ESCUELA TECNICA SUPERIOR DE INGENIERIA ICAI
GRADO EN INGENIERÍA ELECTROMECÁNICA

PROYECTO FIN DE CARRERA

DISEÑO TECNICO Y FUNCIONAL DE UN CENTRO DE CONTROL PARA LA GESTION INTELIGENTE DE ACTIVOS RENOVABLES

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Madrid, Julio 2017

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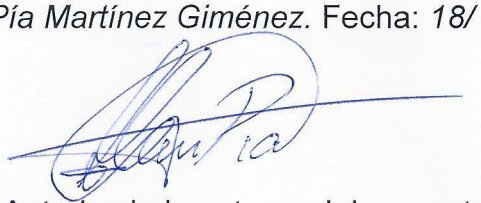

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DISEÑO TECNICO Y FUNCIONAL DE UN CENTRO DE CONTROL PARA LA GESTION INTELIGENTE DE ACTIVOS RENOVABLES

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Director: González Hierro, Francisco

Entidad Colaboradora: ICAI – Universidad Pontificia Comillas

RESUMEN DEL PROYECTO

INTRODUCCIÓN

Tras el pacto de estrategia energética europea de los "cinco veintes" y las nuevas políticas y objetivos energéticos fijados por los estados miembros, ratificados en el Acuerdo de París, las energías renovables juegan un papel cada vez más importante en la generación de energía eléctrica. Sin embargo, debido al carácter fluctuante de estas fuentes, los sistemas de red eléctricos de los diferentes países se han visto obligados a transformarse para poder integrar la mayor cantidad posible sin que se vean afectados el suministro y la calidad.

España fue uno de los países pioneros en integrar los sistemas inteligentes de información en su red eléctrica. En 2006 Red Eléctrica de España creó dentro del CECOEL (Centro de Control Eléctrico) el CECRE (Centro de Control de Energía Renovable) con el fin de controlar y gestionar en tiempo real la producción de energía renovable. Esta evolución del sistema implicó el desarrollo de un nuevo marco legislativo, el Real Decreto 661/2007. Lo establecido en el mismo en relación con centros de control para instalaciones de energía en régimen especial fue reforzado por el actualmente vigente Real Decreto 413/2014, en el que se fija que toda planta de producción (o paquete de plantas de producción) renovable de más de 5 MW ha de:

1. Estar adecuadamente conectada al CECRE
2. Tener la capacidad de ser controlada, gestionada y comandada a distancia en tiempo real.
3. Contar con los profesionales adecuados para asegurar una Buena interconexión entre la planta y REE.

En este contexto se encuentra "El Quijote"[1]; una empresa independiente poseedora de plantas de producción eólicas y termo-solares distribuidas por todo el territorio nacional. Su actividad se basa en la gestión, operación y mantenimiento de dichas plantas con el fin de obtener una máxima rentabilidad y un flujo de caja estable. Como consecuencia, la compañía necesita un centro de control que le permita:

- Informar a la red eléctrica nacional sobre la producción de cada planta de generación para cumplir la normativa vigente (función de despacho delegado)
- Llevar a cabo un seguimiento interno tanto técnico como económico que le permita optimizar la toma de decisiones. (Función de Business Intelligence)

Su centro de control externo actual garantiza la comunicación con REE pero cuenta con una dimensión de gestión muy limita. Por ello, el objetivo de este proyecto se ha basado en el diseño técnico y funcional de un nuevo centro de control que cumpla ambas funciones.

METODOLOGÍA

En primer lugar se ha desarrollado un estudio sobre los centros de control actuales y los sistemas de SCADA (Supervisión, Control y Adquisición de Datos), órgano principal de todos ellos y por ende también del centro de control diseñado

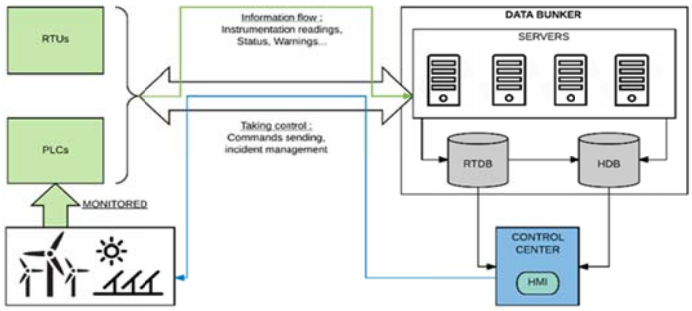

Figura 1: Esquema integración del sistema SCADA en un centro de control

Los SCADAs incluyen sensores de campo y actuadores (RTU y PLC) que recogen en tiempo real toda la información (analógica, digital y alarmas críticas) de los diferentes componentes de la instalación permitiendo rastrear en todo momento su funcionamiento, identificar los problemas y modificar en consecuencia la actividad de una máquina si es necesario.

[1] *Nombre en clave ya que la empresa desea mantenerse en el anonimato.*

Sin embargo, el SCADA en sí sólo trata información bruta, Por ello, para que el centro de control pueda cumplir sus funciones de despacho eléctrico y de herramienta de gestión inteligente, ha de enriquecerse con otras fuentes de datos y contar con la estructura de comunicación y aplicación gráfica adecuadas.

Dicho esto, antes de comenzar con el diseño del centro de control ha sido necesario conocer el contexto y las obligaciones de la actividad de la empresa. Para ello, se ha analizado el funcionamiento del mercado eléctrico español; los protocolos de operación fijados por REE; la integración de los sistemas SCADA en las tecnologías implicadas; los actores externos e internos que intervienen en la actividad de la empresa; así como la información, características y funcionalidades requeridas.

Posteriormente se ha procedido con el diseño del centro de control. Dicho diseño contiene las especificaciones necesarias para que sea desarrollado por una empresa especializada. El proceso ha seguido tres etapas claramente diferenciadas:

En primer lugar se han definido todas las fuentes de información así como el ciclo de vida de los datos según su Centro de datos. Por consiguiente, el centro de datos [2] ha de tener la capacidad y los servidores necesarios para unificar, recibir, identificar, relacionar y gestionar toda la información procedente de los diferentes SCADAs, los informes de los agentes vendedor y meteorólogo, los informes de mantenimiento, las consignas de REE y diferentes web de interés como las de OMIE y OMIP.

En segundo lugar se ha realizado el diseño técnico de la estructura de comunicación necesaria para la implantación del centro de control[3].

La comunicación entre elementos se realiza por internet utilizando una Red Virtual Privada (VPN) según un protocolo de comunicación HTTP a través de un servidor web de tipo REST. Cada "interlocutor" está conectado a dicha red privada por fibra óptica o por VSAT (según sus características) excepto REE. En este caso, la estructura de comunicación sigue las pautas establecidas en los procedimientos P.O. 8.2 y P.O.9.

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[2] *El dimensionamiento y las especificaciones técnico-informáticas del Data Bunker serán realizados por las empresas especializadas*

[3] *El diseño ha sido realizado en base a la localización de los diferentes interlocutores, los sistemas utilizados por otros centros de control y las exigencias fijadas por REE entre otros.*

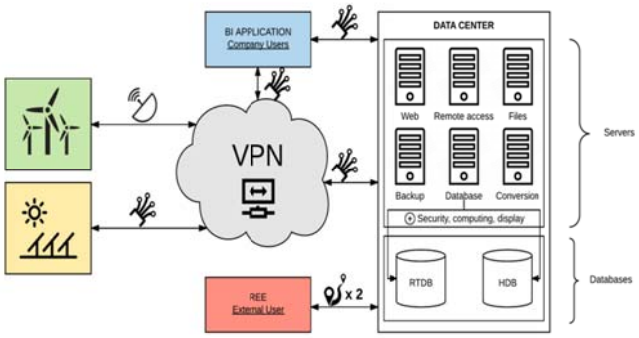

Figura 2: Esquema estructura de comunicación

La tercera fase del proyecto engloba el diseño funcional de la aplicación de gestión inteligente (Business Intelligence Application o BIA). La BIA diseñada está compuesta por 70 pantallas estructuradas según los seis tipos de usuarios potenciales.[4] Hay cuatro bloques de pantallas comunes a todos ellos: Global, Históricos, Previsión e Informes. Mientras que los tres primeros representan imágenes multidisciplinares de presente, pasado y futuro de la actividad de los activos; la sección de informes es la que permite seleccionar datos y realizar informes personalizados.

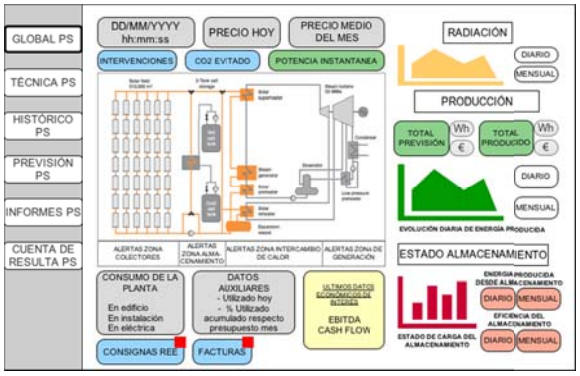

Figura 3: Ejemplo pantalla Global del gerente de una planta solar

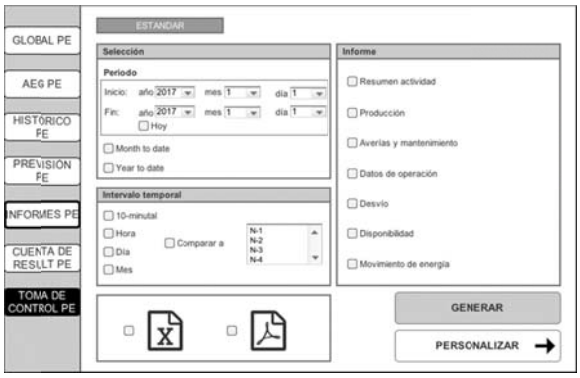

Figura 4: Ejemplo pantalla principal de la sección de informes estandarizados del gerente de un parque eólico

La aplicación propuesta incluye figuras, imágenes, valores y comandos deliberadamente escogidos con el fin de integrar y plasmar la información relevante de todos los ámbitos implicados en la actividad de la empresa (mercado, sistema, operación, previsión, finanzas…) de forma estructurada e intuitiva. Además, en el diseño funcional también se han definido las características pertinentes de cada uno los elementos presentados (frecuencia de refresco, código de colores, datos implicados, ciclo de vida, relación con otros elementos...).

[4] *Los usuarios potenciales son: El COO, los responsables de cada tecnología (Solar y Eólica), el responsable de mercados y regulación, los gerentes de los parques eólicos Y plantas solares.*

EVALUACIÓN ECONÓMICA Y CONCLUSIONES

Una vez concluidas las fases de diseño se ha procedido con la evaluación económica del proyecto tomando como referencia la situación actual. Para ello se han planteado cinco escenarios dependiendo de la internalización o externalización de diferentes aspectos del centro de control diseñado. Tras estimar los costes de inversión inicial y OPEX, se ha desarrollado un análisis basado en dos estudios. El primero, engloba el Valor Actual Neto (VAN) y la Tasa Interna de Retorno (TIR). El segundo, observa la sensibilidad del OPEX frente a la variación del tamaño de la empresa.

Dado el número actual de plantas y las expectativas de crecimiento de la empresa, abandonar el centro de control actual e invertir en el nuevo centro de control se presenta como la opción más rentable. En concreto, entre las soluciones planteadas, se recomienda apostar por un centro de control con servicios combinados en el que la función de despacho delegado recaiga sobre el agente vendedor y se utilicen servicios hosting para la gestión del Centro de Datos. En este caso, con una inversión de 242581,5 € se obtiene un VAN del ahorro en OPEX respecto a la situación actual (considerando una tasa de descuento del 5%) de 75098,8 € y una TIR del 16%, ambos evaluados para un periodo de cinco años (periodo estimado antes de que haya que hacer un reinversión en actualización de equipos)

Dicho esto, el diseño funcional del centro de control todavía queda abierto a posibles mejoras que le permitan adaptarse a futuros cambios de la compañía, sobretodo una vez éste haya sido desarrollado e implantado.

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TECHNICAL AND FUNCTIONAL DESIGN OF A CONTROL CENTER FOR INTELLIGENT MANAGEMENT OF RENEWABLE ASSETS

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Collaborating Institution: ICAI – Universidad Pontificia Comillas

PROJECT SUMMARY

INTRODUCTION

Following the "five-twenty" European energy strategy pact and the new energy policies and targets set by the member states, renewable energies play an increasingly important role in the generation of electricity. However, due to the fluctuating nature of these sources, the electricity grid systems of the different countries have been forced to evolve to be able to integrate as much renewable energy as possible without affecting supply and quality.

Spain was one of the pioneers in integrating intelligent information systems into its electricity grid. In 2006 Red Eléctrica de España (REE) created within CECOEL (Electric Control Center) the CECRE (Renewable Energy Control Center) in order to control and manage in real time the production of renewable energy.

This technological development of the system implied a regulatory development of the electricity sector. Thus, after the ratification of the Royal Decree RD 661/2007 by the Royal Decree RD413 / 2014 today, in Spain, any production plant or (renewable production package) of more than 5 MW is obliged under law to:

1. Be properly connected to CECRE 24/365
2. Have the ability to be controlled, managed and commanded remotely in real time at any moment
3. Have the right professionals to ensure a good interconnection between the plant and REE.

In this context we find "El Quijote", an independent company that owns wind and thermo-solar production plants distributed throughout the national territory. Its

activity is based on the management, operation and maintenance of these assets. Its mission is to obtain maximum profitability and a stable cash flow. Consequently, the company needs a control center that allows it to:

- Inform the national electricity grid about the production of each generation plant as stated by the current regulations (delegated dispatch function)
- Carry out a technical and economic internal follow-up in order to optimize decision making. (Business Intelligence Function)

Its current external control center guarantees communication with REE (function 1) but has a very limited management dimension (function 2) Therefore, the objective of this project is to develop the technical and functional design of a new control center that fulfills both functions.

METHODOLOGY

The first step of the project involved a previous study of the existing control centers and the SCADA (Supervision, Control and Acquisition of Data). These systems are the main organ of any control center, and therefore, the starting point of the design.

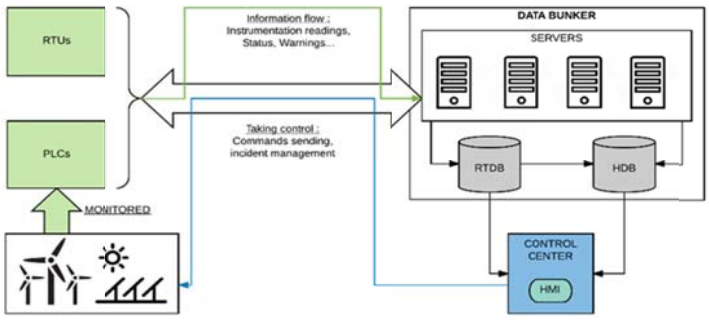

Figure 1: Diagram of the integration of the SCADA on the Control Centers.

Field sensors and actuators (RTU and PLC) that collect information (analogue, digital and critical alarms) of the different components in real time compose SCADAs. This allows the assets managers to track the production plants at any time, to identify critical problems and to modify the activity of a machine if necessary or applicable.

However, the SCADA itself only deals with raw information. Thus, in order to fulfill the company's needs and obligations, the data from the SCADA must be enriched by other sources of information; the communication infrastructure must be the most

suited to perform the tasks in hand; and the control center must include a graphical application adapted to the requirements.

That said, before starting with the design of the control center it was necessary to know all the details about the context and obligations of the company's activity. For that purpose, an in-depth study was undertaken on the operation of the Spanish electricity market, the operating protocols set by REE, the integration of SCADA systems into the participating technologies, the external and internal actors involved in the company's activity; as well as the information, features and functionalities required.

Subsequently, once all the relevant information had been gathered, the design of the control center was approached. The formulation of this design includes all the pertinent specifications to be properly developed by a specialized company. The process entailed the following three stages:

The first stage involved the definition of all sources of information and the life cycle of the data in the different bases of the Data Bunker according to their nature (frequency of updating, derived data ...). As a result, it was stated that the data center (or Data Bunker) must have the capacity and the necessary servers to unify, receive, identify, link and manage all the information provided by the SCADAs, the reports of the market and weather forecasting agents, maintenance reports, REE instructions; and several websites of interest such as those of OMIE and OMIP.

The second stage consisted on the technical design of the communication infrastructure of the control center[1].

The sharing of information between elements is done by Internet using a Virtual Private Network (VPN) and a HTTP communication protocol through a REST web server. Most of the parties involved are connected to this private network either by fiber optic or by VSAT depending on its characteristics (See figure 3). Yet, the permanent bidirectional communication with REE is assured by a particular infrastructure that follows the guidelines established in the P.O. 8.2 and P.O.9.

[1] *The design takes into account different aspects such as the location of the different parties involved, the systems used by other control centers or the requirements set by REE among others.*

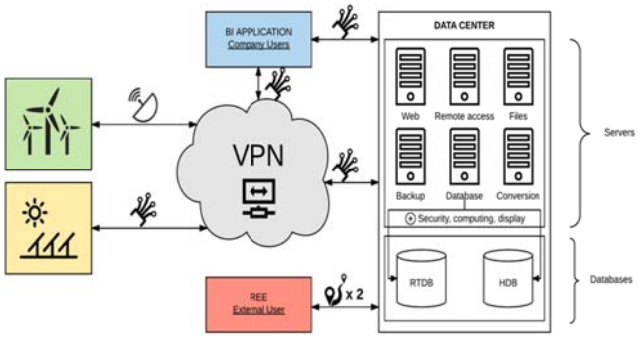

Figure 2: Diagram of the Communication Infrastructure

The final phase of the project encompassed the functional design of the Business Intelligence Application (BIA). The proposed BIA is composed of 70 screens structured according to the six types of potential users.[2] There are four screens common to all them: Global, Historical, Forecasting and Reports. The first three interfaces correspond to the multidisciplinary images of present, past and future of the assets activity. The windows located on the Reports section enable the user to create both standardized and personalized reports.

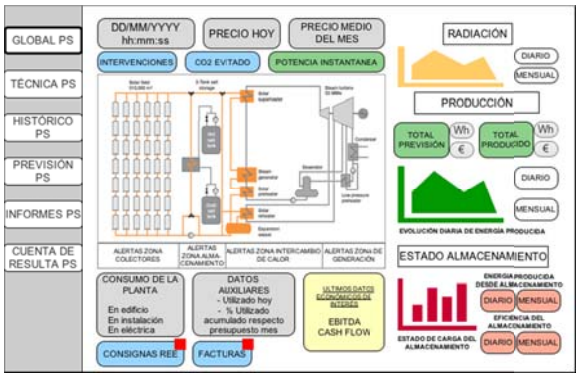

Figure 3: Example of the CSP Park Manager Global Interface

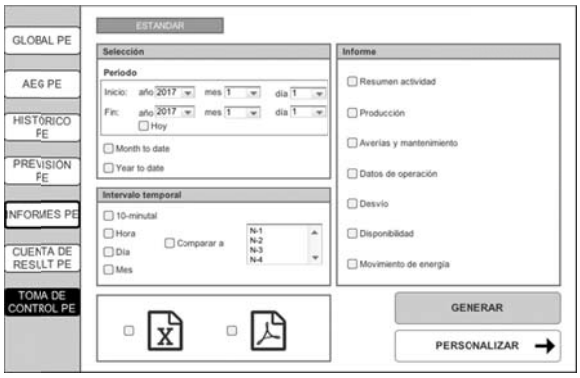

Figure 4: Example of the Wind farm Manager Standard Reports Home Page

The pages layout integrate figures, images, numerical values and commands deliberately chosen to cover all the relevant information from all the intervenient fields (electricity market, electric network, operation, foresight, performance, finance ...) in an intuitive, handy and clear way. This graphical design comes with a detailed description that specifies the main characteristics of each one of the elements included (refresh rate, color code, data involved, life cycle, relation with other elements ...)

[2] *The potential users are: The managers of the wind farms, the managers of the PV parks, the head of the wind technology department, the head of the PV technology department, the market and regulation manage and the COO*

ECONOMIC EVALUATION AND CONCLUSIONS

Once the design was completed, the development and implementation of the project was economically evaluated. The assessment implied, before all, the estimation of the initial investment and the OPEX. Thereupon the actual analysis was carried out. For this, five possible scenarios were proposed (internalizing and externalizing services) and opposed to the current situation. The analysis was based on two studies. The first one approached the NPV and IRR of the project. The second one, observed the sensitivity of the OPEX to the variation of the company's size in terms of number of assets.

As a result, it was concluded that given the current number of plants and growth expectations of the company, abandoning the current control center and investing in the new control center is presented as the most cost-effective option. In particular, among the solutions proposed, it seemed recommendable to bet on a control center with combined services in which the function of delegated dispatch would rely on the market agent and hosting services are contracted to manage the Data Center. In this case, the project would entail an investment of € 242581.5. This would imply an OPEX saving compare to the current situation of NPV 75098, 83 € (considering a 5% rate of return) and a 16% IRR, both evaluated during a five years period.

That said, the proposed design is still open to possible improvements to adapt it to future changes of the company's strategies or other requirements that may arise after the actual implementation.

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ESCUELA TECNICA SUPERIOR DE INGENIERIA (ICAI)
GRADO EN INGENIERÍA ELECTROMECÁNICA

MEMORIA PROYECTO FIN DE CARRERA

DISEÑO TECNICO Y FUNCIONAL DE UN CENTRO DE CONTROL PARA LA GESTION INTELIGENTE DE ACTIVOS RENOVABLES (EN)

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CHAPTER I:

INTRODUCTION

I.1) THE ROLE OF RENEWABLE ENERGY IN TODAY'S SOCIETIES

The shortfall of fossil resources, the increase in energy needs and the fight against climate change have implied a shift on the modes of energy production. Accordingly, during the last decade, the European Union has focused their effort on developing an Energy Policy that could lead Europe on the path to a sustainable future, with a low-carbon economy and lower energy consumption.

Thus, on January 2007, the European Commission has transmitted to the European Council and the European Parliament the Communication: "An Energy Policy for Europe". On this Energy Policy there were several objectives defined than revolved around three main axes:

1. Ensure the security of energy supply
2. Specify an interconnected, competitive internal market able to provide energy at an affordable cost.
3. Reduce greenhouse gas emissions.

To do so, the Energy Policy included the "five twenties commitment" that targeted for 2020:

- 20% reduction in greenhouse gas emissions.
- 20% reduction in energy consumption fostering greater energy efficiency.
- 20% production of primary energy from renewable sources.

These objectives were ratified in the 2015 Paris Agreement.

As a result, during the last years the renewable sources have become increasingly important on the electricity production. This new approach had imply the adaptation of the electricity markets and networks to deal with the intermittency of the renewable sources of energy, the variability on production and consumption of the different actors, and the evolution of the national and international regulations.

I.2) INTEGRATION OF THE RENEWABLE ENERGIES IN SPAIN

Due to the implementation of the energy policies the integration of the renewable energies on the electricity production share, the European electricity transport networks have evolved towards what are known as “Smart Grids”.

These so-called "smart" grids are the result of the blending of new IT technologies and conventional transport networks. They are characterized by high adaptability, two-way flow of electricity and information, and high security. They allow real-time control and continuous development which optimizes the efficiency of the electricity system.

These new “electricity highways” have foster the opening and pooling of energy between countries as well as the integration of the renewable energy into the system through continuous flows of information at real time. However, to do so, the countries have had to overhaul and set up an intelligent network management system adapted to the evolution of the needs of this new complex electricity landscape

Having said that, within this European framework Spain has been pioneer in adapting its network and evolving towards these intelligent systems.

Red Eléctrica de España (REE) is the corporation in charge of the transport and operation of the Spanish electrical system. Its mission as a system operator is to ensure the correct operation of the electrical system and to ensure at all times the continuity and security of the electric power supply.

During the last years REE has invested on strengthing the network’s management and the country's energy mix and developing tools for integrating renewable resources into the existing national network.

Since 1985, REE centralizes the management of the traditional network in a control center, the CECOEL (Electric Control Center). This control center is the responsible for the operation and coordinated supervision of the generation and transport of the electrical system. It receives the daily production of installations from all over the country and acts as an intermediary between the production and distribution of electricity in order to match offer and demand.

However, since the earlies 2000 in Spain we find an energy mix where renewables have been playing an increasing role reaching the 37% of the country's production in 2015. Due to this, the safe integration of these new technologies became the major challenge for REE.

Accordingly, REE developed the renewable energy control center, the CECRE (Center for Control of Renewable Energies), within the previously introduced CECOEL. This project, created in 2006, was a pioneer in the sector. The CECRE receives information from each renewable about the electricity production (voltage, phase, net W produced) every 12 seconds. Consequently, REE has gained the capacity to identify the risks and to anticipate and control the variable nature of these alternative sources of energy which difficult the management of the network and its ability to meet domestic demand.

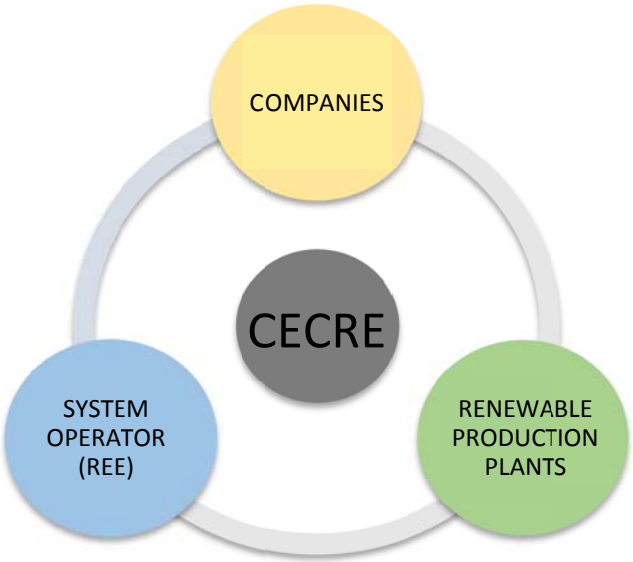

Figure 1: Diagram of the integration of the CECRE in the system

That said, the operation of the CECRE has made it possible for renewable energy generation to have represented nearly 40% of the annual supplied energy in the Spanish peninsular electricity system during the last past years.

Figure 2: Integration of Renewables (% of Demand) Source: REE

Nevertheless, these results couldn't have been possible if this technological development hadn't come with a series of reforms on the regulatory framework of the energy sector.

Due to the objectives set by the European Union in the "20-20-20" program, Spain has put in place a series of laws to enable effective integration and management of renewable resources.

Since the first Real Decree of 2005 RD1454/2005 there have been several regulatory measures and Protocols of Operation that has set and modified the obligations of the producers of renewable electricity. This Real Decree, which was modified in 2007 on the Real Decree RD 661/2007, stated that every installation with more than 10 MW must:

1. Be adequately connected to CECRE
2. Have the possibility to be controlled, managed and monitored in real time
3. Have HHRNs trained to ensure reliable interlocution

In 2014 the RD 661/2007 has been ratified by the Real Decree RD 413/2014. This ratification stated that since 1st June 2015 any installation of more than 5 MW was concerned by the previous obligations.

Consequently, all the companies framed on the here-above conditions have had to ensure a technical follow-up of the installations in order to respect the law in force of the current energy framework.

I.3) OUR CORPORATE CLIENT

On this Electricity landscape we find our corporate Client, to which we will refer from now on as “El Quijote”.

“El Quijote” is a Yield co that quotes in euros and whose main purpose is to provide value to its shareholders by investing in renewable energy infrastructures that generate stable and predictable cash flows. That said, the business area of our corporate client is not the construction of electricity production infrastructures but the purchase, management, maintenance and production of the installations. Today, the portfolio of our company includes are wind farms and thermosolar plants all over the Iberian Peninsula.

As a result, even though we may consider “El Quijote” as a mere energy producing company the “Yield status” imposes a totally different view of their business. For our company, production facilities are assets that must be managed optimally to maximize dividends. Accordingly, its activity is focused on the following short- and long-term objectives:

- Achieve total profitability.
- Optimize the efficiency of the operating processes.
- Implement a good risk management policy.
- Develop mechanisms to enhance asset strength and stability.
- Pursue international expansion and growth of the company.

“El Quijote” like any producer of renewable energy framed on the Spanish Electricity market has an outsourced control center:. This control center was created in 2007, when the transmission of information on renewable energy production in real time to REE (Electric Dispatch) became mandatory. Added to that, besides the real-time transmission of information requested by REE, the current control center generates regular reports on the production and sales activities of the company's plants. However, these reports are very standardized and so the Business Intelligence dimension of this control center is quite limited.

I.4) MOTIVATION OF THE PROJECT

Today, three years after the creation of the company, they are considering the possibility of creating their own Control Center. As we have seen, a good asset management is mandatory for the company if they want to become more competitive and performant. However the functionalities of the current outsourced control center concerning this field are quite reduced.

Hence, the company aims to have a control center endowed with two main functions:

- Electric Dispatch Function: It enables the company to inform REE about the electricity production of each plant in real time according to the current regulation.
- Remote control center and control panel function: It enables the company to keep a technical and economic internal follow up of its activity to optimize the decision making. (Business Intelligence dimension).

The Delegate Dispatch function is intrinsic to any existing control center for renewable energy production plants, including the company's current control center. Thus, this project will be focused on the design of a control center that acts as an "Intelligent" Management Tool.

To do so, the following steps will be carried out:

1. Contextualization and knowledge the operation of the existing control centers.
2. Study of the company's environment and needs.
3. Design the interfaces of the control center's monitoring tool.
4. Search of the most appropriate technical solution.
5. Analysis of economic viability of the shift toward our control center versus other possible solutions such as outsourcing.

CHAPTER II:

STATE OF THE ART

This chapter present the technologies used by the currents control centers and their Electric Dispatch function,

II.1) TECHNICAL MANAGEMENT OF RENEWABLE ENERGY PRODUCTION PLANTS

As seen on the introduction "El Quijote" is active on the operation, maintenance and management of its infrastructures. That said, this section focuses on the technology used by the companies of the sector (including ours) to monitor the production of renewable installations.

Today, every production site of renewable energy has a SCADA (Supervisory Control and Data Acquisition) incorporated. The SCADAs are used in most of the industrial process to control and to act on all the machinery of an installation. This technology enables the manufacturers to track the operation of the plant, identify the problems and to modify accordingly the activity of a machine if necessary.

The SCADAs include field sensors and actuators (RTU and PLC) that collect real time information of the different components of the plant such as the meteorological stations, the mechanical modules or the electrical substations. The SCADAs gather **analogical data** (in our case: intensity, power, voltage, pressure, temperature…), **digital data** (states of the different components, switches etc) as well as alarms of critical situations. Their specification and development are carried out by specialized companies according to the needs and budget of the purchaser.

However, a simple SCADA does not meet the Business Intelligent dimension pursued by the company. The SCADA only deals with "raw information" and so it does not provided the added value of manipulating, optimizing and personalizing the data depending on the needs of the different actors. Yet, the SCADA's represent the basis and starting point of the design of any control center.

a) SCADAs and wind power installations

The wind technology covers most of the installations of our company. Therefore, knowing how the SCADA is integrated on the wind farms' operation is imperative.

Even if the SCADA's are design based on the needs of the purchaser, the SCADA's of most of the wind farms deal with the same operational data. Based on the study of other

control centers, it can be deduced that the common elements that are monitored in any wind farm in order to achieve an optimal management of its activity are:

- Anemometric towers (wind speed, direction, density, pressure etc.)
- Wind generators (generated electrical power, wind speed, cumulative generated energy)
- The network of each wind turbine (Tension and Intensity per phase, power per phase, exported and imported energy, network frequency)
- The reactive capacity of each wind turbine (actual capacity of the batteries, capacitor states, capacitor operations, connection time of each capacitor)
- The substation network (Voltage and Intensity per phase, power per phase, energy exported and imported, frequency of the network)
- The reactive capacity of the substation (actual capacity of the batteries, capacitor states, operations in the capacitors, connection time of each capacitor)
- Stator and energy recorder on average (Exported and imported energy, imported and exported inductive reactive energy, imported and exported capacitive reactive energy)

This set of data is transformed by the control centers into standardized technical reports. In most of the cases, the control centers generate the following reports:

- Energy movement (energy flow, consumed, produced, etc.)
- Production by wind turbine
- Equivalent hours of production (comparison with production at 100%)
- Wind characteristics (airspeed and wind turbines)
- Availability of generators (% availability, losses by unavailability)
- Power curve (curve calculation per time interval)
- Energy deviation (losses in the intervals where the machine is available)
- Maintenance (response time, repair time, comparisons, etc.)
- Prediction of production

b) SCADAs and thermo-solar installations

On the other hand, the other technology operated by the company is the Concentrated Solar Power. As in the case of wind turbines, there are some fundamental technical parameters of production such as the operating temperature of the heat transfer fluid, the efficiency of the heat exchange, the heat storage status or the speed of rotation of the steam turbines.

In terms of SCADA, and therefore of supervision and control on the machinery, most of the conclusions regarding the wind turbines are applicable to the solar plants due to the parallelism of the operation of the generation. However, there are some modifications to be taken into account. In this case, for instance, the SCADA monitors solar radiation rather than wind speed or exchange temperature rather than the wing speeds. Moreover, the reports to be produced are qualitatively the same since the interest in availability, energy movements or maintenance time is common to the all types of production.

