Executive Summary:
A large share of the recent renewable energy sources (RES) installed capacity has already taken place in insular electricity grids, since these regions are preferable due to their high RES potential. However, the increasing share of RES in the generation mix of insular power systems presents a big challenge in the efficient management of the insular distribution networks, mainly due to the limited predictability and the high variability of renewable generation, features that make RES plants non-dispatchable, in conjunction with the relevant small size of these networks. In parallel, the Smart Grid initiative, integrating advanced sensing technologies, intelligent control methods and bi-directional communications into the contemporary
electricity grid, provides excellent opportunities for energy efficiency improvements and better integration of distributed generation, including RES such as wind and photovoltaic systems, coexisting with centralized generation units within an active network.

SINGULAR investigates the effects of large-scale integration of renewables and demand-side management on the planning and operation of insular (non-interconnected) electricity grids, proposing efficient measures, solutions and tools towards the development of a sustainable and smart grid. Different network operation procedures and tools, based on innovative approaches of predictive electricity network operation, developed. A set of electricity network planning procedures and tools has been developed to implement robust insular electricity network planning. The goal is the generation of effective solutions and information so that the integration of insular and highly variable energy resources is maximized. The operation and planning tools and procedures have been applied in different insular electricity grids in five countries across Europe for extensive demonstration, allowing the development of generalized guides of procedures and grid codes specific for future generation of smart insular electricity grids.

The activities of SINGULAR are shared between the partners and divided into twelve (12) different workpackages (WPs). SINGULAR is organized in two main phases with distinct Work Packages (WPs). Two additional WPs (WP1 and WP12) are dedicated to the project management and the project dissemination and span the entire duration of SINGULAR. The organization of the phases and the respective WPs is presented in the following:

1st Phase: RES forecasting, Power Analysis, Scheduling & Planning Tools (Work Packages: 2-7) The first phase of SINGULAR was comprised: a) the development of RES forecasting tools, b) the investigation of EES management methods, c) the development of power analysis tools, d) the development of scheduling tools, e) the development of innovative market design schemes oriented to the introduction of competitiveness in the operation of insular electricity grids, and f) the development of planning procedures and tools for distribution grid development. Hence, this first phase was strongly connected with the technology creation stage, based on advanced and wide-ranging R&D activities developed in Universities, Polytechnic Institutes, and SMEs. Specifically, this phase included the following Work Packages (WPs):

- WP 2: Development of RES Forecasting Tools (M1-M36)
- WP 3: Investigation of EES Management Methods for Insular Networks (M1-M12)
- WP 4: Development of Power Analysis Tools (M1-M12)
- WP 5: Development of Scheduling Tools (M4-M21)
- WP 6: Competitive Operation of Insular Electric Networks (M10-M18)

2nd Phase: DSM, Testing & Validation, Grid Codes, Evaluation & Conclusions (Work Packages: 8-11) The second phase of SINGULAR comprised: a) the implementation of DSM, b) the testing and validation of the developed models and tools in selected pilot sites, c) the development of grid codes for the connection of RES in insular electricity grids, and e) the evaluation, recommendations and roadmapping of SINGULAR. Hence, this second phase was strongly connected with the demonstration stage, including large-scale production-line demonstrators for validation and market applications in DSOs, Enterprises and SMEs. Specifically, this phase included the following Work Packages (WPs):

- WP 8: Implementation of DSM (M13-M30)
- WP 9: Testing and Validation (M22-M36)
- WP 10: Development of Grid Codes (M28-M33)
- WP 11: Evaluation, Recommendations and Roadmapping (M29-M36)
Project Context and Objectives:
SINGULAR provided recommendations as well as scalable and replicable solutions for all regulatory, technical and economic challenges of integrating a very large share of RES in insular electricity grids, while maintaining secure, reliable and high-quality power. Specifically, it focused on the development of:

a) smart insular electricity network operation tools,
b) insular electricity network planning procedures and tools for grid integration, and
c) insular electricity network grid codes for grid connection of DG plants, further explained in the sequel.

Smart insular electricity network operation tools, including the short-term and very short-term forecasting for medium-/small-scale RES, risk management techniques for network failures, the integration of forecast uncertainty in optimal power flows, the state estimation in distribution networks with substantial RES penetration, the optimization of network reconfiguration and scheduling of DG resources, etc., have been thoroughly developed, providing valuable assistance towards the improvement of the distribution network operation.

In all these methodologies and tools, the modeling of risk and uncertainty was the key to successful sustainable grid integration of DG, for both secure operation and economic incentives. In addition, the limited predictability and high variability of RES injection also required higher operational reserves to ensure that the network can operate in a safe, reliable and efficient manner. Thus, special attention has been given to the qualitative and quantitative determination of the required reserves, using innovative stochastic optimization models, so that specific reliability targets are met.

In parallel, the gradual increase of DG in insular electricity grids facilitates the introduction of a competitive market operation. Up to recent years, economies of scale in insular systems, i.e. the large size of the production facilities relative to the size of the market, prevented the introduction of competitive electricity markets in small insular power systems. Nowadays, with the boost of DG and the involvement of new electricity producers, conditions of perfect competition (large number of small-sized producers and consumers) are being formed, which, in turn, may allow the operation of a competitive electricity market in small insular systems. However, since a large portion of the DG has been intermittent and volatile renewables, innovative market designs has been required to cope with the increased uncertainties and associated market risks introduced by the RES. In this context, innovative market design schemes have been examined, especially for the short-term (i.e. day-ahead, intra-day and real-time) market operations in order to cope with the limited predictability and high variability introduced by RES, using frequently revised forecasts, sub-hourly dispatch periods, lookahead features, and advanced stochastic optimization models and tools.

State-of-the-art and new methods proposed as tools for the efficient, reliable and secure operation of the power system has been implemented in insular electricity grids with increased RES penetration.

These methods include:

a) the increasing Electrical Energy Storage (EES), e.g. in the form of hybrid plants (RES plants coexisting with pumped-storage plants),
b) the participation of plug-in electric vehicles, and c) the aggregation of intermittent and volatile renewable generation with different types of reserves (including also flexible loads, EES and electric vehicles) into a portfolio that collectively behaves reliably as dispatchable thermal generation.

Additionally, control and communication technologies provided the end-users of energy with the ability to manage their electric loads in real-time in response to volatile energy prices. The Distribution System
Operator (DSO) needs to manage these demand response opportunities, which are similar to the wholesale sell and buy bids but much more numerous and geographically dispersed. The successful implementation of DSM programs is crucial for the establishment of smart grids in insular electricity networks. In this context, SINGULAR focused on the installation of a specific number of smart metering devices along with their associated IT equipment in order to demonstrate the potential of demand response and resource aggregation.

Regarding the long-term planning horizon, SINGULAR team focused on effective distribution network planning procedures in terms of the geographical assessment for potential DG integration, the optimization of the network expansion and reinforcement, the distribution network flow and contingency analysis, and the economic impact of grid investments. Long-term combined generation and transmission and distribution expansion models have been developed and applied in the project-related insular power systems, in order to derive the overall expansion cost minimization under largescale RES penetration, increased reserve requirements, demand response programs and with the presence of EES technologies (e.g. hybrid plants, plug-in electric vehicles, etc.). The insular specificities have been evaluated in terms of their economic impact on the overall social welfare in the long- and mid-term.

The RES support mechanisms have been evaluated in terms of (a) their fitting with the existing electricity market design, and (b) their economic impact on native islanders, considering social-driven criteria motivating the permanent residence in these islands.

The presence of DG in distribution networks changes the occurrence of fault currents and harmonic distortion, having an impact on power factors and their direction from the viewpoint of the network’s protection system. The protection of DG has been coordinated with the protection of the distribution network and all possible operating conditions considered.

Another issue comes from the operational engineering requirements of the networks where DG is connected, such as the need for managing islanding operation and the characteristics of the protection systems operating at the network interconnection.

The use of DG has a significant impact on the distribution network performance and this emphasises the need for new optimized connection and protection schemes, real-time supervision and operation measures, and remedies for harmonics and other disturbances that could be generated by power electronic interfaces. The respective solutions require active real-time management of DG and loads, considering appropriate coordination with the distribution network operation.

All aforementioned operation and planning tools and procedures have been applied in different insular electricity grids, in combination with DSO’s experience and the distribution network regional context, thus replicable distribution network grid codes specific for the future generation of insular electricity grids have been provided. These distribution network grid codes addressed critical issues such as the energy quality, DG technology requirements, suitable procedures for the DG units, the network operation and protection, etc.

Since the insular electricity grids are expected to be more dependent on renewables as compared to other electricity networks, the implementation of all these new methodologies, tools, services, guides and grid codes for the efficient operation and planning of insular networks is more challenging than for the interconnected distribution networks, taking into account the variability of renewable generation. However, the outcome of the proposed research in pilot insular networks could be partially extended and generalized for the interconnected networks, as well.

The novel and singular aspect of SINGULAR arises precisely from targeting these insular electricity grids, as occurs in several countries in Europe, such as Portugal (Azores islands), Greece (Crete island), Spain...
(Canary islands), Italy (Pantelleria island), Malta and Cyprus (themselves island nations). In addition, for an eastern European country, such as Romania, an island is considered in a small region close to the Danube delta (the Great Island of Brăila). Still, this region has different characteristics from the ones of other islands bringing a complementary perspective.

Project Results:

WP2 – Development of forecasting tools
Work package objectives:
• Generate meteorological forecast information and gather the needed technical information for construction training and parameterization of the forecasting services.
• Development forecast models for different generation (wind, hydro, PV, wave, geothermal, cogeneration, biomass) and for consumption.
• Deployment of the forecasting systems for the target locations in the multiple islands (São Miguel, Crete, Brăila, La Graciosa, Pantelleria and El Hierro).
• Generating continuous forecasts, for all target locations, for the remaining report period, to stay operational after the end of the project.

Progress towards objectives:
Summary:
• Activities that summarize the progress towards the objectives:
• Data gathering from DSO information;
• NWP meteorological forecast service;
• Research in innovative mathematical models, for different forecast applications;
• Development of a web platform to share and show online forecasts;
• Continuous forecast service;
• Performance evaluation of the forecast models;
All the objectives have been accomplished:
• Some pilots have more complete and accurate forecast systems, depending on the data that was available to develop the correspondent forecast system. The most complete and robust forecast systems were implemented for the most significant pilots, São Miguel (Azores) and Crete.
• Additionally to the initial objectives, an extra pilot have been implemented, the island of El Hierro (Canary Islands, Spain).
• The service is free and available for all the pilots, providing to the insular DSO a practical continuous contact with new approaches of forecast, with possibility of integration in their power system management process.
• The probabilistic forecast developments were much more interesting (modeling, results and applications) than what was initially planned in the objectives.
• The performance of the forecast models is at the best level of the most current state of the art, becoming better than the expected in what was initially planned in the objectives.
• All milestones and deliverables have been accomplished:
  o Report with the state-of-art and model description, with a very high number of downloads (Deliverable 2.1);
  o Web platform with all forecast services for all pilots (Deliverable 2.2);
Performance Analysis of the forecast models, evaluating real measurements and continuous forecast service (Deliverable 2.3).

Progress towards objectives detailed for each task:

Task 2.1: Data gathering for target locations and power variables to be forecasted (M1 – M3)
This task collected a set of information related with the renewable power plants, wind farms, PV plants, small-hydro, wave, geothermal, cogeneration, other. Real time series about the generation and environmental measured variables were collected for one year of historical data, a reference period selected for construction and training the forecast models. For modeling demand side, real time series of consumptions in the substations were collected for the distribution substations or feeders, for the distribution systems selected in the several islands.

Task 2.2: NWP reanalysis for target locations, for an historical period of 1 year (M4 – M6)
Once the target locations and type of forecast needed were defined in Task 2.1 the setup and parameterization of the meteorological forecast (NWP) followed up. The same setup and parameterization ran permanently along all the time of the project. Were also executed every day 4 runs of the forecasts for the next seven (7) days, for all the target locations, for the meteorological variables needed, and with a time resolution of one (1) hour.

Task 2.3: Development of forecast models (M4-M12)
Multiple forecast models were developed in this task, namely:
- Wind farm power forecast, based on Kernel Density Estimator models, designed to forecast the power output of a whole wind farm. Meteorological forecast information (wind speed, wind direction, pressure, temperature, wind gust) was utilized. Different forecast techniques were tested and compared. Models were created to produce forecast uncertainty evaluation (probabilistic and quantile models).
- PV plant power forecasts, based on a mix of analytical solar irradiation model assimilating meteorological forecast. The meteorological forecast (irradiance, temperature, cloud cover, fog was assimilated in the model in order to integrate the meteorological effect in the PV plant generation. The modeling of uncertainties based on quantile regression approach was also implemented.
- Small-hydro power generation, based on a mix of analytical hydrometric models for day forecast. The analytical model uses the meteorological forecast of precipitation to evaluate the daily increase or decay of small-hydro generation. The daily forecast resulting from this model is used as input to predict the hourly power output of the hydro plant.
- Power generation from waves: The analytical models considered here are of two types: wave prediction models and wave energy converter power prediction model. The former aim to predict the incoming wave in a wave farm and it is based on the modeling of the sea dynamics (wind, tide, streams, temperature, etc) on a wide area around the wave farm. The latter uses the output of the former to simulate the control of the plant and predict the power output.
- Independent small thermolectric generation (cogeneration, biomass and geothermal) forecasts. These forecasts are based in operation strategy; the forecast methodology consisted in capturing of the seasonal and periodic baseline pattern of the plant operation. Time series were used for the implementation of these models.
- Load forecast on distribution substations (active and reactive power). Also KDE and time-series analysis were used to capture the seasonal and cyclic pattern and exceptions. Some meteorological variables (temperature, humidity, cloud cover) were used to adjust the forecast to the meteorological influence factors. These models were designed to be adapted to different types of loads characteristics and sizes.

Task 2.4: Training and parameterization of forecast models (M7-M18)
For each target location, the models were parameterized and trained. In this process, information from Task 2.1 and Task 2.2 was used in the models developed in Task 2.3. This task was done in approximately 6 months. However, it was also done in parallel with Task 2.3 where the earlier developed models would be first trained and parameterized.

Task 2.5: Deployment of forecasting services (M13-M36)
The deployment of the forecasting service included the development of the web service platform and the link with local utility information systems. The system is operational, producing for each target location one (1) hour interval forecasts for a seven (7) days horizon, refreshed four (4) times per day. After the setup of the operation, the forecast system provided forecasts permanently for the rest of the project time and continues providing the service after the end of the project. This continuous stream of forecasts is monitored in order to validate the models, and the forecasts were used in the other WP. This task was coordinated by Smartwatt but the role of the local utilities partners or partners that worked close with the utilities was very important for the usage and test of the service products. The forecasting services were used to evaluate the performance of the models, producing analyses of the forecasts and evaluations of the contribution of the forecast application to the objectives of SiNGULAR.

Significant results:
• State of the art characterization about different RES and load forecast, published in Deliverable 2.1 published in the SiNGULAR Book.
• Data, models and forecast benchmark for different insular locations, available in the web platform.
• Probabilistic forecast and pdf representation for most of the forecast applications.
• Continuous Forecast in the web platform, available at (http://smartwatt.net/SingularWeb/).

WP3 – Investigation of EES Management methods for Insular networks
Workpackage objectives:
The aim of WP3 is to define and evaluate advanced methods for managing EES with the objective of stabilizing and optimizing insular electricity grids. The proposed EES management methods, for different types of RES integration mix, together with the real-world characteristics of various insular networks, will permit to properly assess the value and benefits of EES for this particular type of system in what regards operational security, reliability, emissions, sustainability and cost effectiveness.

