QNRF – NATIONAL PRIORITY RESEARCH PROGRAM

<table>
<tr><td>NPRP ID</td><td colspan="3">NPRP9-173-1-032</td></tr>
<tr><td>Project title in English</td><td colspan="3">Dust forecasts for Solar photovoltaic systems (SolarDust)</td></tr>
<tr><td>Project title in Arabic (optional)</td><td colspan="3"></td></tr>
<tr><td>Type of Application</td><td colspan="3">◉ New
○ Resubmission
○ Renewal</td></tr>
<tr><td>Type of research</td><td colspan="3">○ Basic Research
◉ Applied Research
○ Experimental development / Translational Research</td></tr>
<tr><td>Submitting Institution</td><td colspan="3">Qatar Environment and Energy Research Institute (QEERI)</td></tr>
<tr><td>Lead PI (title, name, position)</td><td colspan="3">Dr. Luis Martin Pomares, Scientist</td></tr>
<tr><td>List of participants (PIs' names, collaborative institutions, PIs' residency)</td><td colspan="3">
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<tr><td>Total funding requested</td><td>USD</td><td>Project duration</td><td>36 months</td></tr>
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Research Plan

1. PROPOSAL SUMMARY

Qatar's solar energy future is steadily developing. With average daily sunshine of around nine-and-a-half hours, low cloud cover conditions and seemingly plentiful space, there is great scope for solar rooftop as well as large-scale solar power projects in the country. Qatar's global horizontal irradiance (GHI) is 2,189 kWh per m2 per year, which makes it well suited for solar photovoltaic (PV) systems. In addition to solar PV, Qatar has very good potential for concentrated solar power (CSP) as its DNI value is around 2,015 kWh per m2 per year which is above the minimum threshold of 1,800 kWh per m2 per year. The country is geographically well positioned to tap its tremendous solar energy potential and has set a target of twenty percent renewable energy contribution in the national energy mix by 2020, which is an objective identified by the latest Qatar National Research Strategy (QNRS) held in May 2013. Solar energy has multiple advantages for Qatar in the form of energy security, improved air quality, reduced greenhouse gas emissions, apart from augmenting water and food security.

Among other impacts on weather, climate, ecosystems and health, airborne dust can severely affect solar energy production (Schroedter-Homscheidt et al. 2013). Solar power forecasting prevents energy loss and improves the management of solar power plants. Airborne dust obscures the sun and its deposition makes the mirrors dirty, reducing the energy production and demanding laborious and costly maintenance and clean-up tasks. Operators require forecasts of solar insolation to help predict their contribution to the power grid. Moreover, when a significant dust event is foreseen, the moveable elements can be turned to a parked position that affords the biggest protection. Recent studies have shown that the accuracy of existing weather models to predict solar irradiance is not always satisfactory and that a large proportion of the uncertainty can be attributed to the lack of accurate aerosol data (e.g. Ruiz-Arias et al., 2011; Gueymard, 2012). The need for precise dust observation and prediction products is particularly important in the Middle East, where private companies have designed ambitious projects on solar energy production.

The aim of the ***Dust forecasts for Solar photovoltaic systems (SolarDust)*** project is twofold: (1) to develop a complete, innovative, and validated tool that provides short-term prediction of irradiance and mineral dust over Qatar, and (2) to demonstrate the benefit of such prediction tool in the management of solar power plants. The prediction shall serve the purposes of PV and Concentrated Photovoltaic (CPV) installations through the accurate estimation of GHI and DNI. Furthermore, the quantification of mineral dust deposition over the solar structures will improve the management of photovoltaic plants by identifying the periods when the solar panels need maintenance and clean-up tasks. The Earth Sciences Department at Barcelona Supercomputing Center (BSC-ES) has large experience in the field of mineral dust modelling. A state-of-the-art numerical model of the dust life-cycle will be implemented, evaluated and applied to the domain of Qatar. By coordinating and guiding impact modellers and in-house software developers, SolarDust project will help solar energy managers to obtain skillful DNI, GHI and mineral dust short-term forecasts.

2. OBJECTIVES / SIGNIFICANCE

2.1. SCIENTIFIC OR TECHNICAL OBJECTIVES

Renewable energy technologies are a focus for meeting current concerns regarding energy security, the environment, and global climate change in developed and developing nations. Among these clean-energy approaches, solar technologies continue to grow in residential, commercial, agricultural and industrial applications. For electricity generation, photovoltaic (PV) and concentrated solar-thermal power (CSP) systems are the main technologies used to convert the sun's abundant radiation in energy. The energy delivery of a solar-energy system is generally associated with the sun's available irradiance and spectral content, as well as a variety of environmental and climatic factors and inherent system and component performances. However, other external factors relating to geographical location and conditions can have even greater impacts on system performance. The focus is on both transmissive surfaces (e.g., those used for flat-plate photovoltaics or for concentrating lenses) and reflective surfaces (e.g., mirrors or heliostats for concentrating power systems). The most important cause of loss of reflectivity is contamination of the mirror surface, generally a result of contamination from the atmosphere. One such externally not generally considered in deploying and operating most solar systems is the impact of sedimentation (i.e. dust or dirt particles) on intermediate or exposed surfaces. Dust inherently disrupts the intended function at that first surface/light interface, which can significantly reduce the power output and efficiency or can completely terminate system operation. Only recently has the issue of dust come to the forefront because of increased interest and deployment in those parts of the world where dust can have even greater impacts on system performance. Among these, *soiling* of a PV module is a growing area of concern for performance and reliability. Soiling is the sedimentation of particulate matter on the exposed surfaces of solar collectors. In the case of PV, *soiling* is commonly overlooked or underestimated the issue that can be a showstopper for the viability of a solar installation. On the other hand, high-relative humidity, dew or soft rain may function as a natural cleaning agent on hydrophobic surfaces, as it causes cementation layers on the surfaces. Today the most effective mitigation technique is physically washing the surfaces of the solar devices with water or detergent solutions. This technique is labor and resource (water) intensive, which in turn, can lead to high operation and maintenance cost. Furthermore, in the regions where solar availability is most abundant, water resources are typically scarce, thus making wet cleaning an unfavourable approach.

The ***Dust forecasts for Solar photovoltaic systems (SolarDust)*** project has two main objectives, (1) to investigate the impact of dust aerosols on GHI and DNI predictions through the explicit modelling of direct effect of aerosols on radiation within a meteorological model, and (2) to provide insights to be able to predict the effect (reduction) in the power output of a solar system based on dust accumulation mechanics, chemistry and optics in the region of Qatar. Overall, we plan to demonstrate the benefit of such prediction tool in the management of solar power plants. The development of novel tools that provides weather and dust short-term predictions will strongly benefit solar power generation sector, by predicting reduced radiation at the surface impacting the final electric production from solar power plants and allowing better planning of maintenance and cleaning of their collecting and transmitting elements. This latter is especially important in desert areas where water required for cleaning should not be wasted. In this context, the main outcomes of the project will be the following:

- deployment of a weather-dust modelling system configured for the study region of Qatar,
- model evaluation for a complete annual cycle: meteorology (solar radiation and temperature) and dust (dust deposition, dust load and surface concentration),
- estimation of DNI and GHI modelled fields considering the direct effect of mineral dust on radiation,
- quantification of the potential solar power energy in Qatar using modelling techniques (including the effect of the dust deposition on the PV panels).

The access to accurate forecasts products of GHI, DNI, and mineral dust deposition may significantly contribute to define more efficient procedures in the operation of solar plants. Two main impacts of dust on solar power plants will be addressed in SolarDust:

a. *Impact of mineral dust on solar radiation*

Radiation interacts with a variety of atmospheric gases as well as aerosols. Usually in the atmosphere, the total column concentration of longer lived gases such as CO_2 and O_3 do not change on timescales shorter than several days. However, the cloud and aerosol optical depths (i.e. AOD) or thicknesses may undergo large variation and are considered important variables which affect DNI and GHI.

Clouds, when present, are very effective at reflecting sunlight. Aerosols largely determine DNI on a cloudy free day. The magnitude of interaction is a function of their size, composition, and concentration all of which are constantly undergoing rapid alterations and are quantified by AOD. Typical values of AOD for continental areas range between 0.2 and 0.4 which for DNI results in a decrease due to aerosol alone of between 18% - 33%. However, the episodic nature of certain aerosol components should be taken into account. Mineral dust and biomass aerosol concentrations may increase more than an order of magnitude in over a period of several hours while other aerosols formed from gas to particle combustion tend to vary somewhat more slowly. During these events, visibility is reduced and AOD maximizes possibly reaching values between 0.5 and 2, depending on the distance from the source.

b. *Impact of mineral dust on PV and CPV infrastructure*

Throughout the past 70 years of solar research, the vast majority of studies have been observations of the reduced performance (e.g.,power reduction from a PV module) due to dust accumulation and related environmental factors as a function of exposure time at a particular test site or facility. There is some criticism about the general applicability of such conclusions because dust accumulation occurs at various rates in different parts of the world. An important conclusion was that the effect of dust on the performance of PV panels could no longer be correlated simply to the exposure time in a given site, as suggested by many previous researchers. The results strongly indicated that the nature of the dust–such as dust composition, its size distribution, and the dust deposition density–strongly influences the loss of output power from the PV panels (Sarver et al. 2013). (El-Nashar, 2013) compared the effect of dust accumulation in the United Arab Emirates on the performance of evacuated-tube and flat-plate types solar–thermal collectors over different time periods, extending from one month to a year. A decline in glass transmissivity is seasonal, between greater than 10% month during summer and about 6% month in winter. However, a 70% reduction in the collect or performance was observed when the collector was left without cleaning for the entire year.

