster	Juergen Dersch	Impact of DNI Nowcasting on Annual Revenues of CSP plants	26 – 29 September 2017	SolarPACES 2017, Santiago , Chile	Scientific Community, Industry, policy makers	N/A	World-wide
7	Oral presentation	Bijan Nouri	Nowcasting of DNI Maps for the Solar Field Based on Voxel Carving and Individual 3D Cloud Objects from All Sky Images	26 – 29 September 2017	SolarPACES 2017, Santiago , Chile	Scientific Community, Industry, policy makers	40	World-wide
8	Oral presentation	Pascal Kuhn	Shadow camera system for the validation of nowcasted plant-size irradiance maps	4–8 September 2017	EMS Annual Meeting: European Conference for Applied Meteorology and Climatology 2017, Dublin, Ireland	Scientific Community, Industry, policy makers	65	World-wide
9	Oral presentation	Laurent Vuilleumier	Validation of Direct Normal Irradiance from Meteosat Second Generation	4–8 September 2017	EMS Annual Meeting: European Conference for Applied Meteorology and Climatology 2017, Dublin, Ireland	Scientific Community, Industry, policy makers	65	World-wide
10	Oral presentation	Stefan C. Müller	Difference in the performance of satellite based DNI nowcasts in complex and flat terrain	4–8 September 2017	EMS Annual Meeting: European Conference for Applied Meteorology and Climatology 2017, Dublin, Ireland	Scientific Community, Industry, policy makers	65	World-wide
11	Oral presentation	Heiner Körnich	Data assimilation for short-range solar radiation forecasts	4–8 September 2017	EMS Annual Meeting: European Conference for Applied Meteorology and Climatology 2017, Dublin, Ireland	Scientific Community, Industry, policy makers	65	World-wide
12	Oral presentation	Andreas Kazantzidis	Estimation of cloud coverage/ type and aerosol optical depth with all-sky imagers at Plataforma Solar de Almeria, Spain	4–8 September 2017	EMS Annual Meeting: European Conference for Applied Meteorology and Climatology 2017, Dublin, Ireland	Scientific Community, Industry, policy makers	65	World-wide
13	Oral presentation	Marion Schroedter-Homscheidt	Satellite-based DNI nowcasting based on a sectoral atmospheric motion approach	4–8 September 2017	EMS Annual Meeting: European Conference for Applied Meteorology and Climatology 2017, Dublin, Ireland	Scientific Community, Industry, policy makers	65	World-wide
14	Oral presentation	Martin Gastón	Optimized DNI forecast using combinations of nowcasting methods	4–8 September 2017	EMS Annual Meeting: European Conference for	Scientific Community,	65	World-wide

			from the DNICast project		*Applied Meteorology and Climatology 2017, Dublin, Ireland*	*Industry, policy makers*		
15	*Poster*	*Andreas Kazantzidis*	*Cloud Classification in All-Sky Images Using Residual Encoding of Local Descriptors*	*27 – 29 June 2017*	*4th International Conference Energy & Meteorology (ICEM), Bari, Italy*	*Scientific Community, Industry, policy makers*	*180*	*World-wide*
16	*Oral presentation*	*Martín Gastón*	*A combination of HARMONIE short time direct normal irradiance forecasts and machine learning: The #hashtdim procedure*	*11-16 October 2016*	*SolarPACES 2016, Abu Dhabi. UAE*	*Scientific Community, Industry, policy makers*	*40*	*World-wide*
17	*Oral presentation*	*Marion Schroedter-Homscheidt*	*Classifying 1 minute temporal variability in global and direct normal irradiances within each hour from ground-based measurements*	*11-16 October 2016*	*SolarPACES 2016, Abu Dhabi. UAE*	*Scientific Community, Industry, policy makers*	*40*	*World-wide*
18	*Oral presentation*	*Philippe Blanc*	*Short-term forecasting of high resolution local DNI maps with multiple fish-eye cameras in stereoscopic mode*	*11-16 October 2016*	*SolarPACES 2016, Abu Dhabi. UAE*	*Scientific Community, Industry, policy makers*	*40*	*World-wide*
19	*Oral presentation*	*Andreas Kazantzidis*	*Application of simple all-sky imagers for the estimation of aerosol optical depth*	*11-16 October 2016*	*SolarPACES 2016, Abu Dhabi. UAE*	*Scientific Community, Industry, policy makers*	*40*	*World-wide*
20	*Oral presentation*	*Natalie Hanrieder*	*Atmospheric Extinction in Simulation Tools for Solar Tower Plants*	*11-16 October 2016*	*SolarPACES 2016, Abu Dhabi. UAE*	*Scientific Community, Industry, policy makers*	*40*	*World-wide*
21	*Poster*	*Laurent Vuilleumier*	*Evaluation of Rotating Shadowband Irradiometer accuracy*	*11-16 October 2016*	*SolarPACES 2016, Abu Dhabi. UAE*	*Scientific Community, Industry, policy makers*	*470*	*World-wide*
22	*Poster*	*Lars Klueser*	*A continuous gap-free satellite-derived desert dust aerosol dataset for solar energy nowcasting purposes*	*11-16 October 2016*	*SolarPACES 2016, Abu Dhabi. UAE*	*Scientific Community, Industry, policy makers*	*470*	*World-wide*