Progress towards objectives:
Summary: The objectives described above were met through working on the Tasks associated to WP3 that are explained below. No issues were identified through completing the following tasks. Regarding Task 3.3 the management methods were test through modelling simulations and were also tested in WP9.

Progress towards objectives detailed for each task:
Task 3.1: Assess and quantify the requirement for the application of EES in insular networks
In task 3.1 the present insular grid code requirements were reviewed. Furthermore, the main constraints imposed by present insular grid codes towards the large-scale integration of RES (e.g. onshore wind and photovoltaic power) were assessed and quantified. In order to make conclusions and recommendations regarding grid codes for storage systems the existing codes from the project pilots were compared to grid codes from countries with high renewable energy penetration like Germany and Denmark.

The types of EES were reviewed according to their applications in insular networks and their economic benefits. An assessment of the benefits and drawbacks of each category of EES based (among others) on their storage cycle was also conducted. Also, the requirements of EES in insular networks were determined.
Task 3.2: Define EES management methods for insular networks

For the purposes of Task 3.2 the following work was carried out:

• Detailed analysis of EES management methods: Management methods for storage systems were reviewed. The literature review covered a variety of systems and roles of storage within insular networks.

• Comparison between storage and Demand Side Management (DSM): The analysis includes a summary of research based participatory schemes on demand side management to improve flexibility features on energy consumption, in comparison with other mechanisms like storage, generation management and grid reinforcement. Based on the information collected DSM was compared to storage in a variety of concepts.

• Comparison between energy storage and connection with mainland networks: The connection of island networks to the mainland network is another strategy that could be competing with storage. In order to investigate this case a mathematical model was developed and Crete was used as an example. The interconnection of the Crete Island to the mainland network was assessed as an alternative to the installation of storage, in order to assess the impact on the RES penetration and if even in this case storage systems would still be required.

• Economic benefits from storage systems in insular networks: The economic aspects of storage were analysed. For that the cases of La Graciosa and Crete are used as an example. The effect that the installation of storage will have on the systems is shown through calculating the cost of electricity and the investment costs.

• The role of storage in a cost effective decarbonization of the energy sector: A model was developed with the aim to highlight the fact that the objective of a cost effective CO2 reduction must consider all energy forms, namely electricity, heating & cooling and transportation fuels. These statements are backed up by scenario modelling for simple energy systems with real consumption and weather data (complete year, hour by hour). The role of storage in these scenarios was also highlighted.

• Development of management methods for insular networks: Based on the literature review on management methods for insular networks the following management methods were developed for different applications.

  • The first one refers to frequency regulation through batteries and a hybrid system comprised of a battery and a power energy storage (supercapacitor and flywheel). A real-time control strategy was developed, consisting in a first-order low pass filter to smooth the primary frequency control signal to set the Energy Storage (ES) output while the Power Storage (PS) deals with the high frequency signal. The single EES responds to the “raw” frequency signal. Real frequency data from the Island with 1 second resolution (1Hz) was used as input for the implemented primary frequency control strategy.

  • The second management method refers to a hydrogen generation and storage system that uses curtailed wind power. Two scenarios were studied; one where the stored hydrogen is converted back to electricity and in the other it is used for heating purposes.

  • For the island of La Graciosa a management method applies to a Low Voltage system with several micro-generation sources. The objective of the control strategy is to optimize the cost but at the same follow the requirements of the DSO.

  • Based on insular system requirements another management method was developed for coupling a desalination plant with a wind farm and storage. For this case the objective of the management method is to minimize the cost of the desalinated water by reducing the energy consumed in the desalination processes.

  • Finally a management method for bulk energy storage was developed. For this case the objective is to increase the lifetime of the storage system and at the same time increase the penetration of renewable
energy to the network. This study also had the objective to calculate the total storage capacity that will have to be installed for the cases of Crete and São Miguel. Two categories of storage, batteries and Pumped Hydro Energy Storage (PHES), were evaluated by the mathematical model developed.

Task 3.3: Test the advanced EES management methods tailored for insular networks

For Task 3.3 the management methods developed for insular networks were tested in the test cases specified. The testing was done through mathematical modelling for which real data for power generation and demand from the project pilots were used. The optimal sizing and storage cycle type of EES based on the grid code requirements were assessed. Finally, the value and benefits of EES systems for insular networks were assessed and quantified.

Task 3.4: Consolidation of obtained results and provision of recommendations

In Task 3.4 recommendations for updating the existing insular grid codes regarding EES and for incentives towards the development of EES incentives were made.

Significant results:
The above mentioned tasks were successfully completed and incorporated in the deliverables of WP3. Grid code review and recommendations

Among the main results of this WP are the recommendations that were made for updating the existing grid code requirements in insular networks. After a careful examination of the grid codes that are applied to the project pilots and the grid code requirements in other countries several conclusions were made. The proposed additions to the existing grid codes will assist the implementation of RES in insular networks. Through an extensive search on grid code requirements it was concluded that even though regulations regarding the quality of the supplied energy exist, specific regulations for EES systems in most countries have not been proposed.

It will be essential for insular networks where the need for storage systems is high, the characteristics of the supplied energy and the function of the aforementioned systems to be well regulated in order to achieve much higher penetration of renewable energy to the network, better regulated power flow and system reliability.

As an outcome of above actions it was recommended that the following should be added to the grid codes of insular networks:

- A detailed definition of EES systems of all scales (include smaller scale systems that can be used in smaller networks)
- Provisions for the quality of the power provided by EES systems
- Information regarding the ramp rate, minimum operation hours and minimum production of EES
- A scheduling plan that will also include both Hybrid Power Plants (HPP) and EES
- Regulation regarding harmonics
- Regulation regarding droop characteristics for the regulation of frequency and voltage
- Provisions regarding safety regulations, system protection, monitoring and information exchange

Another significant result of WP3 is the review of the current EES management methods. These were assessed based on their suitability for insular networks and recommendations regarding the specific requirements of the project pilots were made.

Value of storage systems

The work done in WP3 showed the value of storage and the benefits that storage can have when deployed in insular systems. Based on the more generic approach that was followed at the model developed for the decarbonization of the energy sector, it was shown that the cost and emission optimal solution space, the Pareto frontier, is pushed towards lower costs and emissions when a complete energy system is
considered. Furthermore, it was shown that when electric and thermal energy storage is included in the system a more cost effective reduction can be achieved.

The value of storage and the impact of introducing bulk energy storage to an insular network were also shown. By using data from the island of Crete, and by assuming a five (5) hour storage system, it was shown that when storage is introduced in the system and for a certain percentage of renewable energy penetration to the network the levelized cost of electricity can be reduced.

For the case of La Graciosa a similar result was obtained. In this case PV power is used instead of wind and again when the RES is over a threshold storage becomes economical. The following chart (figure 3) shows the LCoE for different RES penetration to cover the energy needs of the island and the optimal topology for each case.

We can compare in terms of LCoE the implementation of RES based in solar energy with or without storage. The current situation is showed at first point at left (0% of RES: 0.194 €/kWh). As solar energy is installed in La Graciosa the LCoE starts to decrease until the excess of RES is excessive. At this moment (46% or RES penetration) Storage is a feasible option until 70% of RES penetration. At 70%, a sensitivity analysis is showed in function of storage investments costs (from 600 €/kWh to 1000 €/kWh).

Management methods for storage systems in insular networks

Regarding the developed management methods for the energy storage systems the key findings were:

For the community storage system where storage is located at a low voltage network the objective of the management method was to:
• Reduce the global cost of the energy consumed by the community
• Send to Grid operator the forecast of the energy flow through PCC and the Energy and Power available in the battery during the next hours.
• Receive orders from the Grid Operator in case of emergency
• Ensure that the energy flow through the PCC is within the range of the forecasted value.

Regarding the case of an EES supporting insular networks the pilots of Crete and S. Miguel are used. For these two examples a BESS (Battery Energy Storage System) and a PHES system were modelled and implemented and the energy stored during the operation of the systems was shown. It is obvious that the systems would benefit from the implementation of storage by integrating more energy produced by renewable sources. One of the main conclusions of this task was the charging sensitivity analysis that was performed for the BESS. Initially the model was set to charge the battery at all points satisfying the condition ‘generated energy > demand’. It is well known though that charging cycles reduce the life of the battery it is important to consider whether, under certain circumstances, the battery does not require charging. If the amount of excess power generated over the demand is minimal it may be more beneficial to the battery system to ignore the additional power and reduce the number of charging cycles performed. Analysis was performed to assess this assumption and consider whether increasing the criteria to only charge the battery when generating a set percentage over the demand would assist in reducing the cycle count and improving the battery life.

The implementation of a very small excess on the charging criteria greatly reduces the number of cycles performed and thus greatly improves the battery life. Overall, a compromise is made, suggesting the most efficient excess criteria to be around 4% for the two cases that were studied.

Regarding the use of energy storage for frequency regulation and based on the mathematical model developed, it was found that a hybrid system, battery combined with a supercapacitor or flywheel, will be preferred to a stand-alone energy storage device. The developed management method for the hybrid system resulted in higher system availability, longer lifetime for the battery and the total energy provided by
the system was increased when compared to a standalone battery.

The second management method developed was for a hydrogen generation and utilisation system. The outcome of this study was that the use of curtailed renewable energy for the production of hydrogen can be feasible especially in the case when the produced hydrogen is used as a fuel for transportation or heating. This method can be seen as an alternative approach and as an indirect storage of curtailed renewable energy.

The developed cost model demonstrated some first cost results for the scenarios described above. The initial capital investment for a system described under scenario 1 is around 57 m€ and the levelized cost of H2 is 12.41 €/kg whereas the electricity price is 0.75 €/kWh. The second scenario has a higher capital investment of around 76 m€ excluding the hydrogen burner and the transportation cost and a similar cost of H2 of 12.14 €/kg and the heat price is 0.36 €/kWh.

Storage compared to other options
Finally two competing solutions to storage were analysed. Regarding the assessment of DMS, it was concluded that storage and DSM can serve the same purpose but they can also be combined. Regarding the connection of island networks to the mainland, it was concluded that storage can allow higher renewable energy integration. The interconnection of the island to the mainland grid, via HVDC transmission lines, has been an active area of research aiming to better explore the renewable energy resource of Crete. In this work, minimal operational constraints for the Crete network are established and maximum renewable energy penetration limits are estimated for different load conditions with and without HVDC interconnection. The operational constraints of the Crete power system are based on the minimum primary reserve requirements to support maximum infeed losses and to limit the Frequency Rate of Change (FRoC) in all load conditions. Based on the defined constraints, the minimum capacity in MW of power plants operating in Crete should not be less than 60% of the peak load. The total amount of RES energy (GWh) that can be integrated into the electrical network will strongly depend on how flexible the conventional power plants can operate, increased operational range and inertia constants are two critical parameters to allow higher RES shares.

Different solutions aiming to allow higher RES shares in the island were analysed, namely: the solution of connecting the island with one or two 350MW HVDC cables to the mainland, increase the flexibility of the operating conventional power plants and include energy storage systems to supply a percentage of the required primary control reserve.

During low demand periods, between midnight and 6 am, the network is operating almost in its minimal operating limit (minimum load of conventional power plants) without flexibility to allow higher shares of RES. Substantial new renewable energy can be integrated on Crete with small to moderate increase in the flexibility of the running conventional power plants or adding storage systems, without the need for HVDC interconnection.

Based on this analysis we estimated that storage systems providing 30% of the required primary reserve of the network, storage capacity between 6 to 10MW, and a 10% reduction in the minimum operational set point (min. load) of the conventional power plants would allow higher RES shares than a one cable 350MW HVDC transmission solution. 20% reduction in the minimum load of the operating conventional power plants, and the aforementioned storage system, would permit the same RES penetration than the two cables HVDC transmission system.

Applications and role of storage
Finally, the future applications of storage systems were assessed during WP3. The main conclusion from this literature search was that storage systems have various benefits and applications at different voltage
levels and different locations within a power network. There are plenty of opportunities for storage systems in all voltage levels of the distribution network to support higher shares of RES integration, to optimize the assets of customers and the utilization of the electrical network infrastructure. In the near future local policy, regulations and market conditions are still going to be key factors for the deployment of energy storage systems.

In the low voltage level, energy storage systems are expected to play an important role. They can allow higher integration of distributed generation at the existing infrastructure, support the system voltage stability, mitigate concerns related to multidirectional power flow and increase the supply reliability by providing UPS services to customers and/or provide ways for the DSO to reduce the duration of shortages.

At the medium voltage, multi-directional power flow is expected, and, again, the protection system coordination and voltage stability are key issues to be addressed. Energy store systems can support the stability of the network providing ancillary services, as voltage regulation, and smooth RES variability, that should reduce voltage instabilities. Medium voltage customers can take the advantage of storage systems capabilities to support the network to make their business more profitable – providing demand side response and other ancillary services. While, at the same time, reducing their energy costs and increasing the supply reliability.

Significant costs and loss of production can be avoided by guaranteeing the security and quality of the electricity supply for industrial customers, at the high voltage level. Energy storage systems have already been applied in several sectors to mitigate these issues. There are a strong trend to increase the integration of energy storage systems, CHP and distributed generation to optimize the industrial resources, reduce the electricity costs while increasing the supply security and quality.

Deliverables D1, D2 and D3 were submitted on time with a short delay on the submission of D2.

WP4 – Development of power analysis tools
Workpackage objectives:
The objectives of WP4 are the following:
• Definition of the data structures and models of the power and distribution system components.

• Development, testing and validation of the computational tools for power flow and fault calculations, market-based security assessment, reliability and power quality assessment.

• Preparation of the documentation to assist the application of the computational tools in the development of analysis and optimization tools in other WPs.

Progress towards objectives:
Summary: The objectives have been reached in the first period of evaluation. All the WP4 Deliverables have been reviewed and approved in the first review meeting. During the second period of evaluation, the activity has been carried out concerning the publications referring to the WP4 topics. The review process of some papers has been relatively long for some contributions, also requiring in some cases to revise the writing in order to respond to the Reviewers’ comments and remarks.

Progress towards objectives detailed for each task:
Task 1: Data structures and models of the power and distribution system components
Achievements made with reference to planned objectives: The data structures for power flow calculations have been prepared with reference to the implementation of power flow calculations with time interval
data. The modelling framework has been established on the basis of a literature review of the state-of-the-art and of the partners’ experience for most of the components, in such a way to provide the input data for the power flow calculations. The activity has resulted in preparing the data for the implementation of the new tool called DERMAT (Distributed Energy Resource calculations with MATlab®), developed in WP4 to cover different aspects of the power system analysis, in particular for steady-state analysis. The DERMAT tool has been developed with the intention to be used in the project, with flexible routines coded in such a way to be usable in other procedures. The inputs and outputs are managed through data files of text type with predefined formats. The details of data structures have been included since the beginning in the specific DERMAT Users’ Guide.

A unified framework has been constructed to introduce the active power patterns (and for the models with non-controllable voltage/reactive power also the reactive power at the node) at the relevant node of the network. The information on the power patterns are determined from a pre-processing phase with respect to the power flow calculations with time interval data. The environmental data on wind and solar irradiance have been gathered from the available sources, using consistent modelling with respect to what indicated in WP2 (with Beta probability distributions), as well as an extended model taking into account the correlations among the probability distributions. A novel function has been developed to handle data inputs at different time steps and representation (e.g. regular or irregular in time) and obtain a regular pattern to be processed from the power flow solver within the user-defined time period; the results are published. Dedicated models have been formulated and applied for different types of system components. The aggregate residential load has been characterized by resorting to a probabilistic approach based on load variations. The approach has been extended to the direct generation of aggregate residential load patterns, with a novel procedure that takes into account their coupling in time; this procedure is suitable to construct a set of aggregate residential load patterns to be used in scenario studies. The generation of load patterns for scenario studies has been also addressed by resorting to artificial neural networks. A further contribution has addressed the determination of the time intervals in which the aggregate residential demand is more flexible as a whole.