Nonetheless, thermo-solar installations can be considered as factories whose product is electricity which raises some specifications. The production of electricity based on thermos-solar is more complex and requires more buildings and non-production elements that act source of electricity consumption and affect Equilibrium of energy movement. Therefore, the SCADA system of these installations includes much more sensors and deals with a bigger quantity of information. In addition, we have a heat storage energy system that must be monitored too to evaluate heat loss and its performance.

II.2) GENERATION CONTROL CENTERS

Every renewable plant (or cluster of renewable plants) with a nominal power of at least is assigned to a Generation Control Centers (GCC). The GCCs receive the information from the installations attached to them, transmit it to the renewable energy control center (CECRE) and, if necessary, transmit CECRE's orders back to the plant to ensure that renewable energy can be safely integrated into the system. At present, in Spain there are 46 Control Centers connected to the CECRE.

a) General Structure

The SCADA system above-mentioned is the main source of information of the control center. Yet, in order to fulfill its function, the control center must include a data bunker and the appropriate communication infrastructure.

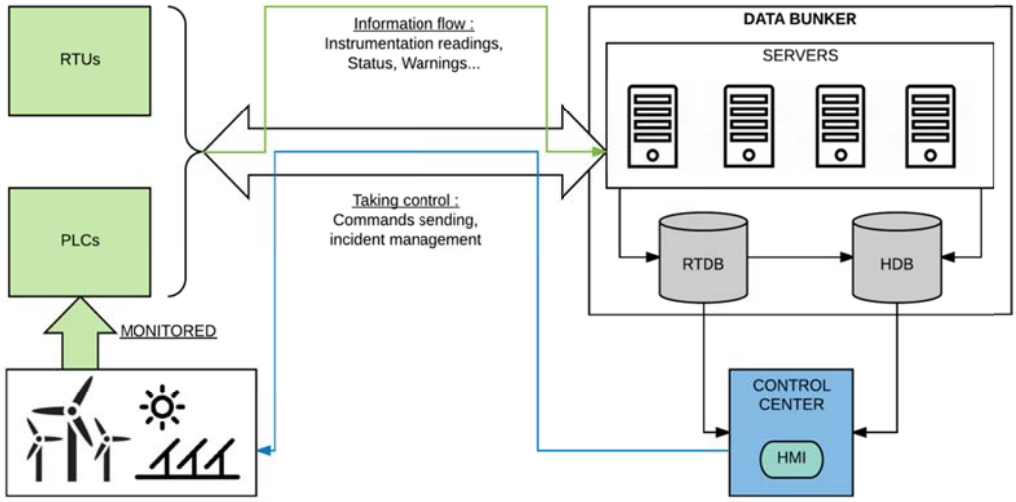

Figure 3: Diagram of the structure between the SCADA and the Control Center

The data collected by the SCADAs is unified in the OPC (Open Platform Communication) into a protocol understandable by the control center. Once the information is properly adapted it is transmitted to the Data Bunker. The components of the Data Bunker are grouped in two main parts: the servers (File server, Conversion server, Display server…) and the databases (Real Time and Historical Data base) The election of servers and the complexity of this structure depend on the functionalities required by the operator of the plants.

b) Electric Dispatch function

The fundamental function of any Generation Control Center is the Electric Dispatch function. Beyond the requirements and needs of the company, the control center must include the corresponding hardware and software needed to ensure the regulatory compliance.

The Electric Dispatch function refers to the module responsible of the exchange of information between the Control Center and REE. This function is regulated by the operation protocols P.O. 9.0 and P.O 8.2.

Accordingly, in general terms, the System must fulfill the following tasks:

Extract from the Real Time Data Base:

- The parameters that regulate the communication with REE
- The data requested by REE[1]

Extract from the Historical Data Base:

- The structural data of the production sites
- The manual instructions entered by the user

Write on the Real Time Data Base:

- The data and instructions received from REE
- The information, logs and warnings of the communication process

Write on the Historical Data Base:

- The connectivity status of the production plants
- Logs and warnings of the instruction optimization processes.
- The optimized limitations.

Added to that, the communication between both sides must be dual and redundant so that the reception and sending of information are guaranteed at all times.

[1] *At present, the Data requested by REE is specified on the Operation Protocols P.O. 9.0 and P.O 8.2. However these data is open to modifications.*

CHAPTER III:
PROJECT BACKGROUND
RELEVANT INFORMATION

This chapter includes relevant information for the design of the control center. Thus, this chapter is divided in two blocs:

1. *Parties involved and potential users*
2. *The Spanish Electricity Market*

III.1) PARTIES INVOLVED AND POTENTIAL USERS

Before starting with the design of the control center, the parties involved on the control center and users must be specified.

a) Market Agent and Forecast Agent.

From the previous chapter we can deduce three of the relevant actors: the Company, the production plants and the network operator REE. However, they aren't the only ones.

On one hand we find the Market Agent. It is the one in charge of the commercial activity of the production plants. Our corporate client delegates the Market Agent function to an external company under contract. In return, this company receives a proportional part of the benefit obtained from the commercial activity. Consequently the contracted company needs to follow up as precise as possible the operation of the production plants.

On the other hand we find the Weather Forecast Agent. This function is carried out by a Weather Forecast agency. This agency calculates the expected production using the weather data and the power curves of the generators of the production plants. However, it must be said that the Weather Forecast Agent it is not connected to the control center. Indeed it is connected to the Market agent that transmits the information to the control center.

b) The users inside the company

As stated above, the added value of the new control center is that it includes a Business Intelligent tool that would enable the company to optimize the management and operation of the production plants. Thus, in order to know who are going to be the actual users of this tool, the operative structure of the company must be analyzed.

The structure of "El Quijote" showcases the two main strands of its core business: the optimization of the assets and the finance of the company. Consequently, organization structure is divided into two very distinct modules:

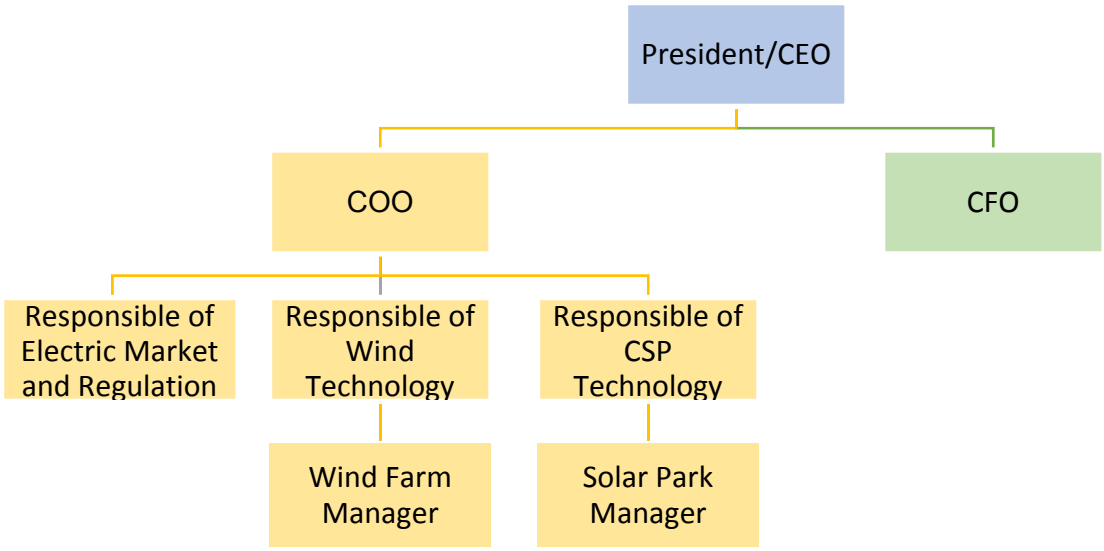

Figure 4: Operative Structure of the company

On one hand, the Chief Operating Officer (COO) is responsible for the operative performance of the company's assets. Below him there are the Responsible of the Wind technology and the Responsible of the CSP technology. Finally, bon the bottom of the hierarchy there are the managers of each production plant. Added to that, at the same level of the COO, we find the person in charge of the communication with the national electricity grid and the follow-up of the evolution of the national regulation.

This part of the organization chart constitutes the group responsible for the direct management of the company's assets. It is in charge of the decision making and operation of the production plants. Thus, they are the ones that must have access to a working tool which facilitates the follow up and monitor of the production plants.

On the other hand, we find the Chief Financial Officer (CFO), responsible for the financial aspects of the company which has as subordinate the managers of the administrative part and the acquisitions of new assets.

Knowing the organization char orientates the development of the control center's functional design since it presents the potential users of the control center and facilitates the segmentation and evaluation of the usefulness of the data to the various members of the company.

III.2) THE SPANISH ELECTIRICITY MARKET

As seen, the core business of the company is based on energy sales, so understanding how the electricity market works is essential to develop a control center that optimizes its business.

The electricity market is where the activity of sale and purchase of energy is carried out. It is composed of several submarkets. Among them, three main ones are: daily market, the intraday market and the long-term market.

The daily market or "pool" concentrates most of the commercial activity. It is managed by the OMIE (Operator of the Spanish Iberian Market) and operates according to an auction system. In this market the different players present their offers for the following day and by summing these and crossing them with the national demand, the daily price (PMD) is fixed. The daily market is so, a marginal market and the producers whose price overpasses the “pool price” stay out of the trading. The Market agent is the one in charge of sending the offers. In order to minimize the deviations, the offers normally include groups of production plants.

The intraday markets serve mainly to minimize the cost of deviations. By selling energy in this market, companies get closer to the quantity offered. Consequently, an intraday price related to this commercial activity appears. However, as this market is much more volatile, sometimes is precisely used by the market agents to “play” and enhance the revenues.

All installations sell most of their production in the daily market at the PMD price. The cost of the penalties due to deviations is close to 1 € / MW. At the end of the commercial activity, the facilities consider a single selling price that corresponds to the corrected PMD (deviations and intraday prices included), affected by the kurtosis coefficient which varies according to the technology. The kurtosis coefficient is the correction factor that reflects if the technology produces more or less in the peak hours of the pool. The Wind farms production is in accordance with the energy demand and so it causes the PMD to drop. Conversely, thermo-solar systems produce more when the demand is not that high and so it

causes the PMD to increase. Consequently, wind activity involves lower prices and solar activity in reverse. As a result, the kurtosis coefficient of wind power plants is 0.889 while that of the CSP plants is 1.027.

In addition, it should be noted that at the time of presenting the production offers, wind and photovoltaic renewable energies offer at zero price, assuring that they will participate in the sales activity of the next day.

Finally, there is a last commercial possibility through futures contracts previously negotiated with other players in the electricity market. However, this practice is less common. For example, our client does not have any signed contracts at this time. ON this field the OMIP (Long-Term Operator) information plays an essential role.

To conclude, Apart from the commercial activity, it is important to know that renewable energies receive additional revenue in concept of installed capacity denominated compensation for the investment (Ri) according to the date of launch of the installation. The purpose of this grant is to promote the investment on renewable technologies. It should be noted that older plants do not receive this subsidy since they are considered to be already depreciated.

CHAPTER IV:

THE CONTROL CENTER

This chapter includes the design of the control center. It is divided in two main parts: The functional analysis and the design.

The design of the control center includes the relevant specifications to be developed by a specialist. That said, the functional dimesion is based on the analysis of the needs of the company and the segmentation and selection of the relevant data to be monitore as well as the visual desing of the Business Intelligence Application. The technical dimesion approaches the specification of the data lifecycle process, the communication infrastructure and the interfaces of the BIA

IV.1) FUNCTIONAL ANALYSIS

Once we have contextualized the environment of the renewable energy sector and the activity of our client in that one, the next step is to fully understand the demand of our client and the added value that we must bring to him

a) The company's requirements

After discussion with the COO of the company, the essential functionalities and constraints of the control center are:

1. Ensure permanent communication with REE as set by the current regulation.[2]
2. Ensure access to all the information we need for our control center.
3. Have simple, intuitive and fast access interfaces.
4. Provide flexibility for data management and customizable reporting.
5. Know that the value of information lies on the comparison either with previous years or with the budget.
6. Hierarchical information, ie, that every member of the company must have access to information from members of the lower levels.

That said, our mission is based on the selection of data and the design of interfaces that allow our client to manage its assets while respecting the functions described above

.

b) The users' needs.

Before starting with the design of the interfaces the content to be displayed must be specified.

The analysis of the relevant data is based on preliminary studies of other control centers and discussions with professionals of the sector. The summary of all the information gathered is grouped per employee. This allows us to structure the interfaces of the control center.

[2] *See section II.3 Electric Dispatch Function*

PRODUCTION PLANT MANAGER

The aim of an installation manager is to ensure that the plant is achieving high performance at present and that it would do it on the future. Its main objective is therefore optimal operation.

It should also be noted that we have a significant operational difference between production technologies. The windmill managers are responsible of more than a plant. Added to that, since there is no need to have a manager on site, most of the protocols and actions can be realized automatically from a distance. Conversely, solar thermal power plants function like factories. They have central buildings with offices, chemical storage facilities and others. Because of their complexity, the manager works in situ.

Taking into account all these constraints and the elements monitored by the SCADA of the installation, the data to be included on the interfaces of the Installation Manager is:

- Meteorology: forecasts and measurements (speed-wind direction, solar radiation ...)
- Measurements and status of the components.
- Power curve (wind turbines)
- Failure rate
- Availability of wind turbines
- Availability of storage (solar)
- Specific plant information (eg number of wind turbines for the wind turbine or number of employees for solar power)
- Maintenance and repair operations:
    - Description of the operation
    - Type: predictive, preventive or corrective
    - Costs
    - Time employed,
    - Energy not produced.
- Bills
- Yield

- Production:
    - Installed Capacity
    - Actual production
    - Forecast
    - Variation:
        - Forecast
        - Historical
- Financial Performances
- Trading track record
- REE warnings and alerts

TECHNOLOGY MANAGER

Their mission is to ensure the proper functioning of their sector. Since they are placed hierarchically above the directors, they must have the possibility to access all the technical information of a particular plant at the same level of detail as these. Thus, all the information presented must be added before the following elements:

- Production:
    - Absolute (total and per plant)
    - Forecast (total and per plant)
    - Role of each plant in total (%)
    - Production Variation to:
    - Forecast
    - Last year
- Financial result of each plant and total
- CO2 avoided per plant and in total
- Sector result

ELECTRICAL MARKET AND REGULATION MANAGER

The electrical market and regulation manager must have a complete knowledge of the actual production of the installations and the forecasts made. In addition, he is responsible for

the follow-up of the exchanges with the electric operator and he must know the updated state of the markets and the relevant regulations. Thus he tracks the activity of the market and agents as well as that of weather forecasters.

Therefore, the information deemed relevant to this employee is:

- Regulation planned and updated: Access BOE
- Electric market:
    - Data from OMIE (Peninsular Electricity Market Operator - Spanish Pole). Daily information (energy prices, supply and demand.)
    - Data from OMIPT (Operator of the Peninsular Electricity Market-Portugal Pole). Price information in future.
    - Web page access: ESSIOS.REE (Electrical System Operator Information System). Market, generation and consumption information.
    - Daily offer from the company
    - Weekly reports of business activity.
    - Energy derivatives of the company
- Other markets:
    - Oil prices
    - Dollar - euro exchange rate
- Information exchanged with REE.

CHIEF OPERATING OFFICER (COO)

Its mission is to ensure the well-functioning and profitability of all the company's assets. Due to the hierarchy of the organization chart, he has access to all the information presented previously, to which the following is added:

- Total installed capacity
- Production:
    - Actual (total, by sector and by plant)
    - Change: expected, last year.

        - Yield: production / capacity.
- Trading track record:
        - Quantity
        - Revenues
        - Price: current, daily variation, monthly variation
        - Energy derivatives
        - Bonus
        - Planned comparison.
- Financial Results:
- Co2 avoided

This functional analysis sets a global but precise vision of what the interfaces of the new control center must include to contribute and add value for the company. However, in order to succeed on the display of the data, the sources of information, the data management and the communication infrastructure need to be defined.

IV.2) DESIGN OF THE CONTROL CENTER

The objective of the following pages is to provide a precise analysis of our proposition for the control center in order to allow the client and the potential developers to simply evaluate the optimality and feasibility of the whole project.

In consequence and trying to be as methodical as possible, the approach has been divided in two main parts:

The first one develops the technical feasibility of the Control Center. We analyze there all the data sources that are present in the production scheme of the company in order to evaluate and develop the hardware and software, which we call communication infrastructure, that are needed to integrate and store the total amount of information. In addition, we introduce different ways of optimizing the communication, computational and needed storage capacity.

The second one focuses on the user interfaces, displaying for each screen and user its objective, the value added by it, its functionalities and the sources and calculus needed for all the data showed (numerical values and charts). In other words, each screen is defined by its graphical display and a complete written description. In addition, we introduce how to navigate between the different screens of the Business Intelligence Application and the hierarchy of each user. In order to simplify the reading, we have divided the screens by employee; each package of information is personalized and contains the important information for its day to day work.

The design is formulated to create a RFQ so that specialized companies can develop it consequently, the formulation includes all the relevant specifications that the control center must respect to fulfill the fixed functionalities and needs. However the in-detail characterisitics such as the computer design or equipment sizing remain subject to the developers of the project.

a) Technical Specifications

i) Sources of Information

The control center has to deal with data coming from many different sources of information. In this section we will present the different sources from which the data displayed in the control center is extracted. We will specify the nature and format of the data, the frequency at which it is collected and its life cycle in the control center's databases.

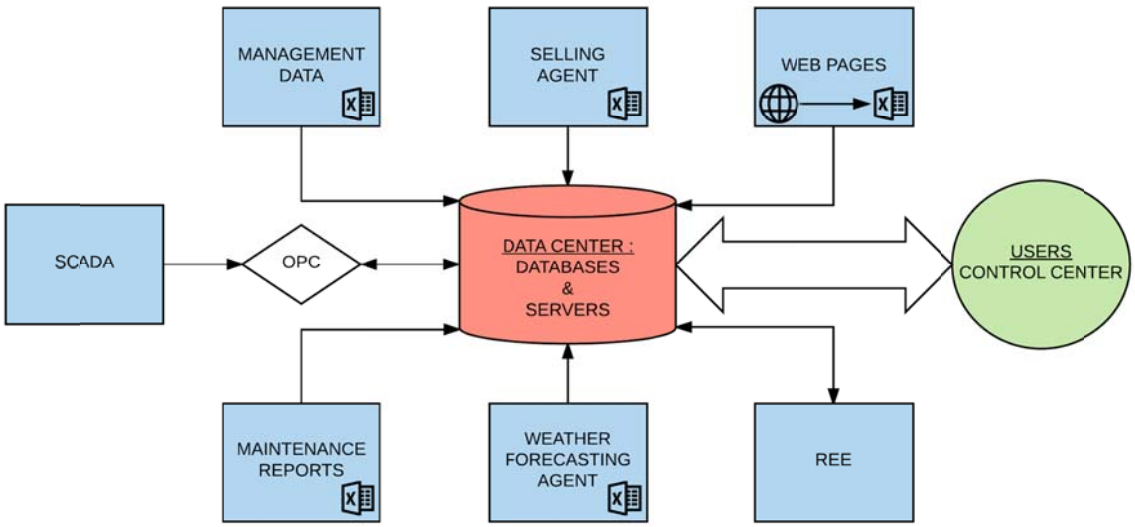

Figure 5: Diagram of the Data Sources

SCADA

The first and main sources of information are the SCADA systems of the different production plants. The SCADAs include field sensors and actuators that collect real time information of the different components of the plant. This information is collected and sent to the bunker database every 12 secs. When the control center receives new information, it is stored in a real time database (RTDB) and in the historical database (HDB). The RTBD only retains the last values received (measures and states). Once the information is updated on the RTBD, it is sent to the BDH.

The BDH only hold the information of the last 3 years (The current year and the two previous ones). Even if the data is collected every 12 seconds, in the BDH the information is cluster so that the minimum unit of time is 10 minutes. Throughout the day, the information is also stored per hour. Once the day is finished, the values per day are saved too. The values per hour are kept during the following months. The values per day are kept during the whole year. Furthermore, the values per month and year are also calculated and stored once each

month is finished. However, these ones do not imply the elimination of the previous ones. Every other temporal data grouping such as week, fortnight or trimester will only be calculated if requested and it won't be stored.

MANAGEMENT DATA

The management data regards all the information concerning the production plants managed by the company.

First of all, on one hand we have the **configuration data** which includes all the characteristics and details of each entity of the control center.

- For each production plant it will be stored: the identifier, the capacity, the description (Dimensions, capacity, nominal powers, GPS position, start-up date…), the responsible details, the corresponding selling agent… as well as all the information provided by other sources and files associated by the "file server".

- For each weather station, it will be stored: the identifier, the manufacturer, the location, the model, the technical specifications, the GPS location, the serial number, the starting date... as well as all the information provided by other sources and files, associated by the "file server"

- For each wind turbine, it will be stored: the identifier, the corresponding wind farm, the serial number, the model, power curve, the manufacturer, the corresponding set…. as well as all the information provided by other sources and files associated by the "file server".

- For each SET of a wind farm, it will be stored: the identifier, the start up date, the GPS position, technical details, the corresponding wind turbine, the corresponding switch and its characteristics… as well as all the information provided by other sources and files associated by the "file server".

- For each solar collector, it will be stored: the identifier, the start up date, the

corresponding solar plant, the corresponding line position, the technical details, the manufacturer, the model, the power curve…. as well as all the information provided by other sources and files associated by the "file server".

- For each heat exchange unit, it will be stored: the different elements, the identifiers, the manufacturer, the technical details, the models, the serial numbers… as well as all the information provided by other sources and files associated by the "file server".

- For each electricity generator engine of the solar plant, it will be stored: the different elements, the identifiers, the manufacturer, the technical details, the models, the serial numbers… as well as all the information provided by other sources and files associated by the "file server".

- For each stockage unit, it will be stored: the different elements, the identifiers, the manufacturer, the technical details, the models, the serial numbers… as well as all the information provided by other sources and files associated by the "file server".
- ...

As it can be noted, the solar plants are not divided by elements but by functions. Thus each functional unit must include all its different elements and their corresponding information.

The configuration data is permanent and therefore it doesn't have an "expiration date". Once the values have been included, they can only be edited or removed manually.

On the other hand, the management data concerns the **accounting information of the company i.e the budgets, the income statements etc…** The accounting information is stored in excel files and thus are managed within the data center due to the "file server".

The most recent accounting files are stored in a RTDB. Once a new version is uploaded, the last one is replaced and sent to a HDB. In order to enable the management of the files and the data mining, all the documents have to be adjusted to a standard template.

To conclude, the management data includes **all the information set and laid down**

by law or official institutions, such as the technological peak coefficient, as well as **the operational critical values**. This data can only be included, edited or removed manually.

MARKET AGENTS REPORTS

The Market Agents' reports enable the company to get all the information concerning the commercial activity of the production plants.

There are two types of reports: **the Energy Settlement report** and the **Daily Details report.** Both reports are excel documents, thus, the must be managed by the "file server".

The first report describes the market settlement per plant breaking down the revenues and penalties of the commercial activity. The second reports contain all the information regarding the final prices of the different markets as well as the real and the forecast productions of each plant. Added to the data provided itself by the reports, this information enables the company calculate, inter alia, the real peak coefficient per plant.

Both reports are sent by the different market agent every two weeks. The most recent ones are stored in a RTDB. Once the new versions are uploaded, the last ones are replaced and sent to a HDB. Just as the SCADA's data, the information will be stored in a HDB three years.

To conclude, all the documents have to be stored and fulfilled according to standard template so that the control centre can extract the data desired.

MAINTENANCE REPORTS

The maintenance reports are the documents filled-in by the technicians with **descriptions of the maintenance work.** This reports have to be stored so that the "file server" can link their information with the one provided by the scada (warnings, unavailability, lost energy…) and fin the reports desired by: plant, type (preventive, scheduled, corrective…), object etc ... As in the preceding instances, the reports will be stored in the data center three years.

WEATHER FORECASTING AGENTS' REPORTS

The Weather forecasting agents' reports enable the company and the market agent to know the production forecast in order to make the offers and to plan ahead their activity.

The weather forecast agents provide the company and the market agents with three types of report: **the fortnightly report, the daily market forecast and the report regarding the intraday adjustments of the forecast.** All of them are excel sheets.

The fornthiglty report contains the production per plant and is updated every day. The daily market forecast report contains the official forecast sent to the market operator and to the company, on the eve of the respective day. To conclude, the intraday report is provided before each intraday market session.

The three types of report are excel sheets that are stored in a RTDB until, an updated version arrives. The the old ones are sent to the HDB, where they are kept for three years.

WEBPAGES

Added to the external reports, there are some official webpages from which the control centre must extract data. The sources are:

- **OMIE (Iberian Electricity Market Operator)**
  http://www.omie.es
  This website provides all the data regarding the selling prices of the daily and intraday markets. The website offers the possibility of exporting all the values to excel. The market data must be extracted in real time.

- **REE (Red Eléctrica Española)**
  http://www.ree.es/
  REE is the operator of the spanish national electricity grid where he is in charge of the operation of the transmission system.
- **E-Sios (System Operator Information System)**

https://www.esios.ree.es

This website provides all the data resulting of the System Operator market operations, or other information of public interest, related with the electricity markets is published by REE.

- **European Central Bank Exchange Euro-Dollar**

  https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html

  This website provides the data concerning the exchange rate between the Euro and the Dollar.

- **Organization of the Petroleum Exporting Countries**

  http://www.opec.org/opec_web/en/data_graphs/40.html

  This website provides the data concerning the OPEC Basket Price.

- **BOE Energy Ministry**

  https://www.boe.es/boe/dias/2017/01/13/indice_departamentos.php?d=11&e=MINISTERIO+DE+INDUSTRIA%2C+ENERG%CDA+Y+TURISMO

  The BOE (Spanish Official Gazette) includes all the legislation concerning the ministry of energy and therefore, the company's activity.

- **Spanish Stock Market**

  https://www.bolsamadrid.es/esp/aspx/Portada/Portada.aspx

  This page allows the market and regulation responsible to know the status of the Spanish stock Market since it affects the electricity market.

<u>REE</u>

To conclude, the last source of information is REE. REE and the production plants are in continuous communication.[3] The monitoring at real time of the electricity production is indeed a demand of the REE to control and manage the electricity system. Thank to the control centres REE can regulate the production by sending messages **including inter alia**

[3] *See Communication infrastructure to know how the information is transmitted and Users-REE to find out the information sent to REE*

measures to be taken by the plants, alerts etc..

ii) Communication Infrastructure

In this section we will study the composition of the communication network implemented between the different sources of information defined hereinabove, the data center and the data users. The structure is synthesized in the following scheme that will be developed:

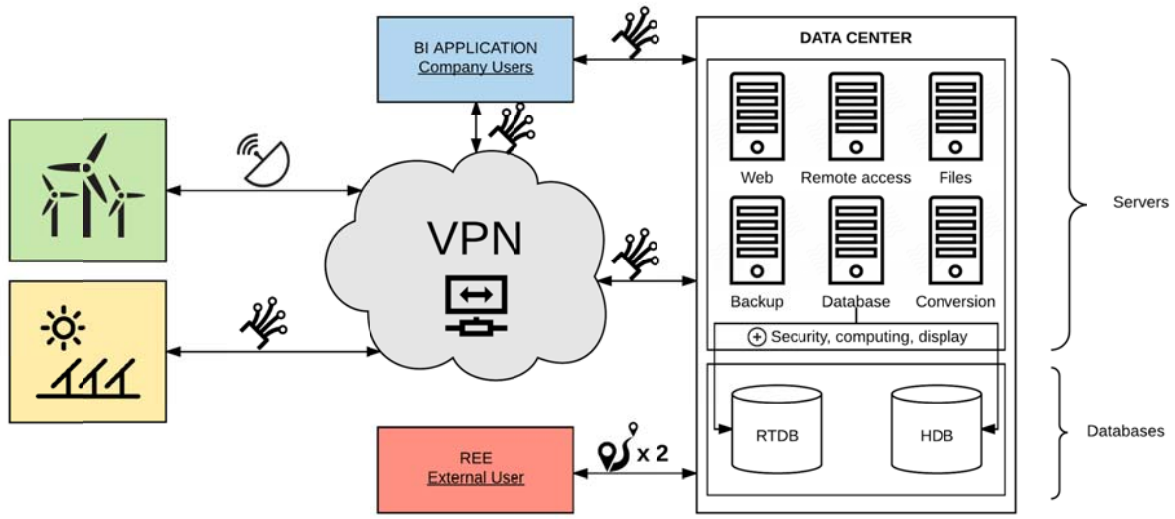

Figure 6: Diagram of the communication infrastructure

Firstly, the communication between all the elements is made via the internet with the implementation of an HTTP protocol via a web service like REST (Representational State Transfer). In consequence, we are obliged to go through a Virtual Private Network (VPN) in order to allow the different users to receive and send data across a public network (internet) as if they were in a real private network owned by the company itself (intranet).

The implementation of a VPN benefits the control center communications providing the management and security functionalities of the company's intranet as it works as an extension of the last one. The authorized employees and external users will be able to remotely access to the data center where all the information is stored and managed.

Once we have defined the usage of the VPN, we have to analyze which are the different components of the infrastructure, how they are connected through this virtual

extension and with which language and protocol.

Wind farms are situated in remote places and must be connected via VSAT (Very Small Aperture Terminal) which is a two-way satellite ground station with a dish antenna. Solar farms are situated near urban areas and can be connected via optical fibre which assures a better stability and connection rate.

The problem resides in the different languages and procedures that are used by each installation in the communication with their SCADA. In consequence, we are obliged to use, in each wind and solar farm, an Open Platform Communication (OPC) server which is a set of communication standards for industrial control processes that offers a common interface for the control center (operating system) and the SCADAs. Those OPC will have a double mission of communicating with the SCADA (implementing the different protocols used) and sending the same received information in a unified protocol which would be the understood by the control center. As we have defined above that the communication will be done via the internet and based in an HTTP protocol, we will have to use OPC XML DA or OPC Unified Architecture types to provide a neutral platform appropriate to internet-based data traffic.

Added to that, we find the data center which is the chore of the control center and accesses to (and can be accessed through) the VPN thanks to an optical fibre connexion. Its architecture is divided in two main parts, the servers and the databases.

The servers constitue the “engine responsible” for the functionalities of the control center. Consequently, there are different (dedicated or not dedicated) servers that cover the whole spectrum of our requirements. We need the following ones:

- Web server: receive and distribute the information via HTTP protocol.
- Remote access server: allow and control via authentication the access to the control center.
- File server: On one hand: store, associate and distribute the files from the different sources of information. On the other:create, visualize and manage the different reports generated by the system.
- Conversion server: convert different files in SQL format in order to store them

in the databases.

- Database server: provide database service (access, storage etc.) to the control center users.
- Calculation server: allow to do all the calculations needed for the business intelligence application such as the monthly cumulated generated power, the mean selling price or the maximum of the daily energy lost due to unavailability.
- Display server: coordinate input and output of the human interface machine (HMI) to and from the rest of the control center elements.
- Security server: protect the control center from external threats (malwares, non-authorized intrusions etc.).
- Backup server: data copy and restitution.

Those servers allow managing all the information defined in the previous section and to control and take action using the Business Intelligence Application.

The databases are the second part of the data center and are where all the information received is stored. We have a Real Time Database (RTDB) and a Historiacal Database (HDT) which functioning has been explained in the sources of information introduction. They are the only source of information of the Business Intelligence Application and are directly linked to the Database Server.

Finally, the two last elements of the communication infrastructure scheme are the users of the control center.

On one hand, we find the company's employees, which are the ones that use the Business Intelligence Application (BIA) and connect to the data center directly or through the VPN, depending from where they connect, with an fibre optic cable connexion.

On the other hand, we find the operator of the national electric network (REE), which is connected to the data center by a double point-to-point network, each one managed by a different mobile operator. This type of architecture is imposed by REE.

Together, all these elements constitute the control center. The communication infrastructure between them is what allows the users to have an active interaction with the managed information. Their role will be developed in the next section.

b) User interfaces: Functionalities and data management

In this part we define the graphical display of the Business Intelligence Application. The structure of the information packages is almost identical independently of the employee's hierarchy in order to simplify the navigation of the users that have access to different packages. Four screens are common to each user: Global, Historic, Forecast and Reports. The first three may be considered photography of the present, future and past performance of the assets. The last one allows the user to generate personalized reports. Every screen will be developed hereunder.

We present the interfaces in an increasing order from the hierarchical point of view, developing, for each one, the relevant specifications.

i) Wind Farm Manager

This package is only accessible for the user accredited as "plant manager" of the corresponding wind farm or for those who are higher in the company hierarchy such as the Wind Responsible, the COO or the CEO.

The Wind Farm Manager is the direct responsible of the installation and its production. Thus, in order to assure an optimal management of the farm, he has to be able to access to all the real-time information of the plant, as well as to all its historical data. He wants to know how much we are producing, how much we have produced, how much we are going to produce and why. In addition, he has to keep an eye in the economic (incomes) and mechanical (maintenance) issues of the plant.