Despite this exceptional body of experimental information, much remains to be understood about the complex relationship between dust and performance of these solar devices — and more importantly, the mitigation of these issues. Primarily, the deposition rates were the controllable and/or measurable parameters in these studies. In some cases, these rates can be misleading due to climate conditions (e.g., precipitation, windstorms) that were not always noted during the outdoor exposures. Even more fundamental, the issues relating to the forces holding the dust to the surface and the materials that may be in the dust (e.g.,organic matter) that hold the particles together have only begun to be investigated and understood.

Understanding the relationships between the physical properties of dust particles (e.g., size, geometry, and chemistry) and the performance of a solar collector (panel) is potentially the critical key to develop effective mitigation and prevention techniques. We will address the chemistry, topology, and morphology of dust particles. Of course, the physical nature of the dust and the deposition characteristics are governed by the region of the world in which the dust studies are conducted.

2.2. SOCIAL, HEALTH, ECONOMIC AND ENVIRONMENTAL CONTEXTS

The Qatar National Vision 2030 (QNV2030) is a master vision and roadmap towards Qatar becoming an advanced society capable of sustainable development with the goal of providing a high standard of living for all citizens by the year 2030. Power generation in all forms, be it solar or natural gas, is one of the engines powering Qatar’s grand 2030 vision forward. With population and rates of power consumption increase, the need for clean and sustainable sources of energy is extremely necessary. Moreover, Qatar is emerging as a key Gulf country that is leading progress of the GCC region. Worldwide events like upcoming FIFA World Cup 2022 are clear evidences of Qatar’s growing importance. However, local resources must follow up with new socio-economic events in Qatar.

The SolarDust project aligns with Qatar National Vision 2030 (QNV2030), “undertake a comprehensive assessment of solar energy resources in Qatar for the purposes of developing a National Research Agenda” and it promotes the four pillars that the QNV2030 is based on, these are: human, economic, environmental, and social development. The project promotes “human development” through developing a technology that enhances the quality of lives and wellbeing of all Qatari people and enables them to sustain a prosperous society. Also solar energy usage promotes “Economic Development” as it reduces local consumption of gas and oil and spares them for export. Also solar energy promotes “Environmental Development” as it is a clean source of energy that reduces the production of harmful emissions. Finally the research promotes a knowledge-based society that is capable of playing a significant role in the global partnership for development.

2.3. ADVANCES ON STATE-OF-THE ART

On the one hand, the presence of mineral dust in the atmosphere has an impact in the solar power generation sector, by reducing solar radiation at the surface impacting the final electric production from solar power plants (Mani et al., 2010; Sarver et al., 2013). On the other hand, based on the observed time-dependent degradation, many authors derived a correction factor or a guideline for cleaning frequency. There is some criticism about the general applicability of such conclusions because dust accumulation occurs at various rates in different parts of the world (i.e. Zorrilla-Casanova, 2011; Qassem et al., 2012).

The **SolarDust** project will be based on weather and mineral dust simulations performed with the state-of-the-art model **NMMB/BSC-CTM** (Pérez et al. 2011; Jorba et al. 2012; Spada et al., 2014; Badia and Jorba, 2015) developed at BSC-ES. The model is a multi-scale non-hydrostatic atmospheric chemistry and weather prediction system comprised of an atmospheric driver (the Non-Hydrostatic Multi-scale Model on the B grid, NMMB) developed at NOAA/NCEP and a Chemical Transport Model (BSC-CTM) coupled online and implemented by BSC-ES. It contains advanced physics, chemistry and aerosol packages, and has the unique ability to be configured as a global model or as a very high-resolution regional model, both with embedded 1- or 2-way static or moving nests. Seven types of tropospheric aerosols are included: sea salt, dust, black carbon, organic matter (both primary and secondary), sulfate, nitrate and volcanic ash. The model also includes the option to solve the comprehensive chemistry of the troposphere with a detailed gas-phase chemical mechanism with 51 chemical species and 156 reactions. Physical processes include dry deposition, gravitational settling, wet deposition (including rainout and washout in and below the clouds), and the direct effect of aerosols on radiation explicitly considering the attenuation of the radiation by atmospheric aerosols. The online approach makes the NMMB/BSC-CTM model as a perfect tool to address the feedbacks of aerosols on radiation.

BSC-ES mantains mineral dust forecasts with the model and contribute to the WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) Regional Center for a regional domain comprising Northern Africa, Middle East and Europe (http://sds-was.aemet.es/), where it is combined with other dust model forecasts from collaborating institutions (ECMWF, SEEVCC, Met Office, NASA, NCEP, EMA and CNR) and all systems are evaluated in near-real time. The model also runs operationally (7 days a week, 365 days a year) at the Barcelona Dust Forecast Center (BDFC; http://dust.aemet.es/about-us) with a horizontal resolution of 10 km for the same region. At the global scale, the model contributes to the International Cooperative for Aerosol Prediction (ICAP) Multi Model Ensemble (Sessions et al., 2014), which is built from the following systems in addition to the NMMB/BSC-CTM: ECMWF MACC, JMA MASINGAR, NASA GSFC/GMAO, FNMOC/NRL NAAPS, NOAA NGAC, and Met Office Unified Model.

To ensure the accuracy of the model, a set of observational databases and real time measurements in Qatar (ground-based and satellite observations) will be used to evaluate the model skills to predict GHI, DNI and mineral dust deposition. QEERI is running one radiometric and meteorological station in Doha since 2012 and 13 new stations will be installed by the end of 2015. Besides, there is solar radiation and dust deposition measurements from the Solar Test Facility.

QEERI is developing the Qatar Solar Atlas which is based mainly in ground surface radiometric measurements and remote sensing from satellite observations. Nowadays, there is no modelling of solar radiation which takes into account the effect of dynamic dust aerosols obtained from model forecasts.

DNICast which is a project founded by European Union to improve the integration of solar energy by developing DNI Nowcasting methods for optimized operation of concentrating solar technologies. It is mainly focused on the physical modelling of aerosols and specially dust for the region of North of Africa.

2.4. PRELIMINARY DATA OR STUDIES

Desert dust models are essential to complement dust-related observations, understand the dust processes and predict the impact of dust on weather and climate, ecosystems, health, agriculture, transportation and solar energy production. For example, in Gallisai et al. (2014) use the modelled dust deposition values of the BSC-DREAM8b to analyse statistical correlations between dust deposition over the Mediterranean Sea and surface chlorophyll concentrations at ecological time scales. Pérez et al. (2006) demonstrate how the inclusion of mineral dust radiative effects in a regional model could lead to a significant improvement in the radiation balance of numerical weather prediction models with subsequent improvements in the weather forecast itself.

The mineral dust module of the NMMB/BSC-CTM model has been evaluated at regional and global scales (Pérez et al., 2011; Haustein et al., 2012; Gama et al., 2015). At the global scale, the model is within the top range of 15 global dust models involved in the framework of AEROCOM project (Huneeus, et al, 2011) in terms of performance statistics for surface concentration, deposition and dust optical depth (DOD) (Pérez et al., 2011). At regional scale, Haustein et al. (2012) compared the model against data taken from the Saharan Mineral Dust experiment (SAMUM-1) and the Bodélé Dust Experiment (BodEx) field campaigns, Pérez et al. (2011) with AERONET data and satellites, and locally in Cape Verde in Gama et al. (2015) with AERONET data and PM10 sites. In these studies, the model was able to reproduce the spatial and temporal features of dust cycle.

3. EXPECTED IMPACT OF THE PROJECT

3.1. SOCIAL, HEALTH, ECONOMIC, AND ENVIRONMENTAL IMPACT

The performance of PV and CPV systems is affected by local geographical and climatic challenges, including high temperature, humidity, soiling and atmospheric composition (i.e. aerosols/dust). The aim of the present proposal is to provide reliable modelling tools to improve the predictability of the solar power resource and contribute to solar feasibility studies.

Improved and more reliable DNI, GHI and forecast dust concentrations estimations will increase the efficiency of PV, thus contributing to cost decrease and a massive deployment of renewable energy technologies, and will further strengthen the Qatar position in the field of PV. This will have important effects in terms of job creation, and other socio-economic benefits. The results of the project also will be fundamental for the discussions of mitigation techniques, including deposition/cleaning mechanics, surface alterations, coatings and active dust-prevention technologies. Such effects are very important for the economics of the installation (sizing, and the cost-benefit relationships for the cleaning procedures and /or surface treatments). The **SolarDust** project will also positively impact the scientific community through a better knowledge of end-users real needs and an optimization of the data definition for solar energy production. The exchange of expertise and communication inside the project will also allow the identification of new user-oriented products.