Advanced modelling of renewable energy sources has been addressed, by formulating an energy conversion model for photovoltaic (PV) systems, based on the environmental predictions already compared with experimental results. In the representation of solar irradiance measurements data, used in evaluations referring to the operation of PV systems, the presence of irradiance spikes depending on the “broken clouds” phenomenon has been found to be relevant on 1-min scale, becoming smoothed on 15-min scale. The results also show that the application of the PV system model developed in the paper (comparing the experimental measurements with the power output coming from the model) may provide useful information for the fault diagnosis of a portion of a PV array. Solar irradiance profiles have been normalized in time and amplitude, in order to avoid the differences caused by the evolution of the Sun in the different days of the year. The bi-normalization procedure produces comparable normalized patterns for the various type of days of the year. The normalized patterns have been subject to clustering in order to obtain a meaningful grouping of similar days.

A comprehensive approach has been used to address the sea wave energy production, passing from the characteristics of the sea waves to the electrical power production, also taking into account different forms of storage inside the specific Inertial Sea Wave Energy Converter (ISWEC) installed in the island of Pantelleria (Italy) before the end of the project. After initial testing as hardware-in-the-loop, a model using wave forecasts has been developed and used for dynamic simulations as well as for analysing the effects of faults in the case of grid connection through inverters. Specific modelling has been developed for multi-
energy systems, demand response also in a multi-energy context, and storage.

Task 2: Power flow and fault analysis tools

Achievements made with reference to planned objectives: the routines included in the tool can handle the deterministic and probabilistic load flow considering all the possible network structure (i.e. radial, weakly meshed and meshed), fault currents and voltage dips calculation. The DERMAT tool has been structured with the possibility of creating links with external Matlab modules calculating the active and reactive power patterns of generators and loads by using specific information (on the technologies and on ambient variables) and models. Furthermore, lately a harmonic probabilistic power flow has also been included. In all the calculations, the correlations among loads and generation can be taken into account.

The DERMAT tool has been implemented in the base Matlab® language (the Statistics toolbox is needed only for the probabilistic power flow calculations) and without preparing dedicated graphical interfaces, in order to be more easily portable to be integrated in other tools. The power flow calculation methods supported include: (i) Backward/Forward Sweep (BFS) for radial networks, (ii) BFS for weakly meshed networks, and (iii) full Newton-Raphson AC power flow for meshed networks.

The probabilistic power flow takes into account correlations among the random variables [WP4.16]. From the power flow results, the short circuit currents at the nodes (for three-phase, phase-to-phase and phase-to-earth faults) are computed. All the power flow calculations are carried out sequentially at different time periods. Specific features are introduced in the computational modules to represent the interface with the grid through different types of connections (with transformers or converters) including the steady-state voltage control capabilities. The results of the fault analysis are also used to provide the basic information for the power quality modules used in Deliverable D4.3 (voltage dip analysis, integrated in DERMAT).

Task 3: Security assessment tools

Achievements made with reference to planned objectives: some changes to the original schedule have been introduced in this Task (see section 1.4 for details). The initial “market-based” view of the security assessment tools has been reformulated without considering the effect of competitive markets in the islands. Within this framework, a specific module has been set up to perform N-1 contingency analysis in an optimal power flow (OPF) of a distribution network minimizing resistive losses and considering embedded generation. The formulation of the OPF takes into account the interconnection switches in the service restoration process. In the mathematical formulation, the system is modelled through linear expressions transforming the Non-Linear Problem into a Mixed-Integer Linear Problem (MILP). It includes binary variables to represent switches, which can be opened or closed depending. Moreover, the system maintains radiality through different switching combinations. The MILP model has been used to study islanding conditions in a network containing wind power and storage. For a system containing a synchronous generator, a local generation connected to the grid through an inverter and some loads, the contribution of the inverter to the short circuit current during a fault in the network has been simulated. The Low Voltage Fault Ride Through (LVFRT) capability has been assessed for this model by considering the possibility of the local system supplied by a power converter to remain connected during short circuit faults.

Dynamic analysis for weak networks has been reviewed and then has been addressed by resorting to a novel type of solver to address dynamic calculations, based on the Torelli’s control box (TCB). The general concept of TCB is that a mathematical programming problem can be formulated by using a set of differential equations, with the solution of the problem reached at the equilibrium point. If the solution satisfies suitable properties (from Lyapunov conditions) and belongs to the region of attraction of the initial conditions, it can be guaranteed that the solution point is reached, determining the solution point through...
the convergence of an artificial dynamic model. The use of the TCB approach enables the user avoiding the drawbacks of some numerical algorithms that could fail to converge because of high non-linearity of the first-order conditions. The TCB approach has been also used to construct a new type of solver for distribution network optimal reconfiguration.

On the control point of view, a key result has been obtained by the development of an advanced control technique for inverter-interfaced generation behaving as a Virtual Synchronous Generator (VSG), whose simulated behaviour has led to promising results. A Direct Lyapunov control technique is applied to enable continuous injection of the maximum active power at the fundamental frequency from the local generation source to the power grid, compensating the reactive power and harmonic current components of the grid-connected loads. The method has been applied by addressing the DC-voltage variations at the DC-side of the interfacing system. The passivity-based control technique is considered to analyse the dynamic and steady-state behaviours of local generation units during grid integration and power sharing with loads. The compensation of instantaneous variations in the reference current components of the local generation units at the AC-side, and DC-link voltage variations at the DC-side of the grid-interface converters, are considered in the control loop of DG units, which is the main contribution and novelty of this control technique over other control strategies.

Task 4: Reliability and power quality assessment tools

Achievements made with reference to planned objectives:

A number of tools have been implemented in order to address reliability, power quality and security assessment aspects. The specific features of the tools implemented for reliability analysis are the possibility of determining the distribution system reliability indices in deterministic and probabilistic frameworks, and the possibility of incorporating the calculation of the reliability costs in the reliability study. Reliability objectives have been considered in a multi-objective optimization framework applied to distribution systems, solved with the powerful ε-constrained numerical technique.

For power quality analysis, the harmonic power flow has been integrated in the DERMAT tool, also developing a probabilistic harmonic power flow version. Power quality has been addressed by calculating the related indices for different distribution systems structures with distributed generation. Likewise, voltage dip analysis has been integrated in DERMAT through the calculation of the voltage dip matrices starting from the results of the short circuit calculations.

Moreover, the possibility of addressing multiple measurements of voltage and current waveforms from three-phase systems to calculate the relevant indicators for harmonics and interharmonics, as well as combined indicators of harmonic/interharmonic distortion and unbalance, have been implemented in the new tool WUDIS (Waveform Unbalance and DIStortion), calculating the waveform distortion and unbalance indicators in unbalanced systems operating under waveform distortion. The WUDIS tool allows for the elaboration of the field measurements starting from an input text (.TXT) file with two alternative data formats (1: time, voltage at phase 1, currents at the three phases; 2: time, voltage at the 3 phases, currents at the 3 phases). Furthermore, there is the possibility of elaborating multiple data gathered at successive time intervals during a measurement campaign on the field (e.g. sequences of 10-periods data gathered each 15 min). The indicators calculated take into account the simultaneous presence of harmonic/interharmonic distortion and network unbalance, and include harmonic distortion indicators (for harmonic groups and subgroups), interharmonics indicators (for interharmonic groups), network unbalance indicators (evaluated for the phase currents and for the neutral current). The WUDIS tool has been applied to data coming from a PV system operating in variable sky conditions, including partial shading. On the same PV system, the presence of supraharmoinics due to the operation of the grid
connecting inverters has been studied by using experimental results. Finally, active filtering for eliminating harmonics in the distribution networks has been addressed by indicating a specific control strategy for the interconnecting converters.

**Significant results:**

The main results can be summarized into:

- Implementation of the tool DERMAT (power flow/short circuit/harmonic analysis with uncertainties)
- Implementation of Optimal Power Flow (OPF) for distribution systems
- Analysis of Inertial Sea Wave Energy Converter (ISWEC)
- Detailed characterization of photovoltaic (PV) systems
- Implementation of the tool WUDIS (harmonic analysis)
- New control technique applied to a Virtual Synchronous Generator (VSG)
- Network reconfiguration and dynamic analysis with the Torelli’s Control Box (TCB)
- Scientific publications in international journals and conference proceedings

**DERMAT**

Formulation and implementation of the software tool DERMAT, operating in a multi-slack framework with multiple executions in a given time frame at user-defined time steps. The implementation has been designed to be open for the integration of further modules (with possible update of the internal code), with specific innovations on:

- Treatment of the data input from information gathered at different time steps.
- Handling data uncertainty from correlated probability distributions.
- Automatic selection of the solver on the basis of the network data.
- Calculation of the probabilistic harmonic power flow in a time interval.

**OPF**

Implementation of distribution system Optimal Power Flow (OPF), with specific innovations on:

- Study of the conditions for N-1 contingency analysis in an optimal power flow (OPF) of a distribution network minimizing resistive losses and considering embedded generation.
- The formulation of the OPF takes into account the interconnection switches in the service restoration process.
- In the mathematical formulation, the system is modelled through linear expressions transforming the Non-Linear Problem into a Mixed-Integer Linear Problem (MILP). It includes binary variables to represent switches, which can be opened or closed depending on the context.
- The system maintains radial configurations through different switching combinations.

**ISWEC**

Analysis of the Inertial Sea Wave Energy Converter (ISWEC) on the basis of the design data of a real prototype, with specific innovations on:

- Estimation of the ISWEC performance starting from the sea waves characterization, to produce wave height patterns and determine the power output and the productivity in a given time period.
- Analysis of the power transfer scheme inside ISWEC, also taking into account internal storage (flywheel, batteries and ultracapacitors).
- Study of the power output with the impact of the internal storage on decoupling the generated power from the power delivered to the grid, smoothing the power output and provide constant power to the grid in some time intervals, to delay and condition the variation of the delivered power level in order to make it more predictable.
- Analysis of the ISWEC connection to the grid, including short-circuit assessment for internal and external...
faults.

PV
Detailed characterization of PV system modelling, with specific innovations on:
• Detailed model of PV conversion from solar irradiance to AC power output and comparison among measurements and short/term predictions.
• Representation of solar irradiance data in a bi-normalized way to identify similarities among the days of the year through clustering procedures.
• The PV model is useful also for diagnosis purposes, enabling the operators discovering failures in the PV system when discrepancies between PV power measurements and simulations are found.

WUDIS
Implementation of the harmonic analysis tool WUDIS (Waveform Unbalance and DIStortion), with specific innovations on:
• Implementation of the tool for calculation of the harmonic distortion and unbalance indicators (based on the symmetrical component transformation) from on-site measurements processed through a data acquisition system.
• Extension of the harmonic distortion indicators to unbalanced networks and of unbalance indicators to the systems with distorted waveforms, with application to photovoltaic systems characterized by their structural unbalance and unbalance from partial shading.

VSG
Development and simulation of an advanced control technique for inverter-interfaced generation behaving as a Virtual Synchronous Generator (VSG), with specific innovations on:
• Detailed voltage control loop with modelling of inverter capability and non-idealness of the inverter (losses).
• Set up of the reference voltage in order to guarantee good transient response in normal conditions.
• Dedicated inverter protection scheme to allow appropriate fault ride-through capability.

TCB
Proofs of concept and solutions of dedicated problems of network reconfiguration and dynamic analysis with the TCB, with specific innovations on:
• Solution of distribution system reconfiguration with minimization of the network losses.
• Solution of the dynamic equations for distribution networks.
• Dynamic calculations on weak distribution networks.

WP5 – development of scheduling tools
Workpackage objectives:
The objectives of WP5 are the following:
• Development of innovative advanced stochastic optimization models and tools for the short-term and very short-term operation of insular electricity networks under large-scale RES integration.
• Incorporation of state-of-the-art and development of new methods for the efficient and reliable operation of the power system (e.g. hybrid plants, storage, plug-in electric vehicles, VPPs, etc.).
• Development of integrated software tools to operate as stand-alone applications or incorporated in the associated EMS of the insular power systems.

Progress towards objectives:
Summary: In order to meet the aforementioned objectives, since the beginning of the project the associated work was organized in four distinct tasks (Tasks 5.1-5.4). The partners involved in WP5 did not
encounter substantial problems to fulfill the prescribed activities and complete the relevant deliverables on time. The work progress in all Tasks for the entire duration of the project is briefly summarized as follows:

**Progress towards objectives detailed for each task:**

**Task 5.1: Scenario generation for the modeling of the random system and unit parameters**
In this Task, the methodologies for the creation of the scenarios regarding various system and unit parameters (i.e. insular system load, RES injection, units’ availability) has been first developed. Two different approaches, one based on probabilistic analysis and one based on time series analysis (ARIMA models), were developed for the generation of the system load and the RES production scenarios that capture the spatial and temporal correlations of the corresponding variables. Monte Carlo simulation was adopted for the creation of the units’ availability scenarios. Appropriate scenario reduction techniques were applied in order to alleviate the computational complexity and burden on the scheduling tools, while preserving the features of the original scenario sets. In order to account for the statistical correlation of the power output from neighboring RES plants, an appropriate algorithm has been implemented for the generation of spatial cross-correlated scenarios regarding the RES electricity injection.

**Task 5.2: Development of scheduling models**
In this Task, the core scheduling models for the short-term operation of the insular power systems have been developed. Regarding the mathematical formulation, two different approaches have been followed, described as follows:

The first approach was oriented to the development of short-term scheduling optimization models based on mixed-integer linear programming (MILP). Various novel deterministic and stochastic unit commitment and economic dispatch models were developed, aiming at the minimization of the total operating cost of the conventional (thermal) generating units in an insular power system for the next 24-48 hours, while respecting all system and generating units’ operating constraints. The minimization of the thermal unit cost results in the maximization of the cost-free renewable energy sources (RES) injection. Special attention has been given on the realistic modeling of the conventional generating units’ operating phases (i.e. synchronization, soak, dispatch and desynchronization). A detailed representation of the generating units’ operating and inter-temporal constraints (e.g. start-up/shut-down procedures, minimum up/down time constraints, ramp rate limits, power output and reserves provision constraints, etc.) have also been provided. The transmission network representation was properly incorporated in the optimization models under a DC power flow approximation. Moreover, special attention has been given to the qualitative and quantitative determination of the required reserves (primary, secondary, tertiary spinning/non-spinning) through innovative stochastic optimization models, so that specific reliability targets posed by international rules and practices are met.

The second approach was based on risk analysis to address the increase of RES variability and uncertainty. An advanced probabilistic unit commitment and economic dispatch model was designed to minimize the sum of the estimated costs based on risk cost analysis. These costs are the sum of the estimated real operation costs and the estimated costs of operating outside normal conditions. The probabilistic estimation of costs is not based on scenarios, but on the expected risk estimation approach that uses directly the probability density functions. In this approach a reserve level is not predefined, but reliability and irregular operation risk minimization leads to solutions with enough dynamic reserve levels. This scheduling model consists in evaluating the adequacy of each possible combination of thermal generators online in the unit commitment problem for each hour of a probabilistic net load forecast, avoiding the need of developing a large number of scenarios, modeling explicitly the impact of the forecast uncertainty and considering the possibility of single thermal unit failure. The fuel consumption curves of
thermal units, the probabilities of the thermal generators operating inside/outside of their appropriate range of power (i.e. risk of load shedding and wind shedding necessity based on probabilistic forecasts) and the probability of normal operation after the occurrence of wind spillage were also considered in the objective function of the problem.