This package will be the tool that allows the Wind Farm Manager to monitor all the different components of the production chain as well as all the different external events that happen in the day-to-day.

That said, the package structure will be divided into seven main pages. The first six ones correspond to the control center as an information management tool and are: Home

Page, Aeg (aerogenerators), Historical, Forecast, Reports and Income statement. The last page, Command, corresponds to the control center as a control tool that allows the manager to modify the performance of the wind farm. In each page the user will find the following pieces of information and features.

1 GLOBAL

It's the main page of the package and it's the first one the Wind Farm Manager will see when he accesses the control center, it is the home page of his user interface. It shows a global picture of the real-time status of the plant. It displays the following information:

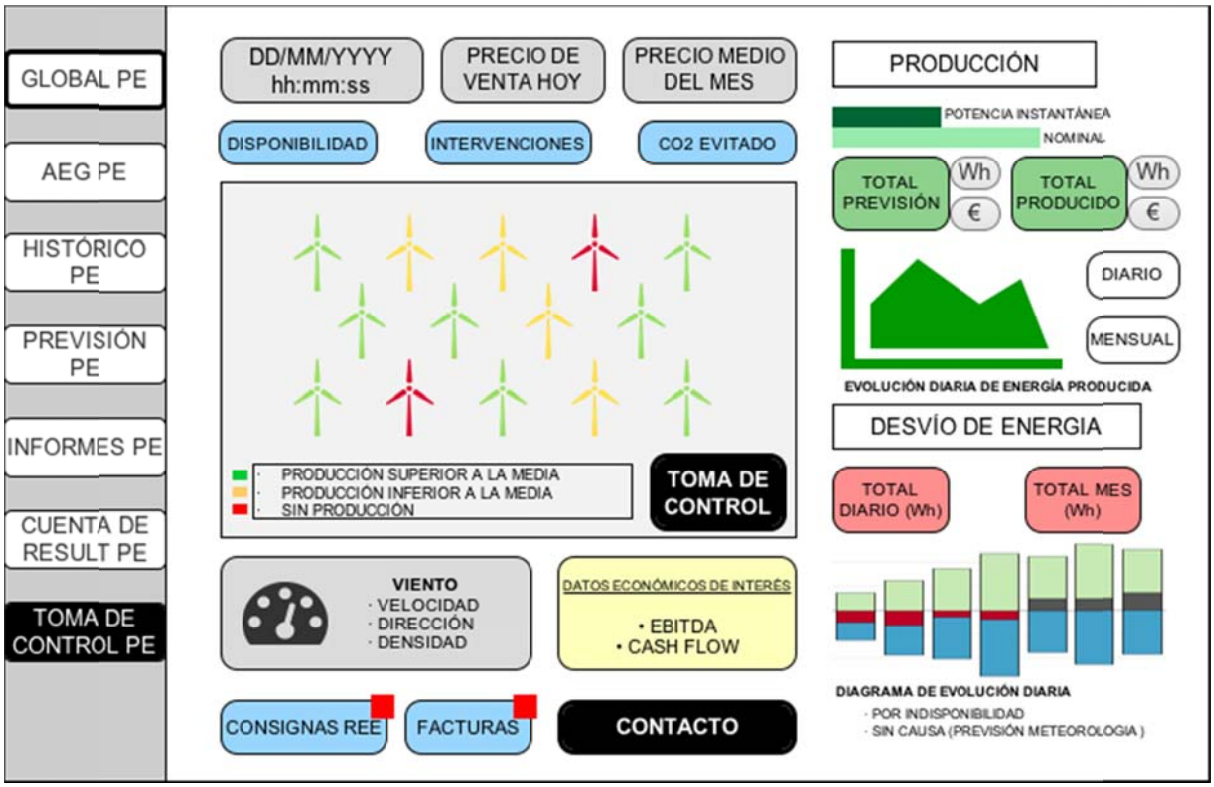

Figure 7: Wind Farm Manager Global Interface

-DAILY DATA (Grey)

In the upper left of the Global page we find the date and hour at the time of consultation of the control center as well as the actual electricity sale price or Pool price that is **extracted from OMIE's platform each hour**, and the average real sale price of the month, that is actualised **each day and comes from our Management database,** in order to compare them.

- WIND FARM MAP

Located in the middle left, it is the main part of the Global page and shows all the windmills of the farm physically disposed as in the real life field.

It provides a global and quick overview of the status of the production of the installation as it displays a colour code that informs the Wind Farm Manager which set is producing and which is not (red). Moreover, in the first group of windmills, it will show the ones that are producing what they should theoretically produce (or above) as observed in their power curve (green) and below it (orange). **The production data is obtained in the SCADA (substation energy meters) each 10 minutes and the power curves from the management database.**

It will also give direct access to the information of the aerogenerator the Wind Farm Manager will select. This information will be developed in page "AEG".

-WIND DATA (Grey)

Under the Wind Farm Map, the Manager will be able to see the real-time wind information **obtained in SCADA (anemometers of the installation) every 10 minutes**. This box will display the speed, direction and density of the wind, which are key factors that determine the production of the plant. The speed of the wind is indicated by a speedometer that will inform if this data exceeds critical values and, in consequence, a protocol has to be implemented.

The critical values are **introduced in the initiation of the control center and saved in the management database.**

- ECONOMIC DATA (Yellow)

At the bottom of the page, next to the wind information, the yellow box presents the economic data. This box will show the most important values of the most recent balance sheet such as the EBITDA and the Cash Flow. **It is obtained in the management database**.

-GENERATED POWER DATA (Green)

Located in the upper right, it is one of the main parts of the page. It regroups different information concerning the real-time, the predicted and the daily production. From top to bottom we have:

Two bars that represent the real-time power production **obtained in the SCADA (substation energy meters)** and the total capacity of the plant which is information **present in the management database**, where each bar is followed by its numerical value. The comparison between the two bars allows to quickly evaluating the instant performance of the wind farm, it represents graphically the capacity ratio.

A line chart with the power produced in the y axis and time in the x axis. Two lines are generated and can be compared, one representing the real daily production per time period **which is refreshed each 10 minutes and comes from the SCADA** and the other one representing the evolution of the planned production calculated with **the theoretical power curve and the data from the Management database with the reports from the weather forecasting agent refreshed 8 times each day**. Moreover, next to the chart we find the numerical values for the cumulated power produced and the predicted one. This information allows the Manager to assess the daily performance of the installation and the accuracy of the forecast. It also makes easy to spot the gaps where the status of the production has been more critical, thus, where to focus the research effort in order to find the causes and to optimize the production of electricity. Finally, we have the option to change from daily to monthly production, in consequence the x axis will represent the days of the month and the information of the real production and the past forecasts will be **extracted from the management database**. The main objective and utility of the monthly comparison stays the same than the daily one.

-ENERGY DEVIATION DATA (Red)

Following the previous part, in the lower right, the difference of the energy produced between the forecast and the real data is presented. We call this difference the energy deviation.

First of all, we find the numerical value of the daily energy deviation, which is the **difference between real production founded in the SCADA (substation energy meters) and forecast given 8 times a day by the weather forecast agent (weather forecast agent**

reports), in watt hours and its equivalent in euros, which is obtained with the price of the national electric market for today **extracted from OMIE's web platform each hour.** This value represents the negative deviation, which is considered a loss. If the wind farm has produced more than predicted, this box will display the number zero (if the deviation is positive it will be considered production and will be shown in the previous chart). This information complements the production chart as it materializes the difference between the two curves, directly giving to the manager the impact of the performance of the wind farm in the energy we are able to sell.

In the bottom of the page we have a bar chart, with watt hours in the y axis and time in the x axis. This chart displays the energy deviation during the course of the day. Each bar is divided in two, one part represents the energy deviation due to the unavailability of one or more sets **calculated with three values : the time of maintenance that windmills have undergone which is given by the SCADA (time the aerogenerator switch is in maintenance mode) and the time the switch was on "On" but the SCADA showed null production, the characteristics of the wind during those periods from the SCADA (anemometric towers) and the power curve of the windmill from the management database.** The other part shows the deviation caused by the power curve breach, where the power curve represents the theoretical production of installation with a given wind and it is **found in the management database and it is calculated comparing these theoretical values with the real production given by the SCADA (substation energy meters) and refreshed each 10 minutes**. The bars can be positive or negative, independently of the nature of the deviation. This chart allows the Manager to quickly evaluate which factor has been more damaging in the critical situations where the energy deviation has been more important.

As in the previous production chart, the display can we switched to monthly energy deviation data, with the same consequences than before in the source of information as **data is extracted from the management database**. **Deviation will be calculated by day and the numerical values will be the total cumulated of the month.**

-STATUS INFORMATION (Blue)

Spreaded throughout the page, inside blue boxes, we find the different numerical values that represent the principal characteristics of the daily functioning of the wind farm.

Above the wind farm map, we find the availability of the plant, that is to say, the

percentage of windmills that are producing which i**s found in the SCADA by subtracting the aerogenerators with no production and dividing by the total of windmills**. Next to this value we have the number of technical interventions that have been made through the day **presented in the management database** and the avoided CO2 emissions thanks to the production of renewable energy of our plant which is **calculated from the amount produced shown in the SCADA each 10 minutes and the equivalent emission if the same amount had been produced by non-renewable sources obtained in the management database**.

-ALARMS

At the bottom left of the page we find two checkboxes that will pop-up if new alarms linked to the operation of the wind farm, **obtained in the REE web platform**, or new bills appear (**punctual information uploaded on the management database**).

- CONTACT AND COMMAND

Finally, we observe two black buttons which are the contact (Contacto) and command (toma de control). The first one displays the postal address of the wind farm and the name, job, telephone number and de email address for every employee of the plant (responsible, operators…). The second one is an access button to the "Command" interface that allows the user to modify the operation parameters of the wind farm and that we will present later.

2. AEG

This page allows the Manager to access to all the technical information that reflects the performance of every windmill of the plant and of the components linked to them (SET). It is accessible from the left column of the control center interface or if the user selects the respective windmill icon in the wind farm map from the global page.

2.1 MAIN SCREEN

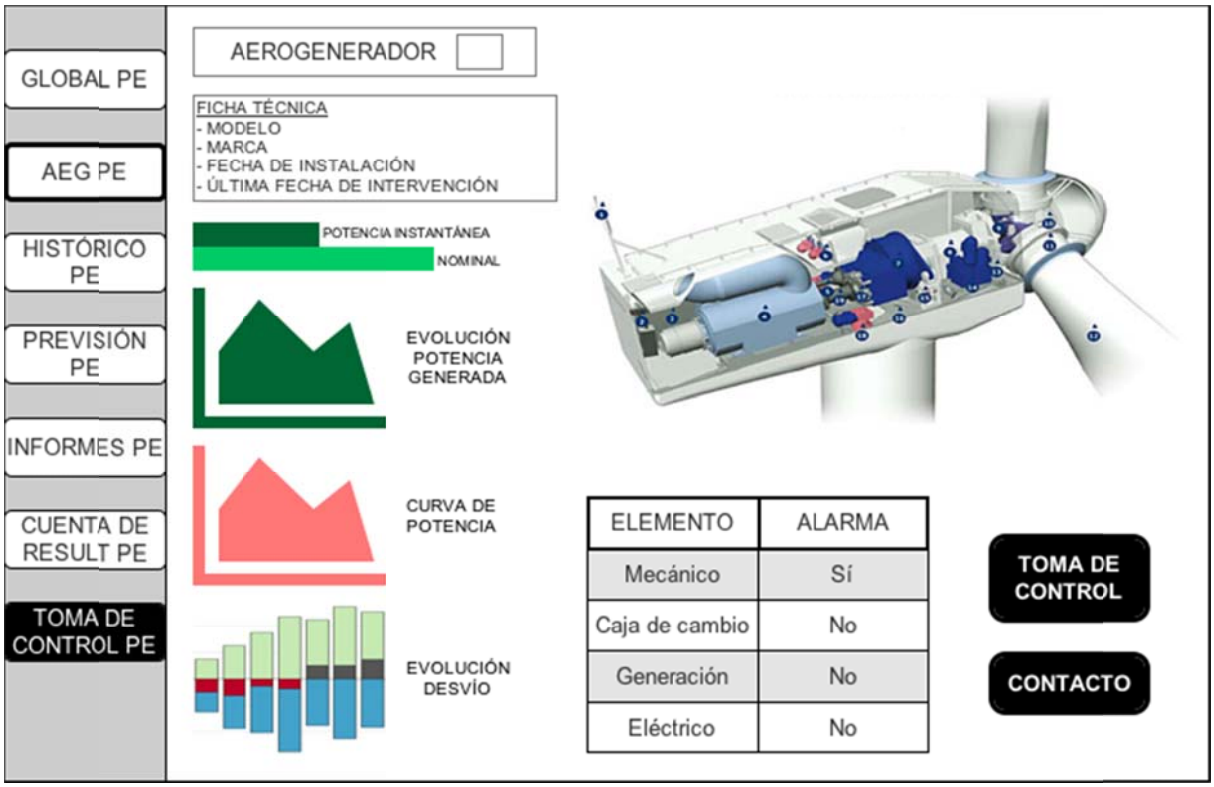

Figure 8: Wind Farm Manager Wind Turbine Interface-Main Page

-SELECTION

The Manager is allowed to select individually the windmill he wants to evaluate or to generate the data for the entire wind farm. This function is accessible from the upper left of the page. Once the selection done, the control center will display the data as follows.

- DATA SHEET

In the upper left, just under the selection box, we find the datasheet of the windmill where the model, the brand and the installation date are specified, **all this information is in the management database.** Moreover, the date of the last intervention linked to any kind of maintenance is displayed and extracted from the **database (bunker)**.

- GENERATED POWER DATA (Green)

Occupying half of the left side of the page, we find the information about the individual real-time and daily production of the windmill which keeps a parallelism with what we have shown in the global page. From top to bottom we have:

Two bars that represent the real-time power production **obtained in the SCADA (substation energy meters) each 10 minutes** and the total capacity of the windmill from the **management database**, where each bar is followed by its numerical value. The comparison between the two bars allows to quickly evaluate the instant performance of the windmill.

A chart that represents the evolution of the daily production of the windmill **obtained by the SCADA** It is defined by watt hours in the y axis and time in **10 minute periods** in the x axis. This information allows the Manager to assess the daily performance of the windmill and the individual contribution to the whole wind farm result. It also makes easy to spot the gaps where the status of the production has been more critical, thus, where to focus the research effort in order to find the causes and to optimize the production of electricity. We have the option to change from daily to monthly production, in consequence the x axis will represent the days of the month and **the information of the real production will be extracted from the wind farm**. The main objective and utility of the monthly comparison stays the same than the daily one. Finally, next to the chart we find the numerical value of the total cumulated in Wh.

Just under this chart, we find another one that represents the power curve **from the management database** of the windmill that shows the power generation of the unit for given wind characteristics. This chart opposes the theoretical curve to the real daily curve **from the SCADA (substation energy meters)**. It also has the possibility to show monthly real curve that would be extracted **from the management database.** The difference between them is the energy deviation caused by the power curve breach which is represented in the bar chart in its right and which we would explain hereunder. This opposition gives the opportunity to quickly estimate if something wrong is happening to the unit as its performance moves away from the ideal one.

- ENERGY DEVIATION DATA (Multicolour)

At the lower-left part of the page we have a bar chart, with watt hours in the y axis and time in the x axis. This chart displays the energy deviation during the course of the day. Each bar is divided in two, one part represents the energy deviation due to the unavailability of the windmill **calculated with three values: the time of maintenance that the selected windmill has undergone which is given by the SCADA (time the aerogenerator switch is in maintenance mode), the characteristics of the wind during those periods from the**

SCADA (anemometric towers) and the power curve of the windmill from the management database. The other part shows the deviation caused by the power curve breach, where the power curve represents the theoretical production of the sets with a given wind and it is **found in the management database and it is calculated comparing these theoretical values with the real production given by the SCADA (substation energy meters) and refreshed each 10 minutes**. The bars can be positive or negative, independently of the nature of the deviation. This chart allows the Manager to quickly evaluate which factor has been more damaging in the critical situations where the energy deviation has been more important.

As in the previous production chart, the display can we switched to monthly energy deviation data, with the same consequences than before in the source of information as **data is extracted from the management database**. **Deviation will be calculated by day and the numerical values will be the total cumulated of the month.**

-AEG DISPLAY AND SCADA DATA TABLE

Occupying the whole right part of the screen we find two important elements that are correlated and show us valuable technical information **directly obtained by the SCADA**.

The first one, in the top, is the display of the aerogenerator that schematically presents the different parts of the windmill: the mechanic part (blades, rotor, orientation engine…), the gearbox, the generation part (transformer…) and the electrical part. The elements which scada values are out of the correct interval are shown in a different colour. In additions, each element is a link to its "SCADA data page" that we will introduce later.

The second one, in the bottom, is a table that resumes the elements of the wintrubine presented in the scheme. It displays the name of the parts of the windmill accompanied by another column that indicates if there is some SCADA value that is in the correct interval. Each name also is a direct link to its "SCADA data page".

-CONTACT AND COMMAND

Finally, we observe two black buttons in the right bottom of the page, which are Contact (Contacto) and Command (toma de control).

The first one displays the address of the wind farm and the name, job, telephone number and de email address for every employee of the plant (responsible, operators…). **This information is extracted from the Management Database.**

The second one is an access button to the "Command" interface that allows the user to modify the operation parameters of the windmill that has been selected. This screen, that is also accessible from the right column of the interface, will be presented later in the last section of this package that corresponds to the Wind Farm Manager.

2.2 SCADA DATA PAGE

This screen is accessible from the main AEG page selecting one of the parts of the aerogenerator in the AEG display or in the table. The objective of this screen is to break down each element of the selected part that has a **corresponding SCADA value**.

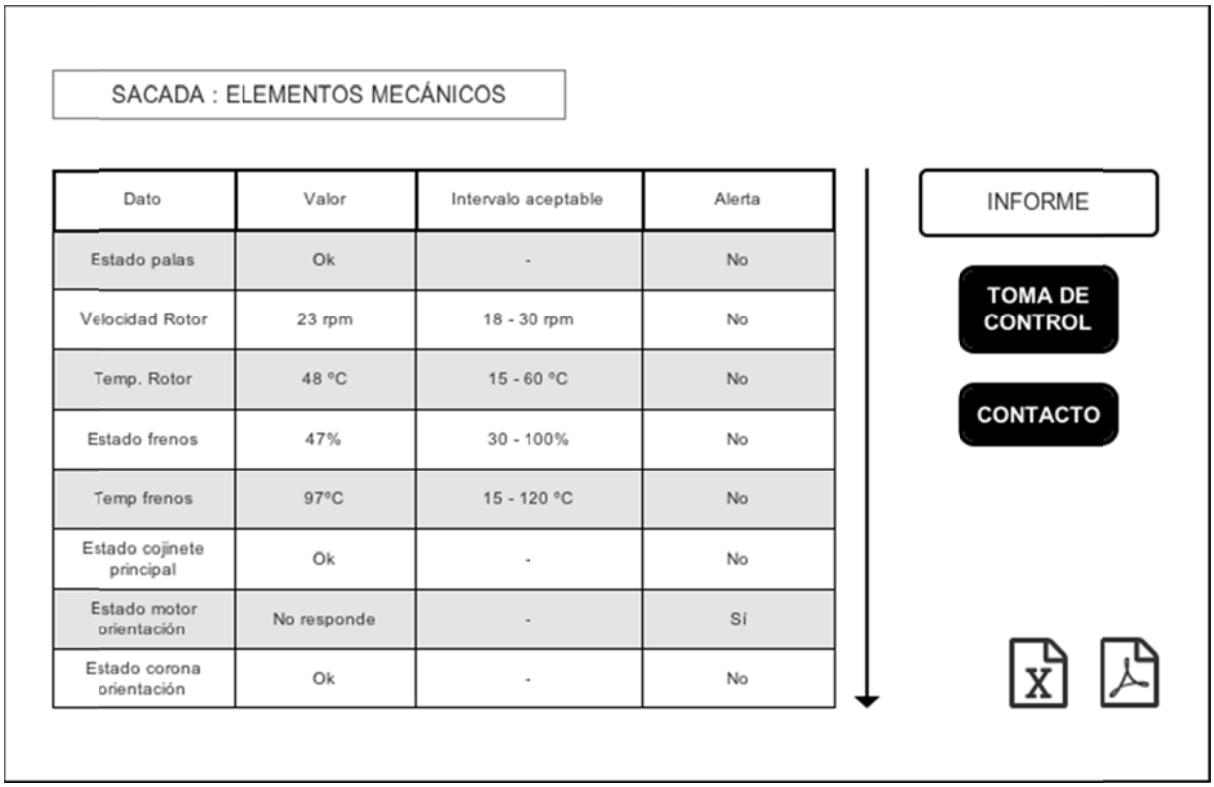

Figure 9: Wind Farm Manager Wind Turbine Interface- SCADA data page

First of all, we observe a table, that occupies nearly all the page, which is divided in four columns: the name of the element which data is controlled, the real value, the acceptable

interval and the last one that show if the alert corresponding to an abnormal value has been notified. This table can be exported to excel or pdf.

Moreover, in the right part of the screen we find three buttons that are direct links to different functions. The first one "report" sends the user to the "SCADA" report page in order to easily manipulate all the different values and to personalise the time interval and the charts the manager wants to generate (report section will be explained hereunder). The other two black buttons have the same function than in the principal page, giving access to the email address and telephone of the plant workers (contact) and to the interface that allows the user to directly control the operation characteristics of the aerogenerators (command).

3. HISTORICALS

This page allows the Manager to access to the historical (past) data that reflects the operational performance of the wind farm. It is accessible from the left column of the control center interface.

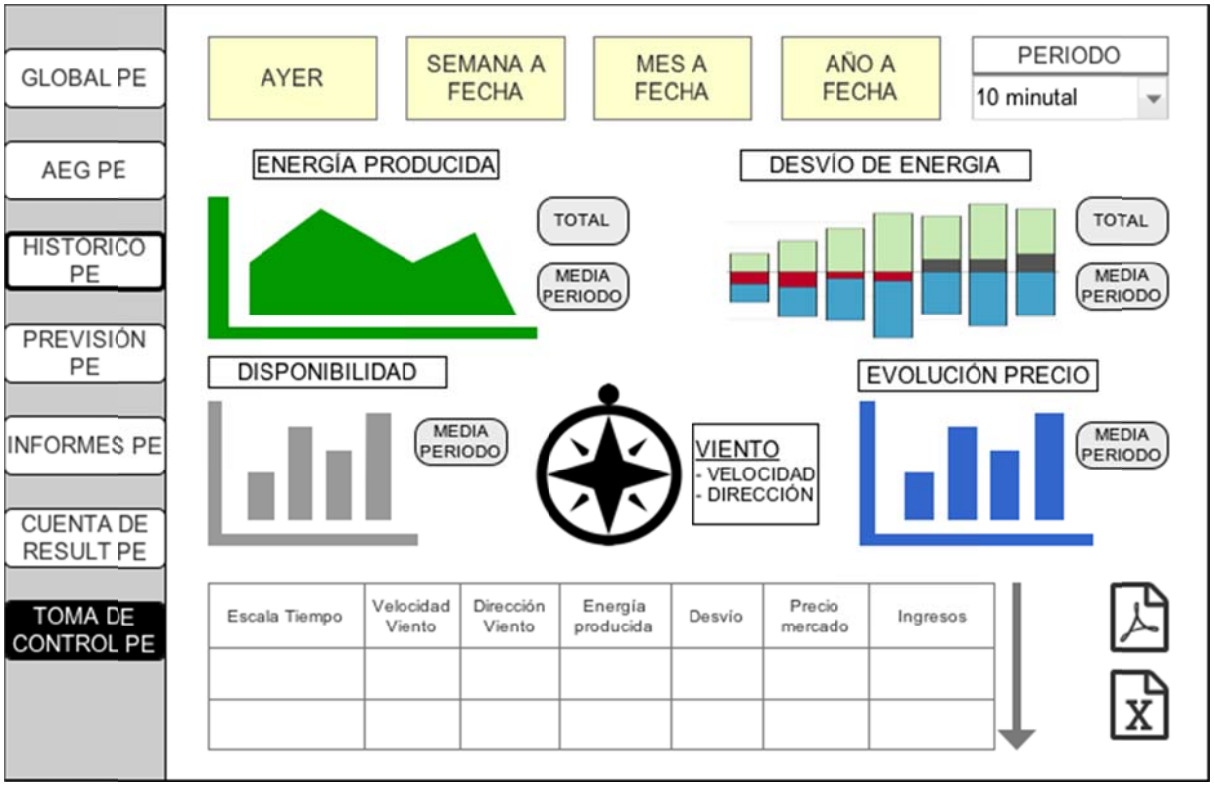

Figure 10: Wind Farm Manager Historical Interface

- SELECTION

Just as you access to the page, in yellow, on the top of the page and horizontally displayed, the Manager is able to select the time interval in which the data will be subtracted from the databases. The interval is chosen by clicking on the "yesterday" (the last 24h are considered), "week to date" (the last seven days are considered), "month to date" (the current month is considered) or on the "year to date" (the current year is considered) button.

Just after the yellow time interval selection buttons, in the upper right corner of the page, the user is able to select the "period" which corresponds to the time grouping (the quantity of time that corresponds to an individual value). If the user has selected the yesterday time interval, he can choose between the 10-minute and hourly period. If he has selected the week time interval, he can choose between the hourly and daily period. If he has selected the month time interval, he can choose between daily and weekly period. Finally, if he has selected the year time interval, he can choose between daily, weekly and monthly period.

-CHARTS AND SCHEMES

Just under the selection elements and once the time selection done, one line chart, three bar charts and a wind rose are generated. They are the chore of the historical page. They synthesize all the data presented in the table that is under them which we will present hereunder in the section "Data table". **As this page shows past data, all the information used will be obtained from the company's database (SCADA data transferred to databases) and used to generate different graphics and to calculate the total and the mean of the values during the selected time period**.

In order from top to bottom and right to left, we find:

*The_energy production line chart_*(in green), with watt hours (and euros) in the y axis and time in the x axis, that gives us the evolution of the production of the wind farm connecting the points that represent the real production for each time period. It is accompanied by two numerical values: the total cumulated and the average of the time interval.

The energy deviation bar chart (in green and blue), with watt hours in the y axis and days in the x axis, that displays the energy deviation during the course of the time interval.

Each bar is divided in two, one part represents the energy deviation due to the unavailability of one or more sets calculated with three values : the time of null production, the wind characteristics during this time and the power curve of the windmill/wind farm. The other part shows the deviation caused by the power curve breach, where the power curve represents the theoretical production of the windmill with a given wind (it is calculated comparing the theoretical power curve and the real production). It is accompanied by two numerical values : the total cumulated and the average of the time interval.

The availability bar chart (in grey) with a scale from 0 to 100 in the y axis and days in the x axis, that shows the average percentage of windmills producing each day. This value is obtained counting the number of aerogenerators whose substation energy meter displays a positive production. It is accompanied by the numerical value of the average of the time interval.

The wind rose that informs about the velocity and direction of the wind recorded during the period studied. The direction is directly observed in a wind rose, velocity is determined by a color code as shown in the image above and the occurrence of a couple direction-soeed (the percentage that represents combination of one value of each characteristic) is determined by the area occupied by the corresponding color in the corresponding direction. The manager has the possibility to see this percentage when the pointer is above the area. The wind rose is accompanied by the numerical value of the average velocity of the time interval.

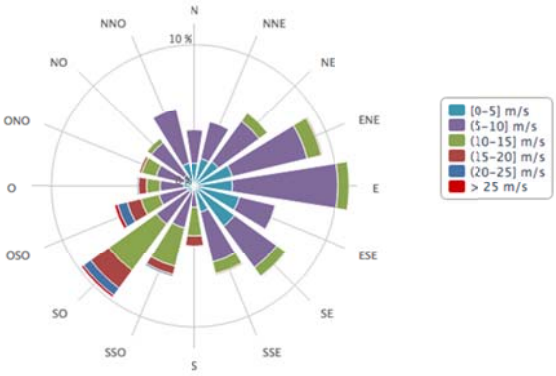

Figure 11: Diagram of the wind speed Rose. Source: REE

The price evolution bar chart (in blue), with price in the y axis and days in the x axis, that informs about the price of the wind technology in the spanish market in each day of the period. It is accompanied by the numerical value of the average price of the period.

-DATA TABLE

It occupies all the rest of the page and contains, for each time unit (time grouping), the corresponding values of the graphics displayed above:

- Velocity of the wind
- Direction of the wind
- Energy produced
- Energy deviation
- Market selling price
- Incomes linked to the energy sale

The wind farm manager can export the charts and the data table to excel or PDF by clicking on icons on the right bottom of the screen.

4. FORECAST

This screen allows the Manager to access to the predicted data that reflects the expected operational performance of the wind farm. It is accessible from the left column of the control center interface by clicking in the corresponding button.

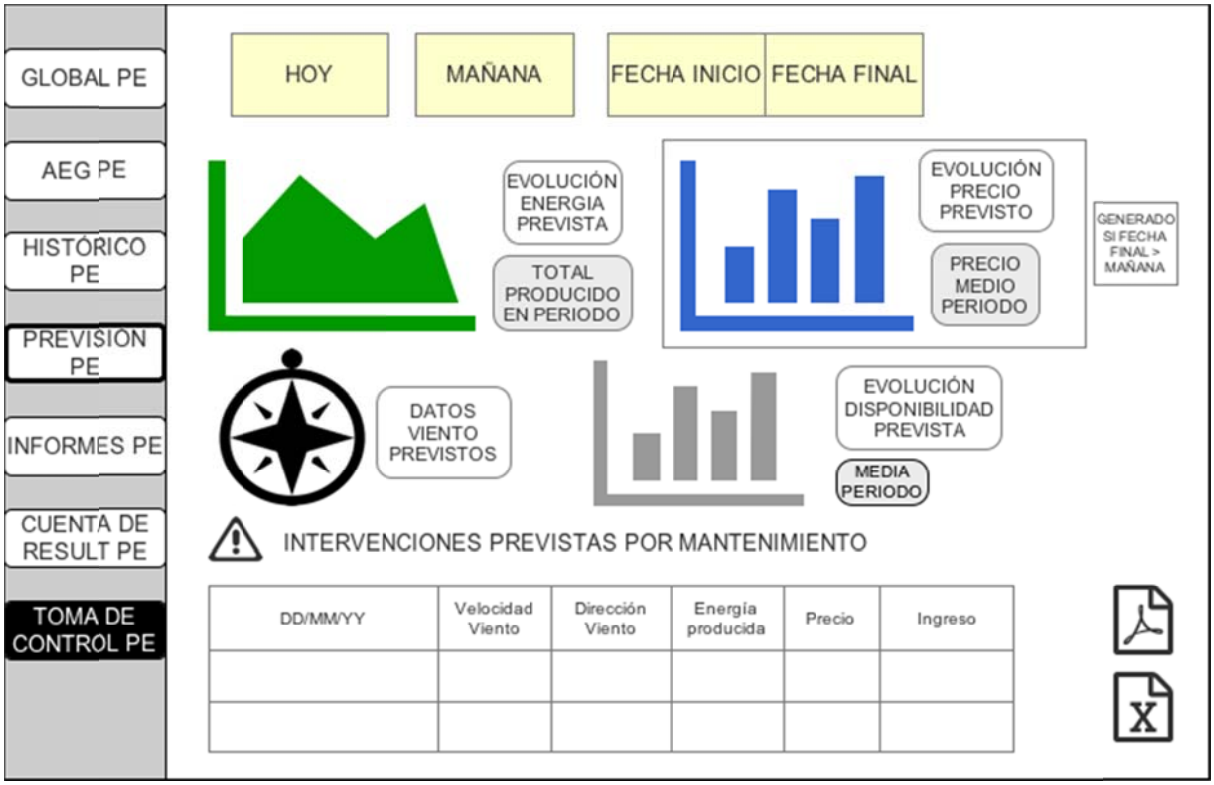

Figure 12: Wind Farm Manager Forecast Interface

-SELECTION

In yellow, on the top of the page and horizontally displayed, the Manager is able to select the time interval in which data would be considered for the forecast. The interval is chosen by clicking on the "today" (the remaining hours of today are considered) or on the "tomorrow" (the 24 hours of tomorrow are considered) button. The other possibility is selecting the initial and the final date of the interval (with a maximum of ten days between today and the finish date). The data will be displayed for each hour included in the selected interval.

-CHARTS AND SCHEMES

Just under the selection elements and once the selection done, we find one line chart, two bar charts and a wind rose that are the chore of the forecast page. They synthesize all the data presented in the table that is generated after the selection of the time interval and which we will present hereunder in the section "Data table". **As this page shows predicted data, the information comes from the crossing between the weather forecasting agent report (management database), the predicted price from OMIP (official web page) and technical information from the management database.** In order from top to bottom and right to left, we find:

The_energy production line chart (in green), with watt hours (and euros) in the y axis and hours in the x axis, gives us the evolution of the production of the wind farm connecting the points that represent the predicted production for each hour. It is calculated with the predicted wind and the theoretical technical characteristics of the aerogenerators (from the database). It is accompanied by the numerical value of the total cumulated during the time interval.