3.2. QNRS ALIGNMENT/NPRP PROGRAM OBJECTIVES

The main focus of this project is on renewable energy integration and air quality modeling. The proposed research supports a comprehensive solar energy research program (EE.2.1) aimed at improving the efficient use of energy and the reduction of greenhouse gas emissions in Qatar (EE.3.1), enabling a more sustainable urbanization and a healthier living environment (EE.5.4), and lowering Qatar's emissions of greenhouse gases (repeated from EE.3.1) (EE.6.1).

The project is aligned with the Energy Security Grand Challenge in the 2014 QNRS, with specific reference to the establishment of Qatar as the hub for photovoltaic (PV) technologies. According to the 2014 QNRS, Qatar needs to be ready to produce 1GW of solar energy capacity for power generation. To achieve this objective, high penetration of PV energy into the Grid needs accurate predictions of solar power electric production. Moreover, the proposed research will benefit the understanding of aerosols in general, and particularly dust, for air quality security and PV adoption in Qatar. At the same time, this project will help to maintain the reliability of electricity supply despite the intermittency of solar power generation. The project is intended to foster a research culture in Qatar. We will promote capacity building of Qatari researchers and trainee to build a human capacity in Qatar. Besides, we will create a research infrastructure in Qatar with a new Aeronet station and transfer the capacities to model dust in the new high performance computing capacity of QEERI. Also, we will "promote scientific excellence in Qatar" publishing in top international journals. This project will be also an "opportunity to collaborate with outstanding researchers" in the field of solar energy and air quality dust modelling. Young Qatari researchers and scientists from HBKU and other universities in Qatar will acquire and/or enhance its skills in the field with training exchanges and knowledge transfer with BSC-ES in Barcelona. It will give an opportunity to gradually create a knowledge-based national economy. Results and data from the study will be disseminated through QEERI's data portal and web site. Finally, it will lead to research outcomes that have an impact on the society of Qatar as it will be also the base to develop the PV prediction system to manage the Smart Grid in Qatar, improve operation of PV plants and improve air quality and dust storm prediction.

3.3. COMMUNICATION AND EXPLOITATION OF RESULTS

The communication and exploitation plan designed in the **SolarDust** project is oriented for a science project that aims at developing a proof-of-concept solution from science to operational demonstration environment. Communication and Dissemination of the project is a central activity in the main objectives of **SolarDust**. Indeed a specific work package on dissemination (WP6) is conceived which runs for the whole project life. Dissemination of **SolarDust** results will be mainly targeted to the solar energy management centers, solar engineer modelling community, atmospheric modelling communities and the impact community. The results suitable for dissemination will be published in refereed international journals and/or presented in lectures and conferences. Furthermore, products/services developed within the project will be disseminated through the website of the project. The project also will be open to all potential stakeholders. In order to reach and involve stakeholders, a call will be published on the dedicated web page to suggest/request participation of potential users. In this project we have identified the following initial stakeholders:

- Qatar Meteorological Department (QMD), Civil Aviation, to improve its meteorological and dust storms predictions. QMD actual system, based on mesoscale numerical prediction model WRF, will benefit directly from a more detailed esquemes of mineral dust emissions..
- Hamad International Airport (HIA).
- Kahramaa to integrate future PV power plants to be developed in Qatar into the Grid.
- Supreme committee for Delivery and Legacy who organizes FIFA 2022 to improve air quality predictions and alerts during the World Cup. Besides, integration of PV rooftop in the stadiums.
- Capacity building for universities and research groups in Qatar(like Hamad Bin Khalifa University (HBKU), College of North Atlantic and Qatar University).

The new user-oriented products will be put available to the general public through the forecast websites of BSC-ES and the new results will be transferred to Regional Center for Northern Africa, Middle East and Europe of the World Meteorological Organization (WMO) Sand and Dust Storm Warning Assessment and Advisory System (SDS-WAS; http://sds-was.aemet.es/) and the Barcelona Dust Forecast Center (BDFC; http://dust.aemet.es/).

3.4. FUTURE PLANS

Solar energy technologies such as PV, solar heating, and solar thermal energy are strongly dependent on aerosol loading and clouds, whose size and distribution are the most relevant factors in the attenuation of solar irradiance at surface. Stakeholders and research in Qatar will benefit directly from the results of this projects as the improvements obtained here will be implemented directly in BSC dust model. Online predictions will be available for free from SDS-WAS center.

This project will be the base to develop a solar prediction system in Qatar that will consider the effect of mineral dust in the radiative balance of the atmosphere. The experience gained during the life of the project will position QEERI in the line to start a regional warning system on sand and dust storms based on modelling techniques. The experience that BSC provides, who is the center which manage SDS-WAS for Europe and North of Africa, will help to achieve the objective of Qatar to be transformed in the regional center for dust modelling recognized by the World Meteorological Organization (WMO). Moreover, the results and knowledge acquired during this project can be applied to other GCC regions. This results can be commercialized in the form of patents and spin-offs for dust storms and air quality alerts and to improve the management , operation and operation of solar power plants into the Grid.

4. PROJECT STRUCTURE

4.1. SCIENTIFIC PLAN

The main goal of the project **SolarDust** is to investigate the impact of dust aerosols on GHI and DNI predictions as well as the effect the dust deposition has over the solar energy generation infrastructures using numerical modelling simulations. The goal will be to develop methods for assessing the suitability of sites for installation of PV and possibly CPV systems in Qatar.

The following specific activities (associated to specific working packages WP) have been defined to achieve the objectives of the present project: (1) Regional dust simulation, (2) Characterization of the study region: In situ-observations in Qatar, (3) Model Evaluation, (4) Assessment of new user-oriented dust product for solar energy community, (5) Dissemination and capacity building. Here we give an overview of the overall project work structure:

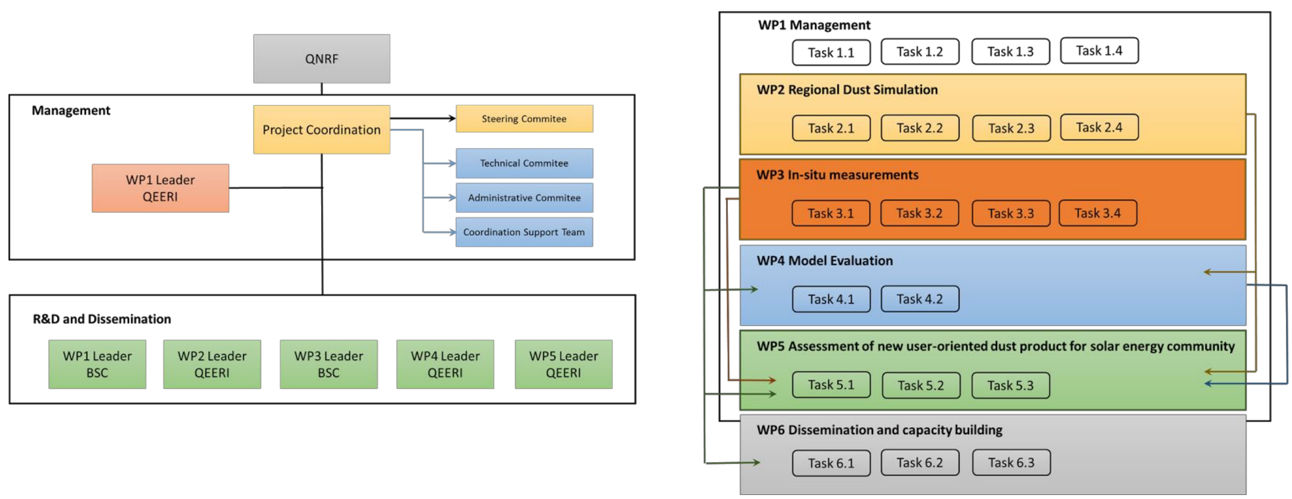


Figure 1. Project Management Structure of the SolarDust project (left) and SolarDust breakdown structure (rigth).

Besides the project management (**WP1**), also **WP2** and **WP3** activities span across the whole project. In fact the project starts with a previous model arrangements that will be indispensable to generate the regional dust simulation (**WP2**) and the in-situ measurements (**WP3**) fundamental for the characterization of our study region, i.e. Qatar. Model simulations will be evaluated in **WP4**. First, a review and an assessment for the quality assurance of dust-related observations will be done and then, these observational datasets will be compared with the modelled values. This regional dust simulation will be used to the definition and assessment of new user-oriented dust products for solar energy community in **WP5**. To better define and assess new user-oriented products, it will be essential to identify and catalogue dust forecast products and assess their suitability for different users and the participation of different stakeholders. Finally, **WP6** will report and disseminate the results and conclusions drawn from the project results as well as to promote the capacity building among the overall stakeholders in Qatar. The tasks associated to each WP are described in detail in Section 4.3.

4.2. PROJECT MANAGEMENT

Management of the project will be based mainly in communicating and reporting to QEERI. Reports have been established periodically on a yearly basis. Monitoring of the project is needed for assuring its correct development. Corrective actions will be applied, if required, to reduce deviations from the original plan. Achievement of milestones will provide information on the proper development of the project. The Project management and monitoring of the project progress is described in the **WP1** in Section 4.3.1.