Task 5.3: Incorporation of state-of-the-art and development of new methods for the efficient and reliable operation of the power system

The state-of-the-art methods for the efficient and reliable operation of the electricity networks that have been evaluated in this activity include: a) the flexible consumption along with dynamic pricing (price-responsive demand) in a smart-grid environment, and b) the increasing electrical energy storage capacity. In addition, special attention has been given to the study of the effects of the expected active participation of electric vehicles into the insular networks, mainly regarding the valuable assistance they can provide (e.g. through the provision of certain types of reserves) towards the large-scale RES integration in these networks. Finally, the concept of Virtual Power Plants (VPPs) has been employed for the coordination of all aforementioned means towards the electricity network efficiency and reliability improvement.

The mathematical formulation regarding the integration of all these novel emerging methods and tools from the system operator perspective in the relevant short-term scheduling models (i.e. unit commitment and economic dispatch models) already developed in Task 5.2 have been completed successfully.

Task 5.4: Development of integrated software tools

The core scheduling models have been developed in high-level commercially available software such as GAMS or MATLAB, which allow for a compact and precise representation of large-scale and complex optimization problems. Such a computational environment also allows for the use of state-of-the-art solvers such as CPLEX, which is a high-performance solver suitable for linear and mixed-integer linear programming.

In this Task, the integration of the various scheduling models in ready-to-use software tools, which operate either as stand-alone applications in the pilot sites or through web-based platforms, was completed successfully. In this framework, two ready-to-use operational software tools were developed, namely, Short-Term Electric Power System Scheduling (STEPS) and Risk-based Power Scheduling Tool (RiSch), each oriented to different generation mix and insular power system size and requirements. Both tools are briefly described in the following paragraph.

Significant results:

In the framework of WP5, significant results have been produced during the entire duration of the project, briefly described as follows:

First, an analytical state-of-the-art review on methodologies and tools proposed by the research community as well as practical applications currently used in the power industry for the short-term scheduling of the electricity networks has been conducted. Special attention has been given on the presentation of state-of-the-art and emerging methods for the efficient and reliable operation of the electricity networks, (e.g. price-responsive demand, storage, electric vehicles, Virtual Power Plants, etc.). As already mentioned, the mathematical formulation of scenario generation algorithms and various complex optimization models that have been developed for the optimal short-term scheduling of insular electricity networks have been developed and implemented in specific real-life insular power systems. The main outcome of WP5 consists in the development and real-life implementation of two ready-to-use short-term scheduling tools, namely, Short-Term Electric Power System Scheduling (STEPS) and Risk-based Power Scheduling Tool (RiSch).

AUTH undertook the development and deployment of the STEPS tool in the pilot site of Crete, Greece.
STEPS is an integrated software tool that currently operates on-line as stand-alone application that is easily accessible by the respective Operator (HEDNO), providing useful information for the daily scheduling of the generating system of the Crete island.

On the other hand, Smartwatt undertook the development and deployment of the RiSch tool in the pilot site of São Miguel-Azores, Portugal. RiSch is an integrated tool that currently operates on-line in a web-based application that is easily accessible by the respective Operator (EDA), providing useful information for the daily scheduling of the generating system of the São Miguel island.

It is noted that both tools have been developed “from scratch” in line with the particular needs of the insular power system of Crete, Greece, and Sao Miguel, Azores, respectively, which are the main SiNGULAR pilot sites. However, they can be easily adapted and parameterized in order to operate in any other insular power system. An overview of both tools as well as further details on their scope, key functionalities and integration aspects can be found in Deliverable 5.2.

Regarding WP5 deliverables, D5.1 has been successfully completed and submitted to the EC in time (M12), while D5.3 (common deliverable with family projects iGREENGrid and SuSTAINABLE) was successfully completed and submitted to the EC with a short delay (M7 instead of M4). Both, were approved during the 1st review (Sep. 2014). D5.2 has been successfully completed and submitted to the EC in time (M21, Aug. 2014) and was also revised following the clarifications and comments following the review, although it did not officially fall within the first reporting period. Some clarifications/additions asked that were carried out and the revised version was submitted to the EC in M26.

During the full duration of the project, the measurable results yielded by the activities of WP5 led to one (1) book chapter, seventeen (17) publications in peer-reviewed scientific journals and twenty-four (24) announcements in energy-related international conferences, listed as follows:

WP6 - Competitive operation of Insular Electric Networks
Workpackage objectives:
The objectives of WP6 are the following:
• Development of market design schemes oriented to the introduction of competition in the short-term operation of insular electricity grids.
• Examination of the applicability of standard market design schemes, already implemented in interconnected power systems, in the project-related insular power systems and subsequent adjustment to facilitate the project targets (large-scale RES penetration, demand response programs, etc.)
• Development of economic models for equitable settlement of the market participants and customers for supplying energy, reserves, demand response and other energy services.
• Formulation and testing of the scenarios under which the development and implementation methods will be validated.

Progress towards objectives:
Summary: In order to meet the aforementioned objectives, since the beginning of the project the associated work was organized in three distinct tasks (Tasks 6.1-6.3). The partners involved in WP6 did not encounter substantial problems to fulfill the prescribed activities and complete the relevant deliverables. The work progress in all Tasks until the end of May 2014 (end of 1st project review period) is briefly summarized as follows:

Progress towards objectives detailed for each task
 Task 1: Economic framework of insular electric networks
In this task the setting-up of the economic framework currently deployed at electric distribution systems
around Europe has been developed. The market players were identified and characterised through their attributes and interface with the market model implemented. Also, for a larger picture, the business issues were investigated at the national levels separately (performed accordingly with the individual application sites from each partner). A special attention was paid to defining the cost-benefit leverage mechanisms, which are of a great importance for the future multi-stakeholders operation of electric systems.

The main goal achieved was the complete analysis of the recent market rules and the remuneration schemes in the distribution network level in order to consider new proposals that improve the insular regulatory framework. The new context where distribution generation (DG) is integrated in the distribution system is the main challenge for distribution companies to be able to meet new technical and operational requirements.

Task 2: Development of risk analysis models and tools

In this task methodologies and tools for analyzing the risk associated to the operation of a selected mix of resources in the insular network application, under different degrees of risk aversion characterizing the stakeholders were developed. Different alternatives, each of which containing set of resources exploiting various energy vectors, were analyzed in order to establish the most convenient solution in terms of economic operation of the insular system and sustainability under uncertainty. The key aspects considered were the availability of energy sources and reserves, the complementary exploitation of different energy sources, the role of storage, the economics of the connection to the insular network, and the effects of the possible connection to external systems.

The core achievement of this research activity was the analysis and reconfiguration of weakly meshed distribution networks through well-established linearized power flow model, using conventional optimization approaches in order to improve their performance. In addition, it focused on optimum power supply and operation analysis being the main objective the minimization of the power losses and operation costs in distribution networks, considering key electrical grid operating parameters as a power system constraint.

Task 3: Scenario analysis for the modeling of the insular electricity grids

The main aspect of this task was the identification of existing and alternative solutions and the conduction of a feasibility study on the economic competitiveness in the short-term operation of insular electricity grids. Two sets of scenarios were constructed. A first set reproduced the characteristics of the insular networks located in the application sites selected for SINGULAR (adding further dedicated options with respect to the installed structures in order to provide a wider assessment). Another set of scenarios were more generally include a wide number of options in order to develop scenario analysis tools operating in an integrated way. The scenarios also considered different options concerning possible incentives or penalties (related to renewable energy deployment, energy efficiency and environmental impact) that have been or could be introduced for the exploitation of the various energy sources.

The ultimate goal of the present task was primarily to create practical tools that may help analyzing distribution networks, and in second place pursue an economical operation through minimization of power losses in distribution systems; in a way that they may perform in a secured and efficient manner from the grid operator’s point of view. A practical tool was achieved, which may help distribution operators to comply with an up to date technical and operational requirements in future distribution grids. Besides, it may contribute to power system stakeholders to become economically benefited from intended savings in operation costs.

Significant results:

At the end of May 2014, Tasks 6.1 6.2 and 6.3 have been completed. Specifically, a state-of-the-art review
on European energy systems technical and legal frameworks proposed by the research community as well as specific network codes currently used in the electricity networks has been achieved.

UCLM has developed algorithms for the analysis and reconfiguration of weakly meshed distribution networks through a well-established linearized power flow model, using conventional optimization approaches in order to improve their performance. In addition, it focuses on optimum power supply and operation analysis where the main objective is the minimization of the power losses and operation costs in distribution networks, considering key electrical grid operating parameters as a power system constraint. With respect to the implementation of all methods and tools developed and presented in the framework of WP6, Smartwatt has undertaken the development and deployment of the electric price signals in insular systems.

POLITO has undertaken the development of the detailed model of the Italian electric power system. The model was constructed starting with the regulatory framework for electricity and to the electricity market. With respect to the implementation of all methods and tools developed and presented in the framework of WP6, Smartwatt has undertaken the development and deployment of the electric price signals in insular systems and the development of the risk aspects in distribution systems and islands. This approach was performed by taking into account the resources availability as well as risk-aversion margins imposed by the demand side and the RES penetration.

AUTH prepared an extensive scenario-based simulation analysis of the Crete power system operation for the year 2015 on an hour-by-hour basis aiming at the evaluation of the impact of RES penetration on the daily power system operation in terms of various power system operation indices, such as the total energy production per generating unit technology, the total CO2 emissions, the total production cost, etc. Additionally, the effect that the installation and operation of a pumped-storage plant may have on the short-term operation of an insular power system was also investigated.

ITC developed a report regarding Lanzarote-Fuerteventura power system, based on a wide array of technologies available and local electricity market constraints.

Finally, the deliverables D6.1 and D6.2 have been successfully completed and submitted to the EC in time. During the first 18-month period, the measurable results yielded by the activities of WP6 led to two announcements in forthcoming energy-related international conferences, listed as follows:

Publications

The publications totally or mainly containing WP6 results include 1 book chapter, 1 article in International journals (published in open access mode), and 15 articles appearing in International Conference Proceedings. The list of papers is reported below, partitioned into similar topics. Journal papers and the book chapter are highlighted in bold. Some papers refer to more than one WP and are reported here to indicate the contribution specifically related to WP6.

WP7 - Planning Procedures And Tools For Distribution Grid Integration
Work package objectives:

The objectives of WP7 are the following:

- Development of robust mathematical models and software tools to address the integration of RES into the planning of European insular distribution systems.
- The effect of RES planning and distribution network planning is addressed as follows: First, the effects of the addition of RES are studied independent of distribution planning. Then, the development of the distribution network is analyzed alone, assuming that RES are fixed. Finally, the effect of both new RES and distribution network expansion are jointly studied. In the last model, the overall social welfare is
optimized instead of total costs, considering demand response, reliability issues, hybrid technologies and EES, among others.

Progress towards objectives:
Summary: In order to meet the aforementioned objectives, since the beginning of the project the associated work was organized in four distinct tasks (Tasks 7.1-7.4). The partners involved in WP7 did not encounter substantial problems to fulfill the prescribed activities and complete the relevant deliverables. The work progress in all Tasks is briefly summarized as follows:

Progress towards objectives detailed for each task

Task 7.1: RES generation expansion model for insular networks
This task is devoted to the formulation of a mathematical model that is able to obtain the optimal expansion of RES in an insular distribution network. The mathematical model contains an objective function for the minimization of all operation and expansion costs of the RES resources. In particular, we consider wind, hydro and solar technologies, among others. The technical constraints related to all these technologies are incorporated into the model. The problem is formulated as a multi-stage RES expansion model and a comprehensive set of scenarios is deployed to account for all sources of uncertainty in the model. Among them, demand, solar irradiation, water inflow and wind speed are the main variables that are considered as stochastic variables for the model. The creation of plausible scenarios that are the result of the combination of all stochastic variables is validated with real data coming from the insular companies of the consortium. The model is programmed in GAMS and MATLAB and both the objective function and the constraints are linearized to attain a stochastic mixed-integer linear programming model (SMILP), whose robustness guarantees to obtain a set of optimum solutions for different scenarios.

Task 7.2: Reliable distribution network expansion model for insular networks
This task models how to expand the distribution network adding new assets (lines and substations) so that the current and future energy supply for the island customers is served at minimum cost and with the quality required. The objective function to minimize is the net present value of the investment cost to add, reinforce or replace feeders and substations, losses cost, and operation and maintenance cost. The model considers several levels of load in each node and investment alternatives for each resource to be added, reinforced or replaced. The nonlinear objective function is approximated by a piecewise linear function, resulting in a mixed integer linear model that is solved using standard mathematical programming. The model allows us to find multiple solutions to analyze from a pool of solutions. In addition to the optimization problem, reliability indices and associated costs are computed for each solution. The implemented model considers that there are several alternatives for each line expansion asset available depending on the size of the conductors or the transformer’s capacity. The model is multi-stage and each stage has several load levels, described by a typical daily load curve occurring in each node at different times. The load is represented as a constant current so that the planning model becomes a mixed-integer linear programming problem (MILP). Quadratic losses in lines and transformers are handled by piecewise linearization so that the problem becomes a mixed-integer linear one, solved by using GAMS/CPLEX. The utilization of MILP techniques ensures fast and efficient solutions for large-size problems.

Task 7.3: Joint RES generation and distribution network expansion model for insular networks
This task is the result of combining the models resulting from the previous tasks, 7.1 and 7.2. In task 7.1 we only assume the expansion of RES in an insular distribution system. In task 7.2 we consider the expansion of distribution assets of an insular distribution system. In this task we put together the previous two models for a complete expansion of the distribution system assets and RES. In addition, we consider reliability in the joint model.
The impact of reliability on the expansion cost is significant. It is essential to know the reliability level to predict the evolution of the most important performance indices before and after distribution network expansions. Therefore, we aim to determine the long-term behavior of the distribution system considering: failure rates of system components, which are known for existing components and estimated for future additions along the time horizon and duration of the interruptions as a function of the repair time, service recovery, switching, or isolation states. The reliability indices studied are system average interruption frequency index (SAIFI), system average interruption duration index (SAIDI), average system availability index (ASAI), and customer interruption duration (CID), customer interruption frequency (CIF), and expected energy not supply (EENS). These data were provided to the consortium by the industrial partners.

The difficulty to incorporate all these reliability indices into distribution expansion is that it is necessary to know the network topology in order to calculate the reliability indices that characterize the system as well as the failure and repair rates, and the placement and response of the protective devices. To solve this problem, the most relevant reliability indices are computed for each solution selected from the pool of solutions (see task 7.2) and, thereafter, the associated costs of these solutions. With this information, it is possible to identify how individual nodes or consumers are affected by every plan of the pool of solutions, as well as the associated impacts on costs.

Task 7.4: Joint RES generation and distribution network expansion planning with demand response, reserves, hybrid storage and plug-in vehicles

Finally, the model developed in task 7.3 is completed by adding other issues relevant to planning in insular distribution systems. First, we take into account demand response, depending on the type of customer: industrial, commercial or residential. Each one of these customer types has its own demand response that is provided by the industrial partners of the consortium. Another important aspect is the treatment of the reserves of the system that is directly linked to the demand data. These reserves also have a direct connection with the reliability indices obtained in task 7.3. The consideration of hybrid technologies as part of RES is also addressed, as well as the possibility of plugging electric vehicles to the system. The latter allows for a flatter demand profile, since vehicles’ charging happens during the night. Finally, due to the presence of demand response, a new objective function is used. In this case, social welfare maximization that considers both generation and demand, replaces cost minimization. This, together with the reliability indices, quantifies the goodness of adding new RES and distribution assets in a long-term planning framework.