The price evolution bar chart (in blue), with price in the y axis and days in the x axis, that informs about the expected price of the wind technology in the spanish market in each hour of the period. It is accompanied by the numerical value of the average price of the period. Note that this graph will only appear if the time interval has a finish date greater than "tomorrow".

The wind rose that informs about the velocity and direction of the wind predicted by the weather forecasting agent during the period studied. The direction is directly observed in

a wind rose, velocity is determined by a color code as shown in the image above (cf historical page) and the occurrence of a couple direction-velocity (the percentage that represents combination of one value of each characteristic) is determined by the area occupied by the corresponding color in the corresponding direction. The manager has the possibility to see this percentage when the pointer is above the area. The wind rose is accompanied by the numerical value of the average velocity of the time interval.

The availability bar chart (in grey) with a scale from 0 to 100 in the y axis and days in the x axis, that shows the average percentage of windmills expected producing each day. This value is obtained subtracting the number of aerogenerators that would undergo any kind of maintenance or other operation that would stop the production. It is accompanied by the numerical value of the average of the time interval.

-DATA TABLE

It occupies all the rest of the page and contains, for each hour, the corresponding values of the graphics displayed above :

- Velocity of the wind
- Direction of the wind
- Energy produced
- Market pool
- Incomes linked to the energy sale

The charts and the data table can be exported to excel or PDF by the wind farm manager clicking on the corresponding icons on the right bottom of the screen.

5. REPORTS

This section is the one that allows the wind farm manager to directly interact with all the information generated in the installations. It is where the added value of the control center resides as it gives the opportunity to manipulate all the elements from different points of views in order to personalise reports with a maximum of useful information for the user. It is accessible from the left column of the control center interface by clicking in the corresponding button.

5.1 HOME PAGE

The home screen of this section is the one that shows the standard reports that can be generated by the user. The page is divided in three principal boxes : selection (Selección), time grouping (Intervalo temporal) and reports (Informe).

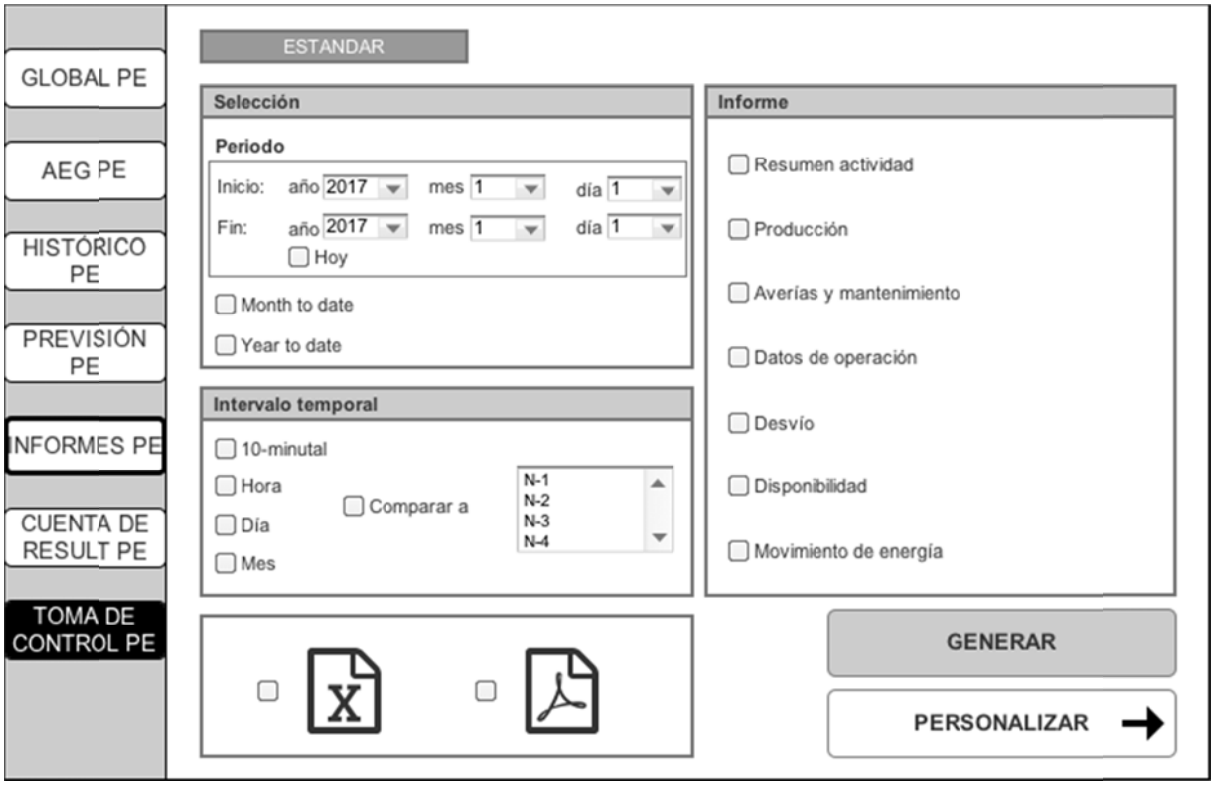

Figure 13: Wind Farm Manager Reports Interface-HomePage

-SELECTION

In this box, the user has to choose the time interval in which the data will be subtracted from the databases. He has three options, selecting the initial and final date (where you can select "today" for the final one thanks to a checkbox), selecting "Month to date" (all the days of the current month will be considered) or selecting "Year to date" (all the days of the current year will be considered).

-TIME GROUPING

In this box, the user has to choose **the time period which corresponds to the time grouping (the quantity of time that corresponds to an individual value)**. There are four options: **10-minute (not choosable if the time interval is greater than a week), hour (not**

choosable if the time interval is greater than 31 days), day and month.

In addition, the user can choose to compare, in the "comparar a" checkbox, the values of the selected time period with the same interval of the past years (selected by clicking on n-1, n-2 etc).

-REPORTS (standard reports)

In this box, the user can choose between seven different reports that, although they are standardised, provide specific information about key topics of the management of the wind farm. The reports are structured as follows:

- Activity Summary (Resumen actividad)

It is the report directly linked with the asset management. It displays the economic data from the electric market and the electricity produced by the wind farm. **All the information is obtained in the management database and in the OMIE online platform.** It generates a table with the following data for each time grouping unit :

  - Real final selling price, budgeted selling price and the variation between them.
  - Real production, budgeted production and the variation between them.
  - Real final income, budgeted income and the variation between them.
  - Market pool (PMD), Sector pool, Deviation penalty, Kurtosis coefficient.

In addition, the three first points are accompanied by a double line chart that shows the evolution of the values (real and budgeted) throughout the selected time period.

- Production (Producción)

This report is the technical continuation of the activity summary as it deepens in the production factors and in the optimization of the asset. It is focused on the installation performance and not on the electric market. **All the information initially comes from the SCADA of the wind farm and is extracted from the management database where it has been stored.** It generates a table with the following data for each time grouping unit :

- Wind farm :
  - Real production, budgeted production and the variation between them.
  - Real final income, budgeted income and the variation between them.
  - Selling price and capacity factor.
- For each aerogenerator :

- Real production, theoretical production (calculated with the power curve as in the AEG page) and the and the variation between them.
- Generating hours (hours it has been producing electricity)
- Availability (in percentage)
- Production / swept area coefficient
- Production / nominal power
- Capacity factor

In addition, the two first points of the wind farm list and the first point of the aerogenerator list are accompanied by a double line chart that shows the evolution of the values (real and budgeted) throughout the selected time period.

- Failures and maintenance (averías y mantenimiento)

This report aims to provide a global view of all the issues linked to mechanical breakdowns and maintenance work that have interfered in the normal production of the wind farm in order to identify the principal problems where the manager has to focus his actions. **All the information is obtained from the SCADA** (the aerogenerators are puted in maintenance mode or do not generate any power) **and from the management database of the wind farm where all the reports complemented by the technicians are stored.** It generates a table with the following data :

- Wind farm :
  - Time employed in predictive, preventive and corrective maintenance
  - The total of time employed in all types of maintenance
  - Average response time
  - Time unavailable (time not producing when it was planned to because of maintenance work and any kind of technical failures)
  - Average wind during maintenance
  - Energy lost during maintenance
- For each aerogenerator :
  - List of all the maintenance work the aerogenerator has undergone during the selected time period :
    - Date of failure / maintenance work
    - Description of the failure / maintenance work
    - Time employed (counting the response time)

- Time unavailable
- Energy lost

In addition, the first points of the wind farm list are accompanied by a bar chart that shows the total amount of time spended on each type of maintenance (the percentage of the total maintenance time they represent). Moreover, the energy lost due to technical issues, of the wind farm and for each aerogenerator, has its evolution during the selected time period represented by a line chart.

- Operation data (Datos de operación)

This report displays the data linked to the technical performance of the plant regardless of the economic data or the budget fixed for the wind farm. The machines and their elements are the central part. **All the information is obtained from the management databases (where the historical information from the SCADA and the technical data is stored).** It generates a table with the following data for each grouping time unit :

- Characteristics of the wind : velocity, direction (density and temperature)
- Real and theoretical generated power (power curve) for each aerogenerator
- SCADA values out of the acceptable interval (with the information about the time it has been out of it and if maintenance work has been needed)

In addition, the characteristics of the wind are showed in a wind rose similar to the one presented in the historical screen. Moreover, the real and theoretical generated power is accompanied by the theoretical vs real power curve represented by a line chart.

- Deviation (Desvío)

This report concerns the difference between the forecasted production and the real one which we call deviation. Although other reports displays the difference of those two elements, this report displays the information making another calculus **with the information from the SCADA (only counting where the switch of the aerogenerator is not in maintenance or off mode) stored in the management database**. It shows for each aerogenerator, for each grouping time unit :

- The energy lost in the periods where the machine was disponible (due to the non respect of the power curve).

Finally, to each aerogenerator there is a bar chart of the energy lost throughout the selected time period.

- Availability (Disponibilidad)

This report displays all the information linked to the state of the aerogenerator in order to evaluate how much time an aerogenerator has been working and the causes if it has not been. The disponibility is a key factor in the accuracy of the budgetisation of the wind farm production. **All the information is obtained from the management databases (where the historical information from the SCADA and the technical data are stored).** It generates a table with the following data for each grouping time unit :

- For each aerogenerator :
    - Time with absence of data about the generated active power
    - Time with unavailability errors
    - Time with voltage absence
    - Time with planned manual stops
    - Time with no generation but with enough wind
    - Time with maintenance work in the machine

In addition, a global bar chart that shows the average availability of each aerogenerator and the energy lost by its unavailability is generated with the previous table.

- Energy movement (Movimiento de energía)

The last standardised report concerns all the energy flows, influx and outflux, during the selected time interval in the wind farm. As the installation consumes energy, it is interesting for the manager to evaluate the net energy produced and, in consequence, the real performance of the plant. **The information is obtained from the management databases (where the historical information from the SCADA and the energy bills are stored).** It generates a table with the following data :

- Energy generated
- Energy consumed by the aerogenerators
- Energy consumed in the control building
- Reactive power flow and energy lost in the wind mill

In addition, each point is accompanied by a line chart that shows the evolution of the value throughout the selected time period.

- GENERATION

Finally, after the time interval, the time grouping and the report selection done, the

user has the possibility to choose between two document formats for the generation of the final report : excel or pdf. This selection is made on the checkboxes present in the low left corner of the screen. Once this last choice has been made, the user has to click in the button “Generation” (Generación) in the low right corner. Once done, the selected report(s) will be generated.

5.2 - PERSONALISATION

However, this section does not end with the possibility of generating different standardised reports, but the wind farm manager has the option to configure its own completely personalised report, adding a whole new aspect to the control center. The personalisation is accessible from the reports home page (5.I) if the user selects the button “Personalisation” (personalización) in the lower right corner.

Once the button is selected, different screens will succeed each other on the user interface and will allow the manager to select and manipulate each data in order to maximize the utility of the information contained in the future report. The personalisation screens are structured as follows:

A. SELECTION

This first screen has a similar structure to the home page of this report section as it allows making the first selections related to the time interval and the time grouping.

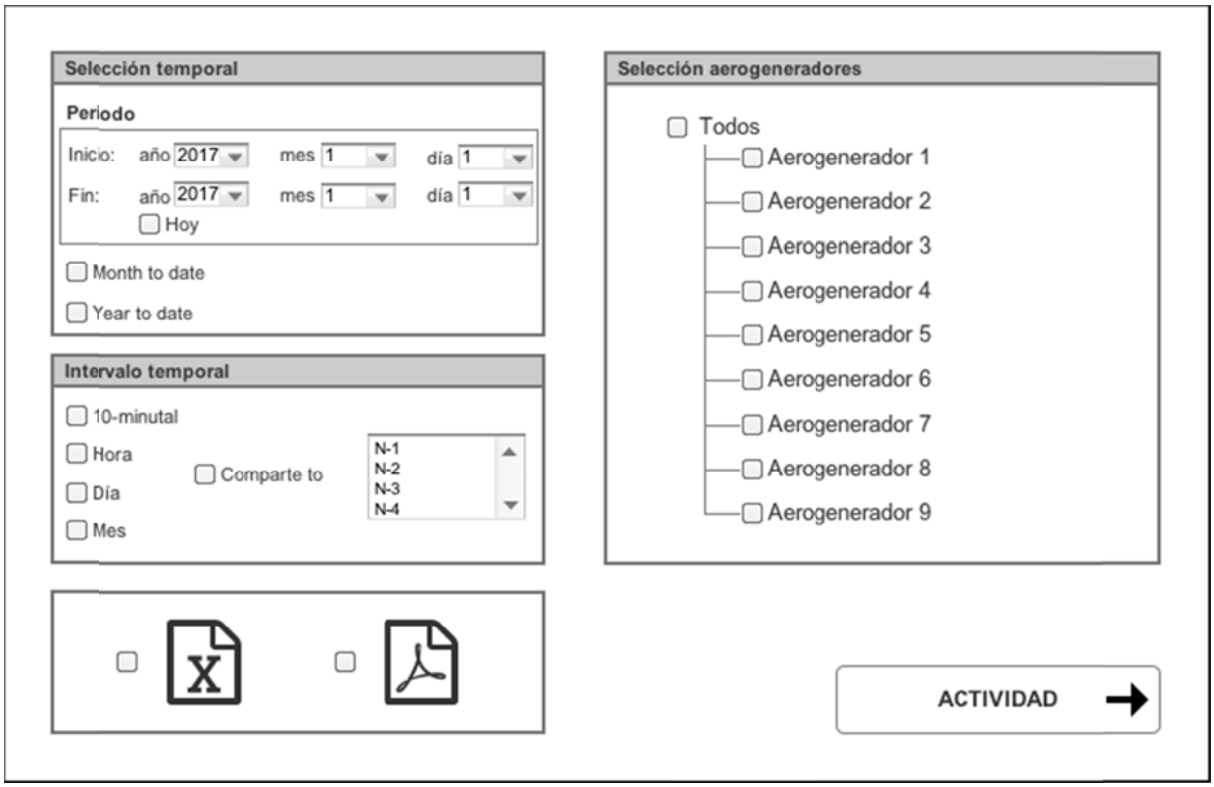

Figure 14: Wind Farm Manager Reports Interface-Personalisation-Selection

The left part of the screen is the same that the one explained hereinabove. There are three boxes that are, from top to bottom:

The time interval selection : In this box, the user has to choose the time interval in which the data will be subtracted from the databases. He has three options, selecting the initial and final date (where you can select "today" for the final one thanks to a checkbox), selecting "Month to date" (all the days of the current month will be considered) or selecting "Year to date" (all the days of the current year will be considered).

The time grouping selection: In this box, the user has to choose **the time period which corresponds to the time grouping (the quantity of time that corresponds to an individual value)**. There are four options : **10-minute (not choosable if the time interval is greater than a week), hour (not choosable if the time interval is greater than 31 days), day and month**. In addition, the user can choose to compare, in the "comparar a" checkbox, the values of the selected time period with the same interval of the past years (selected by clicking on n-1, n-2 etc).

The document generation box: In this box, the user has the possibility to choose

between two document formats for the generation of the final report : excel or pdf.

The right part of the screen differs from the one before. In this screen, the right box allows to user to choose what aerogenerators of the wind farm he wants to study. He has the possibility to select all in order to have a complete overview of the performance of the installation or he can select them one by one in order to focus in certain wind turbines.

Once the selection made, the user has to start the selection of the information he wants his report to display. In order to continue, he has to select the button "Activity" (Actividad) that will show the second personalisation screen.

B. ACTIVITY

Once the Activity button selected, the second personalization screen will show up. This second one is linked to the asset management and takes again the economic data from the electric market and the electricity produced by the wind farm. **All the information is obtained in the management database and in the OMIE online platform.**

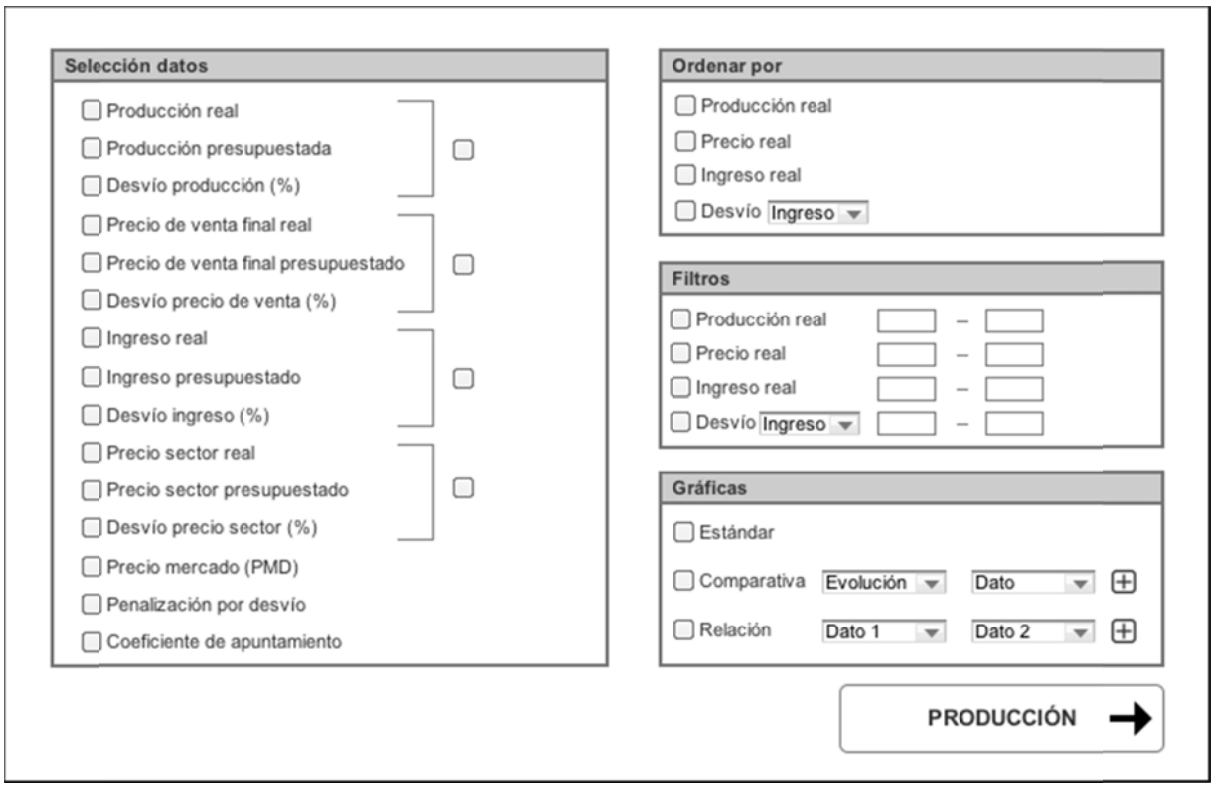

Figure 15: Wind Farm Manager Reports Interface-Personalisation-Activity

It is divided in four boxes, the first one is data selection (Selección datos), it occupies the whole left part of the screen and allows the user to select the specific information he wants to study. He can choose between the following data :

- Real production
- Budgeted production
- Variation between real and budgeted production
- Real final selling price
- Budgeted selling price
- Variation between real and budgeted selling price
- Real final income
- Budgeted income
- Variation between real and budgeted income
- Real technology pool (price of the wind market)
- Budgeted technology pool
- Variation between real and budgeted technology pool
- Market pool (PMD)
- Sector pool
- Deviation penalty
- Kurtosis coefficient

The right side of the screen displays three boxes that are, from top to bottom, the "arrange by", the "sort by" and the chart generation:

Arrange by (Ordenar por) : Allows the user to display the information selected in the table in a specific way determined by the descending order for the values of real production, real final selling price, real final income or variation between real and budgeted from the data selected.

Sort by (Filtrar): Allows the user to only display the data that has the same time and date than the values of real production, real final selling price, real final income or variation between real and budgeted from the data selected included in an introduced interval.

Charts (Gráficas): Allows the user to generate all the charts he wants giving him three different possibilities corresponding to three checkboxes. The first one is generating the standard ones (Estándar, cf Activity Report description), the second one is the comparative one (Comparativa) where the user has to select a value (one of the chosen in the data

selection) and if he wants to display the time evolution or the cumulated of the total period for this selected value. Once chosen, for each aerogenerator and for the total of the plant, a chart will show the time evolution (individual line chart) or the total (global bar chart) of this selected value. The third and last one is the relation chart (Relación) where the user has to chose two values of the selected ones before. Once chosen, a line chart will be generated with the interval of the measured values of the first selected data in the x axis and of the second data on the y axis, showing if there is a visible relation between them.

Once all the boxes completed as the user wants to, he has to click on the Production (Producción) button, marked with an arrow, which will display the next screen.

C. PRODUCTION

Once the Production button selected, the third personalization screen will show up. This third one is linked to the technical production management and deepens in the production factors and in the optimization of the asset, focusing in the installation performance. **All the information initially comes from the SCADA of the wind farm and is extracted from the database where it has been stored.**

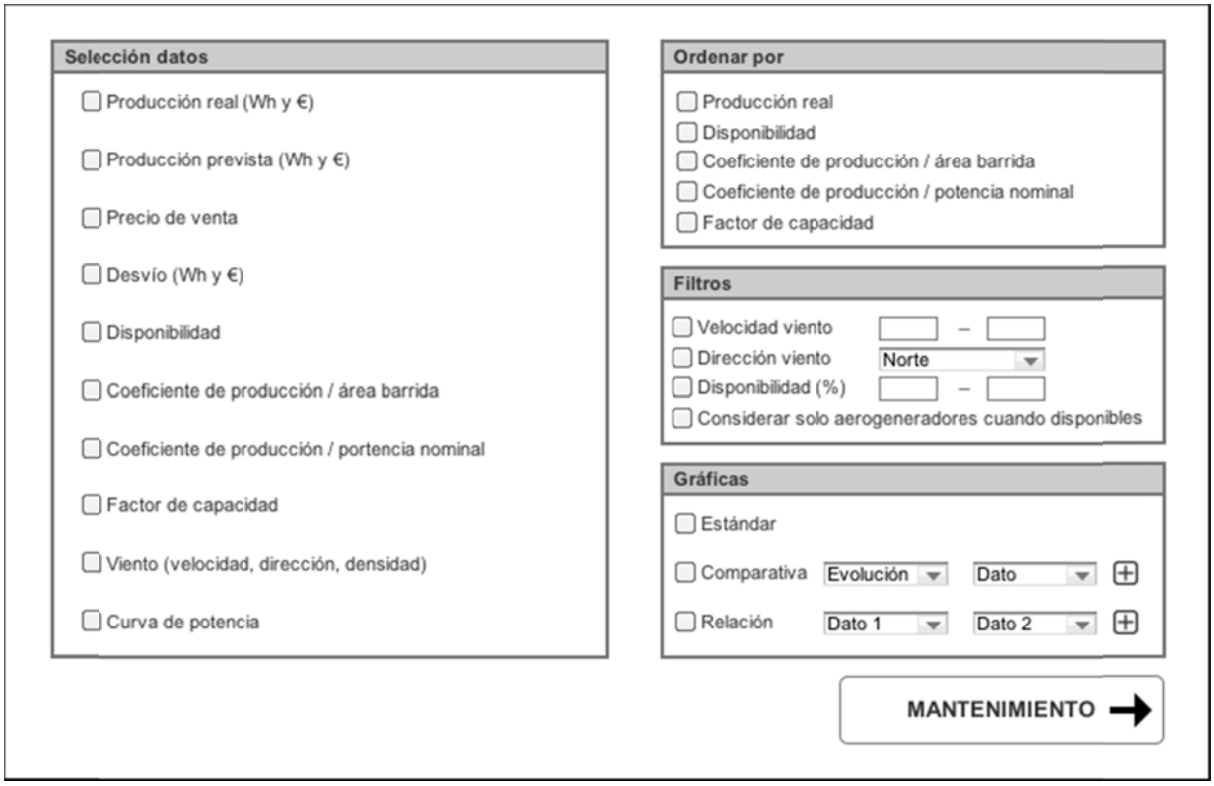

Figure 16: Wind Farm Manager Reports Interface-Personalisation-Production

It is divided in four boxes, the first one is data selection (Selección datos), it occupies the whole left part of the screen and allows the user to select the specific information he wants to study. All the values linked to production performance will be shown for the whole installation as well as for each selected aerogenerator. He can choose between the following data:

- Real production (in Wh, energy production, and in €, selling incomes)
- Budgeted production (in Wh, energy production, and in €, selling incomes)
- Variation from the real and budgeted production (in Wh and in €)
- Real selling price (only displayed for the whole installation)
- Availability (in percentage)
- Production / swept area coefficient
- Production / nominal power
- Capacity factor
- Wind characteristics
- Power curve (comparison between theoretical and real values)

The right side of the screen displays three boxes that are, from top to bottom, the "arrange by", the "sort by" and the chart generation :

Arrange by (Ordenar por) : Allows the user to display the information selected in the table in a specific way determined by the descending order for the values of real production, availability, production / swept area coefficient, production / nominal power and capacity factor.

Sort by (Filtrar) : Allows the user to only display the data that has the same time and date than the values of wind velocity, wind direction or availability included in an introduced interval. It also has the possibility to select the option "only consider the aerogenerator when available" that will change the amount of data considered and the results of the report.

Charts (Gráficas) : Allows the user to generate all the charts he wants giving him three different possibilities corresponding to three checkboxes. The first one is generating the standard ones (Estándar, cf Production Report description), the second one is the comparative one (Comparativa) where the user has to select a value (one of the chosen in the data selection) and if he wants to display the time evolution or the cumulated of the total period

for this selected value. Once chosen, for each aerogenerator and for the total of the plant, a chart will show the time evolution (individual line chart) or the total (global bar chart) of this selected value. The third and last one is the relation chart (Relación) where the user has to chose two values of the selected ones before. Once chosen, a line chart will be generated with the interval of the measured values of the first selected data in the x axis and of the second data on the y axis, showing if there is a visible relation between them.

Once all the boxes completed as the user wants to, he has to click on the Maintenance (Mantenimiento) button, marked with an arrow, that will display the next screen.

D. MAINTENANCE

Once the Maintenance button selected, the third personalization screen will show up. This third one is linked to all the issues linked to mechanical breakdowns and maintenance work that have interfered in the normal production of the wind farm in order to identify the principal problems where the manager has to focus his actions. **All the information is obtained from the SCADA** (the aerogenerators are puted in maintenance mode or do not generate any power) **and from the database of the wind farm where all the reports complemented by the technicians are stored.**

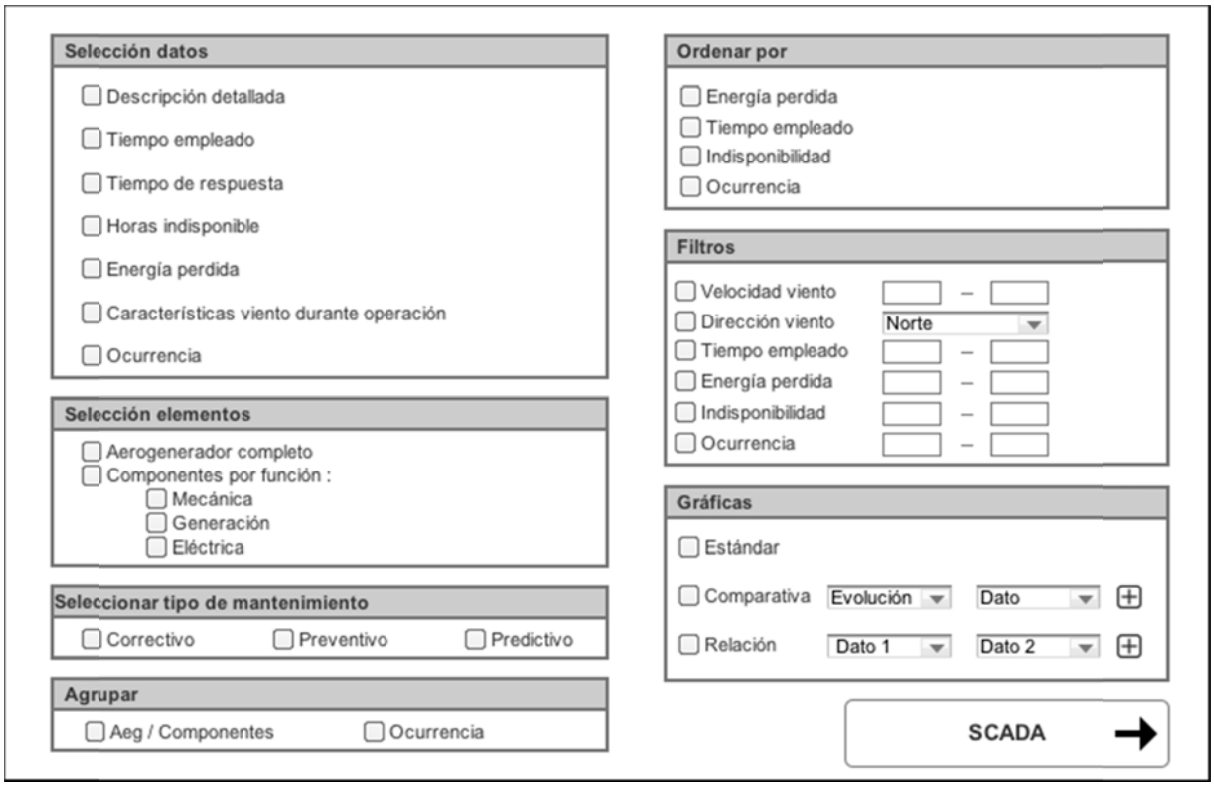

Figure 17: Wind Farm Manager Reports Interface-Personalisation-Maintenance

It is divided in seven cases, four of them are the same than in the other screens and the other ones are linked to the specification of the data studied in this section.

The first one is data selection (Selección datos), it occupies the upper left corner of the screen and allows the user to select the specific information he wants to study. The information will be displayed for each maintenance work made in the selected interval :

- Detailed description of the maintenance work
- Time employed
- Response time
- Time unavailable (time not producing when it was planned to because of maintenance work and any kind of technical failures)
- Energy lost during maintenance work
- Wind characteristics (velocity and direction) during maintenance work
- Occurrence

The left bottom of the screen displays three boxes that are, from top to bottom, the "element selection", the "maintenance type selection" and the "group by":

Element selection (Selección elementos): It allows the user to focus the maintenance information in some parts of the aerogenerator (or the whole one). The user can choose between deepen in the mechanical, the electrical or the generation part (cf Maintenance Report).

Maintenance type selection (Seleccionar tipo de mantenimiento): Allows the user to choose between the three kind of maintenance work that are done in the installation, the corrective, the preventive and the predictive one, in order to narrow the quantity of information managed.

Group by (Agrupar): Allows the user to group all the maintenance works by aerogenerators (all the maintenance information from an individual windmill will be putted together) or by occurrence (the most frequent ones are putted together)

The right side of the screen displays three boxes that are, from top to bottom, the "arrange by" box, the "sort by" box and the chart generation box:

Arrange by (Ordenar por): Allows the user to display the information selected in the

table in a specific way determined by the descending order for the values of energy lost, time employed, time unavailable and occurrence.

Sort by (Filtrar): Allows the user to only display the data that has the same time and date than the values of wind velocity, wind direction, unavailability, time employed, energy lost or occurrence included in an introduced interval.

Charts (Gráficas) : Allows the user to generate all the charts he wants giving him three different possibilities corresponding to three checkboxes. The first one is generating the standard ones (Estándar, cf Maintenance Report description), the second one is the comparative one (Comparativa) where the user has to select a value (one of the chosen in the data selection) and if he wants to display the time evolution or the cumulated of the total period for this selected value. Once chosen, for each aerogenerator and for the total of the plant, a chart will show the time evolution (individual line chart) or the total (global bar chart) of this selected value. The third and last one is the relation chart (Relación) where the user has to chose two values of the selected ones before. Once chosen, a line chart will be generated with the interval of the measured values of the first selected data in the x axis and of the second data on the y axis, showing if there is a visible relation between them.

Once all the boxes completed as the user wants to, he has to click on the SCADA button, marked with an arrow that will display the next screen.