23	Poster	Andreas Kazantzidis	Evaluation of enhancement events of solar irradiance due to the presence of clouds at Patras (Eastern Mediterranean)	11-16 October 2016	SolarPACES 2016, Abu Dhabi. UAE	Scientific Community, Industry, policy makers	470	World-wide
24	Poster	Luca Bugliaro	Derivation and forecast of circumsolar radiation from whole-sky cameras and satellite sensors	11-16 October 2016	SolarPACES 2016, Abu Dhabi. UAE	Scientific Community, Industry, policy makers	470	World-wide
25	Poster	Heiner Körnich	Short-range DNI forecasting by utilizing Meteosat Second Generation data for initializing Numerical Weather Prediction	11-16 October 2016	SolarPACES 2016, Abu Dhabi. UAE	Scientific Community, Industry, policy makers	470	World-wide
26	Poster	Pascal Kuhn	Validation of Spatially Resolved All Sky Imager Derived DNI Nowcasts	11-16 October 2016	SolarPACES 2016, Abu Dhabi. UAE	Scientific Community, Industry, policy makers	470	World-wide
27	Poster	Andreas Kazantzidis	Aerosol optical properties retrieval from surface radiation measurements	19 - 21 September 2016	13th International Conference on Meteorology, Climatology and Atmospheric Physics, Thessaloniki, Greece	Scientific Community, Industry	195	Europe
28	Poster	Andreas Kazantzidis	The effect of clouds on surface solar irradiance from an all-sky camera	19 - 21 September 2016	13th International Conference on Meteorology, Climatology and Atmospheric Physics, Thessaloniki, Greece	Scientific Community, Industry	195	Europe
29	Poster	Andreas Kazantzidis	On the atmospheric water vapour effect on direct normal irradiance under clear skies	19 - 21 September 2016	13th International Conference on Meteorology, Climatology and Atmospheric Physics, Thessaloniki, Greece	Scientific Community, Industry	195	Europe
30	Oral presentation	Andreas Kazantzidis	On the enhancement of solar irradiance due to the presence of clouds at Patras, Greece	19 - 21 September 2016	13th International Conference on Meteorology, Climatology and Atmospheric Physics, Thessaloniki, Greece	Scientific Community, Industry	195	Europe
31	Oral presentation	Andreas Kazantzidis	All-sky imager: a new instrument for the estimation of solar irradiance, cloudiness and aerosol optical	19 - 21 September 2016	13th International Conference on Meteorology, Climatology	Scientific Community, Industry	195	Europe