The management structure is depicted in Figure 1. The main elements are: Project Coordinator, Steering Committee, Technical Committee, Administrative Committee and Coordination Support Team. The Project Coordinator, QEERI, has the overall technical, administrative and financial responsibility for the organisation, planning and control of the project. The Project Coordinator is the official intermediary between the proposed SolarDust project and the QNRF National Priority Research Program as such ensures the punctual delivery of reports and deliverables. The Project Coordinator is assisted by the Coordination Support Team formed by members of BSC.

The main risk associated to the present proposal is the computational cost associated with some analyses and the availability of the observational databases for the model evaluation activity. In this sense, the consortium will explore different strategies as needed, including calculations parallelisation and use of cloud infrastructures as well as to provide high-quality observations (meteorological and dust). Moreover, critical risks for project implementation includes the processes concerned with the probability and impact of adverse events on the advancement of the project. The risk management function will be conducted by the project coordinator and will be carried out in a proactive and consistent manner by all partners during the project duration.

4.3. TECHNICAL DESCRIPTION BY WORK PACKAGE

4.3.1. <u>WP1: Project management and monitoring of the project progress</u>

Work package number	**1**	**Start Month**	m1	**End Month**	m36
Work package title	Project management and monitoring of the project progress				
Name of participant	*L. Martin*	*O.Jorba*	*A.Sanfilippo*	*A.Soret*	
Effort days per participant:	80	18	100	54	
Performance site (if applicable)	Qatar/Spain	Spain	Qatar	Spain	

Objectives of this work package

- To deliver on the scientific and technical objectives of the project within the time and budget constraints of the project.
- To ensure that there is clear and effective communication between partners; to detect management and technical issues as early as possible and bring them to resolution.

- To establish and enforce the requisite management and quality procedures that will result in high quality project deliverables.
- To provide efficient operational management support including: administrative and financial planning and reporting to QNRF, management of project legal aspects including project-related contracts and management of day-to-day operational and technical progress.

Description of work

The following is a list of the tasks required to achieve the objectives of this work package. The high level Management Structure as well as the individual roles and responsibilities within this structure are explained in Section 4.2 of this document. All WP activities and tasks will be carefully and frequently monitored every three months. Quality metrics will be reported annually.

T1.1. Administrative and financial management (m1-m36) (QEERI) Lead by the project manager, this task will establish the corresponding procedures, tools and methodologies to enable a correct project management, including administrative and financial management. It will also coordinate the timely production of deliverables, organize the kick-off meeting and reviews, and organize and manage audits requested by QNRF.

T1.2. Technical coordination (m1-m36) (BSC). Lead by the technical manager, this task will perform the technical coordination of the project, by means of monitoring the progress of the work packages, technical coordination of the meetings, appointing reviewers to assess the quality of the deliverables before their delivery to QNRF, and solving technical conflicts. Work packages progress will be assessed every three months in the form of Management Board teleconferences, and provided to QNRF in the Periodic Reports. This task will also take care of organizing the yearly General Assembly and Scientific Advisory Board meetings, which will focus on detailed project planning.

T1.3. Internal communication strategy definition (m1-m6) (QEERI). In this task, we will determine the appropriate strategy to ensure clear communication channels between all partners in order to facilitate the exchange of critical project documentation and news and to encourage participation in the decision-making process. The direct outcome of this task will be a Project Portal (shared workspace) and a series of Project Distribution Lists.

T1.4. Establishing project management and quality assurance procedures (m1-m4) (QEERI). In this task, we will define and implement the appropriate administrative project management processes that ensure accurate documentation, reporting and justification of the work being carried out. Moreover, we will determine the minimum level of quality required for presentation to QNRF as official outcomes of the project. The high level principles guiding these procedures will be agreed to at the start of the project at the Kick-off Meeting. These administrative project management and quality assurance processes will be documented in the Project Handbook.

Deliverables

D1.1 Project Management and Quality Guidelines (QEERI, BSC) (m2).

D1.2. Project Portal (QEERI) (m4).

D1.3. Y1 Periodic report (QEERI) (m12).

D1.4. Y2 Periodic report (QEERI) (m24).

D1.5. Final Periodic report (QEERI) (m36).

Milestones: M1.1. Kick-off meeting (m1). M1.2. Website Portal release (m4). M1.3. First workgroup progress meeting (m13). M1.4. Second workgroup progress meeting (m25). M1.5. Final workgroup progress meeting (m36).

4.3.2. WP2: Regional dust simulations

Work package number	**2**	**Start Month**	m1	**End Month**	m24
Work package title	Regional dust simulations				

Name of participant	*O.Jorba*	*S.Basart*	*Graduate student 1*	*Lab Technician 1*
Effort days per participant:	218	148	17	17
Performance site (if applicable)	Spain	Spain	Spain	Spain

Objectives of this work package

- To set-up a mineral dust forecast system for Qatar domain based on the NMMB/BSC-CTM online model developed by BSC-ES.
- To improve the representation of the mineral dust size-distribution for the domain of Qatar.
- To calibrate and evaluate the deposition schemes of the mineral dust component based on available observations of dust deposition from the solar test facility.
- To prepare the information of the optical properties of the dust aerosol on the model to simulate the interaction of aerosols with the radiation.
- To enhance the parallel efficiency of the numerical model and the I/O components to allow high resolution simulations.
- To conduct a series of model runs to assess the impact of mineral dust aerosols on the GHI and DNI and quantify the deposition of dust over locations under study.

Description of work

The aim of the present activity is to set-up and improve the current BSC-ES Mineral dust forecast system, based on the NMMB/BSC-CTM, for the domain of Qatar. The modelling system will provide high resolution forecasts of weather conditions, mineral dust aerosol concentration and dust deposition. Both spatial and temporal resolution will be the ones required to reproduce the synoptic and mesoscale phenomena observed in the Qatar domain. This will contribute to deepen in the knowledge of emission and dynamics processes of mineral dust. This will be achieved by analyzing the impact of the spatial resolution on the dust emission scheme, because dust emission plays a critical role on the simulation of the dust life cycle.

The following is a list of the tasks required to achieve the objectives of this work package. All WP activities and tasks will be carefully and frequently monitored every three months and reported to Project Manager group.

T2.1 Set-up of the mineral dust model NMMB/BSC-CTM for the domain of Qatar (m1-m6) (BSC). The first task to be conducted will be the design of the model domains under study. The objective of the modelling system is to provide high- spatial (3 km x 3 km) and temporal (3 hourly) resolution for the area of Qatar. This will be done by defining a nesting configuration with a parent domain covering the whole Northern Africa and Middle East domain at 10 km resolution, and a nesting domain over Qatar. A specific source mask for the area under study will be prepared based on required soil and landuse texture databases provided by QEERI. Initial meteorological conditions will be based on the global meteorological forecasts of the GFS forecast system provided by the National Centers for Environmental Prediction. A sensitivity study about the role of soil moisture content over desert areas obtained from GLDAS or ERA-Interim datasets will be conducted to improve the skills of the model to reproduce the extreme temperature and wind processes observed in the area. A period of study will be defined selecting a series of episodes where sand and dust storms developed over the region of study and have a significant impact on the solar irradiance and relevant deposition over the surface. The system will run 72h forecasts and the skill of the system will be assessed for each forecast window.

T2.2 Model developments specific for the domain of Qatar (m6-m18) (BSC). This task searches to test new model developments to improve the current mineral dust forecast system over Qatar.
a) Sensitivity to the spectral size distribution of mineral dust: The dust transport size spectra have an indispensable influence upon dust budget and spatio-temporal dust distribution. Regional and global model overestimates the emitted fraction of clay aerosols (<2μm diameter) by a factor of ~2-8 relative to measurements. A recent theoretical emitted dust distribution from Kok (2011 PNAS), based on the physics of the scale-invariant fragmentation of brittle materials, will be implemented in the emission scheme of the model and evaluated using a size distribution observational dataset over Qatar.

b) Calibration and evaluation of the mineral dust deposition scheme: the NMMB/BSC-CTM implements a dry deposition scheme based on the resistance analogy. The dry velocity of the aerosol is parameterized following Zhang et al. (2001). The aerodynamic resistance accounts for turbulence and it is calculated using the NMMB surface layer scheme which is based on the well established Monin-Obukhov similarity theory and the parameterizations of a viscous sub-layer for land (Zilitinkevich, 1965) and water (Janjic, 1994). This approximation will be calibrated with a set of available measurements of dust deposition over different locations. After the proper calibration, the whole system will be evaluated with the complete set of observations provided by QEERI. *c) Radiative effect of aerosols on radiation:* In order to couple aerosol and radiation processes, the RRTM radiative transfer module (Mlawer et al., 1997) including aerosol effects is used in the NMMB meteorological model. This radiation module allows aerosols to interact with both short and longwave radiation. For each size bin/mode and wavelength, the extinction efficiency, single-scattering albedo and asymmetry factor are computed with the Mie-theory. Spherical homogeneous particles are assumed. The refractive indices will be derived from the Global Aerosol Data Set (GADS) and the optical properties will be tabulated following the size distribution on transport of the mineral dust. The RRTM computed both GHI and DNI considering, thus, the scattering and absorption effect of the aerosol. Both variables will be saved in the output of the model and evaluated with available observations provided by QEERI. **T2.3 Optimization of the model performance and I/O (m12-m18) (BSC).** The performance of the dust forecast system will be analyzed. Trace analysis of an execution in the supercomputer Marenostrum will be analyzed with advanced performance tools like PARAVER, DIMEMAS developed by the Computer Sciences Department of BSC. The communication pattern of the model, the input/output structure of the system, the coupling of the meteorology with the chemistry and aerosols will be studied. Any improvement on the model performance will have an important effect on the overall forecast time of the forecasting system. **T2.4 Model runs for the prediction of GHI, DNI and dust deposition (m18-m24) (BSC).** A series of forecasts runs will be conducted following the configuration defined in T2.1 and with the scientific and technical improvements developed in T2.2 and T2.3. A specific period of springtime will be selected to run the model in forecast mode and the meteorological variables GHI and DNI and the deposition of mineral dust on the surface will be retrieved and evaluated. The model results will be crossed with available observations to identify the correlation and cross-correlation existing within the dataset. The results of this task will be provided to WP4 for evaluation and WP5 for the assessment of the dust aerosol impact on solar power prediction.
Deliverables D2.1 Report on the model configuration (BSC) (m6). D2.2 Report on the uncertainties in the deposition scheme (BSC) (m9). D2.3 Report on the impact of the surface size distribution of erodible materials (BSC) (m12). D2.4 Report on the sensitivity of dust radiative forcing module in NMMB/BSC-CTM (BSC) (m18). D2.5 Report on the performance analysis and improvement of the NMMB/BSC-CTM (BSC) (m18). **Milestones:** M2.1. Set-up of model outputs (m3). M2.2. Model runs (m24).