E. SCADA

Once the SCADA button selected, the fourth personalization screen will show up. This fourth one is linked to the technical performance of the plant regardless of the economic data or the budget fixed for the wind farm. The machines and their elements are the central part. **All the information is obtained from the management databases (where the historical information from the SCADA and the technical data is stored).**

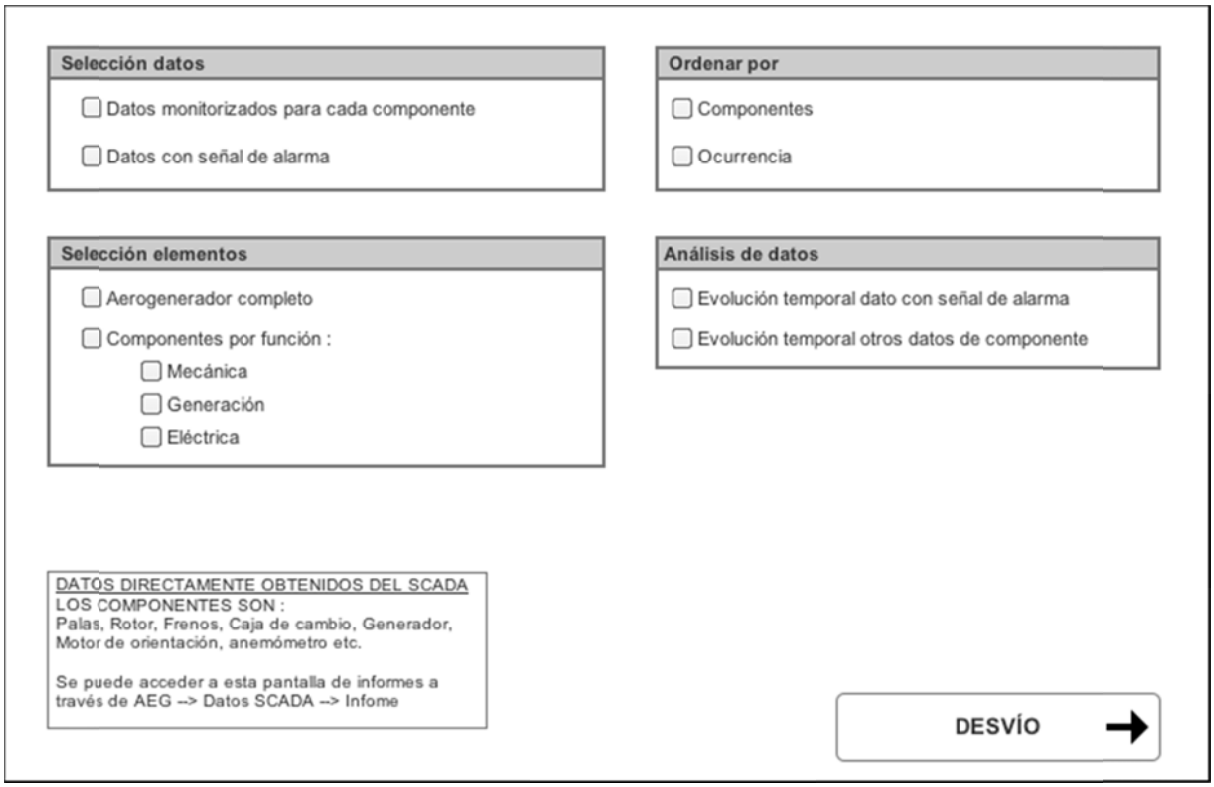

Figure 18: Wind Farm Manager Reports Interface-Personalisation-SCADA

It is divided in four boxes, two on the right side and two on the left, smaller than the others presented before. The first one is data selection (Selección datos), it occupies the upper left corner of the screen and allows the user to select the specific information he wants to study. He can choose between:

- (Every) Data monitored for each component (the value obtained in the SCADA for each component and each time unit will be displayed in the generated table)
- (Only) Data with alarm signal (only when the value obtained in the SCADA is out of the normal interval, the time unit and the component will be displayed in the generated table)

The other three boxes are the element selection (under the data selection box), the group by (upper right) and the data analysis (middle right):

Element selection (Selección elementos): It allows the user to focus the SCADA information managed in some parts of the aerogenerator (or the whole one). The user can choose between deepen in the mechanical, the electrical or the generation part (cf Maintenance Report).

Group by (Agrupar): It is only choosable if the "Data with alarm signal" option has been selected in the first box. Allows the user to group all the displayed data by component (all the alarms from the same component are putted together, if it is not selected, the chronological order will be considered) or by occurrence (the most frequent ones are putted together).

Data analysis (Análisis de datos) : This section is useful for the user as it allows him to display the evolution, as a line chart concerning the selected time period, of the components that have raised an alarm (first checkbox) in order to notice a specific behaviour. It also allows the user to display the time evolution of all the components linked to the one that raised an alarm (second checkbox) in order to discern any possible relation.

Once all the boxes have been filled in, he has to click on the deviation (desvío) button, marked with an arrow that will display the next screen.

F. DEVIATION

Once the Deviation button selected, the fifth personalization screen will show up. This fifth one is linked to the difference between the budgeted production and the real one, which we call deviation, allowing making different calculus than in the production screen. **All the information is obtained from the SCADA (only counting where the switch of the aerogenerator is not in maintenance or off mode) stored in the management database.**

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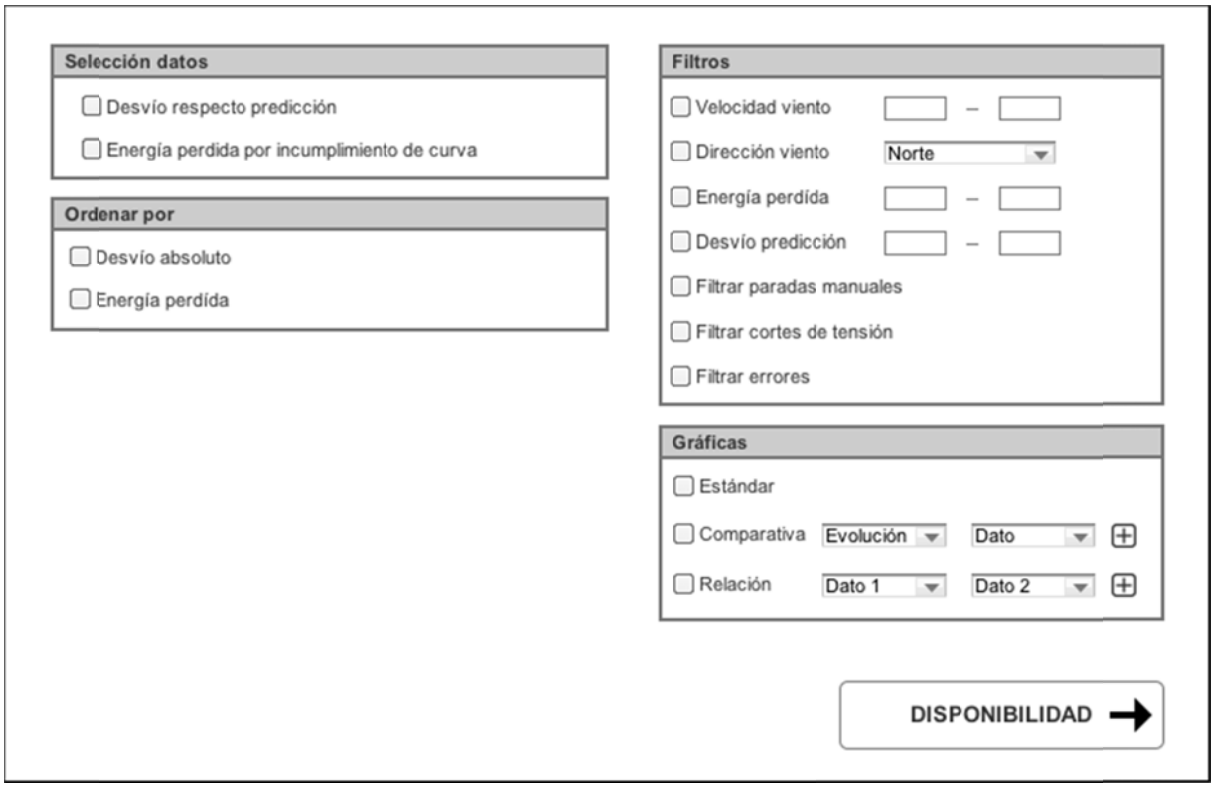


Figure 19: Wind Farm Manager Reports Interface-Personalisation-Deviation

It is divided in four boxes that are, from top to bottom and right to left, the selection data one, "arrange by", "sort by" and the chart generation box:

*Selection data (*Selección datos): Allows the user to select the specific information he wants to study. All the information will be displayed for each selected aerogenerator and the whole plant. He can choose between:

- Variation (deviation) regarding the budgeted production
- Energy lost because power curve breach

Arrange by (Ordenar por): Allows the user to display the information selected in the table in a specific way determined by the descending order for the values of energy lost or deviation.

Sort by (Filtrar): Allows the user to only display the data that has the same time and date than the values of wind velocity, wind direction, energy lost and deviation included in an introduced interval. In addition, the user can filter the manual stops, power cuts and recording errors from the calculus effectuated.

Charts (Gráficas): Allows the user to generate all the charts he wants giving him three

different possibilities corresponding to three checkboxes. The first one is generating the standard ones (Estándar, cf Deviation Report description), the second one is the comparative one (Comparativa) where the user has to select a value (one of the chosen in the data selection) and if he wants to display the time evolution or the cumulated of the total period for this selected value. Once chosen, for each aerogenerator and for the total of the plant, a chart will show the time evolution (individual line chart) or the total (global bar chart) of this selected value. The third and last one is the relation chart (Relación) where the user has to chose two values of the selected ones before. Once chosen, a line chart will be generated with the interval of the measured values of the first selected data in the x axis and of the second data on the y axis, showing if there is a visible relation between them.

Once all the boxes completed as the user wants to, he has to click on the Availability (Disponibilidad) button, marked with an arrow that will display the next screen.

G. AVAILABILITY

Once the Availability button selected, the sixth personalization screen will show up. This sixth one is linked to all the information linked to the state of the aerogenerator in order to evaluate how much time an aerogenerator has been working and the causes if it has not been. The disponibility is a key factor in the accuracy of the budgetisation of the wind farm production. **All the information is obtained from the management and the management databases (where the historical information from the SCADA and the technical data are stored).**

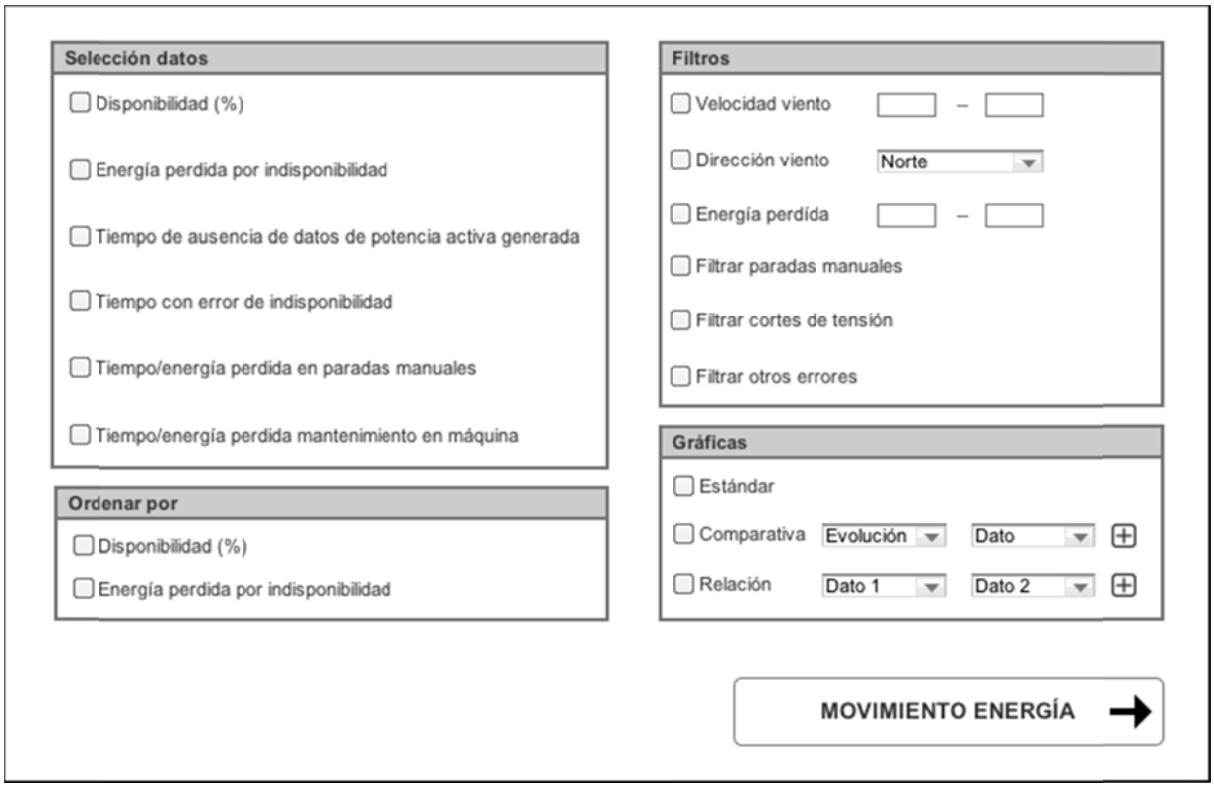


Figure 20: Wind Farm Manager Reports Interface-Personalisation-Availability

It is divided in four boxes, the first one is data selection (Selección datos), it occupies the majority of the left part of the screen and allows the user to select the specific information he wants to study. All the selected values will be shown for the whole installation as well as for each selected aerogenerator. He can choose between the following data :

- Availability (in % of the total selected time period)
- Energy lost due to unavailability
- Time with absence of data about the generated active power
- Time with unavailability errors
- Time with planned manual stops
- Time with maintenance work in the machine

The three other boxes are, from top to bottom and right to left, the "arrange by", the "sort by" and the chart generation:

Arrange by (Ordenar por): Allows the user to display the information selected in the table in a specific way determined by the descending order for the values of Availability and Energy lost due to unavailability.

Sort by (Filtrar): Allows the user to only display the data that has the same time and

date than the values of wind velocity, wind direction, availability or energy lost included in an introduced interval. In addition, the user can filter the manual stops, power cuts and other errors from the calculus effectuated.

Charts (Gráficas) : Allows the user to generate all the charts he wants giving him three different possibilities corresponding to three checkboxes. The first one is generating the standard ones (Estándar, cf Availability Report description), the second one is the comparative one (Comparativa) where the user has to select a value (one of the chosen in the data selection) and if he wants to display the time evolution or the cumulated of the total period for this selected value. Once chosen, for each aerogenerator and for the total of the plant, a chart will show the time evolution (individual line chart) or the total (global bar chart) of this selected value. The third and last one is the relation chart (Relación) where the user has to choose two values of the selected ones before. Once chosen, a line chart will be generated with the interval of the measured values of the first selected data in the x axis and of the second data on the y axis, showing if there is a visible relation between them.

Once all the boxes completed as the user wants to, he has to click on the Energy Movement (Movimiento de energía) button, marked with an arrow, which will display the next screen.

H. ENERGY MOVEMENT

Once the Energy Movement button selected, the last personalization screen will show up. This seventh one is linked to all the energy flows, influx and outflux, during the selected time interval in the wind farm. As the installation consumes energy, it is interesting for the manager to evaluate the net energy produced and, in consequence, the real performance of the plant. **The information is obtained from the management databases (where the historical information from the SCADA and the energy bills are stored).**

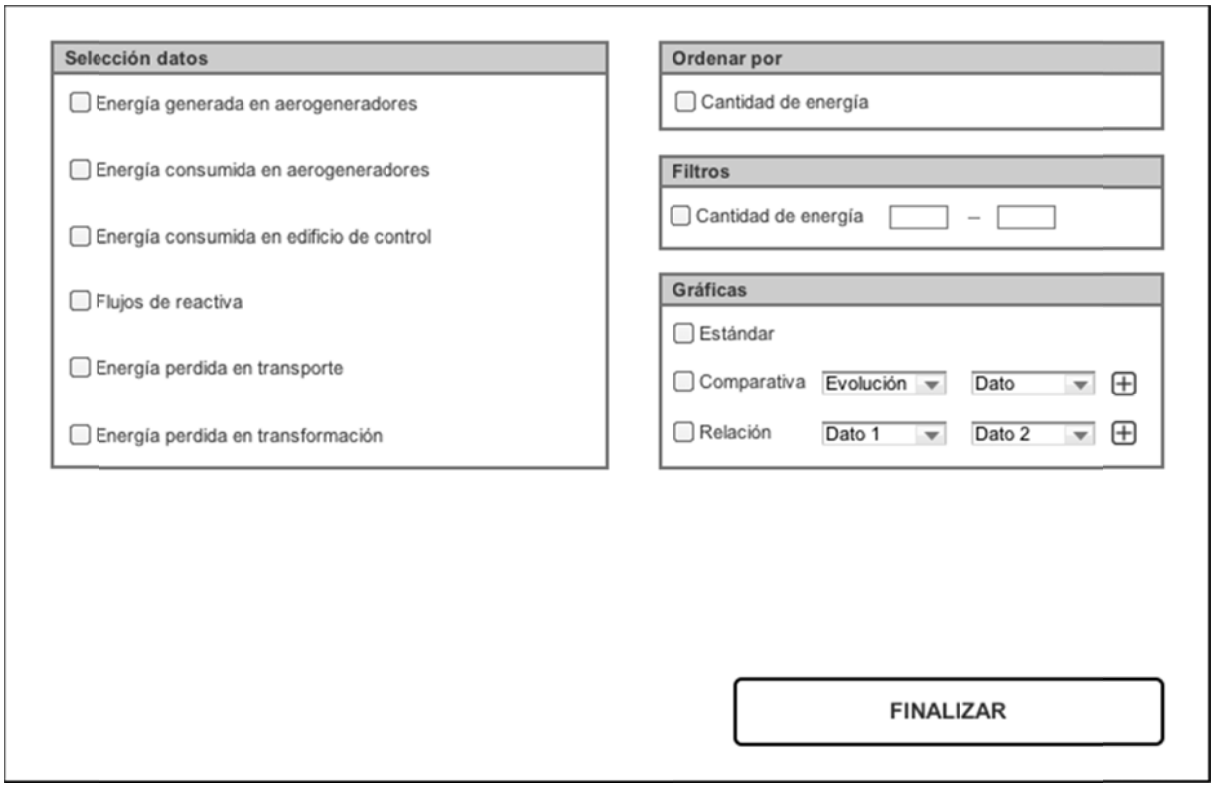


Figure 21: Wind Farm Manager Reports Interface-Personalisation-Energy Movement

It is divided in four boxes, the first one is data selection (Selección datos), it occupies the whole left part of the screen and allows the user to select the specific information he wants to study. He can choose between the following data :

- Energy generated by the aerogenerators
- Energy consumed by the aerogenerators
- Energy consumed in the control building
- Reactive power flow and energy lost in the wind mill
- Energy lost in electric transport
- Energy lost in transformation (from mechanical to electricity)
-

The right side of the screen displays three boxes that are, from top to bottom, the "arrange by", the "sort by" and the chart generation:

Arrange by (Ordenar por): Allows the user to display the information selected in the table in a specific way determined by the descending order for the amount of energy in order to notice where the losses are greater.

Sort by (Filtrar): Allows the user to only display the data that has the same time and

date than the amount of energy included in an introduced interval in order to filter the quantities to study and narrow the number of managed data.

Charts (Gráficas): Allows the user to generate all the charts he wants giving him three different possibilities corresponding to three checkboxes. The first one is generating the standard ones (Estándar, cf Energy Movement Report description), the second one is the comparative one (Comparativa) where the user has to select a value (one of the chosen in the data selection) and if he wants to display the time evolution or the cumulated of the total period for this selected value. Once chosen, for each aerogenerator and for the total of the plant, a chart will show the time evolution (individual line chart) or the total (global bar chart) of this selected value. The third and last one is the relation chart (Relación) where the user has to chose two values of the selected ones before. Once chosen, a line chart will be generated with the interval of the measured values of the first selected data in the x axis and of the second data on the y axis, showing if there is a visible relation between them.

Once all the boxes completed as the user wants to, he has to click on the "END" (Finalizar) button in order to finally generate the completely personalised report in the format chosen before.

6. INCOME STATEMENT

This page of the Wind Farm Manager interface allows him to access to all the purely economic information concerning the performance of the installation as it gives access to all the profit and loss statements for each month and year the plant has been operating.

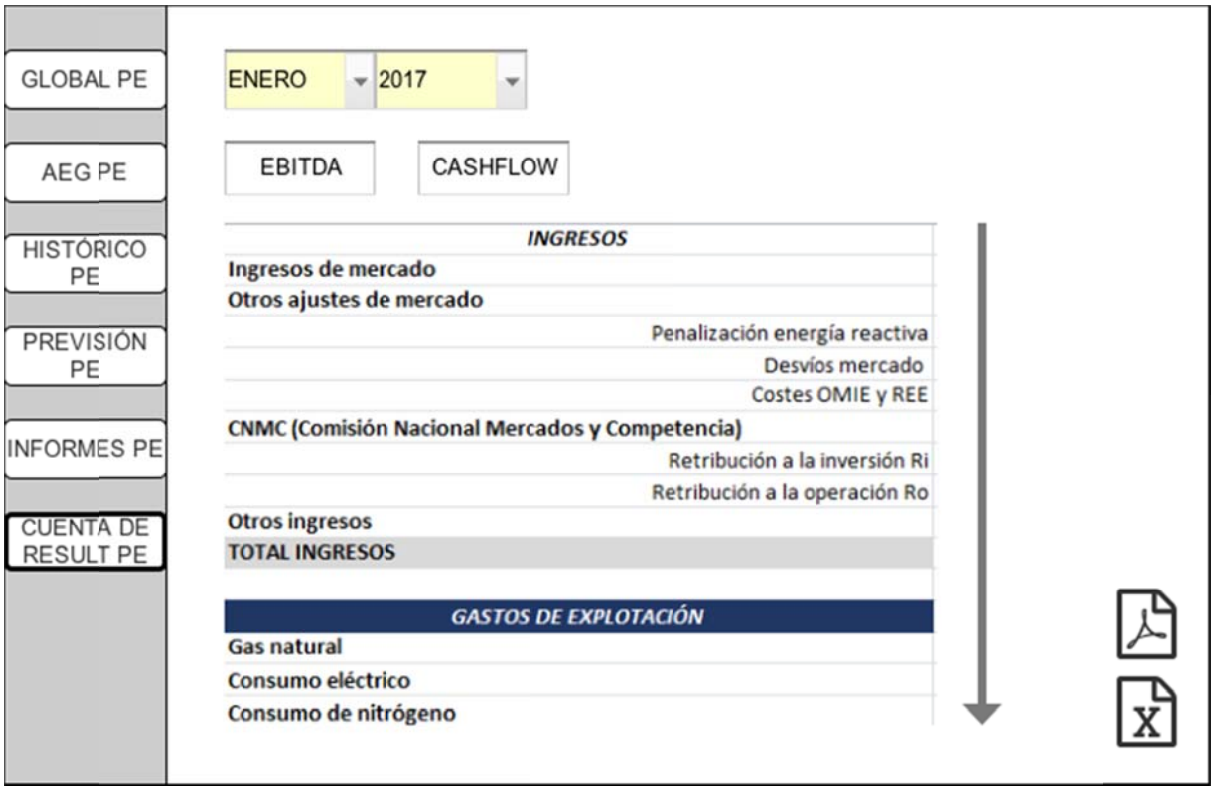


Figure 22: Wind Farm Manager Income Statement Interface

As we can observe in the image above, the only thing the user has to do is to indicate in the yellow boxes the month and year he wants. Once selected, the income statement, **obtained in the management database**, will be displayed. It also allows the Manager to generate a PDF or and Excel with the given information.

7. COMMAND

This is the last page of the Wind Farm Manager interface and it is the only that offers the possibility to actively adjust the operation factors of the total plant or of one particular aerogenerator or set (electrical components that link the aerogenerator to the plant's substation). It is divided in two main parts:

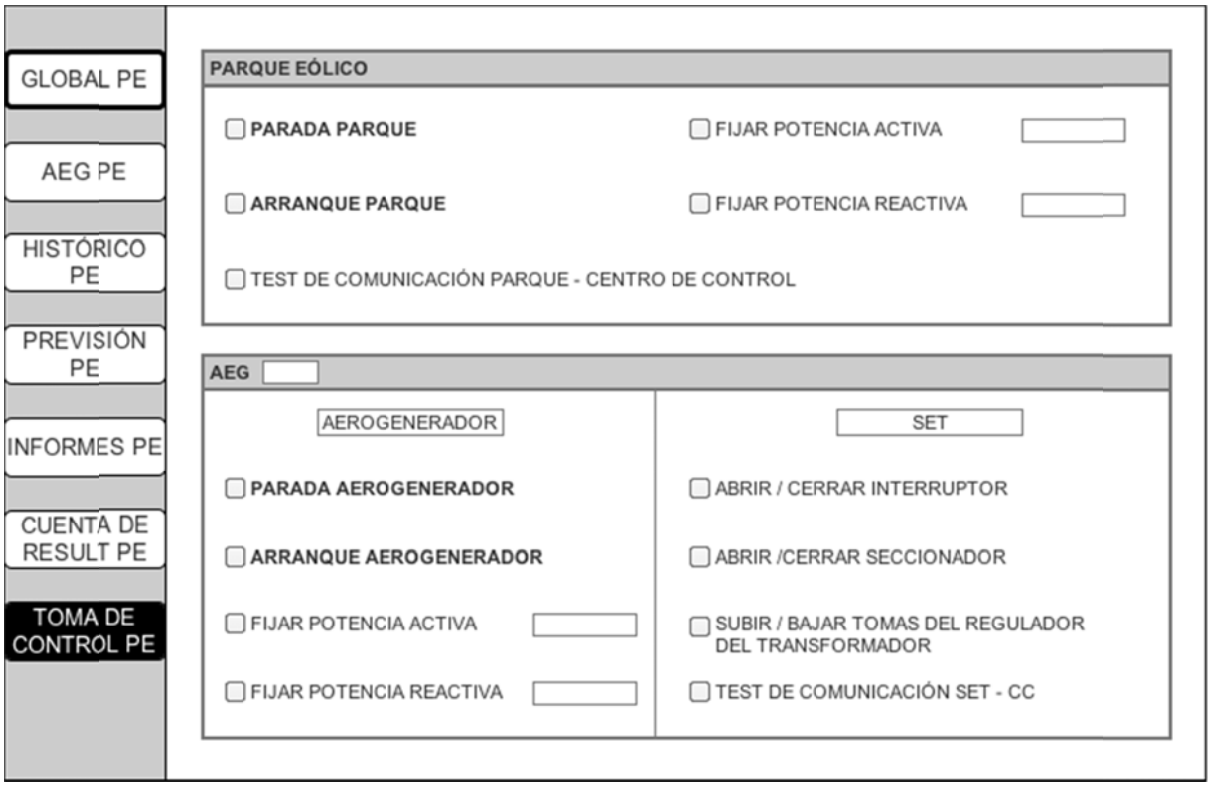


Figure 23: Wind Farm Manager Command Interface

The first one, which is the top rectangle called “Wind Farm” (Parque eólico) concerns the actions that have an impact in the whole plant. The user is allowed to stop / start the whole wind farm production if the situation requires so. He also has the possibility to fix the active and the reactive power (introducing the corresponding value in the box) and to test the communication between the control center and the plant.

The second one, which is the bottom rectangle called “AEG”, offers the user the possibility to select a specific aerogenerator introducing its number in the box (left part “aerogenerador”), including the electrical components than link it to the substation (right part, “set”). The user is allowed to stop / start the production of the selected aerogenerator if the situation requires so, he has also the possibility to fix the active and the reactive power (introducing the corresponding value in the box). In the “set” part, he has the possibility to open / close the switch or the isolator switch, to raise / lower the transformer taps and to test the communication between this ensemble and the control center.

ii) Solar Park Manager

This package is only accessible for the user accredited as "Solar Park Manager" of the corresponding solar park or for those who are higher in the company hierarchy such as the Solar Responsible, the COO or the CEO.

The Solar Park Manager is the direct responsible of the installation and its production. Thus, in order to assure an optimal management of the park, he has to be able to access to all the real-time information of the plant, as well as to all its historical data. He wants to know how much we are producing, how much we have produced, how much we are going to produce and why. In addition, he has to keep an eye in the economic (incomes) and mechanical (maintenance) issues of the plant.

This package will be the tool that allows the Solar Park Manager to monitor all the different components of the production chain as well as all the different external events that happen in the day-to-day.

Having said that, the package structure is divided into six main pages that correspond to the control center as an information management tool and are : Home Page, Technical, Historical, Forecast, Reports and Income statement. The remote control feature showed in the wind farm interface is not implemented as the day-to-day management of a solar park is always done on-site. In each page the user will find the following pieces of information and features:

1. GLOBAL

It's the main page of the package and it's the first one the Solar Park Manager will see when he accesses the control center, it is the home page of his user interface. It shows a global picture of the real-time status of the plant. It displays the following information:

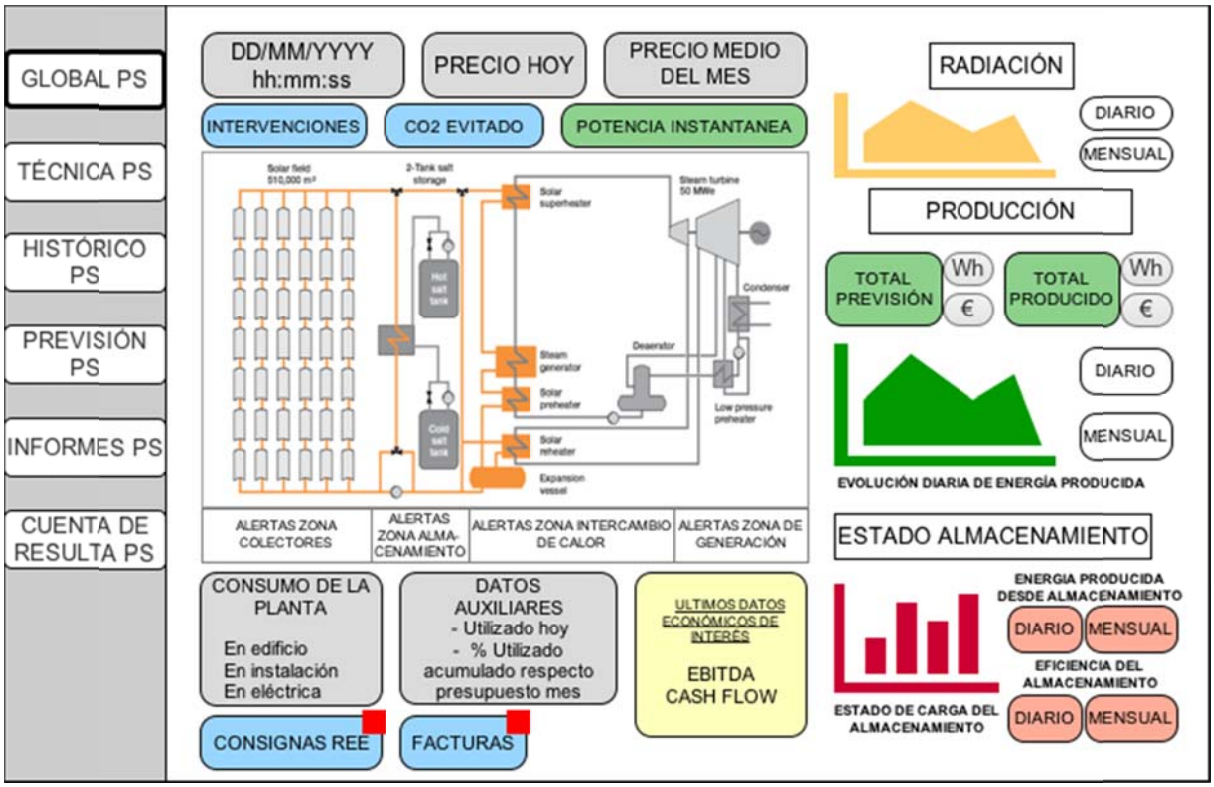


Figure 24: CSP Park Mnager Global Interface

-DAILY DATA (Grey)

In the upper left of the Global page we find the date and hour at the time of consultation of the control center as well as the actual electricity sale price or Pool price that is **extracted from OMIE's platform each hour**, and the average real sale price of the month, that is actualised **each day and comes from our Management database,** in order to compare them.

- STATUS INFORMATION

Just under the daily data, we find three boxes that contain numerical values that represent the status of the production plant, showing the user the characteristics of the daily functioning of the installation.

In the first blue box we have the number of technical interventions that have been made through the day **presented in the management database.** In the second blue box we observe the avoided CO2 emissions thanks to the production of renewable energy of our plant which is **calculated from the amount produced shown in the SCADA each 10 minutes and the equivalent emission if the same amount had been produced by non-renewable**

sources obtained in the management database.

In the green box we find the the real-time power production of the plant **obtained in the SCADA (substation energy meters) each 10 minutes.**

-SOLAR PARK MAP

Located in the middle left, the map is the main part of the Global page and shows all the areas that conform the installation and that are components of the electricity generation : the solar field (reflectors and receiver) where the working fluid (oil) is heated, the thermal storage (salt tanks), the heat exchanger (working oil - water) and the turbine where the power is generated.