			properties		and Atmospheric Physics, Thessaloniki, Greece			
32	Oral presentation	Marion Schroedter-Homscheidt	Classifying 1 minute temporal variability in global and direct normal irradiances within each hour from ground-based measurements	12 – 16 September 2016	16th EMS Annual Meeting & 11th European Conference on Applied Climatology (ECAC), Trieste, Italy	Scientific Community, Industry	70	World-wide
33	Oral presentation	Heiner Körnich	Short-range NWP for Direct Normal Irradiance by Utilizing Meteosat Second Generation Data	12 – 16 September 2016	16th EMS Annual Meeting & 11th European Conference on Applied Climatology (ECAC), Trieste, Italy	Scientific Community, Industry	70	World-wide
34	Oral presentation	Philippe Blanc	Fish-eye camera: a new meteorological instrument of high potential for meteorology and energy	12 – 16 September 2016	16th EMS Annual Meeting & 11th European Conference on Applied Climatology (ECAC), Trieste, Italy	Scientific Community, Industry	70	World-wide
35	Oral presentation	Heiner Körnich	Short-range NWP for Direct Normal Irradiance by Utilizing Meteosat Second Generation Data	22 - 24 August 2016	Nordic Meteorological Meeting 2016, Stockholm, Sweden	Scientific Community, Industry	100	Nordic countries
36	Oral presentation	Marion Schroedter-Homscheidt	Classifying 1 minute temporal variability in global and direct normal irradiances within each hour from ground-based measurements	20 - 24 June 2016	EU PVSEC 2016, Munich, Germany	Scientific Community, Industry	50	World-wide
37	Oral presentation	Jan Remund	Shortest Term Forecasting of DNI for Concentrated Solar Technologies	20 - 24 June 2016	EU PVSEC 2016, Munich, Germany	Scientific Community, Industry	50	World-wide
38	Oral presentation	Luca Bugliaro	Nowcasting of Circumsolar Radiation	20 – 22 April 2016	Fachtagung Energiemeteorologie, Beremerhaven, Germany	Scientific Community, Industry	100	D.CH.A
39	Oral presentation	Tobias Sirch	Kombination von Satelliten und Wolkenkameras für das Nowcasting von Direktnormalstrahlung	20 – 22 April 2016	Fachtagung Energiemeteorologie, Beremerhaven, Germany	Scientific Community, Industry	100	D.CH.A
40	Oral presentation	Magnus Lindskog	Data assimilation for improving short-range DNI forecasting	4-8 April 2016	Joint 26th ALADIN Workshop & HIRLAM All Staff Meeting, Lisbon, Portugal	Scientific Community, Industry	95	Europe
41	Oral presentation	Marion Schroedter-Homscheidt, Tobias Hirsch, Stefan Wilbert	Verification of Sectoral Cloud Motion Based Direct Normal Irradiance Nowcasting from Satellite Imagery	13-16 October 2015	SolarPaces 2015, Cape Town, South Africa	Scientific Community, Industry	40	World-wide

42	Poster	Tobias Hirsch, Marion Schroedter-Homscheidt, Stefan Wilbert	Towards the Definition of Requirements for Direct Normal Irradiance Nowcasting Systems	13-16 October 2015	SolarPaces 2015, Cape Town, South Africa	Scientific Community, Industry	N/A	World-wide
43	Poster	David Schüler, Stefan Wilbert, Tobias Hirsch, Marion Schroedter-Homscheidt,	The enerMENA Meteorological Network – Solar Radiation Measurements in the MENA Region	13-16 October 2015	SolarPaces 2015, Cape Town, South Africa	Scientific Community, Industry	N/A	World-wide
44	Oral presentation	Andreas Kazantzidis	Challenges in solar resource and forecasting	22-24 September 2015	IEA SHC Task 46 “Solar Resource Assessment and Forecasting” 7th Task Experts Meeting and New Task Definition Workshop, Bern, Switzerland	Scientific Community, Industry	40	World-wide
45	Oral presentation	Natalie Hanrieder	Cloud shadow maps from whole sky imagers and voxel carving	26 June 2015	ICEM conference, Boulder, USA	Scientific Community, Industry	80	World-wide
46	Oral presentation	Charlotte Hoppe	Assimilation-based aerosol forecasting at dust sites with a chemical transport model	26 June 2015	ICEM conference, Boulder, USA	Scientific Community, Industry	80	World-wide
47	Poster	Tobias Sirch	Ideal Exploitation of the Temporal and Spatial Resolution of SEVIRI for the Nowcasting of Clouds	12-17 April 2015	European Geosciences Union General Assembly, Vienna, Austria	Scientific Community, Industry	N/A	World-wide
48	Oral presentation	Andreas Kazantzidis	Estimation of aerosol optical properties from all-sky imagers	12-17 April 2015	European Geosciences Union General Assembly, Vienna, Austria	Scientific Community, Industry	60	World-wide
49	Oral presentation	Andreas Kazantzidis	Solar resource and forecasting	26-28 November 2014	10th Greek National Conference for Renewable Energy Sources, Thessaloniki, Greece	Scientific Community, Industry	80	Greece
50	Oral presentation	Tomas Landelius	Modeling and mapping of solar radiation	22 October 2014	Swedish Conference for Meteorological Methods (Solforum) 2014, Linköping, Sweden	Scientific Community, Industry	50	Nordic countries
51	Oral presentation	Andreas Kazantzidis	Induced uncertainties in direct normal irradiance calculations under cloud-free conditions due to aerosol optical depth from MACC re-analysis data	6-10 October 2014	14th EMS Annual Meeting & 10th European Conference on Applied Climatology (ECAC), Prague, the Czech Republic	Scientific Community, Industry	80	World-wide