Significant results:
At the end of November 2015 (End of the project), Tasks 7.1 7.2 7.3 and 7.4 have been completed, while deliverables D7.1 D7.2 and D7.3 have been submitted with no delay. UCLM has undertaken the development and deployment of robust mathematical models and software tools to address the integration of RES into the planning of European insular distribution systems. It encompasses the effect of RES planning and distribution network planning. In D7.1 a distribution expansion planning algorithm has been presented from a centralized point of view. In this algorithm, an optimization model calculates three expansion solutions, among, which is the optimal one. The reliability indexes and their associated costs have been calculated for the previous set of solutions. Finally, an investment decision has been adopted through a comparative analysis. In D7.2 a joint generation and distribution network expansion planning has been presented. The installation of feeders, transformers, substations, and generators has been considered and adequately described in the expansion planning algorithm. This allows a distribution company to obtain the optimal strategy to meet a rise in demand. In D7.3 the activities previously
performed have been enhanced. The inclusion of DR and hybrid storage. DR has been introduced in the model considering elastic demand functions calibrated by load levels. Demanded energy in every load level has been expressed as a function of the elasticity, demand and prices for the incumbent load levels included in the load-shifting horizon and average price.

During the grant agreement period, the measurable results yielded by the activities of WP7 led several submissions to a peer-reviewed scientific journal and four announcements in forthcoming energy-related international conferences.

WP8 – Implementation of DSM

Workpackage objectives:

The objectives of WP8 for the full project duration are the following:

• Install specific HAN web smart meters to selected pilot users that will support the DSM services, offer real-time energy data gathering from pilot sites and feed the cloud MDM system with energy raw data.
• Develop advanced models that allow the integration of real-time information streams of the smart power grid with diverse information pulled from online services, in order to translate the veritable explosion of data that becomes available, into a comprehensive knowledge repository supporting demand response decisions.
• Develop user interfaces and interaction methods that communicate energy-saving opportunities and price / dynamic incentives in an optimized way.
• Develop advanced consumer prioritization methods that continuously consider consumer’s potential for load curtailment and allow utilities to efficiently select the appropriate consumers to apply DR in a given time.
• Develop an innovative cloud-based Meter Data Management system that will support and manage the proposed DSM / DR services to the energy consumer.
• Develop a platform, which will be different for the administrator (utility) and different for the user (consumer) that will participate in the DR programs.
• Develop the DSM strategy, which will include Energy Efficiency tips for savings and DR programs.
• Enhance the developed innovative cloud-based Meter Data Management system that will support and manage the proposed DSM / DR services to the energy consumer in the Crete pilot
• Enhance the platform, which will be different for the administrator (utility) and different for the user (consumer) that will participate in the DR programs.
• Finalize and adapt the DSM strategy, which will include Energy Efficiency tips for savings and DR programs.
• Deploy various DSM signals to the Crete pilot and measure various KPIs and effectiveness level
• Develop various DSM scenarios and measure the Key Goal Indicators and other relevant metrics
• Assess and rate the DSM effectiveness and the ability to expand the service to the commercial Utility market

Progress towards objectives:

Summary: In order to meet the aforementioned objectives for the full period, the work in WP8 was including the involvement of the four tasks below:

• Task 8.1: Smart Meter HAN devices installation and networking (M13-M18)
• Task 8.2: Development of the core cloud Meter Data Management System (M13-M18)
• Task 8.3: Development of Demand Response strategy roadmap and services catalogue (M13-M18)
• Task 8.4: Implementation of DR / DSM events in Real-time (M19-M30)
Task 8.1 faced a delay due to some difficulties that we encountered during the installations of the smart meters (defective data loggers and CTs).

In Task 8.1 of WP8 the installation of specific metering devices has been carried out in Crete (Heraklion). The energy meter selected to be installed in home consumers for the needs of the Demand Response pilot in Crete was a low cost smart meter and a data logger (i-meter) suitable for residential use, which empowers users with full utility monitoring.

The energy meter (Figure below) consists of the following parts:
• Battery Supplied wireless Transmitter with CT jaws
• Monitor Display (with variety of information regarding power consumption on real-time, energy consumption for the previous 1-7 or 30 days. Graphical representation of energy consumed within pre-determined periods of the time and information on temperature).
• Power adapter for the display
• Communication cable between the display and a USB stick.

With the electricity meter, an additional data logger was also installed, the i-meter. Intelen’s iMeter is a smart device that acts as a data bridge between the meter and the Internet and is capable for a series of services, including the following:
• It performs basic calculations in order to translate the raw data that are collected by the specific energy meter to information that can be handled by Intelen centralised (cloud) infrastructure.
• It acts as memory storage (buffer) so that in case of a network or other error, data are not lost, but are stored for transmission as soon as network connectivity is re-established.
• It extracts the appropriate key performance indicators (KPIs) from the raw data received by the energy meter.
• It receives instructions for extra KPIs from Intelen Meter Data Management (MDM) System.
• It performs error handling concerning the energy meter, the connectivity of the system and the iMeter itself.

Tasks 8.2 and 8.3 were successfully completed according to the initial workplan. In Task 8.2 a Meter Data Management System has been developed and deployed along with relevant applications that implement DR and DSM services and supported the communication in between the platform and the consumers. Task 8.3 was successfully completed according to the initial work plan and was adapted in order to meet the Dry-run requirements and the pilot objectives. There was a 7-9 months delay for the pilot deployments and dry-run implementation due to some difficulties that we had encountered during the installations of the smart meters (defective data loggers). In Task 8.3 of WP8 the development of Demand Response Strategy roadmaps and services catalogue were analysed and designed. Firstly, the Demand Side Management tools and techniques were studied as part of the state-of-the-art analysis conducted within this task. Secondly, in this Task the requirements for the technical and the functional core platform that has been developed have been set up. The analysis and specification of the core platform requirements were based on the DSM/DR strategies that have been designed and assessed in this Task.

Task 8.4 was run successfully and many DR events (21) were scheduled in two Phases for the Crete pilot site to test several behavioral motivational patterns for DR efficiency.

The pilot execution required support for the smart meter installations to solve any issues regarding the proper functionality of the metering equipment and the communication with the central system. The support is organized in three levels. The first level support is responsible for the daily monitoring of the smart meter status to identify smart meter failures and telco support activities to solve minor issues with the help of end-users. The second level support performs remote support actions through iMeter’s remote
support functionalities such as rebooting the equipment and updating the network settings among others. A dedicated web application was developed for Singular installers, which simplifies the installation process by providing troubleshooting information regarding the communication of iMeter with the smart meter and the central MDM system.

Progress towards objectives detailed for each task:

Task 8.1: Smart Meter HAN devices installation and networking (M13-M18)

This task was responsible for the installation of specific smart energy meters that would be used for the implementation of the DSM strategies that took place in Task 8.4. First, Intelen in collaboration with the partners that are involved in WP8, has decided on the model of the smart meter that was going to be used. The energy metrics that the meter could provide and the easiness in the installation of this specific meter were the two most significant criteria that have been taken into consideration during the phase of its selection. The energy meter that was finally selected to be installed for the needs of the DSM services pilot, is a low cost smart meter suitable for residential use which empowers users with full utility monitoring. Then the whole smart metering infrastructure was designed by Intelen in order to fulfill the requirements that have been set during the design of the DSM roadmaps. Next step was the order and purchase of the respective equipment. The installation of the meters and simulation of potential DR programs have taken place on one of the pilot islands, the island of Crete in Greece.

Task 8.2: Development of the core cloud Meter Data Management System (MDM) (M13-M18)

In this task the development of the core cloud MDM system that used in SiNGULAR has been designed and deployed along with relevant applications that implement DR and DSM services. The MDM system was designed to receive and send the measurements from the smart energy meters that have been installed under the Task 8.1. Functionalities and services for data validation, integration / storage, consolidation and access have also been implemented within the framework of the MDM system design. Except for the design and the development of the MDM system, in this task the whole SiNGULAR platform design where the DSM strategies took place has been carried out. The platform was designed based on a distributed, service-oriented approach: it consists of several components that are designed and have been implemented as a set of interoperable services. The results of this implementation documented in D8.4.

The four main functionalities of the SiNGULAR platform are the following:

- Data Service: Main functionalities of the Data Service are:
  - Communication with Smart Meters.
  - Data retrieval cleansing and storage.
  - The exposure of stored electric energy data to other components.
- DR System: Main functionalities of the DR systems are the following:
  - User/Household Clustering of the home users that participated in.
  - Savings estimation per DR program.
  - Tip Recommender for the energy efficiency tips.
  - Typical usage profile for each user.
- External Data Sources: An integration system has been implemented in order to retrieve data from external data sources, for example electric energy tariffs files.
- User Interface: The user interface consists of an end-user web application and an administrative web application. Both applications support electric energy tariffs for up to 6 tariff periods, which can change in daily basis.

Task 8.3: Development of Demand Response strategy roadmap and services catalogue (M13-M18)

The scope of this task was to design and develop DSM strategy roadmaps and services catalogues. In
this task the specification of relevant DSM/DR strategy metrics and Key Performance Indicators (KPIs) were defined. In this Task the requirements for the technical and the functional core platform that has been developed in Task 8.2 have been set up. The analysis and specification of the core platform requirements were based on the DSM/DR strategies that have been designed and assessed within the framework of this task. A state of the art analysis of the common technologies that are used in the DR program has been conducted.

Within task 8.3 different DSM policies were studied extensively which include both energy efficiency tips/commitments and Demand Response (DR) programs. Initially a detailed study of the most common passive DR policies a specific DR roadmap has been designed for the needs of the SiNGULAR platform. The DR roadmap could contain 4 DR programs that can be found below:

- **Real Time pricing (RTU).**
- **Time of Use (ToU).**
- **Critical Peak Pricing (CPP).**
- **Demand Bidding Program (DBP).**

Because there was not the possibility to have actual variable or adaptive pricing due to DSO regulations, we decided to focus on emulating the ToU and RTU pricing and focusing a lot on social and behavioral DR in order to measure the effectiveness. Actually we used the proposed DR strategies in a virtual mode with real energy mix data, enhancing a lot the behavioral part to increase motivations for people to follow the DR signals. Also many of the social KPIs were not used because of low (almost zero) use of social networks (Facebook) from the users not the mobile API (lack of smartphones available). Many KGI that are presented in DOW were adapted and re-adjusted in Deliverable 8.4 in order to focus more on the behavioral side of the DR and the various behavioral patterns.

**Task 8.4: Implementation of DR / DSM events in Real-time (M19-M30)**

In average 1-2 DR events were scheduled/week in a real-time mode (immediate emails/platform messages), based on the pricing information and on the consumer profiling, since the DR signals are being sent on different time slots, according to the profiling. The DR events are scheduled and sent through the DR Admin panel of Intelen (see below). The emails are sent before the event and based on the real-time measurements Intelen verifies the DR drop and automatically estimates the consumer’s potential and DR acceptance. Initially the Behavioral DR method was followed, where we sent to the consumers general tips and information about the RES mix; in other words we have informed them to use more “clean energy” in specific time slots (ToU) The behavioral method is actually combined with the Time Of Use (ToU on pricing info) where we inform the consumers of the specific electricity rates in daily slots or weekly slots (ToU and Dynamic Pricing / slot) and additionally we are informing them about the RES mix.

Significant results:

At the end of May 2014 that the first reporting period had also finished, tasks 8.1 8.2 and 8.3 have been completed and the respective deliverables have been submitted to EU. The design of the smart metering infrastructure has been carried out and the installation of the 100 smart energy meters has finished in the home users of the Crete island that the pilot took place. Intelen’s iMeter the data logger that has been used to extract the energy data from the energy meters to the SiNGULAR platform is sending regularly measurements every 15’ minutes. Moreover, the design and implementation of the MDM system and the SiNGULAR platform for the execution of the DSM roadmap has been completed successfully within this first reporting period. Extensive surveys in the state of the art of the DSM strategies and the technologies that are used in them have taken place. After this detailed study, we were in the position to design our own DSM roadmaps for the users of the pilot site. Within task 8.3 different DSM policies were studied.
extensively which include both energy efficiency tips/commitments and Demand Response (DR) programs. An energy tariff system and a point system have also been created for the scope of the pilot. Within task 8.3 different DSM policies were studied extensively which include both energy efficiency tips/commitments and Demand Response (DR) programs that served as the basis for the Task 8.4 for the Dry-run pilot execution and the extraction of many statistics about the DSM strategies. In Task 8.4 the DR events were scheduled successfully and executed on time with some great KPI and statistics results. In particular, we found that given the framework of our research, DR events with energy consumption increase objective are more effective. Not necessarily with respect to participation but in terms of percentage results. Moreover, we found that for the 8 energy consumption reduction DR events there was a pattern of savings between the clusters of low, medium and high consumers. More specifically, the medium consumption cluster indicated the higher stability of savings over the DR events, having produced savings in the 4 out of 8 DR events. The group of medium consumers that included different number of participants each time and different user IDs, had an average of -6.54% energy consumption when requested with maximum reduction touching the -49.85% and maximum increase being 31.31%. The low consumption group indicated savings in 3 out of the 8 DR events with an average of 19.73% increase in consumption over the DR events, a maximum reduction of -18.78% and a maximum increase in consumption of 83.00%. Lastly, the high consumption group that traditionally included the least number of participants and these participants were not residential consumers, reached the target of savings the 3 out of the 8 DR events, indicating a maximum reduction in consumption of -4.59%, while the maximum increase rocketed at the 55.06% increase compared to the baseline. The average increase was 15.46%.

Lastly, findings showed that shortest in duration DR events (up to 2 hours) were much more effective than long lasting DR events (more than 2 hours). Particularly, the performance of shortest DR events was almost to a “no effect” situation and of course significantly lower than longer DR events. Taking into account all short DR events, the outcome was 0.17% increase in consumption with 3 out of the 5 DR event being successful, while the increase of longer DR events was significantly higher, i.e. 11.41% on average, with no successful DR results at all. Figure below shows the difference in effectiveness between the short and the long lasting DR Events.

To that point, we should clarify that such sharp upward differences in energy consumption during the DR events compared to the baseline might be due to inefficiencies of the baseline model utilized. Nevertheless, the trends observed are important and provide insights. Of course, further research should take place in order to reject the hypothesis that DR events might lead, in majority, to the opposite of the desired behaviors direction.

Also, valuable insights about the behavioral DR design were gained through the course of the 8 DR events realized during the 2nd phase of the analysis. In total, 6 different motivational factors were studied and most of them proved to improve the effectiveness of DR events.

More specifically, personalization, competition, feedback (both with and without savings being referred) and setting a certain goal, were found to have a significant impact on energy savings. When intrinsic motives stop driving effective DR events, exploiting other motivational factors to improve the DR effectiveness and boosts energy savings is a good strategy. However, since the effectiveness of the studied motivational factors was not tested in the long term, their impact should not been taken for granted. Because it might be possible that the more participants are getting exposed to the effect, the least will be the perceived impact to lead to energy savings. Then, it might be necessary for monetary incentives to enter the game aiming to enhance the long-term savings.
WP9 – Testing and Validation

Workpackage objectives:
The main objectives of the Work Package 9, on Testing and Validation activities are mainly (i) to implement and evaluate the results of the tools developed during the previous work packages. To achieve the aforementioned objective the development of integrated simulations tools (ii) is needed. These tools will allow simulating the behavior of the insular electricity systems to analyze the performance of each scenario (iii). Finally, the project tries to make a real-life implementation, as far as possible, at the selected pilot islands.

Progress towards objectives:
Summary: SiNGULAR developed during the first half of the project (WP2-WP8) different software tools that were implemented in the pilot sites selected in order to evaluate the tools’ performance. Each tool was framed in a specific work package but with a robust relationship between them, particularly those tools which aims to support the power system operation: probabilistic forecasting (RES and Load), stochastic power flow and advanced scheduling algorithms. Other tools, like optimal planning stochastic algorithms that take into account RES penetration, electrical mobility and demand side management were implemented in some pilots to analyze the performance. The islands selected to implement the solutions developed in a greater or lesser degree were:
- Crete (Greece)
- São Miguel (Portugal)
- Brăila (Romania)
- Pantelleria (Italy)
- La Graciosa (Spain)
- El Hierro (Spain)

To achieve the objectives proposed in this work package a detailed planning was implemented to facilitate the way towards the objectives achievements.