It provides a global and quick overview of the status of the production of the installation as it displays any kind of abnormal value (alarms) observed in the area. If the user clicks on one of the elements of the map, he will be directly redirected to the Technical interface of the corresponding area (see 2 TECHNICAL). **The data used in this map is obtained from the SCADA of the solar park each 10 minutes.**

- ENERGY AND AUXILIARIES CONSUMPTION DATA (Grey)

Under the Solar Park Map there are two grey boxes. The first one is the energy consumption data which is decomposed by area as it shows the consumption in the generation zone, in the electrical elements and in the control building. The second one is the auxiliaries consumption which are water and natural gas, the total consumption of each one is displayed as well as the percentage consumed compared to the budgeted consumption of the month. All the data used is **obtained in from the SCADA of the installation every 10 minutes and from the management database (budgets)**. These two boxes are very useful as they set up in opposition to the generated power, making them key values for a good evaluation of the performance of the solar park.

-ECONOMIC DATA (Yellow)

In the bottom of the page, next to the auxiliaries' consumption information, the yellow box presents the economic data. This box will show the most important values of the most recent balance sheet such as the EBITDA and the Cash Flow. **It is obtained in the management database**.

- RADIATION

Located in the upper right, we find time evolution of the solar radiation represented by a line chart. It displays the values of the radiation throughout the present day (time unit = hour) or the actual month (time unite = day), depending on what the user selects. The graph shows two lines, one representing the expected radiation and the other one representing the real observed radiation. **Both values are obtained from the management database (weather forecasting agent reports) and the SCADA of the installation (solar radiation meter)**.

- GENERATED POWER DATA (Green)

Just under the radiation line chart, we find one of the main parts of the page. It regroups different information concerning the the daily or the monthly predicted and real production, depending on which time interval the user chooses. From top to bottom we have :

Two boxes with two values each one. The first one shows the budgeted production in euros and in Wh. The second one shows the real production also in euros and in Wh. **The data used is obtained from the SCADA (each 10 minutes for the daily real production values).**

A line chart with the power produced in the y axis and time in the x axis. Two lines are generated and can be compared, one representing the real daily/monthly production per time period **which is refreshed each 10 minutes and comes from the SCADA** and the other one representing the evolution of the planned production calculated with **the theoretical power curve and the data from the Management database with the reports from the weather forecasting agent refreshed 8 times each per day**. This information allows the Manager to assess the daily/monthly performance of the installation and the accuracy of the prediction. It also makes easier to spot the gaps where the status of the production has been more critical, thus, where to focus the research effort in order to find the causes and to optimize the production of electricity. If the user chooses the daily data, the x axis will represent the hours of the day, but if the solar park manager places the pointer on the curve, he will able to see the 10-minute interval values. If the user chooses the monthly data, the x axis will represent the days of the month and the information of the real production and the past predictions will be **extracted entirely from the management database**.

- STORAGE STATUS (Red)

Following the previous part, in the lower right, the storage status of the thermal salt tanks is displayed. We observe one bar chart that represents the state of charge in percentage of the tanks during the selected time period (daily or monthly), **information that is extracted from the SCADA of the solar park.**

Next to this graph, we find two red boxes. The first one gives the user the daily and the monthly value of the quantity of energy that has been produced from the thermal storage of the salt tanks. The second one gives the daily and the monthly efficiency of the storage, simply calculating the quantity of energy given to it and the energy produced from those thermal reserves. **All the raw values are obtained by the SCADA, they are then used for calculus in the company's servers and transferred to the company's databases.**

- ALARMS

In the bottom left of the page we find two checkboxes that will pop-up if new alarms linked to the operation of the solar park, **obtained in the REE web platform**, or new bills appear (**punctual information uploaded on the management database**).

2. TECHNICAL DATA

This page allows the Manager to access to all the technical information that reflects the performance of all the areas and components of the production chain of the installation. It is accessible from the left column of the control center interface or if the user selects the respective area of the solar park map from the global page. It is the fastest way to spot the components that are underperforming and get a quick overview of the potential problems.

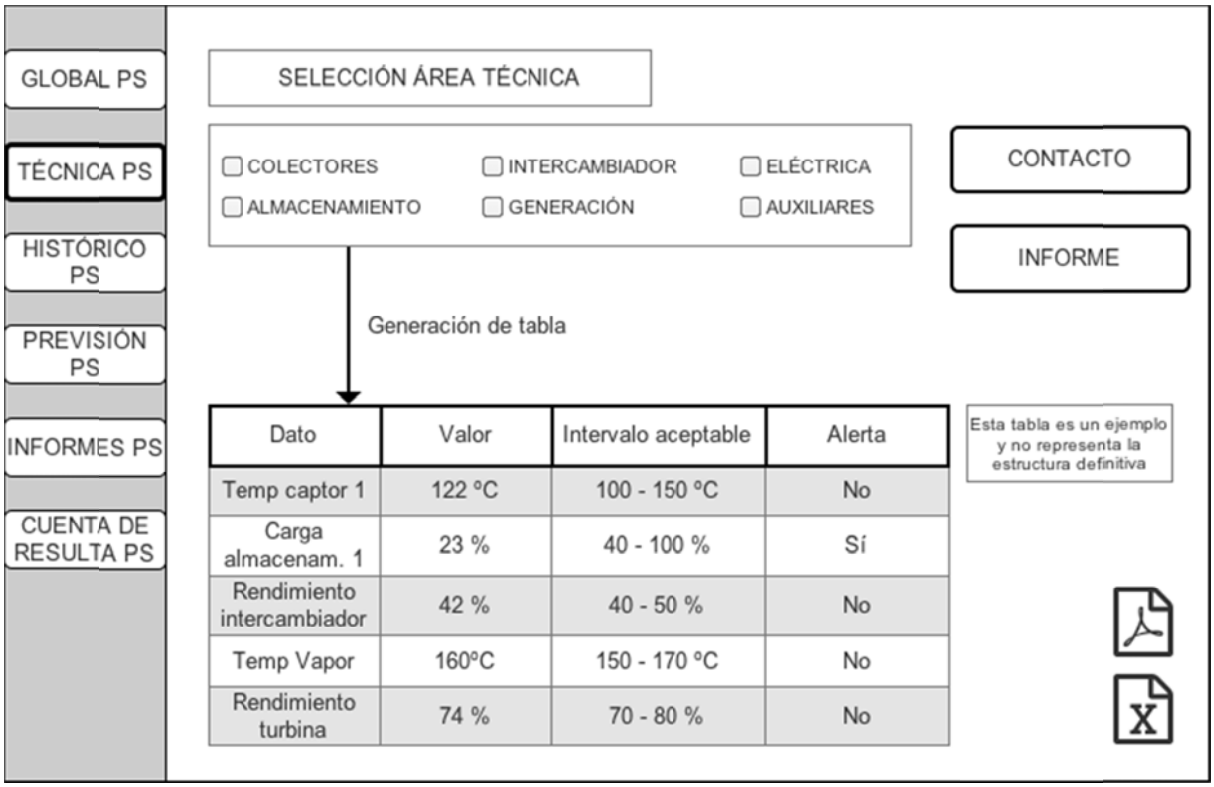


Figure 25: CSP Park Manager Technical Data Inteface

- SELECTION

In the top of the page, clicking on the checkboxes, the Manager **i**s allowed to select individually the area he wants to evaluate. He can choose between the Solar Field (colectores), heat exchanger (intercambiador), electricity network (eléctrica), thermal storage (almacenamiento), generation (generación) and auxiliaries (auxiliares). The user can choose one or more areas if he wants to. Once the selection done, the control center will display all the data corresponding to the selected area(s) in a table with the following elements.

- DATA TABLE

For each area selected by the user, the table will break down all the elements that compose it (and are monitored by the SCADA of the plant). For example, if the area selected is “heat exchanger”, the table will show the temperature of the entering working fluid, entering water, outgoing working fluid, outgoing water etc. For each element of the table, the measured value, the acceptable interval for the value and the presence or not of an alarm related to the element is displayed. **All this data is extracted from the SCADA of the solar park once the request (area selection) is made.** The generated data table can be exported to pdf and excel format clickn ont eh icons on the bottom right corner of the screen.

- LINK BUTTONS

Finally, we observe two buttons on the top right corner of the screen, which are respectively Contact (Contacto) and Report (Informe).

The first one displays the address of the solar park and the name, job, telephone number and de email address for every employee of the plant (responsible, operators…). **This information is extracted from the Management Database.**

The second one sends the user to the "SCADA" report page in order to easily manipulate all the different values and to personalise the time interval and the charts the manager wants to generate (report section will be explained hereunder).

3. HISTORICAL

This page allows the Manager to access to the historical (past) data that reflects the operational performance of the solar park. It is accessible from the left column of the control center interface.

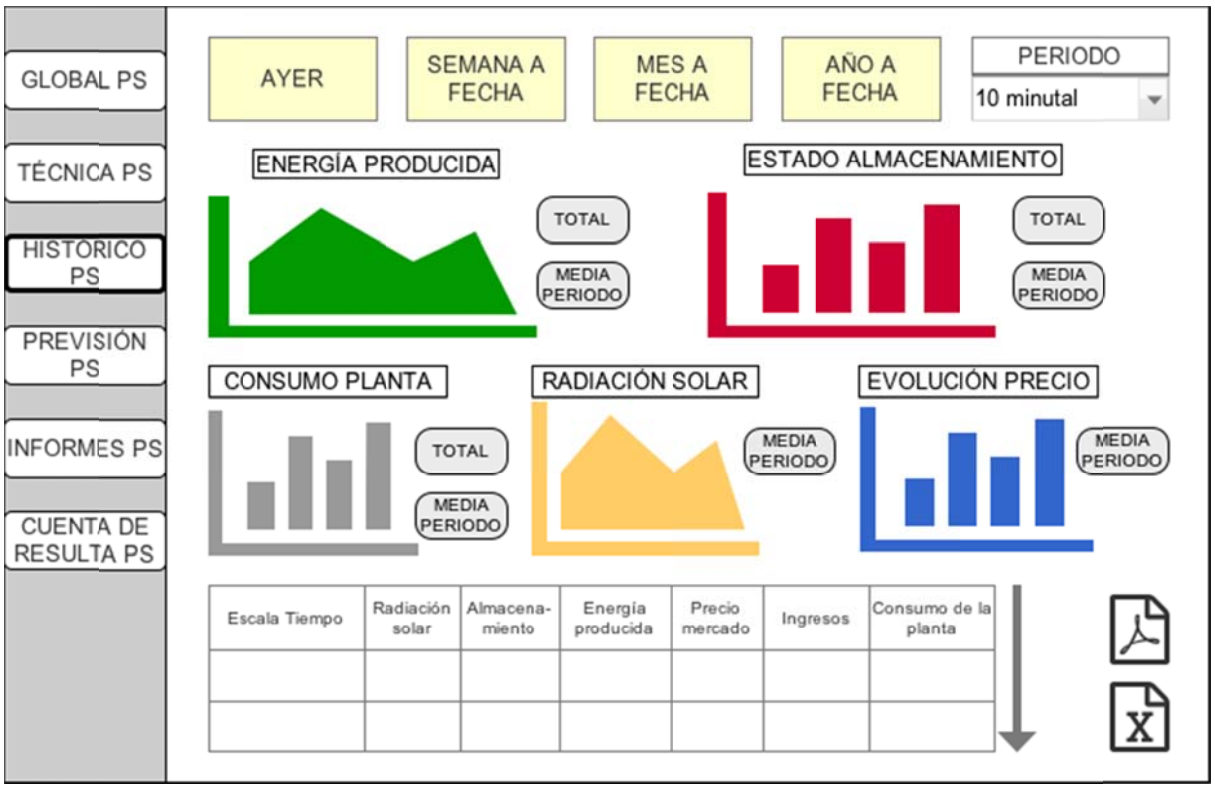


Figure 26: CSP Park Manager Historical Interface

- SELECTION

Just as you access to the page, in yellow, on the top of the page and horizontally displayed, the Manager is able to select the time interval in which the data will be subtracted from the databases. The interval is chosen by clicking on the "yesterday" (the last 24h are considered), "week to date" (the last seven days are considered), "month to date" (the current month is considered) or on the "year to date" (the current year is considered) button.

Just after the yellow time interval selection buttons, in the upper right corner of the page, the user is able to select the "period" which corresponds to the time grouping (the quantity of time that corresponds to an individual value). If the user has selected the yesterday time interval, he can choose between the 10-minute and hourly period. If he has selected the week time interval, he can choose between the hourly and daily period. If he has selected the month time interval, he can choose between daily and weekly period. Finally, if he has selected the year time interval, he can choose between daily, weekly and monthly period.

-CHARTS AND SCHEMES

Just under the selection elements and once the time selection done, two line charts and three bar charts are generated. They are the chore of the historical page. They synthesize all the data presented in the table that is under them which we will present hereunder in the section "Data table". **As this page shows past data, all the information used will be obtained from the company's database (SCADA data transferred to databases) and used to generate different graphics and to calculate the total and the mean of the values during the selected time period**.

In order from top to bottom and right to left, we find:

The_energy production line chart (in green), with watt hours (and euros) in the y axis and days in the x axis, that gives us the evolution of the production of the solar park connecting the points that represent the real production for each time period. It is accompanied by two numerical values : the total cumulated and the average of the time interval.

The storage status bar chart (in red), showed in percentage of the total capacity and time in the x axis, shows the evolution of the storage during the selected time interval. Each

bar is divided in the number of thermal salt tanks that the solar park has. It is accompanied by the numerical value of the average of the time interval.

The energy consumption bar chart (in grey) with watt hours (and euros) in the y axis and time in the x axis, it gives us the evolution of the energy consumed in the whole plant (in the production area, control area etc.), it is given directly by the substation energy meters and the daily price of the electricity. It is accompanied by the numerical value of the average of the time interval.

The solar radiation line chart (in yellow) informs about the evolution of the incident radiation measured in the parabolic collectors (solar field), which directly affects the performance and efficiency of the generation. It is measured in watts per square meter. It is accompanied by the numerical value of the average radiation of the time interval.

The price evolution bar chart (in blue), with price in the y axis and days in the x axis, informs about the price of the solar technology in the spanish market in each selected period. It is accompanied by the numerical value of the average price of the time interval.

- DATA TABLE

It occupies all the rest of the page and contains, for each time period (time grouping), the corresponding values of the graphics displayed above:

- Solar radiation
- Storage status
- Energy produced
- Energy consumed
- Selling price
- Incomes linked to the energy sale

The charts and the data table can be exported to excel or PDF by the solar park manager clicking on the corresponding icons on the right bottom of the page.

4. FORECAST

This screen allows the Manager to access to the predicted data that reflects the expected operational performance of the solar park. It is accessible from the left column of

the control center interface by clicking in the corresponding button.

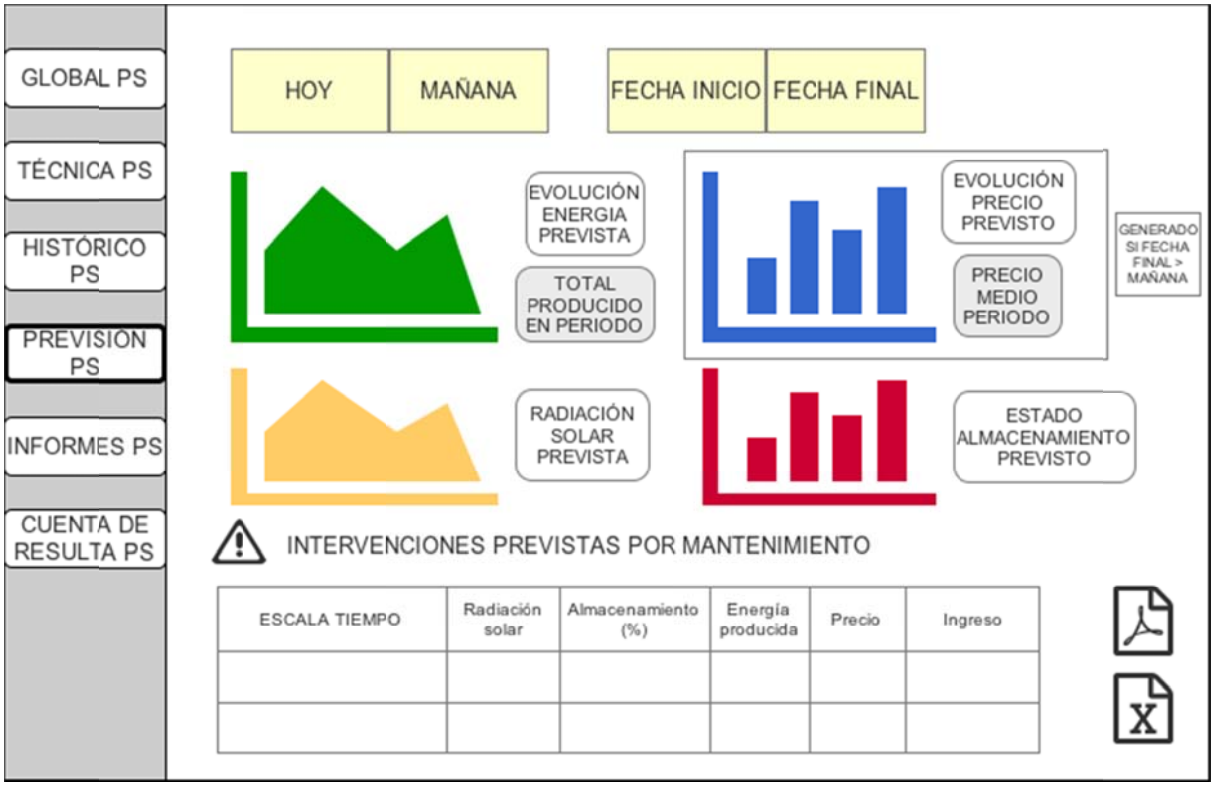


Figure 27: CSP Park Manager Forecast Interface

- SELECTION

In yellow, on the top of the page and horizontally displayed, the Manager is able to select the time interval in which data would be considered for the prediction. The interval is chosen by clicking on the "today" (the remaining hours of today are considered) or on the "tomorrow" (the 24 hours of tomorrow are considered) button. The other possibility is selecting the initial and the final date of the interval (with a maximum of ten days between today and the finish date). The data will be displayed for each hour included in the selected interval.

- CHARTS AND SCHEMES

Just under the selection elements and once the selection done, we find two line charts and two bar charts that are the chore of the forecast page. They synthesize all the data presented in the table that is generated after the selection of the time interval and which we will present hereunder in the section "Data table". **As this page shows predicted data, all the data will come from the crossing between the weather forecasting agent report**

(management database), the predicted price from OMIP (official web page) and technical information from the management database. In order from top to bottom and right to left, we find:

The_energy production line chart (in green), with watt hours (and euros) in the y axis and hours in the x axis, gives us the evolution of the production of the solar park connecting the points that represent the predicted production for each hour. It is calculated with the predicted solar radiation (weather forecasting reports) and the theoretical technical characteristics of the solar park. It is accompanied by the numerical value of the total cumulated during the time interval.

The price evolution bar chart (in blue), with price in the y axis and days in the x axis, that informs about the expected price of the solar technology in the spanish market in each hour (or day) of the period. It is accompanied by the numerical value of the average price of the period. Note that this graph will only appear if the time interval has a finish date greater than "tomorrow".

The solar radiation line chart (in yellow) informs about the expected evolution of the incident radiation measured in the parabolic collectors (solar field) which is predicted by the weather forecasting agent. It is measured in watts per square meter. It is accompanied by the numerical value of the average incident radiation of the time interval.

The storage status bar chart (in red), showed in percentage of the total capacity and time in the x axis, shows the planned evolution of the storage during the selected time interval. Each bar is divided in the number of thermal salt tanks that the solar park has. It is calculated considering the expected solar radiation and energy sold (which depends on the market price and the capacity of the plant). It is accompanied by the numerical value of the average of the time interval.

- DATA TABLE

It occupies all the rest of the page and contains, for each hour, the corresponding values of the graphics displayed above (Solar radiation, Storage status, energy produced, Selling price, Incomes linked to the energy trade…)

The charts and the data table can be exported to excel or PDF by the user clicking on

the corresponding icons on the right bottom of the screen.

5. REPORTS

This section is the one that allows the solar park manager to directly interact with all the information generated in the whole installation. It is where the added value of the control center resides as it gives the opportunity to manipulate all the elements from different points of views in order to personalise reports with a maximum of useful information for the user. It is accessible from the left column of the control center interface by clicking in the corresponding button.

5.1 HOME PAGE

The home screen of this section is the one that shows the standard reports that can be generated by the user. The page is divided in three mainl boxes: selection (Selección), time grouping (Intervalo temporal) and reports (Informe).

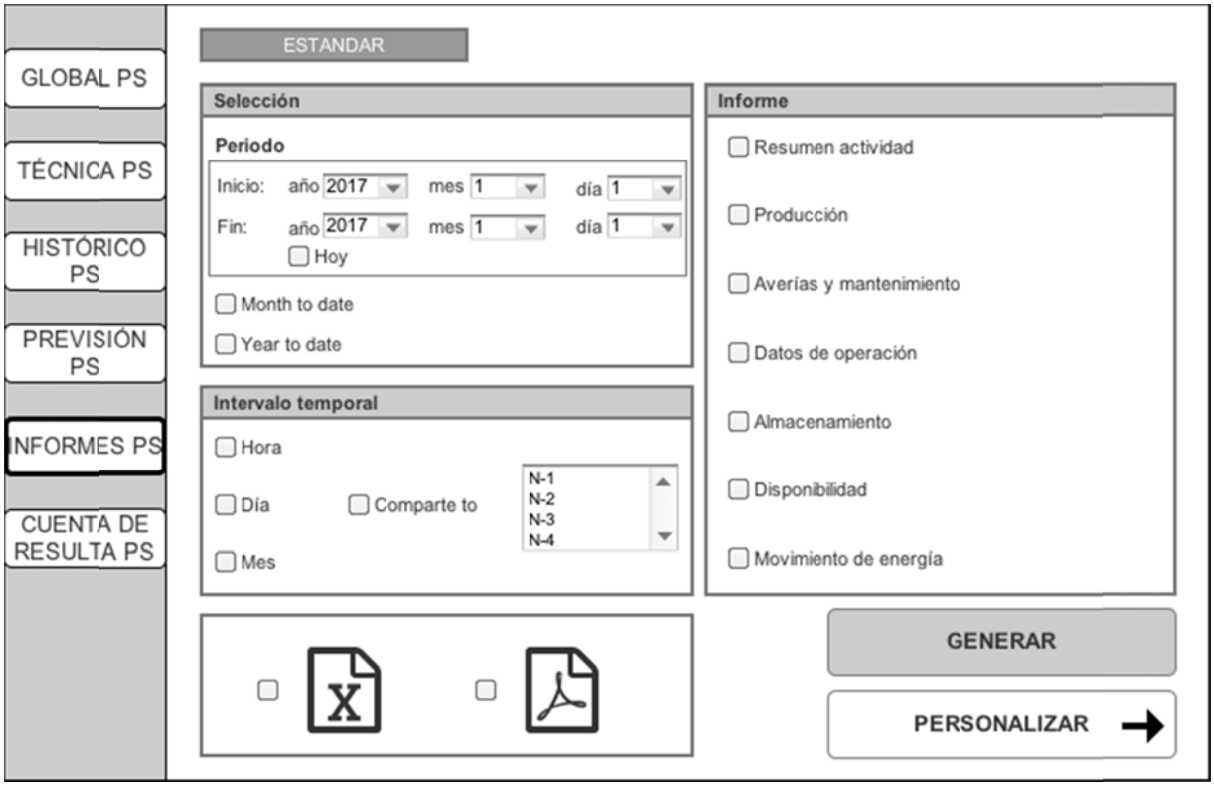


Figure 28: CSP Park Manager Reports Interface-Homepage

-SELECTION

In this box, the user has to choose the time interval in which the data will be subtracted from the databases. He has three options, selecting the initial and final date (where you can select "today" for the final one thanks to a checkbox), selecting "Month to date" (all the days of the current month will be considered) or selecting "Year to date" (all the days of the current year will be considered).

-TIME GROUPING

In this box, the user has to choose **the time period which corresponds to the time grouping (the quantity of time that corresponds to an individual value)**. There are four options: **10-minute (not choosable if the time interval is greater than a week), hour (not choosable if the time interval is greater than 31 days), day and month**.

In addition, the user can choose to compare, in the "comparar a" checkbox, the values of the selected time period with the same interval of the past years (selected by clicking on n-1, n-2 etc).

-REPORTS

In this box, the user can choose between seven different reports that, although they are standardised, provide specific information about key topics of the management of the solar park. The reports are structured as follows :

- Activity Summary (Resumen actividad)

It is the report directly linked with the asset management. It displays the economic data from the electric market and the electricity produced by the solar park. **All the information is obtained in the management database and in the OMIE online platform.** It generates a table with the following data for each time grouping unit:

  - Real final selling price, budgeted selling price and the variation between them
  - Real production, budgeted production and the variation between them
  - Real final income, budgeted income and the variation between them
  - Market pool (PMD), Sector pool, Deviation penalty, Kurtosis coefficient

In addition, the three first points are accompanied by a double line chart that shows the evolution of the values (real and budgeted) throughout the selected time period.

- Production (Producción)

This report is the technical continuation of the activity summary as it deepens in the production factors and in the optimization of the asset. It is focused on the installation performance and not on the electric market. **All the information initially comes from the SCADA of the solar park and is extracted from the management database where it has been stored.** It generates a table with the following data for each time grouping unit :

- Real production, budgeted production and the variation between them
- Real final income, budgeted income and the variation between them
- Capacity factor
- Selling price
- Generating hours
- Production from the solar field
- Production from storage

In addition, the two first points of the list are accompanied by a double line chart that shows the evolution of the values (real and budgeted) throughout the selected time period and the three last points are synthesized in bar charts (the two last ones are displayed in the same graph in order to compare them).

- Failures and maintenance (averías y mantenimiento)

This report aims to provide a global view of all the issues linked to mechanical breakdowns and maintenance work that have interfered in the normal production of the solar park in order to identify the principal problems where the manager has to focus his actions. **All the information is obtained from the SCADA and from the management database where all the reports complemented by the technicians are stored.** It generates a table with the following data:

- Solar park :
    - Time employed in predictive, preventive and corrective maintenance
    - The total of time employed in all types of maintenance
    - Average response time
    - Time unavailable (time not producing when it was planned to because of maintenance work and any kind of technical failures)
    - Average solar radiation during maintenance
    - Energy lost during maintenance

- For each area :
    - List of all the maintenance work each zone has undergone during the selected time period :
        - Date of failure / maintenance work
        - Description of the failure / maintenance work
        - Time employed (counting the response time)
        - Time unavailable
        - Energy lost due to unavailability

In addition, data is accompanied by a bar chart that displays the total amount of time spended on each type of maintenance (the percentage of the total maintenance time they represent). Moreover, the energy lost due to technical issues, for the whole solar park and for each zone, has its evolution during the selected time period represented by a line chart.

- Operation data (Datos de operación)

This report displays the data linked to the technical performance of the plant regardless of the economic data or the budget fixed for the solar park. The machines and their elements are the central part. **All the information is obtained from the management databases (where the historical information from the SCADA and the technical data is stored).** It generates a table with the following data for each grouping time unit:

- Incident solar radiation
- Efficiency of the generation : of the solar farm, the heat exchanger and the turbine (theoretical and real values)
- Generated power (theoretical (power curve) and real values)
- Auxiliaries consumption (theoretical and real values)
- SCADA values out of the acceptable interval (with the information about the time it has been out of it and if maintenance work has been needed)

In addition, the solar radiation and the auxiliaries consumption time evolution is showed in a line chart. Moreover, the real and theoretical generated power is accompanied by the theoretical vs real power curve represented by a line chart.

- Storage (Almacenamiento)

This report concerns the role of the storage on the energy generation of the park.

Although other reports display information about the storage status, this reports synthesises all the data that reveal the performance of the thermal salt tanks, **extracting the**

information of the SCADA of the park. It presents the data as follows:

- Energy generated from storage
- Storage status (in percentage)
- Energy provided to storage
- Energy lost in storage (thermal losses)
- Efficiency of the storage (theoretical vs real)

In addition, there is a triple line chart that represents the time evolution of the energy generated, provided and lost in order to compare the magnitude of each value.

- Availability (Disponibilidad)

This report displays all the information linked to the state of the generation process in order to evaluate how much time the solar park has been producing and the causes if it has not been. The disponibility is a key factor in the accuracy of the budgetisation of the solar park production. **All the information is obtained from the management databases (where the historical information from the SCADA and the technical data are stored).** It generates a table with the following data for each grouping time unit :

- Time with absence of data about the generated active power
- Time with unavailability errors
- Time with voltage absence
- Time with planned manual stops
- Time with no generation but with enough solar radiation
- Time with maintenance work in each area of the generation chain (solar field, heat exchanger, storage, turbine).

In addition, a global bar chart that shows the average availability of each area of the solar park and the energy lost by its unavailability is generated with the previous table.

- Energy movement (Movimiento de energía)

The last standardised report concerns all the energy and auxiliaries flows, influx and outflux, during the selected time interval in the solar park. As the installation consumes energy, gas and water, it is interesting for the manager to evaluate the net energy produced and the auxiliaries consumption and, in consequence, the real performance of the plant. **The information is obtained from the management databases (where the historical information from the SCADA and the energy bills are stored).** It generates a table with

the following data:

- Energy generated
- Energy consumed in the generation chain (solar field, storage, heat exchanger, turbine)
- Energy consumed in the control building
- Reactive power flow and energy lost
- Water consumption
- Gas consumption

In addition, each point is accompanied by a line chart that shows the evolution of the value throughout the selected time period.

-GENERATION

Finally, after the time interval, the time grouping and the report selection done, the user has the possibility to choose between two document formats for the generation of the final report : excel or pdf. This selection is made on the checkboxes present in the low left corner of the screen. Once this last choice has been made, the user has to click on the button “Generation” (Generación) in the low right corner. Once done, the selected report(s) will be generated.

5.2 - PERSONALISATION

However, this section does not end with the possibility of generating different standardised reports, but the solar park manager has the option to configure its own completely personalised report, adding a whole new aspect to the control center. The personalisation is accessible from the reports home page (5.I) if the user selects the button “Personalisation” (personalización) in the lower right corner.

Once the button is selected, different screens will succeed each other on the user interface and will allow the manager to select and manipulate each data in order to maximize the utility of the information contained in the future report. The personalisation screens are structured as follows:

A. SELECTION

This first screen has a similar structure to the home page of this report section as it allows making the first selections related to the time interval and the time grouping.

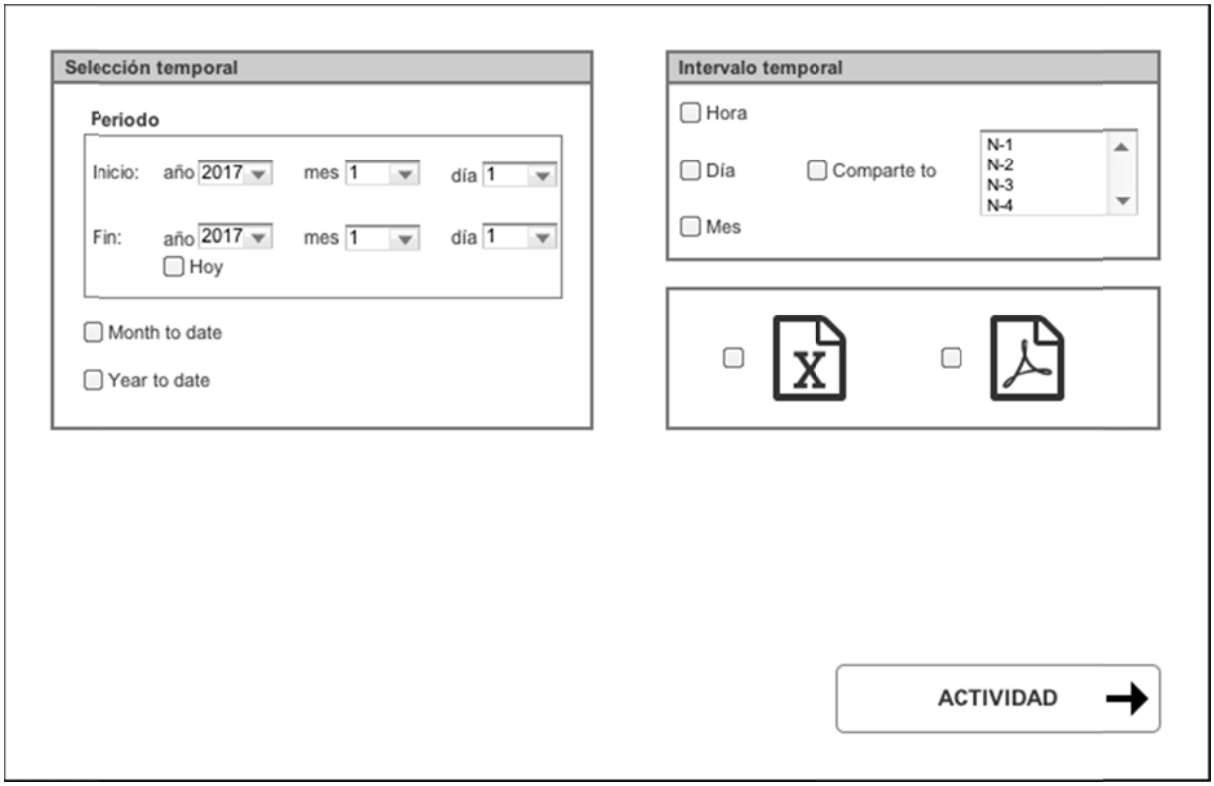


Figure 29: CSP Park Manager Reports Interface-Personalisation-Selection

There are three boxes that are the same than in the first screen of the section, from right to left and top to bottom:

The time interval selection: In this box, the user has to choose the time interval in which the data will be subtracted from the databases. He has three options, selecting the initial and final date (where you can select "today" for the final one thanks to a checkbox), selecting "Month to date" (all the days of the current month will be considered) or selecting "Year to date" (all the days of the current year will be considered).