52	Oral presentation	Andreas Kazantzidis	Development of a neural network model of cloudiness forecasting for solar energy purposes in Greece	6-10 October 2014	14th EMS Annual Meeting & 10th European Conference on Applied Climatology (ECAC), Prague, the Czech Republic	Scientific Community, Industry	80	World-wide
53	Oral presentation	Andreas Kazantzidis	Analysis of results from the COST ES1002 DNI inter-comparison based on cloud detection from all-sky cameras	6-10 October 2014	14th EMS Annual Meeting & 10th European Conference on Applied Climatology (ECAC), Prague, the Czech Republic	Scientific Community, Industry	80	World-wide
54	Oral presentation	Luis F. Zarzalejo	Validation of the procedure for generation of representative solar radiation series (ASR) for simulation of CSP plants	6-10 October 2014	XI Congreso Iberoamericano y XXXVIII Semana Nacional de Energía Solar, Querétaro, Mexico	Scientific Community, Industry	500	Latin America, Portugal and Spain
55	Oral presentation	Luis F. Zarzalejo	Methodologies for the estimation of photovoltaic potential at the national level	6-10 October 2014	XI Congreso Iberoamericano y XXXVIII Semana Nacional de Energía Solar, Querétaro, Mexico	Scientific Community, Industry	500	Latin America, Portugal and Spain
56	Oral presentation	Luis F. Zarzalejo	METAS, Meteorological Station for Solar Technologies	6-10 October 2014	XI Congreso Iberoamericano y XXXVIII Semana Nacional de Energía Solar, Querétaro, Mexico	Scientific Community, Industry	500	Latin America, Portugal and Spain
57	Oral presentation	Luis F. Zarzalejo	ARES, Access to Solar Station Network	6-10 October 2014	XI Congreso Iberoamericano y XXXVIII Semana Nacional de Energía Solar, Querétaro, Mexico	Scientific Community, Industry	500	Latin America, Portugal and Spain
58	Oral presentation	Luis F. Zarzalejo	Estimating the components of solar radiation at the earth's surface from the visible channel of any geostationary satellite	6-10 October 2014	XI Congreso Iberoamericano y XXXVIII Semana Nacional de Energía Solar, Querétaro, Mexico	Scientific Community, Industry	500	Latin America, Portugal and Spain
59	Poster	Luis F. Zarzalejo	Meteorological station for solar technologies (METAS)	9-12 September 2014	13th BSRN Scientific Review and Workshop, Bologna, Italy	Scientific Community, Industry	50	World-wide
60	Poster	Luis F. Zarzalejo	ARES Initiative - Solar Access Network Stations	9-12 September 2014	13th BSRN Scientific Review and Workshop, Bologna, Italy	Scientific Community, Industry	50	World-wide