Progress towards objectives detailed for each task:
Task 1: Development of integrated software tools for the simulation of the insular systems

Achievements made with reference to planned objectives

To analyse the performance of the different tools developed in SiNGULAR, it was necessary to integrate the tools according to the needs of each pilot site and theirs specific characteristics. The integrated tools have been implemented as stand-alone applications, receiving data from the SCADA systems directly or ‘manually’ by email or FTP. The most complete integration was implemented in the island of Crete, where the application STEPS runs in parallel with the actual control center operations in HEDNO’s headquarters.

a) Crete

In Crete four tools have been tested and validated: (i) Load and RES Forecasting, (ii) Power Analysis, (iii) Scheduling, and (iv) Demand Response. Load forecasting, power analysis and scheduling tools were integrated within a single stand-alone software application, called STEPS. RES forecasting (as well as an alternative load forecasting procedure) are performed via a Web-based Forecasting Platform. Finally, the demand response tool has been developed as an external application but with a strong connection with STEPS. In any case, all aforementioned tools communicate with each other by consistently exchanging useful data for their efficient implementation. Full detailed description about the integration of the tools in Crete was made in the deliverable 9.1.

b) São Miguel
In the island of São Miguel four tools were validated: (i) Risk-based Power Scheduling Tool (RiSch), (ii) Renewables Generation and Load Forecast, (iii) Planning and (iv) Power Analysis. Similar to the other pilots, a web platform to share the Forecasting results has been developed. This platform allows an easy integration with other tools, which requires the information supplied by the forecasting algorithms developed in the Work Package 2. In the case of São Miguel the platform sends the information to the Risk-based analysis tools, developed specifically for São Miguel. A specific tool to run the Scheduling in the island was developed, named RiSch. This tool receives the information supplied by the RES and Load predictions directly thanks to the PHP/Python interfaces, interfaces that capture the forecasting from the MySQL databases.

The third tool, planning, was applied using the information about the distribution network provided by EDA. This algorithm was executed with two planning approaches: deterministic and stochastic but there is no way to compare the results with a “real situation” because there is not an existing planning for the distribution network in the island. For this reason, the “validation” was made comparing between all cases simulated.

Regarding Power Analysis, the software DERMAT (developed in the framework of the WP4) has been executed with the information of the Distribution Network supplied by EDA and the probabilistic forecast supplied by the Forecasting Web Platform. Thanks to the different interfaces created during this task, the communication of data between tools is completely reliable, mainly FTP and manual downloading available in the website. DERMAT is prepared to use that information thanks to its flexible interface through configuration files.

c) La Graciosa

In La Graciosa, finally the microgrid is not available yet. For that reason the decision taken was emulation of the microgrid. During this task the information collected by ITC thanks to the measurement stations installed was sent to the forecasting tools through FTP or email, in the format supported by the forecasting algorithms.

For the development and validation of the storage management in this pilot, an emulation of the microgrid was implemented in the framework of this task. The emulator, described in the deliverables 9.1 and 9.2 allowed to run different storage management approaches. The application, developed in MATLAB/Simulink has the interfaces to use the information provided by the measurements stations or the RES and Load forecasting.

d) El Hierro

In the case of El Hierro island, only forecasting tools were validated. For this purpose, GORONA del VIENTO (power plant owner and operator) and SiNGULAR project signed an agreement in May 2015. From that date GORONA send files collected from the Wind Farm control supplying the theoretical power that the wind farm should produce in case that no curtailment and other technical restrictions are applied. The files were received weekly in the binary format supplied by the wind turbines manufacturer (ENERCON). ITC processed the file to calculate the hourly average and to convert it to “csv/text” file, according to the requirements requested by the forecasting tool. Finally the files processed were sent to the Forecasting platform by FTP.

For load forecasting, the process followed was different. The information daily collected from the REE (System Operator) servers was sent, after processing, to the forecasting tool by FTP.

e) Pantelleria

In this it pilot makes no sense to talk about integration, since there is no any available data of RES generation real values. The forecast presented in the platform is only for virtual RES generation: Virtual
Wind Power, Virtual Photovoltaic and Virtual Wave Power.
Regarding Power Analysis, the software DERMAT (developed in the framework of the WP4) has been executed with the information of the Distribution Network supplied by the DSO. DERMAT is prepared to use that information thanks to its flexible interface through configuration files.

f) Brăila
In this pilot, the power analysis tool and the forecasting tools were applied for testing and validation. DERMAT and the WEB FORECASTING PLATFORM were used to do it. As was mentioned above, the information of the distribution grid was formatted according the DERMAT configuration files and the information needed to train the forecasting models was sent by FTP manually to the Web Forecasting Platform, because the direct connection with the SCADA was not possible.

Task 2: Demo Planning and Preparation
Achievements made with reference to planned objectives
During this task, executed in parallel with the task 9.2 the demo planning was developed and the report included in the 2nd Common deliverable (D9.5) with IGREENGRID and SUSTAINABLE projects described the process to demonstrate the solutions implemented in SINGULAR.
During this task, as was planned, the final decisions about how the tools were to be implemented in the sites selected were taken and reported and the issues that limited their implementation were identified. It is important to bear in mind that the project consortium is composed by several utilities that have the responsibility of operate insular power systems guarantying the power supply to their customers and, at same time, test and validate some of the tools developed. It means, that some tools would not be applicable directly on the real dispatching, but in parallel avoiding a direct integration on the actual dispatching processes implemented in the power system control.
All objectives were achieved during this phase.

Task 3: Performance of demo scenarios
Achievements made with reference to planned objectives
During this task the experimental activities to test the tools developed in SINGULAR were developed according to the planning implemented in the previous task. The main objective was to parametrize each tool developed for each island and this objective was achieved. For each island, as reported in the deliverable 9.1 each tool tested was parametrized and adjusted to train the models or configure the tools. All the activities were made according the local specificities.

Task 4: Real-life implementation of the SINGULAR tools at the selected pilot facilities
Achievements made with reference to planned objectives
The main objective of this task was to implement in real-life, as far as possible, the tools developed on each island. Finally, six (6) islands have been included in the SINGULAR project to implement, test and validate the different algorithms developed. El Hierro was the last island to enter the list of application sites. Not all tools were tested and validated in all pilots. Difficulties to access to island operator SCADA systems and to access to information where utilities are not involved in the project restrict the implementation of some tools in the selected islands.
There are not any pilots where the tools have been implemented in the control centers and “in real operation” conditions, but some of them are running in parallel in order to compare the actual operation with the results achieved by the new tools proposed. Crete is the best example, where one integrated application, named STEPS, integrates, in an efficient way, several tools developed in SINGULAR. This integrated application runs in parallel with the control center of HEDNO in Crete.
During this task the validation results have been obtained. The analysis of the values calculated for the
different KPIs used to evaluate the performance was made also, presenting acceptable results. (Results reported in the deliverable 9.2).

Some tools have been difficult to validate, due to the lack of any reference to compare the results. As an example, the RES forecast evaluation could be assessed thanks to the real information gathered from the different pilot sites, but the Storage Management in La Graciosa or the Planning tools was only able to be compared with simulations under different scenarios.

Significant results:
The more significant result obtained in this work packages is that the tool developed during the first period were fully tested and validated in different islands with very good results and transferability opportunities to other insular regions around the world. The reasons is that the pilots used have different sizes in terms of peak loads, voltage levels and generation mixes, trying to have a wide range of different insular power systems.

The tests developed in the six islands, once all the KPIs have been analyzed show the following results:

• The forecasting tools developed for Load and RES generation has demonstrated high level results ensuring the replicability of the algorithms developed once the models have been trained. These results are presented in D2.3 and D9.2.

• Regarding the Planning tool, although a “real” validation could not be performed due to the lack of real planning of the DSOs involved, and the results presented were compared with a Base Case with simulations, the work performed in the WP 7 and validated in the WP9, shows a great potential to optimize the extension of the Distribution network (and not only in islands) taking into account not only the Distribution Generation, but also the Distributed Storage and Demand Response Programs. These results are available in the deliverables reported in the framework of the WP7 and in the deliverable 9.2. The results shows a very flexible tool that need the current grid data and RES

• The tool developed in WP4, named DERMAT, has been used for power analysis in the pilot sites. This tool, as show the validation works performed, is quite replicable and scalable thanks to its interface to configure the tool.

• Regarding Scheduling, two distinct approaches have been developed: (i) an advanced probabilistic unit commitment based on risk analysis, validated in Sao Miguel, and (ii) a second approach based on Mixed-Integer Linear Programming (MILP), validated in Crete. Those approaches have led to the development of two integrated software tools as already mentioned, namely RiSch and STEPS, respectively. It has been shown that their use can reduce the operation costs of the islands. The results also show that:

• RiSch is replicable in small islands with a limited number of fast conventional generation units.

• STEPS approach is more suitable for large islands, where both slow and fast conventional generating units operate.

• Both can be applied to different power systems with moderate effort.

WP10 – Development of Grid Codes

Workpackage objectives:
The objectives of WP 10 are:

• The development of generalized guides of procedures specific for future generation of smart insular electricity grids,

• The incorporation of effective solutions and information so that the integration of insular and highly variable energy resources is maximized, and

• The description of hands-on rules/guidelines that could act as state-of-the-art and could be easily incorporated in the future Network Codes of such insular electricity grids.
Progress towards objectives:

Summary: In order to provide generalized guides for procedures for the management of insular electricity grids, a review of the Grid Codes already issued for various insular grids was necessary. Therefore, at the beginning of this Work Package, a review of existing Grid Codes for insular grids has been performed. Input from various insular networks Grid Codes, such as the Greek Islands, the Canary Islands, the Azores, the Italian islands, the Hawaii state in the US, the French overseas territories and Island countries such as the Caribbean Sea islands (e.g. Jamaica, the Barbados, the St. Lucia), Malta, Cyprus, Mauritius, the Faroe islands and the Pacific Ocean Islands were used in order to identify best practices. These inputs were then combined with the key outcomes of the R&D WPs of SiNGULAR (i.e. WP 2-8 and 11) to meet the objectives of this WP.

In this framework, an extended 200-page document (Deliverable 10.1) was prepared to provide recommendations (hands-on rules and guidelines) for various insular systems (IS) operational procedures, requirements and functionalities. These recommendations could be further incorporated in existing or future Grid Codes allowing for the maximization of RES integration in non-interconnected IS. In brief, this document:

• Summarizes the progress in Grid Codes and common management practices from various Insular Grids that can be used as paradigms for other countries as well.
• Provides hands-on-rules and guidelines based on the SiNGULAR project results that can be incorporated in revised Grid Codes. Emphasis was given on Storage Devices Management and Demand Response.

The main sections of this document are as follows:
• Key issues/challenges in insular power systems.
• Common practices currently followed by DSOs in insular power systems.
• Best practices for large-scale RES integration in insular power systems.

The last section is the most extended one, since it provides the aforementioned hands-on rules and guidelines that could be characterized as best practices for the large-scale RES integration in non-interconnected IS.

The topics addressed in the document are as follows:
• Definitions of the roles of the participants and the Operator of the Insular System
• Typical system requirements in a variety of fields (typical values and deviations, telecommunications, short circuit levels, etc.)
• Technical and tecno-economic data that the should be requested for the Units connected to the IS for the effective management in smart insular networks.
• Forecasting procedures for various random system parameters (e.g. load, RES production)
• Scheduling procedures (Unit Commitment and Economic Dispatch)
• Ancillary services
• Expansion planning
• Functionalities of energy storage
• Pricing Schemes

Progress towards objectives detailed for each task:
Task 1: Definition of the basic structure of the grid codes
This task was essential in order to identify the general structure of the deliverable and the necessary bibliography required to be gathered. This has helped us so that the sections of the deliverable could be defined along with the corresponding bibliography. During the internal SiNGULAR meeting that took place
in Iraklion, Crete, in April 2015, a very concrete implementation plan for the deliverable was presented to the partners.

Task 2: Definition of specific rules
Based on the results of the bibliographic survey, the outline of the document as described in Task 1 and the inputs from other work packages specific rules regarding a variety of operational and planning procedures were suggested. The main part of the document was prepared, while some adjustments and additions to the structure of the document were also made.

Task 3: Integration of Grid Codes
In this Task, the key findings of our research were highlighted. Based on the document as compiled until the month 32 along with the remarks from the partners, we focused on:

• Compiling an homogenous document
• Highlighting the suggested topics that the compilers of Grid Codes should take into account when creating or updating a Grid Code document based on the gathered experience from other DSOs and the findings of the WPs of SiNGULAR.
• Creating an executive summary of the document (about 20 pages). This was deemed necessary to give a concise outline of the document aiming mainly at the key findings of the research. This allows the reader to obtain the key findings of the analysis performed and, if interested, reach a more in-depth analysis in the specific chapters or paragraphs of the deliverable.

Significant results:
Common practices currently followed by DSOs in insular power systems
From the performed analysis, few island territories have implemented sophisticated Grid Codes in terms of Market Complexity. Many of the Grid Codes focus mainly on technical requirements for RES interconnection and operation and, thus, they resemble what is called Distribution Management System Code of the Interconnected Power Systems. Cyprus is the IS, which has planned to make structural changes in the Market Operation similar to large interconnected power systems. Most of the IS have higher values of voltage and frequency deviations compared to the mainland power systems.

A common practice, on most of these IS, is the use of persistence or advice of weather web-sites for forecasting and the use of a simple merit-order list for scheduling. Very few IS, mainly the largest ones, e.g. Crete, have more sophisticated tools for scheduling and forecasting. Thus, the use of tools developed within SiNGULAR and installed at the pilot sites is expected to provide significant aid for the management of the IS.

Regarding Energy Storage, the Canary Islands and the Greek islands have some type of legislation on Energy Storage, while the Hawaii State has already implemented Storage projects as well as the residents have started using Electric Vehicles (EVs).

In some of the islands, e.g. Jamaica, Crete, Rhodes, Cyprus, a common practice that is followed is the use of under-frequency (automatic) load shedding.

One key finding from these common practices is that the networking and co-operation of the insular DSOs facing similar technical challenges can bring about significant benefits on the effective management of these systems. This is the example of the Caribbean Electric Utility Service Corporation (CARILEC) and the Pacific Power Association (PPA).

Hands-on Rules and Guidelines
This was the heart of our efforts and covered the largest part of the Deliverable 10.1. The analysis performed addresses the following topics:
Definitions of the roles of the participants and the Operator of the Insular System and necessary classifications

The outcome of our research is that the classification of IS is essential when preparing Grid Codes, especially for countries with a variety of sizes of islands. This will help in: a) implementing specific rules for larger and simpler islands, and b) the simplification of the market procedures for smaller islands; increased complexity of the market structures in smaller island systems may create adverse results regarding the development of RES and the adoption of smarter approaches. Additionally, as discussed in the section of D10.1 regarding storage, very high penetration levels have been currently reached for small islands.

The recommended classification is either based on their size (e.g. peak demand), or their generation mix and network characteristics. Such a distinction is crucial, since a Grid Code should explicitly define which of the specific operational procedures, requirements and standards should be mandatory for an IS or could be regarded as optional, depending on the size and/or generation and network characteristics of the IS. A typical classification may be on the peak size as follows:

- Very Small IS, when the average peak demand of the previous five (5) years does not exceed 2 MW.
- Small IS, when the average peak demand of the previous five (5) years is between 2 MW and 10 MW.
- Medium IS, when the average peak demand of the previous five (5) years is between 10 MW and 100 MW.
- Large IS, when the average peak demand of the previous five (5) years exceeds 100 MW.