The time grouping selection: In this box, the user has to choose the time period which corresponds to the time grouping (the quantity of time that corresponds to an individual value). There are four options : 10-minute (not choosable if the time interval is greater than a week), hour (not choosable if the time interval is greater than 31 days), day and month. In addition, the user can choose to compare, in the "comparar a" checkbox, the values of the

selected time period with the same interval of the past years (selected by clicking on n-1, n-2 etc).

The document generation: In this box, the user has the possibility to choose between two document formats for the generation of the final report : excel or pdf.

Once the selection made, the user has to start the selection of the information he wants his report to display. In order to continue, he has to select the button "Activity" (Actividad) that will show the second personalisation screen.

B. ACTIVITY

Once the Activity button selected, the second personalization screen will show up. This second one is linked to the asset management and takes again the economic data from the electric market and the electricity produced by the solar park. **All the information is obtained in the management database and in the OMIE online platform.**

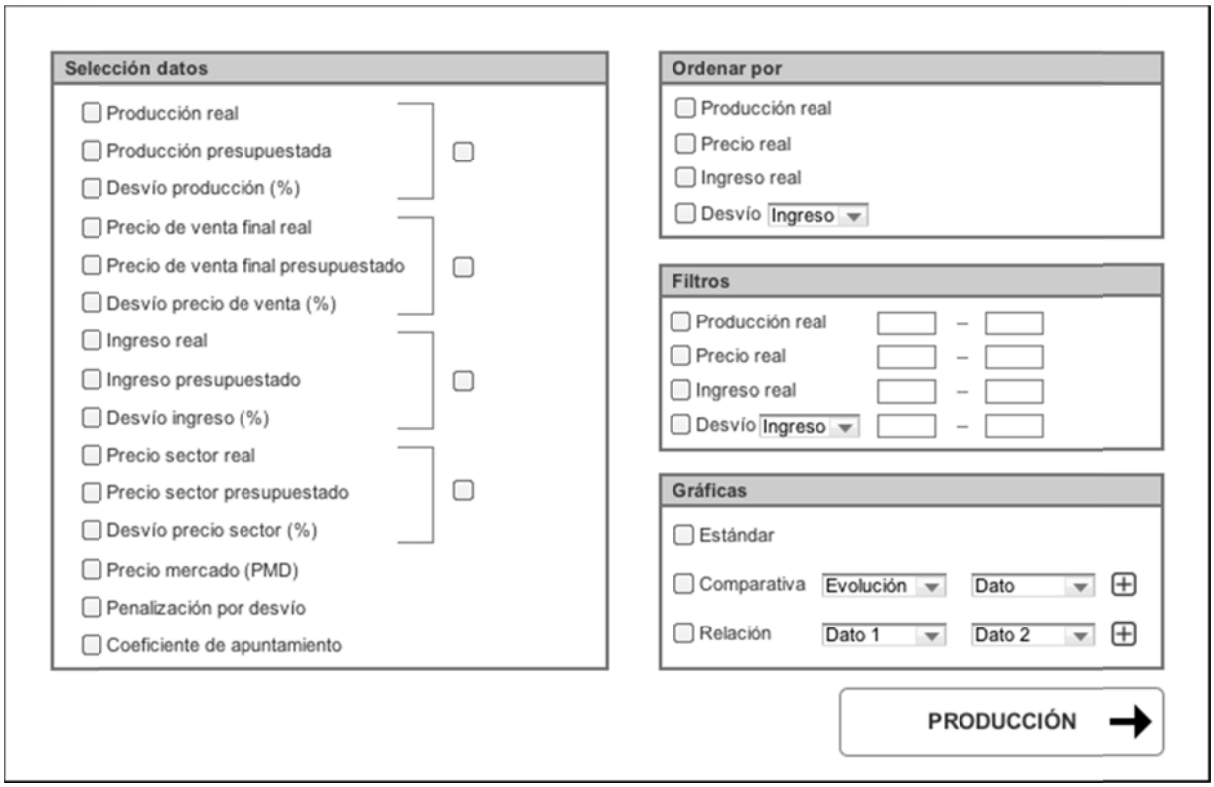


Figure 30: CSP Park Manager Reports Interface-Personalisation-Activity

It is divided in four boxes, the first one is data selection (Selección datos), it occupies

the whole left part of the screen and allows the user to select the specific information he wants to study. He can choose between the following data:

- Real production
- Budgeted production
- Variation between real and budgeted production
- Real final selling price
- Budgeted selling price
- Variation between real and budgeted selling price
- Real final income
- Budgeted income
- Variation between real and budgeted income
- Real technology pool (price of the solar market)
- Budgeted technology pool
- Variation between real and budgeted technology pool
- Market pool (PMD)
- Deviation penalty
- Kurtosis coefficient

The right side of the screen displays three boxes that are, from top to bottom, the "arrange by", the "sort by" and the chart generation:

Arrange by (Ordenar por): Allows the user to display the information selected in the table in a specific way determined by the descending order for the values of real production, real final selling price, real final income or variation between real and budgeted from the data selected.

Sort by (Filtrar): Allows the user to only display the data that has the same time and date than the values of real production, real final selling price, real final income or variation between real and budgeted from the data selected included in an introduced interval.

Charts (Gráficas) : Allows the user to generate all the charts he wants giving him three different possibilities corresponding to three checkboxes. The first one is generating the standard ones (Estándar, see Activity Report description hereinabove), the second one is the comparative one (Comparativa) where the user has to select a value (one of the chosen in the data selection) and if he wants to display the time evolution or the cumulated of the total

period for this selected value. Once chosen, a chart will show the time evolution (individual line chart) or the total (global bar chart) of this selected value. The third and last one is the relation chart (Relación) where the user has to chose two values of the selected ones before. Once chosen, a line chart will be generated with the interval of the measured values of the first selected data in the x axis and of the second data on the y axis, showing if there is a visible relation between them.

Once all the boxes completed as the user wants to, he has to click on the Production (Producción) button, marked with an arrow, which will display the next screen.

C. PRODUCTION

Once the Production button selected, the third personalization screen will show up. This third one is linked to the technical production management and deepens in the production factors and in the optimization of the asset, focusing in the installation performance. **All the information initially comes from the SCADA of the solar park and is extracted from the database where it has been stored.**

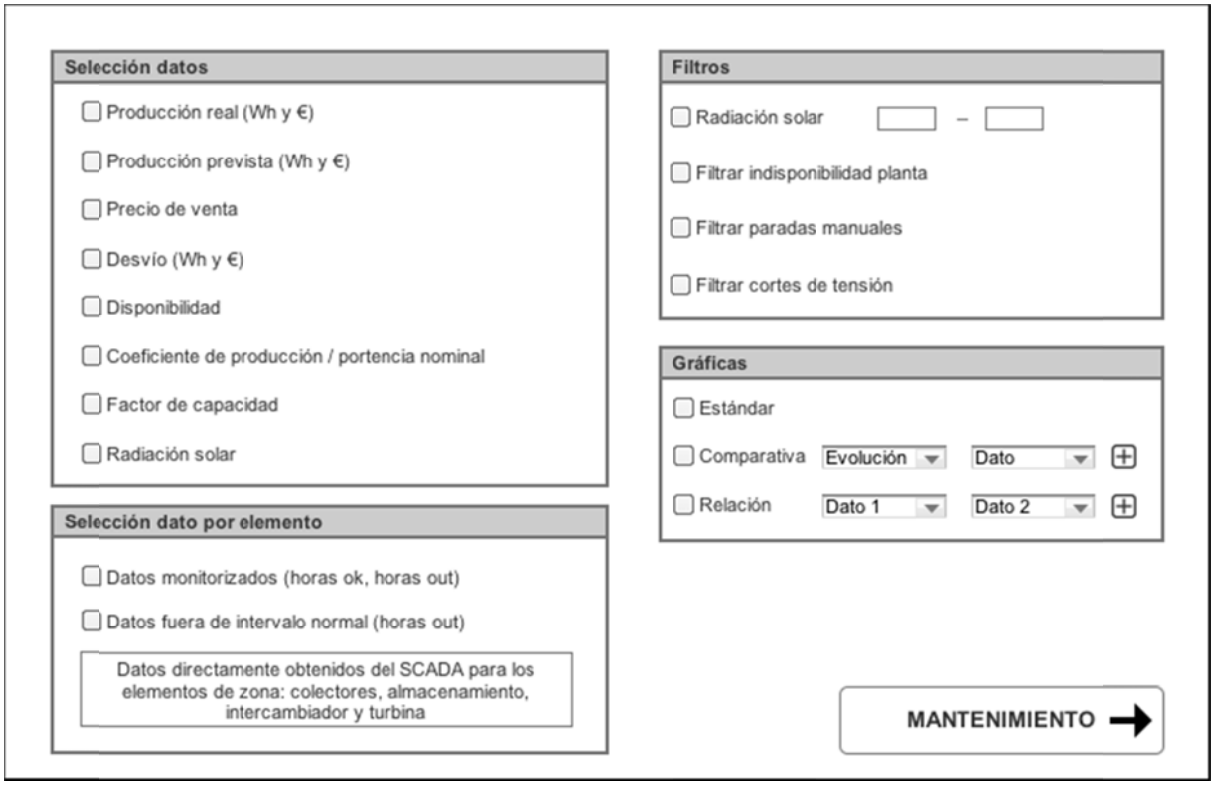


Figure 31: CSP Park Manager Reports Interface-Personalisation-Production

It is divided in four boxes, the first one is data selection (Selección datos), it occupies the upper left part of the screen and allows the user to select the specific information he wants to study. All the values linked to production performance will be shown for the whole installation. The user can choose between the following data:

- Real production (in Watt hour and in €)
- Budgeted production (in Watt hour and in €)
- Variation from the real and budgeted production (in Wh and in €)
- Real selling price
- Availability (in percentage)
- Production / nominal power
- Capacity factor
- Solar radiation

Just under Selection, in the left bottom of the screen we find another box called "Data Selection by element". This box has two options that define the values considered in the report. The user can chose between considering all the monitored data or only considering the data that has given alarm signals (SCADA value out of the normal interval) during the selected time period. This allows the manager to narrow the number of values and to only evaluate the elements that do not have worked properly.

The right side of the screen displays two boxes that are, from top to bottom, the "sort by" and the chart generation:

Sort by (Filtrar): Allows the user to only display the data that has the same time and date than the value of solar radiation included in an introduced interval. The manager also has the possibility to select the option "sort by unavailability" (which only consider the data when the solar park is available), "sort by manual stops" (do not consider the periods when the generation has been stopped by an operator) and "sort by power cuts" (do not consider the periods when the generation has been stopped by a power cut).

Charts (Gráficas): Allows the user to generate all the charts he wants giving him three different possibilities corresponding to three checkboxes. The first one is generating the standard ones (Estándar, cf Production Report description), the second one is the comparative one (Comparativa) where the user has to select a value (one of the chosen in the data selection) and if he wants to display the time evolution or the cumulated of the total period

for this selected value. Once chosen, a chart will show the time evolution (individual line chart) or the total (global bar chart) of this selected value. The third and last one is the relation chart (Relación) where the user has to choose two values of the selected ones before. Once chosen, a line chart will be generated with the interval of the measured values of the first selected data in the x axis and of the second data on the y axis, showing if there is a visible relation between them.

Once all the boxes completed as the user wants to, he has to click on the Maintenance (Mantenimiento) button, marked with an arrow that will display the next screen.

D. MAINTENANCE

Once the Maintenance button selected, the third personalization screen will show up. This third one studies the issues linked to mechanical breakdowns and maintenance work that have interfered in the normal production of the solar park in order to identify the principal problems where the manager has to focus his/her actions. **All the information is obtained from the SCADA and from the reports complemented by the technicians.**

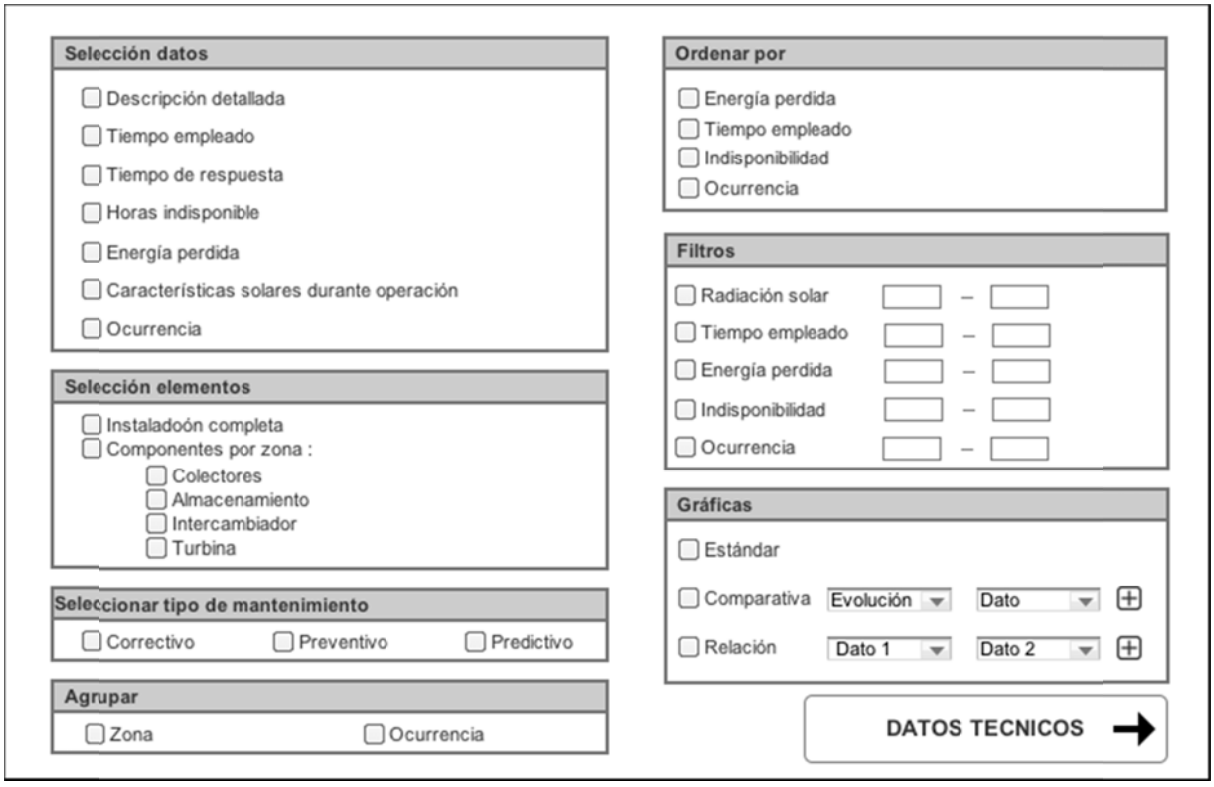


Figure 32: CSP Park Manager Reports Interface-Personalisation-Maintenance

It is divided in seven cases, four of them are the same than in the other screens and the other ones are linked to the specification of the data studied in this section.

The first one is data selection (Selección datos), it occupies the upper left corner of the screen and allows the user to select the specific information he wants to study. The information will be displayed for each maintenance work made in the selected interval:

- Detailed description of the maintenance work
- Time employed
- Response time
- Time unavailable (time not producing when it was planned to because of maintenance work and any kind of technical failures)
- Energy lost during maintenance work
- Solar radiation during maintenance work
- Occurrence

The left bottom of the screen displays three boxes that are, from top to bottom, the "element selection", the "maintenance type selection" and the "group by":

Element selection (Selección elementos) : It allows the user to focus the maintenance information in some areas of the solar park. The manager can choose between considering the whole plant or to select the solar field, the heat exchanger, the storages or the turbine.

Maintenance type selection (Seleccionar tipo de mantenimiento) : Allows the user to choose between the three kind of maintenance work that are done in the installation, the corrective, the preventive and the predictive one, in order to narrow the quantity of information managed.

Group by (Agrupar) : Allows the user to group all the maintenance works by area (all the maintenance information from an specific area will be putted together) or by occurrence (the most frequent ones are putted together).

The right side of the screen displays three boxes that are, from top to bottom, the "arrange by", the "sort by" and the chart generation :

Arrange by (Ordenar por) : Allows the user to display the information selected in the table in a specific way determined by the descending order for the values of energy lost, time

employed, time unavailable and occurrence.

Sort by (Filtrar) : Allows the user to only display the data that has the same time and date than the values of solar radiation, unavailability, time employed, energy lost or occurrence included in an introduced interval.

Charts (Gráficas) : Allows the user to generate all the charts he wants giving him three different possibilities corresponding to three checkboxes. The first one is generating the standard ones (Estándar, cf Maintenance Report description), the second one is the comparative one (Comparativa) where the user has to select a value (one of the chosen in the data selection) and if he wants to display the time evolution or the cumulated of the total period for this selected value. Once chosen, a chart will show the time evolution (individual line chart) or the total (global bar chart) of this selected value. The third and last one is the relation chart (Relación) where the user has to chose two values of the selected ones before. Once chosen, a line chart will be generated with the interval of the measured values of the first selected data in the x axis and of the second data on the y axis, showing if there is a visible relation between them.

Once all the boxes completed as the user wants to, he has to click on the Technical data button, marked with an arrow, which will display the next screen.

E. SCADA

Once the Technical data button selected, the fourth personalization screen will show up. This fourth one is linked to the technical performance of the plant regardless of the economic data or the budget fixed for the solar park. The machines and their elements are the central part. **All the information is obtained from the management databases (where the historical information from the SCADA and the technical data is stored).**

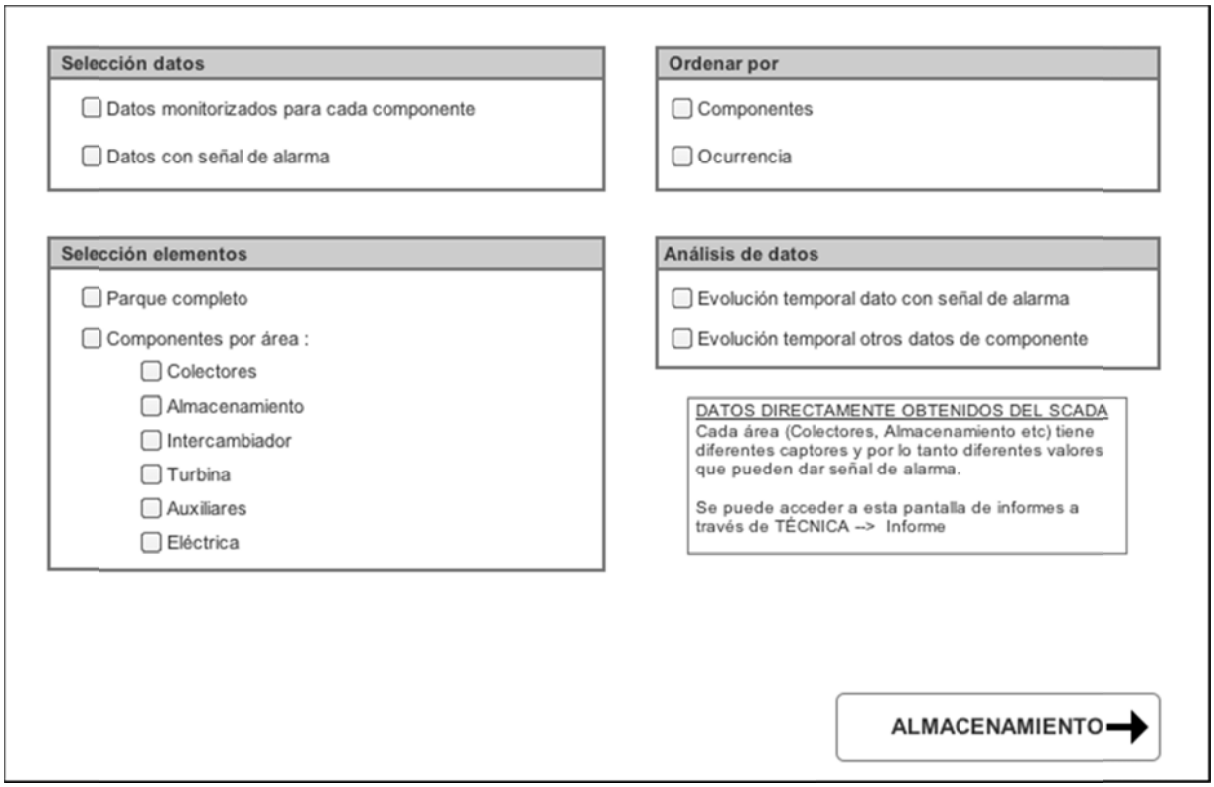


Figure 33: CSP Park Manager Reports Interface-Personalisation-SCADA

It is divided in four boxes, two on the right side and two on the left, smaller than the others presented before. The first one is data selection (Selección datos), it occupies the upper left corner of the screen and allows the user to select the specific information he wants to study. He can choose between:

- (Every) Data monitored for each component (the value obtained in the SCADA for each component and each time unit will be displayed in the generated table)
- (Only) Data with alarm signal (only when the value obtained in the SCADA is out of the normal interval, the time unit and the component will be displayed in the generated table)

The other three boxes are the element selection (under the data selection box), the group by (upper right) and the data analysis (middle right):

Element selection (Selección elementos) : It allows the user to focus the SCADA information managed in some areas of the solar park or in the whole plant. The user can choose between deepen in the solar field, heat exchanger, storage, turbine (cf Maintenance Report), auxiliaries supply and electric network.

Group by (Agrupar) : It is only choosable if the “Data with alarm signal” option has been selected in the first box. Allows the user to group all the displayed data by area (all the alarms from the same area are putted together; if it is not selected, the chronological order will be considered) or by occurrence (the most frequent ones are putted together).

Data analysis (Análisis de datos) : This section is useful for the user as it allows him to display the evolution, as a line chart concerning the selected time period, of the components that have raised an alarm (first checkbox) in order to notice a specific behaviour. It also allows the user to display the time evolution of all the components linked (are part of the same component or process) to the one that raised an alarm (second checkbox) in order to discern any possible relation.

Once all the boxes completed as the user wants to, he has to click on the storage (almacenamiento) button, marked with an arrow, which will display the next screen.

F. STORAGE

Once the storage button selected, the fifth personalization screen will show up. This fifth one is linked to the performance of the storage and its role in the generation process in the solar park, allowing evaluating the flux of energy throughout the thermal salt tanks during the selected time interval. **All the information is obtained from the SCADA of the park.**

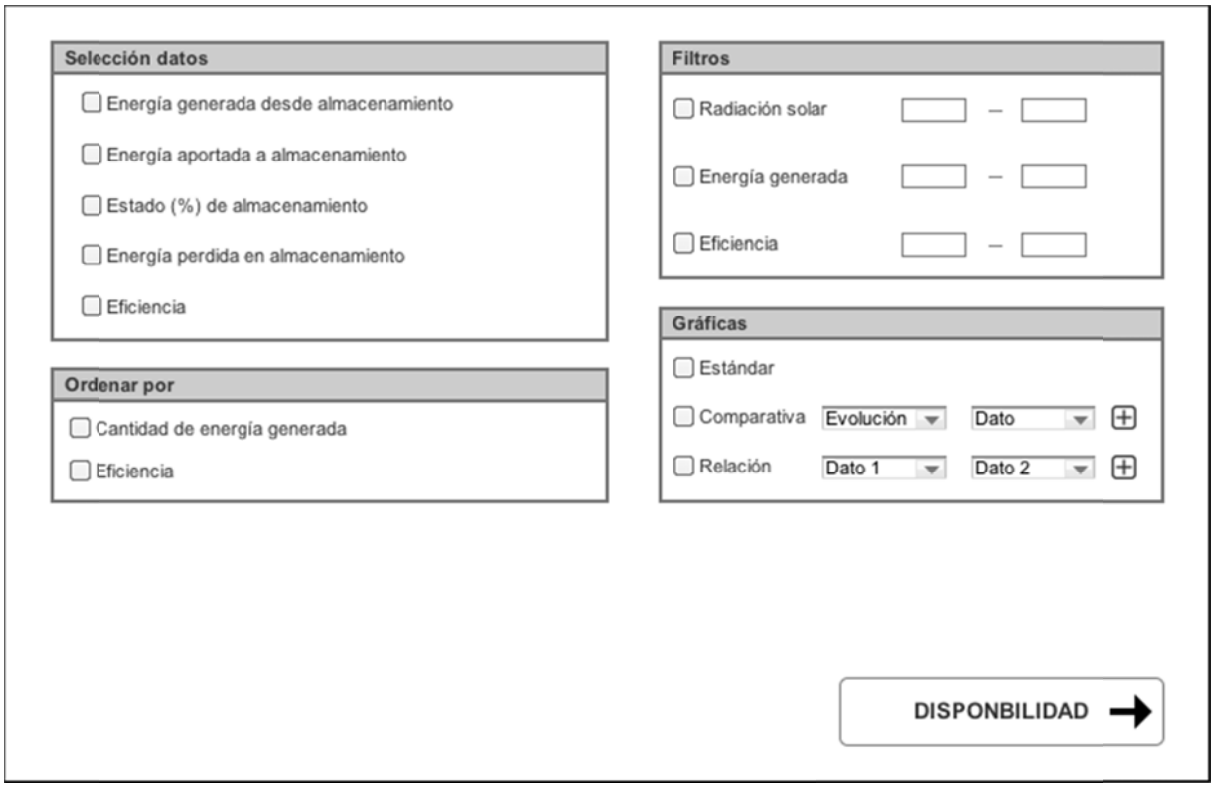


Figure 34: CSP Park Manager Reports Interface-Personalisation-Storage

It is divided in four boxes that are, from top to bottom and right to left, the selection data one, "arrange by", "sort by" and the chart generation box:

*Selection data (*Selección datos) : Allows the user to select the specific information he wants to study. All the information will be displayed for each tank and the whole storage. The user can choose between:

- Energy generated from storage
- Energy provided to storage
- Storage status (in percentage)
- Energy lost in storage (thermal losses)
- Efficiency of the storage (theoretical vs real)

Arrange by (Ordenar por) : Allows the user to display the information selected in the table in a specific way determined by the descending order for the values of the generated energy from storage or the storage efficiency.

Sort by (Filtrar): Allows the user to only display the data that has the same time and date than the values of solar radiation, generated energy and storage efficiency included in an

introduced interval.

Charts (Gráficas) : Allows the user to generate all the charts he wants giving him three different possibilities corresponding to three checkboxes. The first one is generating the standard ones (Estándar, cf Storage report description), the second one is the comparative one (Comparativa) where the user has to select a value (one of the chosen in the data selection) and if he wants to display the time evolution or the cumulated of the total period for this selected value. Once chosen, a chart will show the time evolution (individual line chart) or the total (global bar chart) of this selected value. The third and last one is the relation chart (Relación) where the user has to choose two values of the selected ones before. Once chosen, a line chart will be generated with the interval of the measured values of the first selected data in the x axis and of the second data on the y axis, showing if there is a visible relation between them.

Once all the boxes completed as the user wants to, he has to click on the Availability (Disponibilidad) button, marked with an arrow, to display the next screen.

G. AVAILABILITY

Once the Availability button selected, the sixth personalization screen will show up. This sixth one displays all the information linked to the state of the generation process in order to evaluate how much time the solar park has been producing and the causes if it has not been. The disponibility is a key factor in the accuracy of the budgetisation of the solar park production. **All the information is obtained from the management databases (where the historical information from the SCADA and the technical data are stored).**

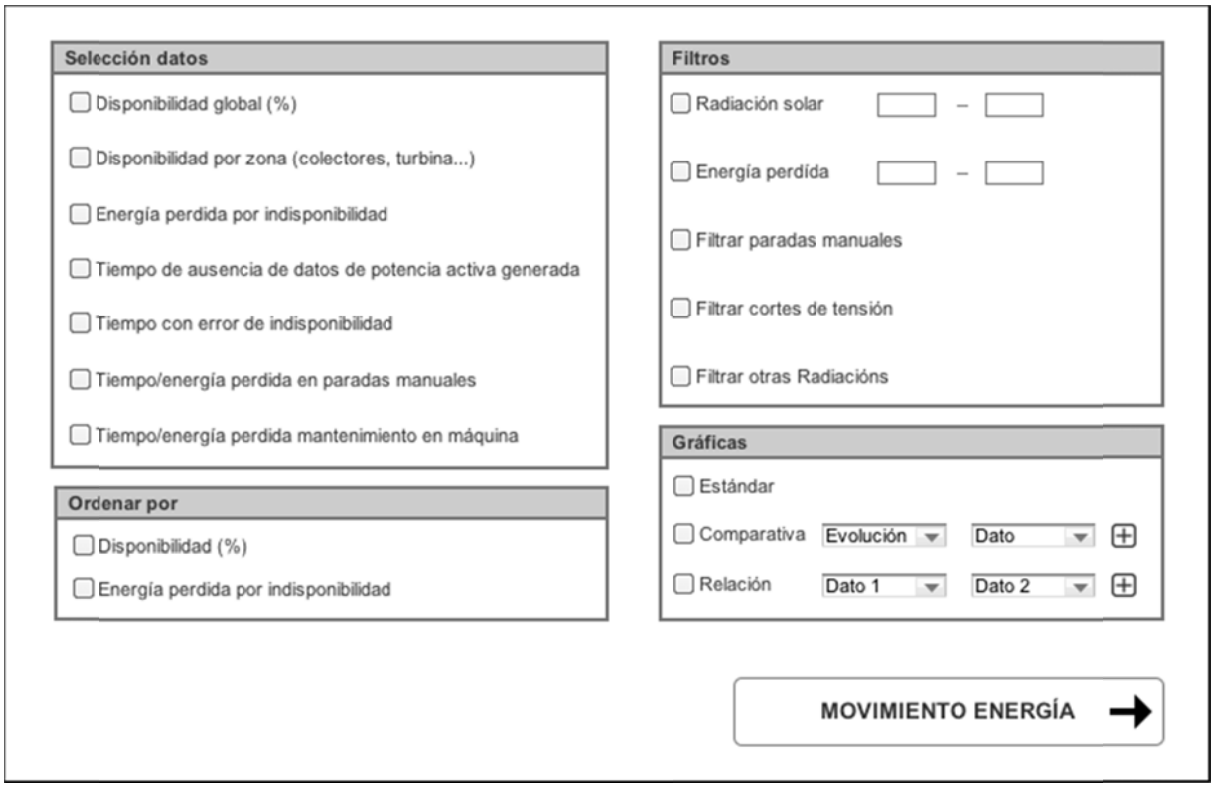


Figure 35: CSP Park Manager Reports Interface-Personalisation-Availability

It is divided in four boxes, the first one is data selection (Selección datos), it occupies the majority of the left part of the screen and allows the user to select the specific information he wants to study. All the selected values will be shown for the whole installation (except the availability per area). He can choose between the following data :

- Availability of the solar park (in % of the total selected time period)
- Availability per area (solar farm, heat exchanger, turbine, storage…)
- Energy lost due to unavailability
- Time with absence of data about the generated active power
- Time with unavailability errors
- Time / Energy lost with planned manual stops
- Time / Energy lost with maintenance work in the machine

The three other boxes are, from top to bottom and right to left, the "arrange by", the "sort by" and the chart generation:

Arrange by (Ordenar por): Allows the user to display the information selected in the table in a specific way determined by the descending order for the values of Availability and Energy lost due to unavailability.

Sort by (Filtrar) : Allows the user to only display the data that has the same time and date than the values of solar radiation or energy lost included in an introduced interval. In addition, the user can filter the manual stops, power cuts and other errors from the calculus effectuated.

Charts (Gráficas) : Allows the user to generate all the charts he wants giving him three different possibilities corresponding to three checkboxes. The first one is generating the standard ones (Estándar, cf Availability Report description), the second one is the comparative one (Comparativa) where the user has to select a value (one of the chosen in the data selection) and if he wants to display the time evolution or the cumulated of the total period for this selected value. Once chosen, a chart will show the time evolution (individual line chart) or the total (global bar chart) of this selected value. The third and last one is the relation chart (Relación) where the user has to chose two values of the selected ones before. Once chosen, a line chart will be generated with the interval of the measured values of the first selected data in the x axis and of the second data on the y axis, showing if there is a visible relation between them.

Once all the boxes completed as the user wants to,by clicking on the Energy Movement (Movimiento de energía) button, marked with an arrow, the next screen is displayed.