61	Oral presentation	Niels Killius	Are NWP and earth observation data useful to retrieve vertical coordinates of clouds?	24-25 June 2014	Sky camera workshop, Patras, Greece	Scientific Community, Industry	45	World-wide
62	Oral presentation	Panagiotis Tzoumanikas	Cloud detection and classification with the use of whole-sky ground-based images	24-25 June 2014	Sky camera workshop, Patras, Greece	Scientific Community, Industry	45	World-wide
63	Oral presentation	Laurent Vuilleumier	All-sky cameras at Payerne: cloud cover estimation and comparison with other methods	24-25 June 2014	Sky camera workshop, Patras, Greece	Scientific Community, Industry	45	World-wide
64	Oral presentation	Stefan Wacker	Cloud observations in Switzerland using hemispherical sky cameras	24-25 June 2014	Sky camera workshop, Patras, Greece	Scientific Community, Industry	45	World-wide
65	Oral presentation	Maria-Christina Kotti	Analysis of results from the COST ES1002 Direct Normal Irradiance intercomparison based on cloud detection from all sky cameras	24-25 June 2014	Sky camera workshop, Patras, Greece	Scientific Community, Industry	45	World-wide
66	Oral presentation	Philippe Blanc	3D motion reconstruction of clouds with pair of fisheye cameras	24-25 June 2014	Sky camera workshop, Patras, Greece	Scientific Community, Industry	45	World-wide
67	Poster	Stefan Wilbert	DNI nowcasting for the optimized operation of CSP plants	5 June 2014	German Congress on Solar thermal energy (Sonnenkolloquium),Konferenzsaal, Germany	Scientific Community, Industry	200	Germany
68	Poster	Tobias Sirch	Nowcasting of cloud cover with MSG	27 April -2 May 2014	European Geosciences Union General Assembly, Vienna, Austria	Scientific Community, Industry		World-wide
69	Oral presentation	Stefan Wilbert	Circumsolar radiation measurements	15-16 April 2014	IEA SHC Task 46, "Solar Resource Assessment and Forecasting," 5th Task Experts Meeting, St. Pierre, Reunion Island	Scientific Community, Industry	40	World-wide
70	Oral presentation	Laurent Vuilleumier	Radiation sensor performance evaluation focused on DNI	27-30 January 2014	MACC–II Open Science Conference, Brussels, Belgium	Scientific Community, Industry	100	World-wide
71	Oral presentation	Stefan Wilbert	DNICast – presentation of the project overview	10 October 2013	COST WIRE Action ES1002, "Weather Intelligence for Renewable Energies WIRE" Status Workshop, Budapest, Bulgaria	Scientific Community, Industry	60	Europe
72	Oral presentation	Stefan Wilbert	DNICast – presentation of the project overview	7-8 October 2013	IEA SHC Task 46, "Solar Resource Assessment and Forecasting," 4th Task	Scientific Community, Industry	45	IEA SHC member countries

					Experts Meeting, Oldenburg, Germany			
73	*Book Chapter*	*Andreas Kazantzidis*	*Renewable Energy Forecasting: From Models to Applications*			*Scientific Community, Industry, Policy makers, others*		*World-wide*
74	*Newsletter*	*Abdelghani El Gharras and Emanuela Menichetti*	*DNICast Newsletter – 8th Issue*	*October 2017*		*Scientific Community, Industry, Policy makers, others*	*100*	*World-wide*
75	*Newsletter*	*Abdelghani El Gharras and Emanuela Menichetti*	*DNICast Newsletter – 7th Issue*	*July 2017*		*Scientific Community, Industry, Policy makers, others*	*100*	*World-wide*
76	*Newsletter*	*Abdelghani El Gharras and Emanuela Menichetti*	*DNICast Newsletter – 6th Issue*	*April 2017*		*Scientific Community, Industry, Policy makers, others*	*100*	*World-wide*
77	*Newsletter*	*Abdelghani El Gharras and Emanuela Menichetti*	*DNICast Newsletter – 5th Issue*	*October 2016*		*Scientific Community, Industry, Policy makers, others*	*100*	*World-wide*
78	*Newsletter*	*Abdelghani El Gharras and Emanuela Menichetti*	*DNICast Newsletter – 4th Issue*	*March 2016*		*Scientific Community, Industry, Policy makers, others*	*100*	*World-wide*
79	*Newsletter*	*Abdelghani El Gharras and Emanuela Menichetti*	*DNICast Newsletter – 3rd Issue*	*December 2015*		*Scientific Community, Industry, Policy makers,*	*100*	*World-wide*