A clear definition of the main IS participants (e.g. IS Operator, Producers, Load Representatives, Demand Aggregators, Users, etc.) as well as their typical responsibilities and obligations is of utmost importance. In many islands the IS Operator may currently be at the same time the owner of all the Generation Units, including RES, Grid Operator and the sole market player. If extended market participation is foreseen, the IS Operator role may have to change but in any case an IS Operator should monitor and ensure the reliable, efficient and secure operation of the power system, carry out the generating units scheduling and dispatch, manage the provision of reserves, compile the power system planning studies, prepare and implement emergency plans and make market transactions. Therefore, before applying market policies the roles of the participants should be clearly defined.

Typical system requirements

Most of the Grid Codes contain detailed information on technical issues on how to earth facilities, what are the interconnection requirements etc. In our approach, the Grid Code should contain generic guidelines on technical issues that should be further described in the fields of:

- Frequency and Voltage levels
- Short Circuit Ratio
- Protection Schemes
- Flicker emissions
- Earthing
- Communication infrastructure

However, detailed ways of calculations should be described in a separate more detailed Manual. This approach is followed also in interconnected Power Systems where Market Operator and Distributed System Operator are different entities. Three key-findings on the system requirements are the following:

- For smaller islands, somewhat larger voltage and frequency deviations should be allowed. This should be made known to the DG producers, so that their equipment is accordingly adapted.
- The acceptable rate of change of frequency (RoCoF), which is a very critical aspect for ensuring the reliability in fully autonomous systems, should be provided. Such rates are expected to be much higher as...
the islands become smaller.

- As the complexity (number and diversification of participants) of the IS increases, more detailed telecommunication infrastructure requirements should be prescribed.

**Technical Requirements for Units connected to the Grid**

Connection requirements may resemble to those prevailing in the interconnected power systems, but some modifications may be required in order to provide frequency stability and voltage stability, which are usually of high significance to the IS. For instance, for the same installed capacity, mainly in smaller IS, the connection requirements may be stricter than in mainland grids.

It is strongly recommended that the IS Operator creates a Database with the typical technical and techno-economic parameters of the IS. Even if no market exists at all, this may significantly improve the performance of the IS and can help the IS Operator more effectively integrate software tools that have already been developed or are under development.

The Grid Code (and/or the respective Manuals), should also provide information of the desired behavior in case of faults even single-phase ones, especially for DGs. Some of these typical requirements have been provided in the Deliverable but, in any case, recommendations from international organizations should be also taken into account.

For any other technical requirements such as black start capability, reserve provision, etc., it should be taken into account that smaller-scale DGs compared to larger interconnected power systems may be requested to provide aid or services to the IS Operator.

**Forecasting**

The common outcome of the review of the current practices is that few references in few existing Grid Codes exist on forecasting procedures for IS. In most of the IS, load and RES forecasting is empirical and very few islands -mainly the largest ones- use more sophisticated tools for load or wind power forecasting. Therefore, in D10.1 apart from the little experience on other Grid Codes about forecasting, the results of WP2 were also taken into account. The suggestions made by this document were about the following:

- The type of forecasting necessary for the operation and management of insular networks (i.e. load, wind and PV forecasting).
- The forecasting horizons and their applicability for various operational procedures (Maintenance scheduling, Unit Commitment, Economic Dispatch and Real Time scheduling).
- The input data (e.g. historical time series, historical and forecasted weather and climate data, time/calendar data, etc.) and the output data (e.g. forecasted values).
- Forecasting models should also be able to deliver probabilistic forecasts instead of single-valued (point) forecasts.
- The forecasting error values and types of evaluation of forecasting errors. More specifically focus was given not only on the Mean Average Percentage Errors (MAPE) but also on how often and how large the forecasting errors should be. Different forecasting horizons require different values of accuracy. This information may be used not only for Grid Codes but also on Tenders for obtaining forecasting tools from the DSO, as already done for HEDNO case.
- The forecasting tools should be able to integrate manual interventions related to Network Operations, e.g. when part of the Grid is under maintenance.

**Scheduling**

The various levels and operational horizons for Generation scheduling should be defined in a Grid Code. These procedures may include:

- Day-Ahead Unit Commitment or Rolling Day-Ahead Unit Commitment
Real Time Unit Commitment and Real-Time Economic Dispatch

For all these functions and for various time horizons, the procedures, the typical algorithms that may be used as well as the contents of exchanged information among all the stakeholders have been described in the D10.1 document. This information is the outcome of the gathered experience in HEDNO, the outcome of the results of WP9 available during the preparation of the deliverable and the results of WP 5. Such information should be defined in a Grid Code document.

The latest advance in operations practices, which is expected to be very useful for IS, is the incorporation of Rate of Change of Frequency (RoCoF) constraints in unit commitment and economic dispatch models. These constraints ensure that, if a credible contingency occurs, the system frequency does not drop so quickly that under-frequency load shedding is activated before generators are able to respond. This way, undesirable load shedding or even black-outs can be avoided.

Ancillary Services

The lack of interconnections and the fact that not many units operate in parallel may increase the requirements for Ancillary Services provision from units of smaller size and of different technology than in an interconnected power system. Load-frequency reserves are of paramount importance for the containment and restoration of the IS frequency in case of a major event (i.e. unit or line outage) or/and the conservation of the system frequency in acceptable margins under normal operating conditions.

For each category and reserve type, potential providers should be specified. For instance, Frequency Containment Reserve (FCR) could be provided by thermal and dispatchable RES units and loads equipped with a droop control system (wind turbines with power converters may also fall in this category). Demand response (including load-shedding) as well as variable speed pumped turbines may also contribute to the provision of FCR.

It is important that calculations on the Reserve requirements or for any other Ancillary Services provisions, take into account load and RES variability and uncertainty, so that the most efficient dimensioning is obtained. These calculations may take into account either deterministic or probabilistic criteria. The quantification of the flexible ramping requirements should be performed based on the forecasted load and non-firm renewable generation, for all scheduling intervals, in order to take explicitly into consideration the possible appearance of steep ramps, due to the volatile and unpredictable nature of renewable energy sources.

Expansion planning procedures

In some Grid Codes there are generic references on what is required for both generation and Grid Expansion planning. The typical approach is N-1 Criterion or the largest Single Infeed (LSI) loss. In D10.1 the approach suggested by the SiNGULAR project in WP 7 has been considered. The main scope of the specific chapter was to provide an insight of which data should be provided and hence should be systematically stored by the DSOs, if such studies are to be implemented. Additionally, the request of typical outputs and the answer to specific questions when considering such studies has been pinpointed.

Various important issues have been identified as of particular interest for the Insular Networks. The first one is the low min/max ratio, which may require as an alternative the rental of the production units for generation expansion. The second one is that the RES capacity to be installed should be limited in order to avoid potential stability issues, i.e. definition of ‘electrical space’ for RES. Thirdly, expansion planning studies should also provide potential solutions that could lead to the relaxation of RES installed capacity limitations and, therefore, allow for considerable increase of the respective RES capacity. Such solutions include interruptible production contracts for RES capacity, introduction of storage systems, demand
response actions, installation of flexible conventional units, etc. Finally, it is recommended that in case of proposals for the interconnection of one IS with another or the mainland grid in order to usually exploit the high RES potential or increase the system reliability, the potential benefit as compared to the independent operation of such systems should be properly quantified (e.g. through a cost/benefit analysis).

Demand response
Currently, very few examples of very limited Demand Response in insular Grid Codes exist. For instance, in Cyprus specific loads shall be disconnected in case of emergency, (e.g.. frequency excursion), while for the Greek islands, a specific paragraph referring on the common management of Desalination plants and RES dedicated to the Desalination plant and interconnected at the same island network with application on the island of Milos, was identified.

Therefore, a Grid Code should first define the roles and responsibilities of the participants that are involved in the provision of DR services. Communication and coordination between the involved participants (e.g. IS Operator, load aggregators, consumers) should be robust with clear distinction of the various assignments.

The specifications of each DR product should cover, at least, a list of elements, such as the activation time, the price of the bid, the minimum and maximum quantity, the duration of the event, the mode of activation, the frequency of activations, the penalties for non-compliance, etc.

Since there is no "one-size-fits-all" best approach, baseline methodologies should balance accuracy, simplicity and integrity and produce consistent results that are unbiased in either over-predicting or under-predicting the actual performance. Additionally, brief information on the necessary communication infrastructure in order to implement the DR actions is also provided. Advanced metering infrastructure (AMI) could provide substantial aid to the implementation of such actions.

A special paragraph on specific code requirements for Electric Vehicles (EV) has been incorporated. The IS Operator should also determine if high-capacity charging stresses the IS and, thus, whether EV Charging Systems should be restricted at low-capacity charging.

Since the integration of EVs in IS is an innovative project, for the sake of simplicity, it is proposed that the Grid Code should first foresee and specify the implementation of unidirectional interaction between EVs and the Grid.

Storage
International practice with IS presenting very high RES penetration, exceeding 60%, has shown that storage is essential to achieve such penetration levels. However, an IS Operator is not generally allowed to retain facilities that can produce electricity and generally participate in the energy markets. Thus, installation and management of storage facilities by the IS Operator to make profit is hardly acceptable by the Regulatory Authority.

However, storage can provide substantial aid towards the efficient management of IS by:
- Enhancing local reliability and, especially, response to contingencies.
- Smoothing the demand; this is more important in IS, since such systems usually present extremely low minimum/maximum ratio with significant cost difference from season to season.
- Giving the opportunity to absorb excess electricity from RES units that otherwise would have been curtailed. Thus, the installed RES capacity and penetration may increase.

The following guidelines should be considered:
- Single installation of energy storage facilities without additional production capacity. The most simplified approach is either to use storage as a service, or face it as a producer during high-cost hours and as a consumer during low-cost hours, or when RES production is expected to be curtailed.
• Combined operation of RES and storage facilities to formulate Hybrid Power Stations (HPS). In such a case: i) RES capacity and penetration can be increased and the HPS is the sole responsible to provide inputs to the energy scheduling performed by the IS Operator. ii) RES units (especially wind and PV) can become more dispatchable and less volatile in their production providing aid for the Ancillary services provision and participate in market operation.

The typical precautions for management of Storage Devices combined with RES along with a detailed analysis of the scheduling procedures were provided in the document. Additionally, typical signals that should be exchanged between storage devices and the DSO Control Centers were also suggested. This may help both the owner of the storage devices and the DSO to set up the necessary measurements and communications.

A special form of Storage is the Thermal Storage in Solar Thermal Power Stations. Since such Power Stations are of high capacity compared to the peak demand of the islands, operational precautions should be taken into account. A list of questions that the compilers of an updated Grid Code should be able to answer in their updated Grid Codes has been provided in the document. Some typical commitment rules for STP stations combined with thermal storage were also provided based on the Greek Experience.

Market Organization and Pricing Schemes
The Grid Code should be able to implement transparent pricing and operations mechanisms, applicable independently of generation ownership and demand representation.

Four types of remuneration may exist for insular networks, listed as follows:
A) Remuneration for electricity injected to the grid (€/MWh)
B) Remuneration for Capacity Availability (€/MW)
C) Remuneration for Ancillary Services
D) Remuneration on Emergency plans

There may be variations depending on the dispatchability of the Units and the use of fuel or RES. Additionally, especially for RES, any incentives or feed-in tariffs should be also taken into account so that the DG unit is neither over-remunerated nor under-remunerated.

Regarding, demand side participation, energy and capacity charges should be defined either by national or regional tariff system.

Additionally there should be clauses for the payments for the absorption of electricity for charging the storage devices of either single storage devices facilities or as part of Dispatchable Hybrid Power Stations. Moreover, suggestions on how to take into account imbalances, deviation and sanctions should be provided. It is our opinion that such clauses should be outlined in a Grid Code and further elaborated in the Manuals of the Grid Code. In the Grid Code however, the variety of Accounts that should be established for the market operation should be defined.

Finally, some parameters for pricing may be requested to be regulatory defined such as values for Regulatory Asset Base or additional Variable Operation and Maintenance Cost mainly of Conventional Units.

During the full duration of the project, the measurable results yielded by the activities of WP10 led to two (2) publications in peer-reviewed scientific journals and one (1) announcement in energy-related international conference.

WP11 – Evaluation, recommendations and roadmapping
Workpackage objectives:
• To evaluate the outcomes of the project, elaborating recommendations and a roadmap for futures developments;
• To analyze the effects of large-scale integration of renewables and DSM on the planning and operation of insular electricity grids;
• To develop an overview of the different methodologies, procedures, tools, services and grid codes proposed for the efficient short-term operation and long-term planning of insular electricity grids.

Progress towards objectives:

Progress towards objectives detailed for each task

Task 11.1: Evaluation (M19-M24):
This task defined the assessment criteria and the evaluation mechanism that was applied. An important aspect of the work carried out was the definition of the evaluators that participated in the assessment process, along with the evaluation tools (mainly peer reviews, on-line questionnaires, feedback, and discussion groups) that were incorporated. In any case, the use of web technologies had a primary role in the assessment of SINGULAR results.

Task 11.2: Recommendations (M31-M36):
Work synthesized findings from the results of all previous WPs in order to provide an orchestrated report on new solutions and their impact at European level.

Task 11.3: SINGULAR Roadmapping (M31-M36):
Roadmap analysis was based on the results of previous WPs. The roadmap identified new research and technology development areas within and beyond the domains defined by SINGULAR with the aim of contributing to the research and development priorities of HORIZON 2020.

Significant results:
• On December 12th, 2013, SiNGULAR organized the 1st External Advisory Board (EAB) meeting that took place in Las Palmas de Gran Canaria (Canary Islands, Spain), and was hosted by Canary Islands Institute of Technology. A technical visit to El Hierro Wind-Hydro Power Plant was also scheduled for the second day. Overall, all reviewers were impressed with the progress of the project at this early stage, just finishing the 1st year of activities, and their comments and recommendations were useful for the subsequent steps of the research.
• From November 2014 till February 2015, a detailed on-line questionnaire was implemented in order to evaluate SiNGULAR from the point of view of the research community, companies and other experts (institutions, entities, etc.). SNGULAR was considered innovative and interesting by a large majority (81% on average) of the participants. Six New Market Products were developed.
• On June 25th, 2015, SiNGULAR organized the 2nd EAB meeting that took place in Ponta Delgada, Azores, Portugal, and was hosted by EDA – Electricidade dos Açores (Island DSO). A technical visit to a Geothermal Power Plant was also scheduled for the second day. This Meeting focused on Partners coming from the “Family of Projects”, namely SuSTAINABLE and iGREENGRID. As mentioned by the EAB members, “R&D in SiNGULAR was made from scratch. A large amount of work has been done, which is excellent. Validations is proven by the many results obtained”. From the on-line feedback, the aggregated conclusions are as follows (in short): “The project SiNGULAR is of significant depth and shows an impressive array of research activities centered on the development of sustainable insular electricity grids. The sequence of WPs is very coherent and structured. The consortium profile makes a project like this possible. There is presence from all type of entities on wide scale sectors of activity. Congratulations for the extensive dissemination activities and publications.” – including a book published by CRC Press in Florida, USA (http://www.crcpress.com/product/isbn/9781498712125).
• Finally, regarding the “Short report on exchanged experiences on demonstrations and validation of the proposed solutions”, based on the 3rd IGREENGrid-SiNGULAR-SuSTAINABLE Global Joint Conference
that occurred on 26-27 November 2015 in Caparica, Lisbon, Portugal, involving the 3 FP7 projects alongside 6 H2020 projects as guests, six topics of high interest were presented and discussed: 1) energy storage, 2) forecasting, 3) generation curtailment, 4) demand side management, 5) voltage control, and 6) scalability & replicability. The benefits from storage applications were described, identifying promising and innovative applications and some conclusions of energy storage. The use, applications, types and frameworks of forecasting were addressed, as well as its value and evaluation. Generation curtailment was also addressed regarding the situation in some EU countries. Demand Side Management and Voltage Control were also specifically addressed, regarding technical approaches, architectures, and regulatory issues. Finally, the objectives and challenges of the Scalability and Replicability analysis were debated. Overall, a great common experience, with shared knowledge and know-how from different but complimentary perspectives.