4.3.3. **WP3: In-situ measurements**

Work package number	**3**	**Start Month**	m1	**End Month**	m36
Work package title	In-situ measurements				
Name of participant	*Daniel Perez*	*Dunia Antoine*	*Luis Martin*	Benjamin W Figgis	
Effort days per participant:	150	150	10	50	
Performance site (if applicable)	Qatar	Qatar	Qatar	Qatar	

Objectives of this work package

- Selection of instrumentation to measure aerosol optical depth, concentration of particulate matter (PM2.5, PM10).
- Coordination to obtain solar radiation measurements from Qatar Solar Atlas project developed by QEERI.
- Installation of the instrumentation in the location which are suitable following AERONET network recommendations.
- Development of the methodology to calibrate and operate the instrumentation.
- Capacity building of the instrumentation for personnel in Qatar (QEERI, QMD and Universities in Qatar).

Description of work

Ground measurements of aerosol optical depth (AOD) and water vapour are important to validate and improve predictions of numerical models and remote sensing estimations from satellites. AOD is monitored by AERONET project at global scale over land. In the case of Qatar, it is the only country in GCC region which is not operating an AERONET station. As a consequence, we have identified the necessity to install one AERONET station within this project. This new station will improve knowledge on atmospheric research and monitoring, specially for aerosols and mineral dust.

The following is a list of the tasks required to achieve the objectives of this work package.

T3.1. Selection of Qatar AERONET site and acquisition of equipment (m1-m6) (QEERI) This task will follow a procedure to choose the best site in Qatar to install the new AERONET station. This work will be done in collaboration with Qatar Meteorology Department (Civil aviation), Hamad International Airport and Solar Atlas project in QEERI with the intention that all stakeholders in Qatar can benefit as much as possible from this new facility.

In the Qatar AERONET station, we will install the new photometer CE318-T which nowadays is the only instrument approved to measure AOD and water vapour within AERONET network. CE318-T able to perform daytime and nighttime photometric measurements using the sun and the moon as light source. Therefore, this new device permits to extract a complete cycle of diurnal aerosol and water 5 vapor measurements valuable to enhance atmospheric monitoring.

We will acquire two CE318-T sun photometers. One instrument will work as operational and the other will be used as spare to be switched immediately in case of malfunctioning of the operational. Besides, the instruments will have to be sent overseas for calibration and to avoid any lack of measurements, meanwhile the instrument is being calibrated, we will need an additional sun photometer.

T3.2. Operation of AERONET station (m6-m36) (QEERI) This task will establish the corresponding procedures, tools and methodologies to enable a correct operation of the new station following AERONET procedures.

The new AERONET station in Qatar will also contribute to the Sand and Dust Storm Warning Advisory and Assessment System Regional Center for Northern Africa, Middle East and Europe (http://sds-was.aemet.es) hosted by Spanish national weather center (AEMET) and the BSC.

Radiometric station and Lidar-Ceilometer in Education City (Doha) operated by QEERI will provide measurements for the model validation and initial conditions. New 13 radiometric stations will be installed in the next months in a collaboration between QEERI and QMD. All these measurements will be used in this project.

T3.3. Capacity building on aerosol ground measurements and operation of AERONET station (m4-m10) (QEERI). This deliverable will specify all training needs, activities and materials needed during the project. The plan will include details of how existing training channels will be exploited to ensure as wide a take-up as possible.

T3.4. Yearly calibration of sun photometer (m18-m36) (QEERI) The only center in the World qualified to calibrate CIMEL CE318-T sun photometer, the instrument approved for AERONET network, is the Izana center which belongs to AEMET (Barreto et al., 2015). There have been several previous collaborations in the field of this project between Izana center and BSC. Use and operation of the and Capacity building of QEERI and Qatari personal will be done in Izana center for the operation and use of the AERONET instrumentation.

Deliverables
D3.1 Qatar AERONET station report (QEERI) (m6).
D3.2 Calibration and operation of Qatar AERONET station report (QEERI) (m18).
D3.3 Characterization of aerosols in Qatar report (QEERI) (m30).
Milestones: M3.1. Acquisition of the instrumentation (m3). M3.2. Installation of instrumentation (m6). M3.3. Capacity building of the instrumentation (m7). M3.4. Calibration of instruments (m18 and m26).

4.3.4. **WP4: Model Evaluation**

Work package number	4	Start Month	m12	End Month	m36
Work package title	Model Evaluation				
Name of participant	O. Jorba	S. Basart	Graduate student 1	Lab Technician 1	
Effort days per participant:	36	59	13	13	
Performance site (if applicable)	Spain	Spain	Spain	Spain	

Objectives of this work package

- To define protocols and formats for data exchange.
- To develop procedures and protocols for the evaluation of forecast products.
- To discuss the model performance and test and analyse its behaviour with new components through the comparison against observations.

Description of work

The following is a list of the tasks required to achieve the objectives of this work package. All WP activities and tasks will be carefully and frequently monitored every three months and reported to Project Manager group.

T4.1 Compilation of available observations over Qatar (m12-m18) (BSC). Besides the uncertainties in representing dust physical processes, there are enormous challenges in the availability and use of dust observations for evaluation in mineral dust forecasts. The present task will work on the identification of the most suitable observational products over Qatar in coordination with WP3. Additionally to the observations from WP3 other observational datasets from ground-based and satellite platforms will be compiled and analysed in the present task.

a) Meteorological observations. Upper air measurements from radiosoundings provide the provided by the Wyoming University (http://weather.uwyo.edu/upperair/sounding.html) are available for the model comparison of the vertical structure of the atmosphere. METAR and SYNOP stations provide weather observations at ground surface level. SYNOP (surface synoptic observations) is a numerical code used for reporting weather observations made by manned and automated weather stations. These observations contain a large amount of variables such as wind speed, direction wind, temperature, atmospheric pressure, dew point, cloud cover and height, visibility, and precipitation, among other. This information is relatively important due to the high density of available sites over desert dust regions and their frequency of the measurements. Also regional and local solar radiation networks will be considered particularly for GHI and DNI, i.e. available measurements from Qatar Solar Atlas.

b) Mineral dust observations. While satellite dust products have helped identify major dust features, most retrievals only provide qualitative information, particularly over the bright desert regions that are dust sources, where the aerosol signal cannot be easily isolated from the surface reflectance. There are some quantitative aerosol products available over dark targets such as oceans, but these only weakly constrain aerosol loads upwind over the source region. In the present task, a selection of the most suitable aerosol satellite products will be perform. Additionally, surface concentration, vertical profiles, AOD and deposition will be obtained from local and regional networks included in WP3. Comparison between dust modelled and observed values can not be adequately understood if the measurements are not segmented into their more fundamental aerosol

components. Therefore, the present task also will include an accurate aerosol characterization of the measurements in other to discriminate and to monitor different aerosol. Quality controls of the measurements will be conducted for the evaluation complementing WP3 data. **T4.2 Model evaluation (m18-m36) (BSC).** Dust model evaluation is essential to determine the strengths and weaknesses of the model. The dust forecasts and their spatial and temporal variability can be evaluated by means of the measurement of the optical properties of the atmospheric dust, the meteorological variables associated with the dust mobilization, the dust deposition and the vertical dust distribution. In the present task, the available observations compilated in T4.1 will be used for the evaluation of the NMMB/BSC-CTM model outputs obtained in WP2. To conduct the model evaluation it will be necessary to homogenize the observed and modelled (meteorological and dust) data compiled in T4.1. The present task will also deal with the most appropriate way to communicate the models uncertainty for solar energy activities.
Deliverables D4.1 Report on dust observational parameters solar energy operational capabilities (BSC) (m15). D4.3 Report on recommended protocols and formats for harmonisation observational databases (BSC) (m18). D4.3 Report on recommended protocols and formats for harmonisation model simulations (BSC) (m21). D4.4 Protocol for model evaluation to assess their suitability for solar energy operational capabilities (BSC) (m24). D4.5 Report on documentation and communication of quality and uncertainty in dust observations. (BSC) (m36). **Milestones:** M4.1. Homogenized observational databases (m14). M4.2. Homogenized simulated databases (m18).