						others		
80	Newsletter	Abdelghani El Gharras and Emanuela Menichetti	DNICast Newsletter – 2nd Issue	April 2015		Scientific Community, Industry, Policy makers, others	100	World-wide
81	Newsletter	Abdelghani El Gharras and Emanuela Menichetti	DNICast Newsletter – 1st Issue	June 2014		Scientific Community, Industry, Policy makers, others	100	World-wide
82	Article published in the popular press	Abdelghani El Gharras and Emanuela Menichetti	3rd End-User Workshop	August 2017	HELIOSCSP	Scientific Community, Industry, Policy makers, others		World-wide
83	Article published in the popular press	Abdelghani El Gharras and Emanuela Menichetti	The importance of reliable irradiance nowcasting for CST plant output improvement: DNICast Approach	July 2016	OME bi-annual magazine – Global Energy in the Mediterranean (GEM)	Scientific Community, Industry, Policy makers, others	2000	Europe, Africa and the Middle East
84	Article published in the popular press	Abdelghani El Gharras and Emanuela Menichetti	DNICast aims to improve irradiance forecasting	April 2014	CSP Today	Scientific Community, Industry, Policy makers, others		World-wide
85	Webinar	Heiner Körnich	Data assimilation methods	16 December 2016		Scientific Community, Industry, Policy makers, others	30	World-wide
86	Webinar	Philippe Blanc	nowcasting of high resolution DNI maps with multiple fish-eye cameras in stereoscopic mode	26 May 2016	International Solar Energy Society (ISES) Webinar “Solar Resource Nowcasting”	Scientific Community, Industry, Policy makers, others	+100	World-wide

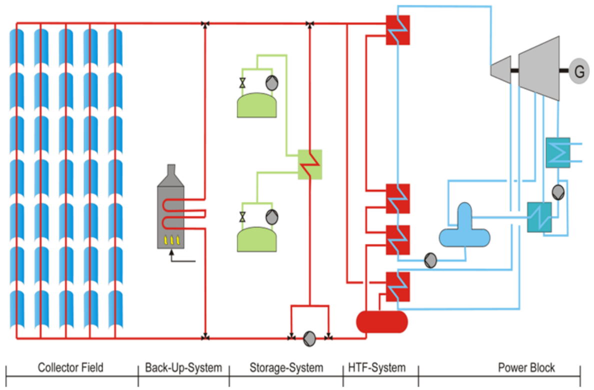
87	*Flyer*		*DNICast Flyer*			*Scientific Community, Industry, Policy makers, others*	*1000*	*World-wide*