WP12 – Dissemination and Exploitation
The objectives of the WP12 were the following, already gathered regarding the major concept of each one, and according the Dissemination Plan.

Strategy And General Concerns
• To develop SINGULAR dissemination and communication strategy;
• To develop and carry out a concrete set of activities that will ensure the success of the communication strategy.
• To monitor and contribute to standardization activities in wireless standards under development.
• To widely disseminate SINGULAR concept, developments and findings to all key actors in the field in an interactive way, integrating their feedback at key points of the specification, design, development and evaluation work;

Constant Communication
• To develop an interactive and user friendly web site to inform the general public and relevant stakeholders about SINGULAR.

Scientific Achievements
• To organize and / or publish results in international conferences and workshops to inform the scientific community about SINGULAR goals and achievements and to gather valuable information on related issues;

Specific and presential Networking Actions
• To plan and realise key workshops and events and administer a User Forum, to support the wide diffusion of the above and guarantee proper input and feedback by key stakeholders;
• To collaborate and exchange knowledge and results with relevant projects to be implemented under task 7.1.1 i.e. SuSTAINABLE, iGREENGRID and coordination actions such as the GRID+ project and the EEGI and to participate in events and concertation activities organized by such projects and coordination activities.
• To cooperate with national projects currently being held in the countries (or in the specific islands, if applicable) involved in SINGULAR, which are relevant with the objectives of SINGULAR in terms of participating in/organizing joint events and activities for knowledge sharing and dissemination.

Exploitation and IPR
• To issue exploitation plans for key project results and oversee IPR management within SINGULAR and beyond.

Progress towards objectives:
Summary: The goal of WP12 is to ensure that the project and its outcomes were widely disseminated. The exploitation potential of results were explored. The objective is to guarantee the wider promotion of SINGULAR outcomes. The SiNGULAR general strategy regarding the three years of the project can be summarized in the following major issues:

- **YEAR 1.** Communication tools. Collaboration procedures. First scientific results
- **YEAR 2.** Scientific Results. Networking with other projects. First analysis exploitation results.
- **YEAR 3.** Scientists final results. Exploitation Plan Results.

Progress towards objectives detailed for each task:

**Task 12.1: Dissemination plans and activities (M1-M36)**
- Communication tools. The existence of tools that ensure continued communication of SiNGULAR: logo, website, leaflet (two sets), forum, continuous feedback and permanent availability of information, always according to the Project, especially those relating to family projects. All communications tools done were running regularly.
- Dissemination of current state of the work done by SiNGULAR on schedule and produced results. This action is the life of the project already in its continued development. Is guaranteed by the communication between partners, and its main reflection in the news that are loaded into the project website. Also in attendance own or organized by Grid + events. During the second period, Concepto Sociológico created a great data base with more than 9.000 international energy experts who receive periodically information about SINGULAR achievements and progress. Few newsletters and other dissemination documents were created and sent to this data base.
- Organizing own events. A total of 10 internal meetings had taken place during the three years of the project, as well as, Global Joint Stake holders Conferences (SuSTANABLE and iGREENgrid).
- Scientific publications. The project has showed great results and scientific publications, which were in its highest level during the second mid-term, reaching a cruise speed according to the relevance of the project achievement. They both, public deliverables and scientific publications (papers accepted in journals and international conferences) have been uploaded to SiNGULAR website, being available to everybody.

**Task 12.2: Business models (M19-M30)**
Its implementation has been carried on during this second period. Firstly, by a market analysis and then, elaborating a feasibility plan.

The elaboration of a market survey for the final business plan was necessary. Its objectives were to identify the project’s results thoroughly, to understand the importance they could have in the market and to elaborate a clear scheme for every single result in order to identify its viability in the market. A double work has been done in which, firstly, the target to which the results could be directed towards international experts has been segmented identifying three important different groups, industry companies, academic and scientific community, and experts in general (other institutions, governments, etc.): international experts as members of companies, organisations and governments, private and state corporations, universities and institutes, all of them related in the broadest sense with the main objective of SiNGULAR, with a view to identifying the Singular principal fields of interest. They have been subjected to a market survey as comprehensive as possible in order to understand the whole value scene of research and results achieved to date by the project.

**SURVEY. Data Sheet**

Universe: international experts specialized in areas related to Singular fields with the following occupations:
• Academic and research universities, institutes
• Industry, DSOs, and Power generation
• Others experts as governments and No Governmental Organizations,

Geographic scope: international
Population register: 9,230 international experts
Level of reliability: 95%
Sampling error: ± 3.4%
Sample size: 759 international experts
Sampling: no sampling has been achieved
Timing of survey: 20/11/2014 – 10/02/2015 (2 months and 10 days)

Secondly, once their opinions were known with a representative sample, we have proceeded properly and, in consequence, we have analysed each result within its specific market future forecast.

Feasibility Plan. Thanks to the previously Market Analysis we have better understood which are the handicaps or barriers that SiNGULAR’s results would have to take into consideration when elaborating a new business plan. In fact, the ecosystem of products for large-scale integration of renewable and demand side management (DSM) in the planning and operation of insular (non-interconnected) electricity grids, proposing efficient measures, solutions and tools towards the development of a sustainable and smart grid that SINGULAR undertook, required the creation of a novel business model, in which few companies and energy providers can offer a set of products.

Task 12.3: Standardization issues (M6-M36)

This task ensures the orderly and recorded communication among partners. Very simple procedures are established for monitoring the dissemination of each partner was doing, home and abroad. The main mechanisms are: check list (9 during all the project), personalized follow up email, bilateral discussions at each meeting, especially for future actions would produce and be able to track (attendance at congress, preparation of scientific articles, etc.).

Task 12.4: Clustering with other projects (M1-M36)

- Networking with other relevant projects: The primary relationship with other projects, for meetings, works and events has been with the so called Family Projects, which includes SiNGULAR, SuSTAINABLE and iGREENgrid. Since the first meetings celebrated during first quarter, which designed a joint work program, the normal organization of events, meetings and regular participation in the committees, and joint events of each one, the network run normally with full collaboration.

- SiNGULAR has been communicated to the national representatives of EEGI as well as the technical secretariat located in Brussels (Zabala Consulting), and it was properly documented. Similarly, SiNGULAR obtained in November 2013 the ranking EEGI Labelled Support Project.

- Joint dissemination activities with SuSTAINABLE and iGREENGRID have been organized during this period. International Workshop in Canary Islands and Athens.

- SiNGULAR has been communicated to the European Energy Research Alliance (EERA) during first six months and currently we are waiting the first scientific results to reinforce technical interaction. Meanwhile SiNGULAR and EERA exchange news and communications.

- Networking with National projects, produced have been done with Italy, Portugal and Spain:
  - Regional project PROMO - Produzione di energia da Moto Ondoso - Regione Piemonte (2012-2014) (Pantelleria, Contact Entity: POLITO)
Significant results:

SiNGULAR logo was created in the first month.

Two Flyers Sets: SiNGULAR Flyers were in SiNGULAR website and printed to use in several conferences, as well as they were sent to our expert database. First set. January 2014 (M2). Summary of the project, its deliverables and its objectives.

Second Set. March 2015 (M28). This second set included a list of products capable of being launched into the market, resulting for the electronic survey information.

Roll ups

Three different models have been designed as a dissemination and communication tool for SiNGULAR’s presentations in the international conferences, congresses and meetings.

Website

SiNGULAR website is uploaded daily with SiNGULAR progress (partners dissemination actions, new scientific publications, presence in international conferences...) as well as with current news and opinions about SiNGULAR research fields, in order to get a continuous feedback and permanent availability of information.

SiNGULAR website has had 461,259 visits during these three years!

Communication and Dissemination Plan made on the website: detailed categories of the different acts:

SiNGULAR website has obtained an average of 3,45 articles/day.

New sections in Communication and Dissemination: Papers / Deliverables:

SiNGULAR has presented 107 papers in the most important and international relevant publications and world Conferences and Congress related with smart grid. In this second period, a new section were designed where all they are showed (Tittle, kind of publication, date, author..) and, the public ones, could be download from “Communication and Dissemination/ Papers” section.

At the same time, another new section were created in order to show all SiNGULAR deliverables (wp leader, title,..). Equally the public ones could be downloaded from “Communication and Dissemination/Deliverables” section.

Other communication tool: data base

Concepto Sociologico has created a data base with more than 9.000 contacts: international experts in SiNGULAR research fields (academics, DSOs and other experts).

Thanks to this data base, Concepto Sociológico opened another channel for further dissemination. These experts have received information about the progress and the results achieved by SiNGULAR periodically, such as newsletters.

Networking + Events:

Contribute to GRID+ and to the implementation of EEGI,

- CIEM 2013 – 7 November 2013 – Bucharest (Romania) – represented by POLITO
- Meeting with EEGI national representative – 11 November 2013 – Madrid (Spain) – represented by CS
- GRID+ / EEGI – 9 April 2014 – Madrid (Spain) – represented by CS

Smart Grids Programme
Other events that Concepto Sociológico attended.
- Presentation of SiNGULAR in XI Congreso Español de Sociología -12 July 2013-. Madrid.
- HORIZON 2020 – 20 February 2014– Toledo (Spain) – SiNGULAR presented by CS and UCLM
- Innogrid 2020+ - 25-26 March 2014– Brussels (Belgium) – attended by AUTH and CS
- Innogrid 2020+ - 31 March-1 April 2015 – Brussels (Belgium) - attended by CS and AUTH

Survey results:
According to this survey achieved results, we can conclude that:
• The project is considered highly interesting and innovative.
• Our practices are praised.

Other results for SiNGULAR:
- Prizes. At the IEEE Powereng conference (Riga, 11-13 May 2015), SiNGULAR got the following awards:
  o Integration of Renewable Energy for the Harmonic Current and Reactive Power Compensation, which won the BEST PAPER AWARD.
  o Uncertainty Characterization of Carrier-Based Demand Response in Smart Multi-Energy Systems, which won the BEST PRESENTATION AWARD.
  o A New Methodology for Solving the Unit Commitment in Insular Grids Including Uncertainty of Renewable Energies, by Gerardo, Juan, Matias et al., won an additional BEST PRESENTATION AWARD.
- Distinctions: in the same way, SiNGULAR partners' merits in their researches have been recognised:
  o Our partners Javier Contreras (UCLM) and Anastasios Bartzis (AUTH) were promoted to IEEE Fellow members, where SINGULAR, with no doubt, contributed to their both long and prestigious professional career.
  o SiNGULAR publishable summary research has been approved by the European Commission and it is the basis for the "Result in Brief" written by CORDIS science editors.

Potential Impact:
1st YEAR
Therefore, early communication impacts and interviews were published in the local and regional press and other media just since the kick-off meeting, celebrated on January 24, 2013 in Covilha, Portugal. The first months were entirely dedicated to the development of graphic materials, organization and corporate identity handbook to be used as material support for the subsequent dissemination and communication of
the project. These materials have been operating since week 6, that is, 6 weeks before the expected time for implementation -12 weeks-. Further information about SiNGULAR Communication Tools can be found in Deliverable 12.1 and 12.2.

In this phase, our social responsibility was to widely inform the civil society about the SiNGULAR project social benefits, several articles were published in press, websites and social networks. During the first months, the project had not already produced enough results even scientific publications. For this reason, only initial presentations explaining summary and objectives could be done. Approximately in month 9 – August 2013-, its first scientific results were already starting to be seen: the two first papers were received last year. Therefore the most important element of this aspect is that the project could be presented at international forums and organizations in month 11 -October 2013 – when the project was presented for the first time in an international research conference held in Romania.

Also in the 11th month of development, Concepto Sociológico had a meeting with Borja Izquierdo, EEGI (European Grid Initiative) National Representative. Few months before, SiNGULAR was labelled.

2nd YEAR

Concepto Sociológico prepared key specific presentations of SiNGULAR for EU entities and relevant institutions, monitoring the relationship with each other. In addition to this, it has participated in the development of Common Deliverables with the family projects -iGREENGRID & SusTAINABLE- collaborating with partners like UBI and AUTH for its realization.

During this year the market research was carried out as the start-up of the business opportunity; the analysis of the market research is detailed in Deliverable 12.5. A large database was created containing a total number of 9.230 international companies and DSO, public and private institutions, NGOs, journals and personal information of experts in this field in relation to the goals of this project. This has been carefully made with two main objectives. On the one hand, they have been subject to a market survey as comprehensive as possible in order to understand the whole value scene of research and results achieved to date by the project. Once their opinions were known, with a representative sample, we proceeded properly and, in consequence, analysed each result within its specific market future forecast. On the other hand, we could carry out a massive communication and diffusion action about the SiNGULAR project and to provide monthly information, from October 2014 until the end of the project, to all of these experts, companies and institutions about its progress.

3rd YEAR

In this final phase, SiNGULAR goals have been achieved and its results are clearly defined thanks to the high scientific level achieved by all the SiNGULAR’s publications and presentations. According to all these scientific results, some of them have been able to become commercial products, services or results available to be exploited by SiNGULAR. After a detailed market analysis, where six different products were defined as well as its market components, we analysed the different possible options for bilateral and multilateral cooperation agreements and propose a suitable model to show us the way forward to exploit SINGULAR results. This can be found in Deliverable 12.6.

SiNGULAR has added up to 56 papers more, 18 of them have been submitted in internationally prestigious journals; the other 38 have been destined to world conferences and events. Concepto Sociológico uploaded this information to SiNGULAR website, and the public ones could be download; as well as Partners Deliverables.
List of Websites:
The SINGULAR website incorporates a structure suitable for inclusion of all current and progressively developed information regarding the project. A special section for secure access to the project’s restricted area for internal workflow is available.

The World Wide Web offers a wide range of possibilities for dissemination of SINGULAR. For this reason, the project website has been developed and will be maintained (after the end of the project) by making information related to SINGULAR available to the wide audience for dissemination of the project. It is intended to provide an overview of the project goals, an introduction to the SINGULAR consortium, and a gateway for discussing SINGULAR-related issues. The SINGULAR website is considered as one of the most effective dissemination channels, since it is a global medium which can be accessed anytime from any interested party. The SINGULAR website offers general information on the project, such as its rationale, the project progress, expected results and partners. Since it serves as a promotional tool, it was enriched during the project with attractive presentations of expected benefits, related reference information (e.g. studies, news, papers) and access to other promotional material such as brochure and poster.

The SINGULAR website contains the project’s identity (logo, colour scheme, etc.), developed as part of the work in WP5, and has been designed in order to provide both the general public as well project partners with useful information concerning SINGULAR.

The idea behind the site is twofold. Firstly, to provide a point of reference for people interested in learning more about the project (with information such as SINGULAR objectives, the expected benefits, participating partners, etc.) and, secondly, as a place from which to distribute documents and information addressed strictly to the partners. Therefore, the SINGULAR website is divided to two sectors, one intended for public access and another for authorized users only. SINGULAR Web site can be found at: http://www.singular-fp7.eu

The structure of the web site is quite standard and at the onset of its operation contains the following basic sections (the public area):

– Home page, which is the main page of the website and shows its structure.
– Motivation.
– Project, which includes information on
  o Partners.
  o Technical Approach.
  o Objectives.
  o Workpackages.
  o Public deliverables.
– Dissemination, which included all publications and publicity material available.
– Info, which includes information on
  o News.
  o Events.
  o Related Websites.
  o Contact.