4.3.5. **WP5: Assessment of new user-oriented products for solar energy community**

Work package number	**5**	**Start Month**	m24	**End Month**	m36
Work package title	Assessment of new user-oriented products for solar energy community				
Name of participant	Dunia Antoine	A.Sanfilippo	*O.Jorba*	*S. Basart*	*Lab Techn. 1*	*L. Martin*
Effort days per participant:	50	50	55	59	3	40
Name of participant	B. W. Figgis	Daniel Perez				
Effort days per participant:	50	*10*				
Performance site (if applicable)	Qatar	Qatar	Spain	Spain	Spain	Qatar

Objectives of this work package

- Use results from WP2 and WP4 to develop new algorithms to model the impact of aerosols on solar radiation.
- Improve results in Qatar Solar Atlas project (QEERI).
- Choose the best locations in Qatar based on solar radiation atmospheric attenuation, dust deposition rates and solar resource levels.
- Improve the management of PV and CSP plants. This knowledge can be used for the creation of a spin-off company to provide services in the region by Qatar.
- Improve knowledge of long-term solar radiation.
- Quantify or diminish the impact of mineral dust deposition over PV, CPV and CSP infraestructures.
- Provide useful tools to manage solar power plants.
- Improve dust storm and atmospheric risks alerts.

Description of work
The following is a list of the tasks required to achieve the objectives of this work package. **T5.1. Study the impact of mineral dust on solar radiation (m24-m36) (QEERI/BSC)** Meteorological and dust storm predictions will be improved for the domain of Qatar. The model will take into account the content of mineral dust dynamically with a spatial resolution of 3km in different layers of the atmosphere. Results from WP2 and WP4 will be used to study the effect of aerosols on solar radiation. From the data and conclusions obtained in previous WP, we will develop the different algorithms to improve the estimation of solar resource. Qatar Solar Atlas project developed by QEERI, which objectives are mapping of solar radiation in Qatar and improve Grid integration of PV technology, will benefit directly from this project. We will improve the long-term estimations of solar radiation. Moreover, this project will allow to have more precise data and estimations on solar radiation atmospheric attenuation, dust deposition rates and solar resource levels to choose the best locations in Qatar. **T5.2. Study the impact of mineral dust on solar energy power plants (m24-m36) (QEERI/BSC)** The Solar Test Facility at Qatar Science & Technology Park supports the adoption of sustainable energy in Qatar by evaluating different solar technologies under local climate conditions. Established by GreenGulf (GreenGulf Inc. QSTP-B) and Chevron (Chevron Qatar Energy Technology QSTP-B). The facility is managed by QEERI and tests photovoltaic and solar thermal devices from dozens of manufacturers around the world (Martinez et al., 2015a; Martinez et al., 2015b). We will use the solar radiation measurements, pv production (from different pv technologies and manufacturers), CPV and fresnel acquired in the Test Facility from 2012 to improve the model and simulation of the production. The results will be extrapolated to the whole domain of Qatar. Additionally, we will evaluate the benefit of mineral dust predictions in the modelling of solar radiation for the management of solar power plants and dust deposition in the following way: ● We will improve the management of PV and CSP plants. This knowledge can be used in the future for the creation of a spin-off company to provide services in the region by Qatar. ● Quantify or diminish the impact of mineral dust deposition over PV, CPV and CSP infraestructures. ● Provide useful tools to manage solar power plants. **T5.3. Connect with stakeholders in Qatar (m24-m36) (QEERI)** Technology transfer with different stakeholders in Qatar will be done to improve the following topics: ● Rooftop and building integrated PV (BIPV) modelling for cities and FIFA 2022 stadiums. We have previous contact with supreme committee for Delivery and Legacy who organizes FIFA 2022. QEERI is starting also project to model pv rooftop in Education City and Doha. ● Dust storm and atmospheric risks alerts in collaboration with QMD. ● PV Grid integration with Kahramaa.
Deliverables D5.1 Modelling impact of aerosols on solar radiation report (QEERI) (m30). D5.2. Impact of mineral dust on solar energy power plants report (QEERI) (m34). D5.3. Stakeholders technology transfer report (QEERI) (m36). **Milestones:** M5.1. Transfer of aerosols modeling to Qatar Solar Atlas project (m30). M5.2. New algorithms to model the dust impact of aerosols in solar energy power plants (m32).

4.3.6. WP6: Dissemination and capacity building

Work package number	**6**	**Start Month**	1	**End Month**	36
Work package title	Dissemination and capacity building				

Name of participant	L. Martin	Antonio Sanfilippo	O.Jorba	S. Basart	A. Soret	Graduate student 1
Effort days per participant:	10	20	36	30	13	3
Name of participant	B.W. Figgis					
Effort days per participant:	50					
Performance site (if applicable)	Qatar	Spain	Spain	Spain	Spain	Spain

Objectives of this work package

- To identify and perform communication and dissemination activities in order to maximize the impact of the project, both in collaboration with other research activities, scientific audiences and industry forums.
- To identify the exploitable results of the project and define the potential commercial products and commercial strategies for these results (target market, business model, distribution channels and promotional strategy) to reach the market.
- To identify and perform training activities in order to engage interested parties in the usage of the results.

Description of work

This WP includes two main areas of action: dissemination and capacity building. These two areas includes activities related to communication, exploitation and training.

T6.1. Communication (m1-m36) (QEERI). An effective communication strategy is crucial to ensure the coherence and effectiveness of the project activities. It will include activities which will aim both to raise awareness of the project and its aims and to engage key stakeholders, an aspect which is particularly important given that their input will be required during the iterative development process. In this task, the communication team will define the objectives of the communication plan, identifying target audiences and setting out appropriate channels and messages to communicate with them, before defining activities and tools to achieve these objectives. The outcome of this task will be the Communication Plan (D6.1). This document will be updated during the project's lifetime as required. All activities will aim to have a direct impact on policy makers, industrial advisors, IT companies, and to society in general.

All communication activities and tasks will be carefully monitored and quality metrics will be reported in the Communication, Dissemination, Exploitation and Training Reports (D6.4 and D6.5).

T6.2. Dissemination and Exploitation (m6-m36) (QEERI/BSC). Through this task the SolarDust consortium will build a deep understanding of the project market and exploitation context, aiming at providing a solid base for further exploitation actions. Activities related with dissemination will also take place in this task, such as publication of the scientific results in international conferences and journals, and presentation of results in exhibitions, workshops, conferences and related events.

T6.3. Training (m25-m36) (QEERI/BSC). This task will include the definition, organization and logistical support of training. The training needs of potential stakeholders will be identified and the courses designed, organized and delivered based on these needs. A Training Plan (D6.3) will be produced which will outline all the activities related to training to be undertaken as part of this task.

Deliverables

D6.1 Communication Plan (QEERI) (m2).

D6.2 Dissemination and Exploitation Plan (QEERI, BSC) (m12).

D6.3 Training Plan (QEERI,BSC) (m28).

D6.4 Communication, Dissemination, Exploitation and Training Report 1 (QEERI,BSC) (m24).

D6.5 Communication, Dissemination, Exploitation and Training Report 2 (QEERI,BSC) (m36).

Milestones: M6.1 Biannual flyers and brochures (m12). M6.2 First Workshop with stakeholders (m12). M6.3 Second Workshop with stakeholders (m36). M6.4 Biannual flyers and brochures (m36).