Annex

Table 5: DNICast project objectives and sub-objectives

Main objectives	Related sub-objectives	Actions
O1: to establish a portfolio of innovative methods for the nowcasting of the DNI, valid for a portion of the space defined by "time horizon – space resolution – space coverage"	1: to formulate the requirements of the nowcasting methods	The consortium interacted closely with potential users of the nowcastings, i.e., the plant operators. Requirements expressed by users were collected and then converted into requirements for the design or improvements of nowcasting methods.
	2: to investigate the role of aerosols in DNI forecast	Aerosols play a leading role in attenuation of solar radiation in the atmosphere. Specific activities were devoted to evaluating and validating nowcasting/forecasting of their DNI attenuation properties
	3: calculation of circumsolar radiation	The circumsolar irradiance can, at times, contribute up to 30% to the energy received by CSP collectors. A software module that includes the required information on circumsolar radiation in DNI nowcasts was developed.
	4: to nowcast the cloud field, its properties and the DNI with all sky imagers	Techniques based on several all sky imagers were developed for the detection and classification of cloudiness, the estimation of cloud height and the retrieval of 3D cloud characteristic. In this way, forecasts of DNI irradiance maps were developed for the next ~30 minutes.
	5: to improve techniques based on satellite images	This was made especially by using additional information on clouds provided by the various channels in the visible and infrared range of the multispectral imager, to provide DNI nowcasts for the 5-360 min window.
	6: to improve NWP nowcasting methods	The capability of NWP models to nowcast DNI for the time span from 60 up to 360 minutes with a spatial resolution of about 1 - 3 km were investigated using rapid model updates and the assimilation techniques of the satellite data on a limited area.
	7: to combine these methods in order to improve accuracy	Nowcasting datasets were prepared and validated, including uncertainty estimation
O2: to validate the nowcasts and to assess the influence of improvement in DNI nowcasting on nowcasting of CST and CPV plant output	1: to collect accurate and reliable ground measurements of DNI, aerosol and cloud properties for sites located in geographical areas of interest	Ground measurements were collected at 15 stations in Western Europe and MENA and at a spatially and temporally highly resolved measurement network at the Plataforma Solar de Almería
	2: to identify typical power plants for the various CST options	Seven configurations (3 CSP and 4 CPV plants) have been selected for an assessment of the influence of the improvement in DNI nowcasting on the nowcasting of plant output; For CSP with storage, a time of delivery (ToD) tariff with different remuneration rates for different hours of the day has been selected
O3: to involve the potential users of nowcasting methods	1: to formulate best practices	General recommendations for DNI measurements and for choosing a nowcasting scheme were produced
	2: to develop a web-based demonstrator	The project produced about 400-thousand files of point forecast data from the various methods used that can be visualised with a demonstrator
	3: to organise bilateral meetings and	Bilateral meetings were organised with key industry experts to take into account end user

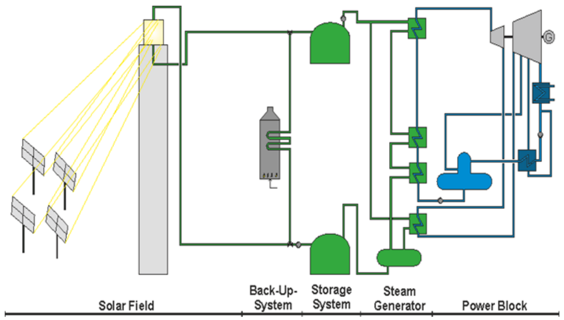
	workshops	needs; 3 workshops were held with an average attendance of 30-40 people each



Source: SolarPACES Guideline for Bankable STE Yield Assessment, 2017

Solar field		Unit
Collector type	Eurotrough 150	
Total number of loops	296	
Maximum bulk HTF temperature	393	°C
Gross electric output	110	MW
Cooling type	Air cooled condenser	
Live steam temperature	383	°C
Live steam pressure	100	bar
Nominal gross efficiency	38.7	%
Storage type	2-tank indirect	
Storage Medium	Solar salt	
Net storage capacity	1420	MWh_{th}

Figure 33: Parabolic trough reference plant



Source: SolarPACES Guideline for Bankable STE Yield Assessment, 2017

Solar field		Unit
Area of single heliostats	120	m²
Heat transfer fluid	Solar salt	
Maximum bulk HTF temperature	565	°C
Power block		
Gross electric output	110	MW
Cooling type	Air cooled condenser	
Live steam temperature	540	°C
Live steam pressure	120	bar
Nominal gross efficiency	43.4	%
Thermal storage		
Storage type	2-tank direct	
Storage Medium	Solar salt	
Net storage capacity	1280	MWh_{th}

Figure 34: Solar tower reference plant

Section B (Confidential[12] or public: confidential information to be marked clearly)

Part B1

The applications for patents, trademarks, registered designs, etc. shall be listed according to the template B1 provided hereafter.

The list should, specify at least one unique identifier e.g. European Patent application reference. For patent applications, only if applicable, contributions to standards should be specified. This table is cumulative, which means that it should always show all applications from the beginning until after the end of the project.

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[13]:	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)

[12] Note to be confused with the "EU CONFIDENTIAL" classification for some security research projects.

[13] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

Part B2

Please complete the table hereafter:

Type of Exploitable Foreground[14]	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[15]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
	Ex: New supercond uctive Nb-Ti alloy			*MRI equipment*	*1. Medical* *2. Industrial inspection*	*2008* *2010*	*A materials patent is planned for 2006*	*Beneficiary X (owner)* *Beneficiary Y,* *Beneficiary Z, Poss. licensing to equipment manuf. ABC*

In addition to the table, please provide a text to explain the exploitable foreground, in particular:

- Its purpose
- How the foreground might be exploited, when and by whom
- IPR exploitable measures taken or intended
- Further research necessary, if any
- Potential/expected impact (quantify where possible)

[19] 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.

[15] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Report on societal implications

Replies to the following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	608623
Title of Project:	DNICast
Name and Title of Coordinator:	Dr. Emanuela Menichetti, OME

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***NO***
2. Please indicate whether your project involved any of the following issues (tick box) :	***NO***
RESEARCH ON HUMANS	
• Did the project involve children?	No
• Did the project involve patients?	No
• Did the project involve persons not able to give consent?	No
• Did the project involve adult healthy volunteers?	No
• Did the project involve Human genetic material?	No
• Did the project involve Human biological samples?	No
• Did the project involve Human data collection?	No
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	No
• Did the project involve Human Foetal Tissue / Cells?	No
• Did the project involve Human Embryonic Stem Cells (hESCs)?	No
• Did the project on human Embryonic Stem Cells involve cells in culture?	No
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	No
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	No

• Did the project involve tracking the location or observation of people?	No
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	No
• Were those animals transgenic small laboratory animals?	No
• Were those animals transgenic farm animals?	No
• Were those animals cloned farm animals?	No
• Were those animals non-human primates?	No
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	No
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	No
DUAL USE	
• Research having direct military use	No
• Research having the potential for terrorist abuse	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	2
Work package leaders	2	6
Experienced researchers (i.e. PhD holders)	11	35
PhD Students	1	6
Other	3	7

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**3**
Of which, indicate the number of men:	2

D Gender Aspects		
5. Did you carry out specific Gender Equality Actions under the project?	O X	Yes No

6. Which of the following actions did you carry out and how effective were they?

	Not at all effective				Very effective
❑ Design and implement an equal opportunity policy	O	O	O	O	O
❑ Set targets to achieve a gender balance in the workforce	O	O	O	O	O
❑ Organise conferences and workshops on gender	O	O	O	O	O
❑ Actions to improve work-life balance	O	O	O	O	O

O Other:

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?

O Yes- please specify

X No

E Synergies with Science Education

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)?

X Yes- please specify: Webinar on data assimilation methods

O No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

X Yes- please specify: Website, etc..

O No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

O Main discipline[16]:

O Associated discipline[16]:

O Associated discipline[16]:

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	X O	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

X No

O Yes- in determining what research should be performed

O Yes - in implementing the research

O Yes, in communicating /disseminating / using the results of the project

[16] Insert number from list below (Frascati Manual).

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)?**	O X	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- O No
- O Yes- in framing the research agenda
- O Yes - in implementing the research agenda
- X Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- X Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- X Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- O No

13b If Yes, in which fields?

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport	

13c If Yes, at which level?

- O Local / regional levels
- O National level
- O European level
- X International level

H Use and dissemination	
14. How many Articles were published/accepted for publication in peer-reviewed journals?	**16**
To how many of these is open access[17] provided?	**12**
How many of these are published in open access journals?	**12**
How many of these are published in open repositories?	
To how many of these is open access not provided?	**4**
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[18]: ……………	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in 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	
	Registered design	
	Other	

17. How many spin-off companies were created / are planned as a direct result of the project?	
Indicate the approximate number of additional jobs in these companies:	

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

X	Increase in employment, or	X	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
X	Difficult to estimate / not possible to quantify		

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:	*Indicate figure:*

[17] Open Access is defined as free of charge access for anyone via Internet.
[18] For instance: classification for security project.

Difficult to estimate / not possible to quantify	X

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?** O Yes X No
21.	**As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?** O Yes X 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	X	Coverage in specialist press
❑	Media briefing	❑	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
X	Brochures /posters / flyers	X	Website for the general public / internet
❑	DVD /Film /Multimedia	❑	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	X	English
❑	Other language(s)		

Question F-10: Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

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)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]