4.4. WPs SCHEDULE, DELIVERABLES AND MILESTONES

Table 1: List of work packages

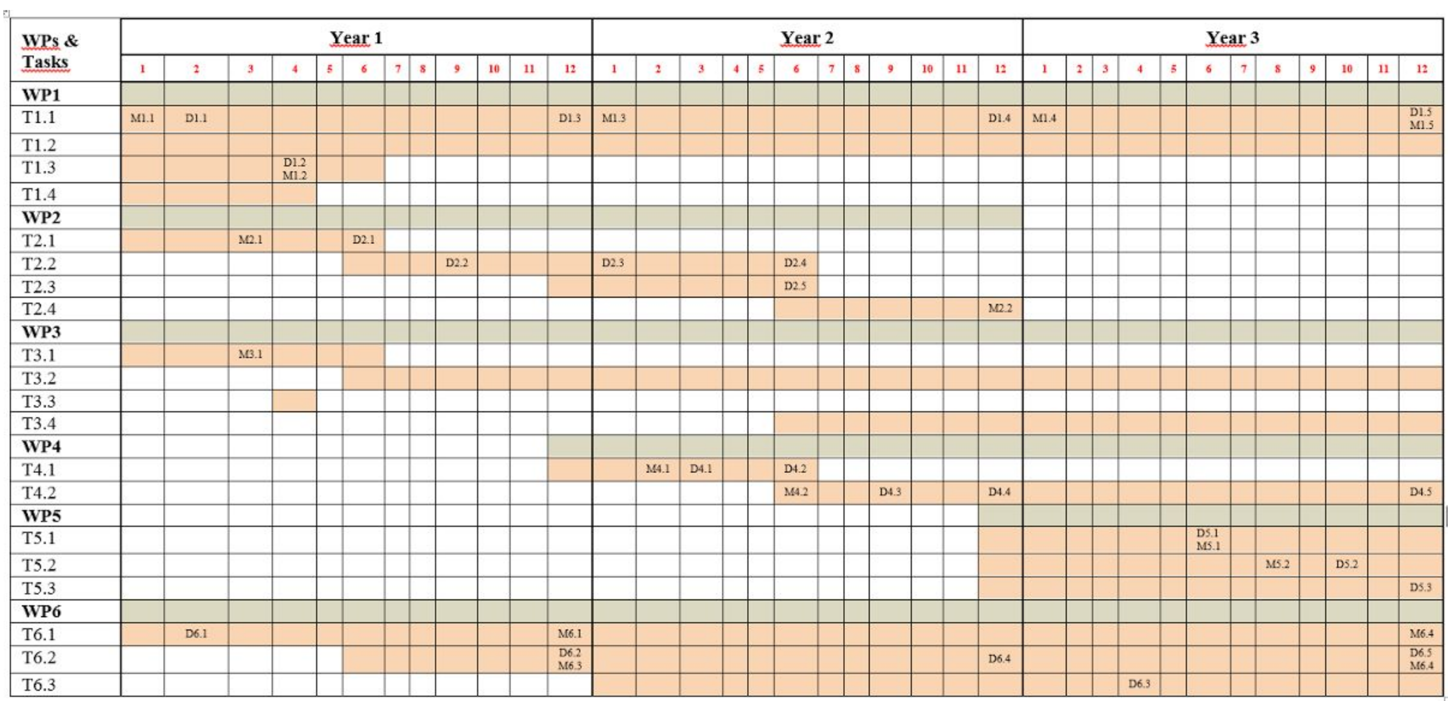
WP number	WP title	Name of the responsible person	Person days inside Qatar	Person days outside Qatar	Start date	End date
1	Project management and monitoring of the project progress	Luis Martin	180	72	m1	m36
3	Regional dust simulations	Oriol Jorba	0	400	m1	m24
3	In-situ measurements	Daniel Perez	860	0	m1	m4
4	Model Evaluation	Sara Basart	0	122	m12	m36
5	Assessment of new user-oriented products for solar energy community	Dunia Bachour	200	117	m24	m36
6	Dissemination and capacity building	Antonio Sanfilippo	80	83	m1	m36
			Total days: 1320	**Total days: 794**		

Table 2: List of deliverables

Deliverable number	Deliverable title	Name of the responsible Person	Type of deliverable	Delivery date
D1.1	Project Management and Quality Guidelines	L. Martin	Plan design	m2
D1.2	Project Portal	L. Martin	Website	m4
D1.3	Y1 Periodic report	L. Martin	Report	m12
D1.4	Y2 Periodic report	L. Martin	Report	m24
D1.5	Y3 Periodic report	L. Martin	Report	m26
D2.1	Report on the model configuration	O. Jorba	Report	m6
D2.2	Report on the uncertainties in the deposition scheme	O. Jorba	Report	m9
D2.3	Report on the impact of the surface size distribution of erodible materials	O. Jorba	Report	m12
D2.4	Report on the sensitivity of dust radiative forcing module in NMMB/BSC-CTM	O. Jorba	Report	m18
D2.5	Report on the performance analysis and improvement of the NMMB/BSC-CTM	O. Jorba	Report	m18
D3.1	Qatar AERONET station report	D. Perez	Report	m6
D3.2	Calibration and operation of Qatar AERONET station report	D. Perez	Report	m18
D3.3	Characterization of aerosols in Qatar report	D. Perez	Report	m30
D4.1	Report on dust observational parameters solar energy operational capabilities	S. Basart	Report	m15

D4.2	Report on recommended protocols and formats for harmonisation observational databases	S. Basart	Report	m18
D4.3	Report on recommended protocols and formats for harmonisation model simulations	S. Basart	Report	m21
D4.4	Protocol for model evaluation to assess their suitability for solar energy operational capabilities	S. Basart	Document	m24
D4.5	Report on documentation and communication of quality and uncertainty in dust observations.	S. Basart	Report	m36
D5.1	Modelling impact of aerosols on solar radiation report	D. Bachour	Report	m30
D5.2	Impact of mineral dust on solar energy power plants report	D. Bachour	Report	m34
D5.3	Stakeholders technology transfer report	D. Bachour	Report	m36
D6.1	Communication Plan	A. Sanfilippo	Plan design	m2
D6.2	Dissemination and Exploitation Plan	A. Sanfilippo	Plan design	m12
D6.3	Training Plan	A. Sanfilippo	Plan design	m28
D6.4	Communication, Dissemination, Exploitation and Training Report 1	A. Sanfilippo	Report	m24
D6.5	Communication, Dissemination, Exploitation and Training Report 2	A. Sanfilippo	Report	m36
D6.6	On-line training material	A. Sanfilippo	Media Action	m36

Table 3: Estimated timeline of the project



5. RESEARCH TEAM DESCRIPTION

5.1. DESCRIPTION, SUITABILITY AND COMPLEMENTARITY OF THE RESEARCH TEAM MEMBERS

The Qatar Environment and Energy Research Institute (QEERI) is built in a new vision and concept to solve the issues that affect Qatar, a rapidly developing country. The priorities of QEERI are Solar Energy, Water security and Clear Air. QEERI can contribute to the success of the present project research with its contribution to the scientific and technological advancement in solar energy and air quality modelling and PV technology in Qatar. QEERI is currently working in the project Solar Atlas of Qatar. This project aims at improving solar radiation predictions for operation of PV plants and integration in the Grid. Besides it aims at producing solar maps through rigorous analysis of solar irradiation components measured through a network of 13 new ground radiometric stations combined with data derived from satellite imagery. Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance (DHI) and Global Horizontal Irradiance (GHI) will be calculated from the images and calibrated and validated with their corresponding ground measured values. Another additional capability of QEERI which benefits the present project is the possibility to access real time and historic data in the Solar Test Facility. Qatar Foundation (QSTP), GreenGulf and Chevron partnered in 2010 to establish the Solar Test Facility. Its purpose is to determine which solar technologies are most suited to Qatar, by measuring their energy production and response to heat and dust. The facility tests photovoltaic and solar thermal devices from dozens of manufacturers around the world. QEERI plans include the setup of both indoor and outdoor facilities to characterize the problem and test newly developed solutions.

PhD Luis Martin-Pomares is a research scientist at QEERI who is expert in atmospheric physics and solar energy forecasting. He has been conducting research using thermal satellite images such SEVIRI data of METEOSAT satellite, as well as optical images. Luis has been awarded in 2011 for his paper “Prediction of global solar irradiance based on time series analysis: Application to solar thermal power plants energy production planning” as the best scientific publication for Solar Energy journal by the International Solar Energy. Luis is a modeler who has been working on solar and environmental modeling since he was graduated.

PhD Antonio P. Sanfilippo is a Research Director at QEERI. He has participated and led projects involving research and technology development across a variety of organizations, including academia, government and the private sector. His scientific focus in these projects has been on data mining, predictive analytics, and knowledge technologies with reference to applications in the areas of health, energy, security and the environment. In addition to his expertise in machine learning methods with reference to clustering, classification, anomaly detection and forecasting, Dr. Sanfilippo brings to this effort his extensive experience in advising and managing research projects involving multiple team members across diverse organizations.

PhD Dunia Bachour is a research associate in the Solar Energy Group at QEERI, working on the project “Qatar Solar Atlas”, consisting of the deployment throughout Qatar of a network of ground solar radiation monitoring stations in order to produce high spatial and temporal resolution solar maps in combination with satellite-derived solar radiation data. She is pursuing her doctoral studies in the same field with the Autonomous University of Barcelona (UAB).

PhD Perez Astudillo is a Research Scientist at QEERI in the Solar Energy Group. He joined QEERI in 2012, leading efforts in Solar Resource Assessment. One of his activities is the use of a ceilometer in the research of atmospheric effects on solar radiation at ground level. He is also working on the Qatar Solar Atlas project, which involves deploying solar radiation monitoring stations throughout the country, in combination with satellite-derived data.

Benjamin W. Figgis is a Research Program Manager at QEERI in the Solar Energy Group since 2014. He is responsible for managing the Solar Test Facility and has extensive experience in outdoor PV testing. He is also involved in research dust accumulation on PV and anti-soiling technologies.

The BSC-ES strongly contributes to the success of the present project research with its contribution to the scientific and technological advancement in air quality modelling and mineral dust forecast. In this sense, the excellent results of the group in the field of mineral dust transport have contributed to the creation of the First WMO Regional Meteorological Center specialized on Atmospheric Sand and Dust Forecast, the Barcelona Dust Forecast Center (BDFC; http://dust.aemet.es/) which includes the operational daily products of the NMMB/BSC-Dust model. The experience acquired with the management, in coordination with the Spanish Weather Agency (AEMET), of the WMO SDS-WAS Northern Africa-Middle East-Europe Regional Center (http://sds-was.aemet.es/) will significantly contribute to the production of excellent research and creation of specialized products for the end-users. Furthermore, BSC-CNS hosts MareNostrum, one of the most powerful supercomputers in Europe which is also part of the PRACE Research Infrastructure as one of the 6 Tier-0 Systems currently available for European scientists. Marenostrum will be used as main computing facility for the executions required by the project.

The following qualified manpower will be participating in the SolarDust project from BSC:

PhD Oriol Jorba (CO-LPI). He is the head of the Atmospheric Composition group of the Earth Sciences Department of the BSC. For the last years, Dr. Jorba has been involved in several European (FP7) projects related to the modeling of the Earth System, like the IS-ENES initiatives, focusing in the improvement of the skills of mesoscale meteorological models for a deeper understanding of the mesoscale phenomena occurring in the atmosphere, with special attention to the boundary layer processes.

PhD Sara Basart. She is a postdoctoral researcher in the the Atmospheric Composition group at Earth Sciences Department of the BSC. Her main research background covers mineral dust modelling, and aerosols. She is member of the WMO Regional Meteorological Center specialized on Atmospheric Sand and Dust Forecast, the Barcelona Dust Forecast Center and the WMO SDS-WAS NAMEE Regional Center, hosted by AEMET and BSC. She also collaborates in international projects as MACC, the International Cooperative on Aerosol Prediction (ICAP) initiative, DIAPASON (EU Life+) and Chemistry-Aerosol Mediterranean Experiment (Charmex) project.

PhD Albert Soret. He is the coordinator of the Services group of the Earth Sciences department at the Barcelona Supercomputing Center. His main expertise includes air quality management in urban areas. He has participated in the Spanish air quality-related project (CALIOPE) and in the EC-FP7 FIELD_AC and IsENES projects.

MSc Kim Serradell. He is the coordinator of the Computer Earth Services group of the Earth Sciences department of the BSC. In charge for the system administration of all the computational resources of the department, he's focused in deploying different earth system models (dust transport, climate or weather forecast) required by the department in a wide range of HPC architectures. He applied with success these skills in projects like IS-ENES (1 & 2), the WMO SDS-WAS NAMEE Regional Center or CONSOLIDER.

MSc Lluís Vendrell. He is PhD. Student in the the Atmospheric Composition group at Earth Sciences Department of the BSC. His PhD. dissertation focus on the study the role of convective meteorological processes on the dust cycle using high-resolution numerical simulations.

5.2. RELEVANT PUBLICATIONS

QEERI

1. Martín, L., Zarzalejo, L. F., Polo, J., Navarro, A., Marchante, R., Cony, M.:Prediction of global solar irradiance based on time series analysis: Application to solar thermal power plants energy production planning. Solar Energy 84 (10), 1772-1781.
2. Bachour, D., Perez-Astudillo, D. Ground measurements of Global Horizontal Irradiation in Doha, Qatar, Renewable Energy, Volume 71, November 2014, Pages 32-36, ISSN 0960-1481, http://dx.doi.org/10.1016/j.renene.2014.05.005.
3. Bachour, D., Perez-Astudillo, D. Boundary Layer Height Measurements over Doha Using Lidar, Energy Procedia, Volume 57, 2014, Pages 1086-1091, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2014.10.094.
4. Perez-Astudillo, D., Bachour, D. DNI, GHI and DHI Ground Measurements in Doha, Qatar, Energy Procedia, Volume 49, 2014, Pages 2398-2404, ISSN 1876-6102, http://dx.doi.org/10.1016/j.egypro.2014.03.254.
5. Bachour, D., Perez-Astudillo, D. Deriving solar direct normal irradiance using lidar-ceilometer, Solar Energy, Volume 110, December 2014, Pages 316-324, ISSN 0038-092X, http://dx.doi.org/10.1016/j.solener.2014.09.022.

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1. Basart, S., Pérez, C., Nickovic, S., Cuevas, E. and Baldasano, J. M.: Development and evaluation of BSC-DREAM8b dust regional model over Northern Africa, the Mediterranean and the Middle East regions, Tellus B, 64, 18539, doi: http://dx.doi.org/10.3402/tellusb.v64i0.18539, 2012.

2. Benedetti, A., Baldasano, J. M., Basart, S., Benincasa, F., Boucher, O., Brooks, M. E., ... and Zhou, C. H. (2014). Operational Dust Prediction. In Mineral Dust (pp. 223-265). Editors: J.-B. Stuut and Peter Knippertz, Springer Netherlands.

3. Jorba, O., Dabdub, D., Blaszczak-Boxe, C., Pérez, C., Janjic, Z., Baldasano, J. M., Spada, M., Badia, A., and Gonçalves, M. (2012) Potential significance of photoexcited NO2 on global air quality with the NMMB/BSC chemical transport model, J. Geophys. Res., 117, D13301, doi:10.1029/2012JD017730.

4. Pérez, C., Nickovic, S., Pejanovic, G., Baldasano, J. M., and Özsoy, E. (2006). Interactive dust-radiation modeling: A step to improve weather forecasts. Journal of Geophysical Research: Atmospheres (1984–2012), 111(D16).

5. Pérez, C., Haustein, K., Janjic, Z., Jorba, O., Huneeus, N., Baldasano, J. M., Black, T., Basart, S., Nickovic, S., Miller, R. L., Perlwitz, J. P., Schulz, M., and Thomson, M. (2011) Atmospheric dust

modeling from meso to global scales with the online NMMB/BSC-Dust model – Part 1: Model description, annual simulations and evaluation, Atmos. Chem. Phys., 11, 13001-13027, doi:10.5194/acp-11-13001-2011.

5.3. QUALIFICATION OF THE LPI

Luis Martin-Pomares born in Almeria (Spain, 7 November 1980), PhD in Physics by the Complutense University, Spain in 2012. He has more than 12 years of experience in solar resources and prediction. In 2004 he begins his professional career working at Plataforma Solar de Almeria (PSA) developing the data acquisition system and all the software for the BSRN station of the PSA. From 2005 until February, 2009 he did his Phd studies at CIEAMT, Spain's National Laboratory for Energy Research in solar energy forecasting. He worked in the spin-off IrSOLaV (www.irsolav.com) where he participated in different tasks covering all the phases needed by CSP and PV projects. At present he is working at QEERI developing Solar Atlas of Qatar and working in solar prediction for the climate of Qatar.

Oriol Jorba born in Barcelona (Spain, 9 July 1975), Ph.D. in Environmental Engineering (Technical University of Catalonia, UPC, Barcelona, Spain, 2005). His research activities and interests have included high resolution mesoscale meteorology and air quality, development of online meteorology-chemistry models, boundary layer studies, chemical mechanisms and environmental impact assessment. In 2005, he was enrolled as researcher at the Earth Sciences Department of the Barcelona Supercomputing Center, and in 2008 moved to the Atmospheric Modelling Group Manager position at BSC.

5.4. CONSULTANTS/SERVICE PROVIDERS INVOLVED IN THE PROJECT

Dr. Emilio Cuevas (Izaña Atmospheric Research Center, IARC) will collaborate in the project as service provider for the capacity building in the operation of AERONET station and calibration of CIMEL sun photometer. He is the Director of the Izaña Atmospheric Research Center (IARC; www.aemet.izana.org), a WMO (World Meteorological Organization) GAW (Global Atmospheric Watch) station of global importance. The IARC is an Associated Unit of the National Research Council (CSIC). He has been a WMO consultant for SDS WAS in West Asia, and a result of this mission he authored the technical report entitled "Establishing a WMO Sand and Dust Storm Warning Advisory and Assessment System Regional Node for West Asia: Current Capabilities and Needs".

5.5. INVOLVEMENT OF STAKEHOLDERS IN THE PROJECT

We have identified the following stakeholders in the project:

- Alexander Baklanov (Responsible of the SDS-WAS project of WMO).
- Qatar Meteorological Department (QMD) which belongs to Qatar Civil Aviation.
- Saleh Hamad Al-Marri from Kahramaa has previous contacts with the people who manage the Solar Test Facility.

Besides, searching for more stakeholders in Qatar and GCC region is one of the task of this project to do capacity building and technology transfer.

6. REBUTTAL

The SolarDust project is a New Submission.

7. RENEWAL JUSTIFICATION

The SolarDust project is a New Submission.

8. RESOURCES

Institution Name	Laboratory Space	Personnel	Facilities	Office and Computer Facilities	Major Equipment
QEERI		**Current available** - 4 PhD researchers - 2 Research associated	**Planned** - 3 fat nodes	**Current available** - 6 Desktops - Internet connection	**Current available** - 1 radiometric station with BSRN standards - 13 radiometric stations (available in the next months) - 1 rotating shadow band radiometer - PV module reliability laboratory - LIDAR - EUMETCast satellite receiving station - Air quality ground stations **Planned** - 2 Photometers CIMEL CE-318T
BSC		**Current available** - 3 PhD researchers - 1 Graduate Student - 1 Lab. Technician	**Current available** - Access to MareNostrum - Access to the modelling system NMMB/BSC-CTM	**Current available** - 4 Desktops - Internet connection **Planned** - 2 Laptops - 1 Desktop	

9. REGULATORY REQUIREMENTS

The SolarDust project does not involve human subjects neither animals in its development.

10. REFERENCES

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