H. ENERGY MOVEMENT

Once the Energy Movement button selected, the last personalization screen will show up. This seventh one concerns all the energy and auxiliaries flows, influx and outflux, during the selected time interval in the solar park. As the installation consumes energy, gas and water, it is interesting for the manager to evaluate the net energy produced and the auxiliaries consumption and, in consequence, the real performance of the plant. **The information is obtained from the management databases (where the historical information from the SCADA and the energy bills are stored).**

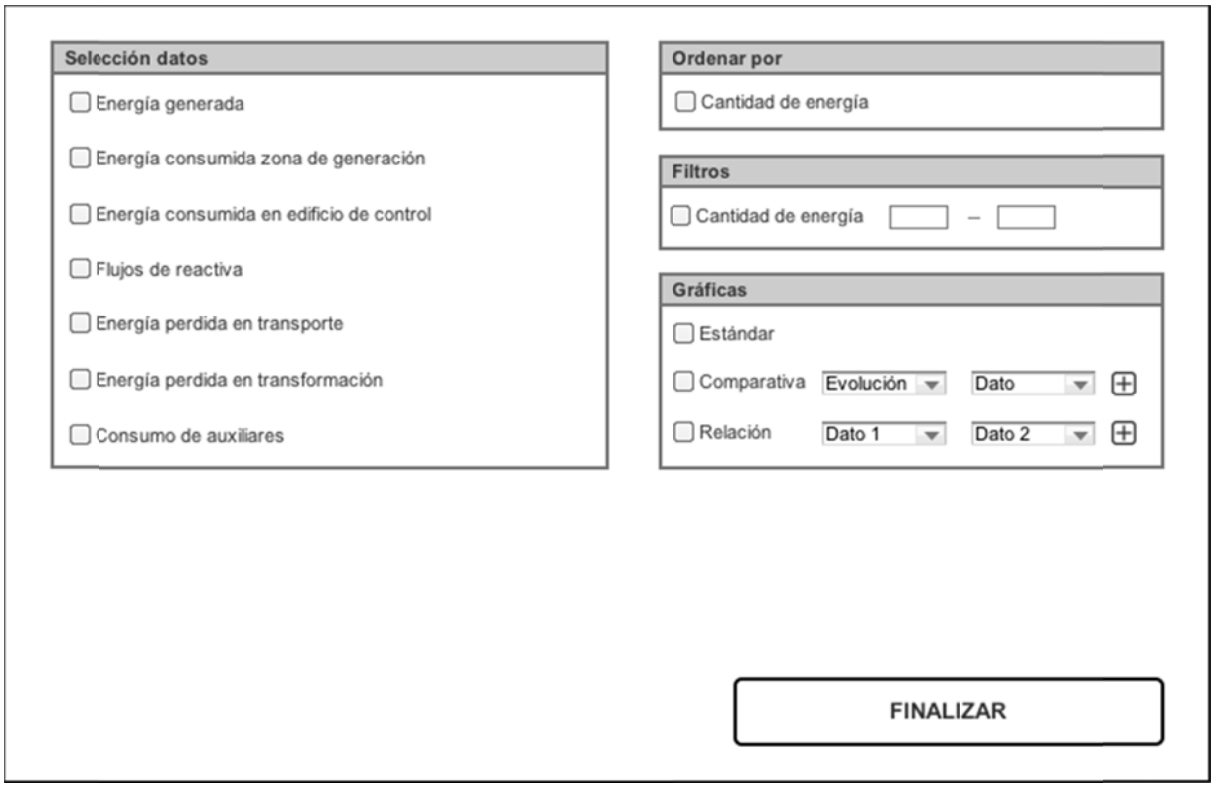


Figure 36: CSP Park Manager Reports Interface-Personalisation-Energy Movement

It is divided in four boxes, the first one is data selection (Selección datos), it occupies the whole left part of the screen and allows the user to select the specific information he wants to study. He can choose between the following data:

- Energy generated
- Energy consumed in the generation chain (solar field, storage, heat exchanger, turbine)
- Energy consumed in the control building
- Reactive power flow
- Energy lost in transportation
- Auxiliaries (Water and Gas) consumption

The right side of the screen displays three boxes that are, from top to bottom, the "arrange by", the "sort by" and the chart generation:

Arrange by (Ordenar por): Allows the user to display the information selected in the table in a specific way determined by the descending order for the amount of energy in order to notice where the losses are greater.

Sort by (Filtrar): Allows the user to only display the data that has the same time and date than the amount of energy included in an introduced interval in order to filter the quantities to study and narrow the number of managed data.

Charts (Gráficas) : Allows the user to generate all the charts he wants giving him three different possibilities corresponding to three checkboxes. The first one is generating the standard ones (Estándar, cf Energy Movement Report description), the second one is the comparative one (Comparativa) where the user has to select a value (one of the chosen in the data selection) and if he wants to display the time evolution or the cumulated of the total period for this selected value. Once chosen, a chart will show the time evolution (individual line chart) or the total (global bar chart) of this selected value. The third and last one is the relation chart (Relación) where the user has to chose two values of the selected ones before. Once chosen, a line chart will be generated with the interval of the measured values of the first selected data in the x axis and of the second data on the y axis, showing if there is a visible relation between them.

Once all the boxes completed as the user wants to, he has to click on the "END" (Finalizar) button in order to finally generate the completely personalised report in the format chosen before.

6. INCOME STATEMENT

This page of the Solar Park Manager interface allows him to access to all the purely economic information concerning the performance of the installation as it gives access to all the profit and loss statements for each month and year the plant has been operating.

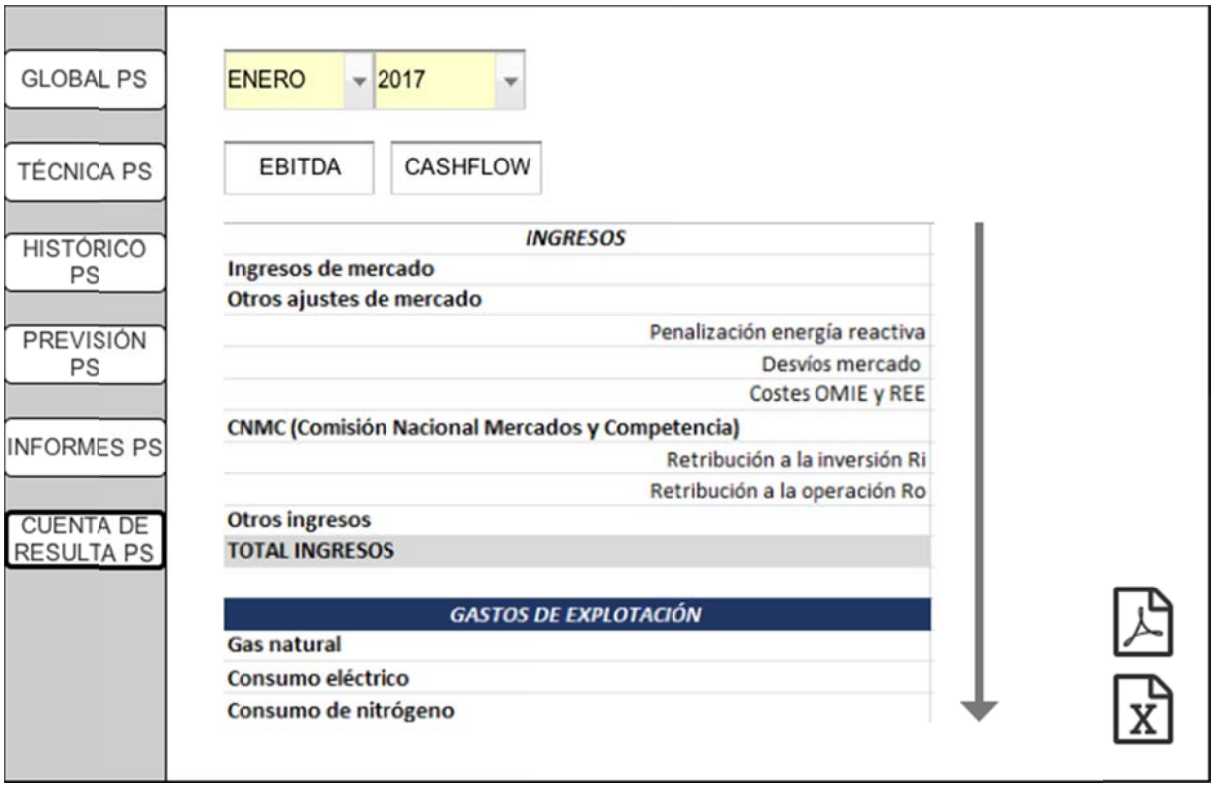


Figure 37: CSP Park Manager Income Statement Interface

As we can observe in the image above, the only thing the user has to do is to indicate in the yellow boxes the month and year he wants. Once selected, the income statement, **obtained in the management database**, will be displayed. It also allows the Manager to generate a PDF or and Excel with the given information clicking on the corresponding icon on the lower right corner of the screen.

iii) Wind Technology Manager

This package is only accessible for the user accredited as "Wind Technology Manager" or for those who are higher in the company hierarchy such as the COO or the CEO.

The wind technology manager is in charge of the supervision and optimization of the activity of the company's wind farms. Thus, in order to assure an optimal management of the farm, he has to be able to access to all the real-time information of the plants, as well as to all their historical data. He wants to know how much we are producing, how much we have produced, how much we are going to produce and why. In addition, he has to keep an eye in the economic (incomes) and mechanical (maintenance) issues of the plant, as well as the role they are playing on the electricity market.

That said, the package consists of five pages: Global, Historicals, Forecast, Reports and Income Statement. Once logged in, the home page displayed is the Global Page. By pressing the buttons of the left main menu, the user is able to move from one page to another.

1. GLOBAL

It's the main page of the package and it's the first one the user will see when he accesses the control center.It shows a photograph of the real-time status of the wind activity.

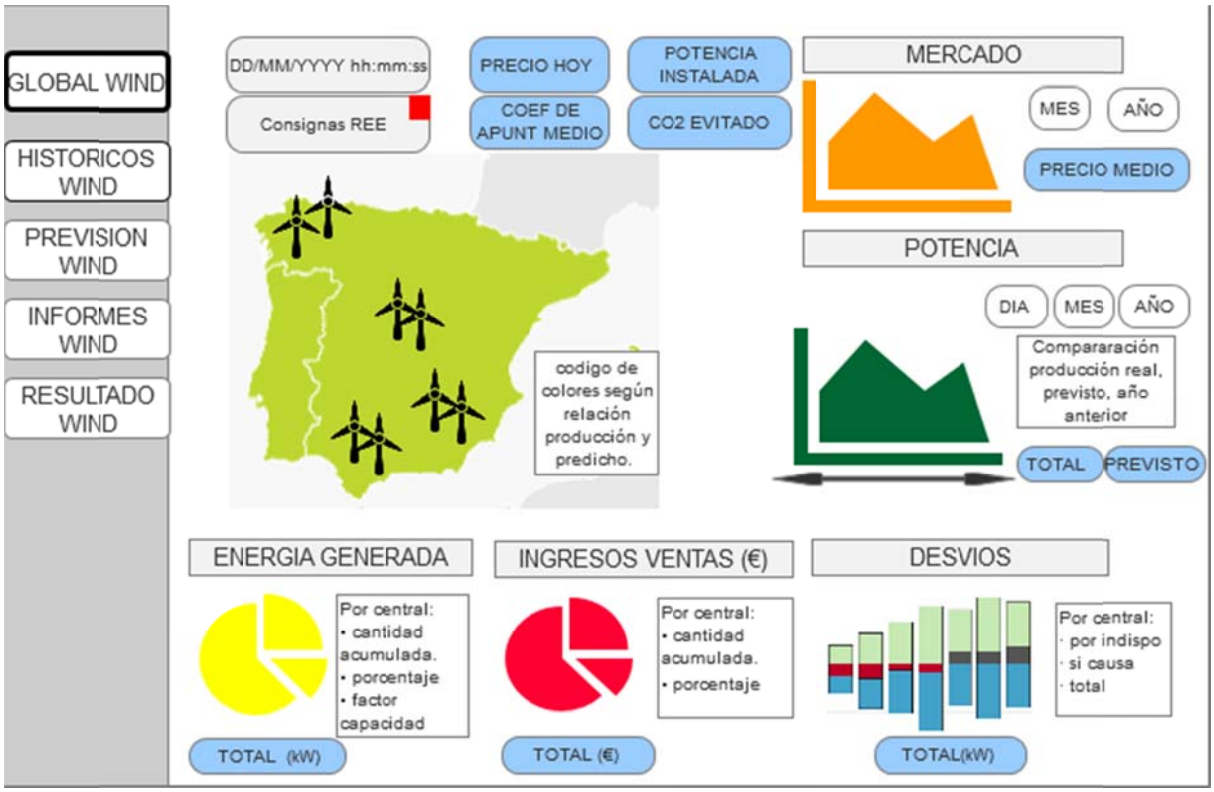


Figure 38: Wind technology Manager Global Interface

-DAILY DATA

In the upper left of the Global page we find the date and hour at the time of consultation of the control center as well as the REE alarms checkbox that will pop-up if new alarms linked to the operation of the wind farms have been received. Next to it, we find, first of all, the actual electricity sale price or Pool price which is **extracted from OMIE's platform each hour**. Secondly, the Wind farm installed capacity and the peak coefficient, which are stored in the management **database and remain unchangeable.** Thirdly, there is the Company's peak coefficient. This coefficient is calculated and stored in the control center's data base. To conclude, there is the CO2 avoided, a figure calculated by the company and used to evaluate how sustainable is the company's activity.

-LOCATION MAP

The plant location's map is on the left side of the screen. It displays the geographic and production status of the plants. The icon used to identify the wind farm is composed by two wind turbines. Depending on the rapport of the real production and the expected production, the icon will be coloured differently.

	If the difference between the farm's real production and the expected production is in a range of of 0 - 10%
	If the difference between the farm's real production and the expected production is in a range of of 10 - 20%
	If the difference between the farm's real production and the expected production is over 20%

The colour of the icons is **updated after every market pool based on the data available on the control center's database regarding forecast and real production.**

To conclude, **the icons also act as buttons that enable the user to access to the package of the responsible of each wind farm** to know more in detail about the plant's activity.

- MARKET.

The aim of the line chart is to reproduce the evolution of the Wind PMD, the Wind Budget price and the company's final selling price. Thus, the Y axis measures price in €/MW while the X axis represents the time. The time scale varies according to the option chosen: days if the option is MONTH and months if the option is YEAR. The default option is MONTH.[4] In both cases the chart includes three curves.

If the selected option is month, the data corresponding to each curve is:

- Wind PMD curve: the daily **price is collected from the markets operator website and it is corrected by the law's wind peak coefficient, available on the management data base.**
- Wind Budget curve: **the monthly budget price is available in the management database.**
- Company's wind final selling price curve: the daily final price **collected from the sale agents' fortnight reports which are stored in the database**.

Concerning the three curves, the values displayed correspond to the mean of the sector. Thus, to display the wind budget curve, the control center must calculate the mean of the budget prices of all the wind plants. By the same token, the final selling price curve results of the mean of the final prices of each Market Agent.

As the Market Agents reports are sent every two weeks, the data refreshes once the new report is received.. Therefore the user doesn't have the information of the current day until this period is finished.

To conclude, if the selected option is MONTH, beside the chart it will be the numerical value of average real price of the company's wind plants commercial activity of the last 30 days. Likewise, the average value of the year will be plotted if the selected option is YEAR.

-PRODUCTION (POTENCIA)

The production chart enables the User to follow the performance and the evolution of

[4] *This graph is the same one that the "WIND MARKET EVOLUTION"one included in the market and regulation managers's global page.*

the production of the wind plants. The chart includes three curves: Real Production, Forecast Production and Year N-1. Depending on the option selected (DAY, MONTH or YEAR) the plotted graphs will be slightly different. In the three cases the the Y axis represents power while the X axis represents the timeline. That said, the default chart is the MONTH.

The DAY's line chart displays in three curves the following information.

- The real production
- The forecast sent to the dairy market (with percentile 10 and percentile 90)
- The corrected forecast

The real production curve is based on the data collected from the meters and the Scada. This information is taken every 10 secs and but **it is recorded aggregated on the database every 10 minutes. Thus, the curve will refresh once new data is stored.**

The other curves derive from the forecasts sent to the intraday market and the dairy market. **The corrected forecast curve is plotted while the production is recalculated and sent to the intradaily market and so it refresh after each intradaily market forecast.** (17.00, 21.00, 01.00, 08.00, 12.00) while the dairy market forecast curve **is updated every day.**

The MONTH's and YEAR chart displays in three curves the following information:

- The real production
- The Forecast production
- The Production of year N-1.

The data used to create the graph comes from the scada and is **available on the historical database.** The **MONTH chart datum correspond to the sum** of the concerning day's real production of all the wind farms. Thus, the MONTH chart **refreshes every day** at the end of it**.** T**he YEAR chart datum correspond to the sum** of the daily productions of all the wind production plants. Thus, the YEAR Chart **refreshes every month.** The last datum, the one corresponding to the current month, shows the production of that month up to date**. The information corresponding to year N-1 is displayed with the same frequency than the one from year N.**

-GENERATED ENERGY. (ENERGÍA GENERADA)

The Generated Energy chart is a pie chart whose aim is to illustrate the contribution of each wind farm to the company's production during that month.

The whole pie represents the total production and each piece of it, a wind farm. The size of the piece depends on the portion of the total production produced by the corresponding plant. By, clicking on each piece, it must be shown:

- The aggregate amount of energy produced by the plant during that month in KW.
- The percentage that it represents of the total wind production.
- The average capacity factor of the plant during that month.

Added to that, beside the chart, the total amount of aggregated energy that has been produced by the wind farms during that month is displayed too.

All this values can be calculated with the information available on the Data Base concerning the daily productions (SCADA) and the daily capacity factor (Management data).

Once the final daily aggregate production per plant has been calculated and stored on the historical data base, the pie chart is updated. **Thus the pie chart and the values concerned refresh everyday.**

-REVENUES (INGRESOS VENTAS)

The revenues chart is a pie chart that illustrates the contribution of each wind farm to the company’s market revenues during that month.

The whole pie represents the total revenue and each piece of it, a wind farm. The size of the piece depends on the portion of the total revenue produced by the corresponding plant. By, clicking on each piece, it must be shown:

- The aggregate revenue produced by the plant during that month in €.
- The percentage that it represents of the total wind production.
- The average selling price of the plant.

Added to that, beside the chart, the total aggregate revenue produced by the wind

technology is displayed too.

The pie chart and the values are calculated with the data provided by the market agents report. Once a new report is received, the revenues and the prices of each plant are extracted and added to the current values. **In this chart, the revenue is calculated as the product of the amount of energy sold and the real final price.**

That said, taking into account that the reports are received every two weeks, **the revenue pie chart must refresh every two weeks**[5] too.

- DEVIATIONS (DESVIOS)

The deviations charts shows the user the performance of the wind farms in terms of accuracy between what it was forecast and what the wind farms actually produced.

This chart is based on the deviations chart displayed on the wind farm manager's global page

In this case, the chart doesn't represent the evolution of the deviations of a single wind farm but the aggregate deviations per farm. That said, on one hand for each plant we find the part representing the energy deviation due to the unavailability of one or more set, which is the cumulative of that same attribute from each of the columns of the "*i-1 Energy deviation data chart.*" On the other hand, the part that shows the deviation caused by the power curve breach, wich is likewise, calculated as the aggregate of this same value from each of the columns of the evolution chart "i- *Energy deviation data.*"

As this graph is based on the wind farm the source of information and the method of calculation are those described before. By the same token, **the chart refresh frequency matches too**. The chart is updated when a new column appears on the *I-1Eenergy deviation DATA* chart of all the farms.

2. HISTORICALS.

This page allows the Manager to access to the historical data that reflects the performance of the wind farms during a last period of time. It is accessible from the left

[5] *The fact that the information concerning the revenues is received two weeks later, leads to a fortnight delay on the update. Thus, from day 1 to day 15 of month M the pie chart displayed will be showing the information concerning the end of month M-1.*

column of the control center interface. More specifically, the historicals page gives the user an idea of the global page of a past period of time, with the advantage that the wind farms concerned can be filtered.

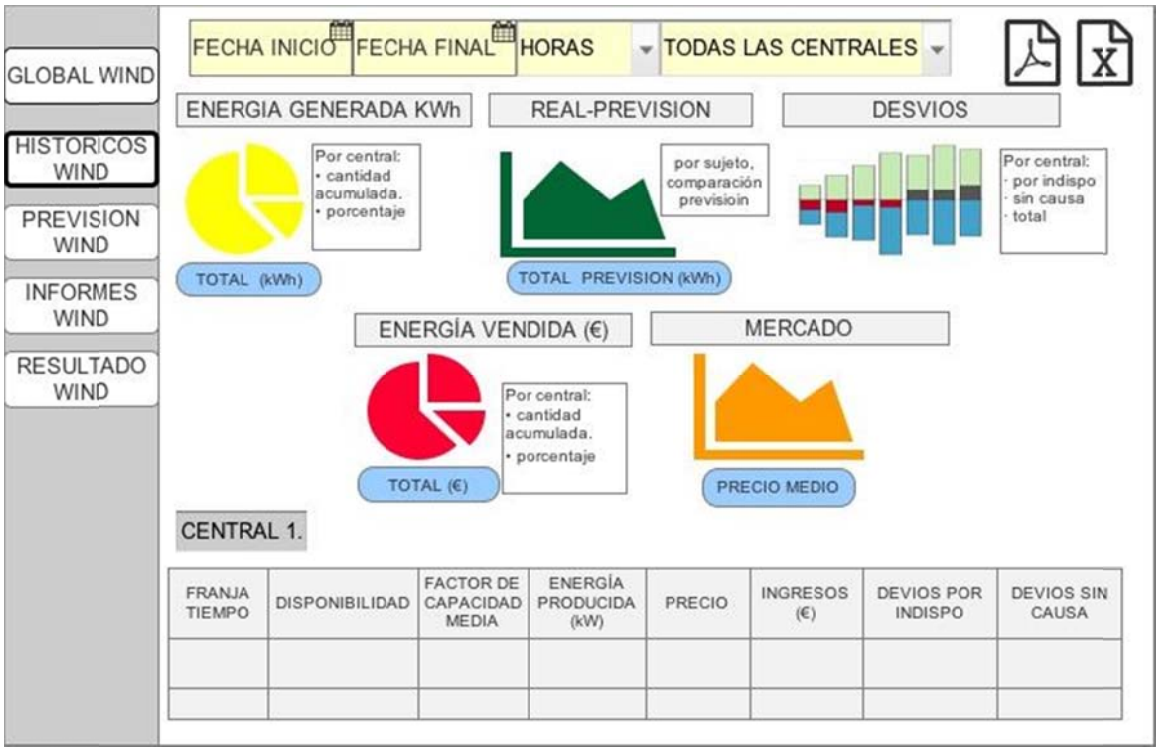


Figure 39: Wind technology Manager Historicals Interface

The page is divided in three sections: Selection, Charts and schemes and Data table. The Historical page doesn't have an automatic refresh frequency. Indeed, once a command has even executed, the screen freezes keeping the outputs until a new request is carried out.

-SELECTION

On the top of the page we find the selection boxes. The selection boxes include: the starting date, the final date, the time unit of time and the wind farms to be included.

Regarding the time selections there are the following constraints:

- The final date is limited by the current date.
- If the time interval is a day, the only possibility of time grouping unit is HOURS.
- If the time interval is between 1-31 days, the possibilities of time grouping unit are DAY and WEEK.

- If the time interval is between 31-92 days, the possibilities of time unit are DAY, WEEK and MONTH.
- If the time interval is between 92-365 days, the possibilities of time unit are WEEK, MONTH and TRIMESTER
- If the time interval is bigger than 365, the possibilities of time unit are MONTH, TRIMESTER and YEAR.

-CHARTS AND SCHEMES

This section is composed of five charts: two of them are evolution charts (The Market Evolution Chart and The Production Evolution Chart) and the other three, cumulative (The Generated Energy Pie-chart, The Revenues Pie-chart and the Deviations Barchart). Depending on the time interval , there are some element that may be modified or not be available.

The generated energy pie chart follows the same philosophy that the *iii-1-GENERATED ENERGY* but framed by the conditions set on the selection boxes.

The *revenues pie chart* follows the same philosophy that the *iii-1.REVENUES* but framed by the conditions set on the selection boxes.

The *deviations graph* follows the same philosophy that the *iii-1 DEVIATIONS* but framed by the conditions set on the selection boxes.

The *production evolution* graph is composed by two curves: The forecast production curve and the real production curve.

The forecast production curve is based on the data sent by the weather forecast agent the eve of the day concerned. The real production curve is based on the data recorded by the scada.

If the chosen interval is a day, as the time unit is an hour, this chart will only be available if the day falls under the last month. Otherwise, the value per hour will not be exist on the control center's data base.

The *market evolution char*t is composed of two curves: The Company's final selling price curve and the market's selling price curve.

The company's final selling price is based on the data extracted from the

market's agent reports. The Market's selling price curve is based on the data extracted from the OMIE's website.

-DATA TABLE

To conclude, at the bottom of the page we find a table corresponding to each centrale, which includes the intermediate numerical values used to create the charts. . The table contains the following columns:

- Temporal instant: computed values based on the time unit chosen on the selection box.
- Disponibility: Recorded by Scada and available on the HDB.
- Capacity Factor: Recorded by the Scada and available on the HDB.
- Produced Energy: Recorded by the Scada and available on the HDB.
- Revenues: Extracted from the Market Agent Reports and available on the Database
- Deviations due to disponibility: Calculated
- Deviation caused by another cause: Calculated

The time constraints must be also respected. If there is no value for such an small time unit, the value of the following unit time will be assumed as the average of all the intermediate ones.

Once the output has been displayed, the user has the option to download it into a excel sheet or a pdf sheet.

3. FORECAST

This screen allows the Wind Technology Responsible to access to the forecast of the wind farms activity in terms of production and market. It is accessible from the left column of the control center interface by clicking in the corresponding button.

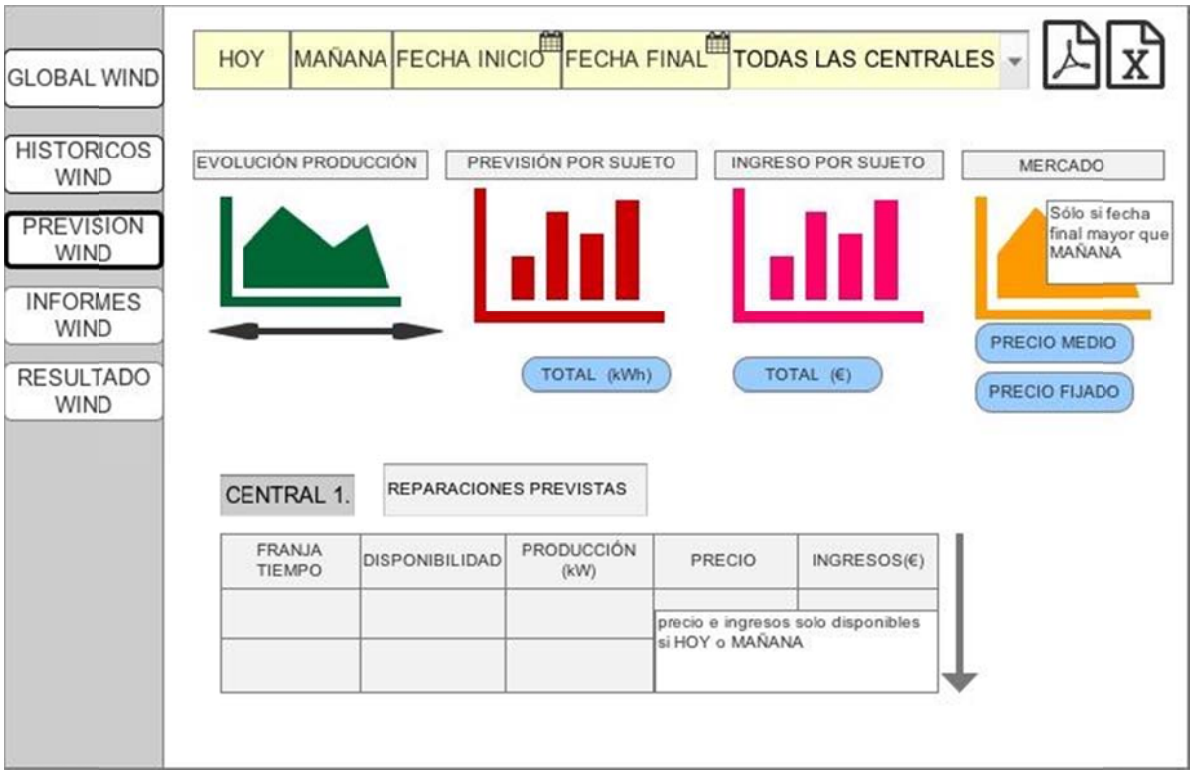


Figure 40: Wind technology Manager Forecast Interface

The page is divided into three sections: selection, charts and schemes and data table.

-SELECTION

On the top of the page we find the selection boxes. The selection boxes include: the starting date, the final date and the wind farms to be included. Added to that, the user has also the option to choose just that day's forecast or the following day's forecast by selecting "HOY" or "MAÑANA"

Regarding the Time selections there are the following constraints:

- The final date cannot be earlier than the starting date.
- The final date must fall under the following three subsequent months.

CHARTS AND SCHEMES

This section displays four charts concerning the behaviour of the production, the revenues and the market throughout the selected period of time.

The *Production Evolution Curve* has three versions depending on the selected period of time.

If the selected period of time is *TODAY* the time axe is divided into intervals of one hour and the chart includes three curves. First of all we find the real production curve with the information available up to the time of consultation. **The data used to plot this curve comes from the information recorded by the scada**. Secondly, we have the market's offer forecast curve, **which is based on the forecast sent by the weather forecast agent the day before.** Finally, to conclude we have the updated forecast curve. The data used to plot this curve **comes from the intraday forecast that the weatherforecast agent estimates for each intraday market pool.**

If the selected period of time is *TOMORROW* there are two possible scenarios. **If the report with the forecast for the following day is available on the data base, the production curve will be based on the data extracted from that report.** Otherwise, if the company hasn't been provided of that report yet, the curve will result from the **data available on the most recent fortnight forecast report available on the control center's data base.** That said, in both cases the time axe is also divided into intervals of one hour.

If the selected period of time falls under the dates included in the most recent fortnight report provided by the weather forecast agent, **the product evolution curve will be based on the data extracted from it.**

To conclude, If the selected period of time doesn't fall under the dates included in the most recent fortnight report available on the control center data base, **the control center will use the production of year N-1 during that period of time to plot the forecast curve.** In this case the unit of the time axe depends on the duration of the period. If the period is shorter than 48 hour, it will be aggregated into hours. Otherwise, it will be aggregated into days.

Having said that, as the curve must include the forecast of all the farms marked on the selection box, the source of the data used to plot the curve must be the same for all of them. I.e The source of information must be the most updated one from which we can extract information of all the desired wind farms.

The production barchart reports the user the contribution per plant of the forecast production.

The sources of information used to create this chart follow the same trend that the one described above. However, in this case, instead of aggregating the values of all the plants for each time unit, **the value to be calculated is the sum of the production per plant during**

the given period of time. Thus, each column of the barchart will represent the total production of each plant through the period selected by the user.

The revenues barchart informs the user about the revenues to come during the desired period of time. The height of each bar represents the revenue that each wind farm will produce.

The value result of the sum of the multiplication of the forecast production and the forecast price of the market at each instant. The values of the production are extracted following the trend described above for the production evolution curve. The price is extracted from the data provided by OMIE's website.

If the end date does not fall under the next 48 hours, as there is no hourly or daily information about the price, this char is not displayed.

The *market evolution curve* represents the expected behaviour of the market's price during the chosen period of time. Depending on the period chosen, the graph presents some variations. If the chosen period is today or tomorrow, the graph will display the hourly data. If the chosen period doesn't fall under the next 48h, the chart will not be displayed. Instead, **it will be displayed the value provided by the OMIE's website concerning the selected time period.**

To conclude, there is a pop up box with the number of maintenance work planned for the chosen period of time. If the user clicks this bottom, he will access to their description (wind farm affected, elements affected, duration…). **This information available from the control center's data base and is extracted from the maintenance reports.**

-DATA TABLE.

Finally, at the bottom of the page we find a table corresponding to each centrale, which includes the intermediate numerical values used to create the charts. The table contains the following columns:

- Instance
- Availability
- Production
- Price
- Revenues

Similarly to the charts regarding price and revenues, the information will only be available if the period of time falls under the subsequent 48 hours.

To conclude, the user can download the output displayed for his request into a an excel sheet or a pdf file by pressing the corresponding button.

4. REPORTS.

This section is the one that actually allows the user to manage and interact with all the data generated by the whole wind technology activity. It is where the added value of the control center lies in as it gives the opportunity to manipulate all the elements from different points of views and personalise reports. It is accessible from the left side menu.

4.1 REPORT'S HOME PAGE

The reports Home Page is the first screen the user sees when clicking on the corresponding button.

This Homepage enables the user to easily generate standard reports. These reports are the same that those described on the Wind Farm Manager Reports section. That said, the page is divided into three sections: Selection, Reports and Files.

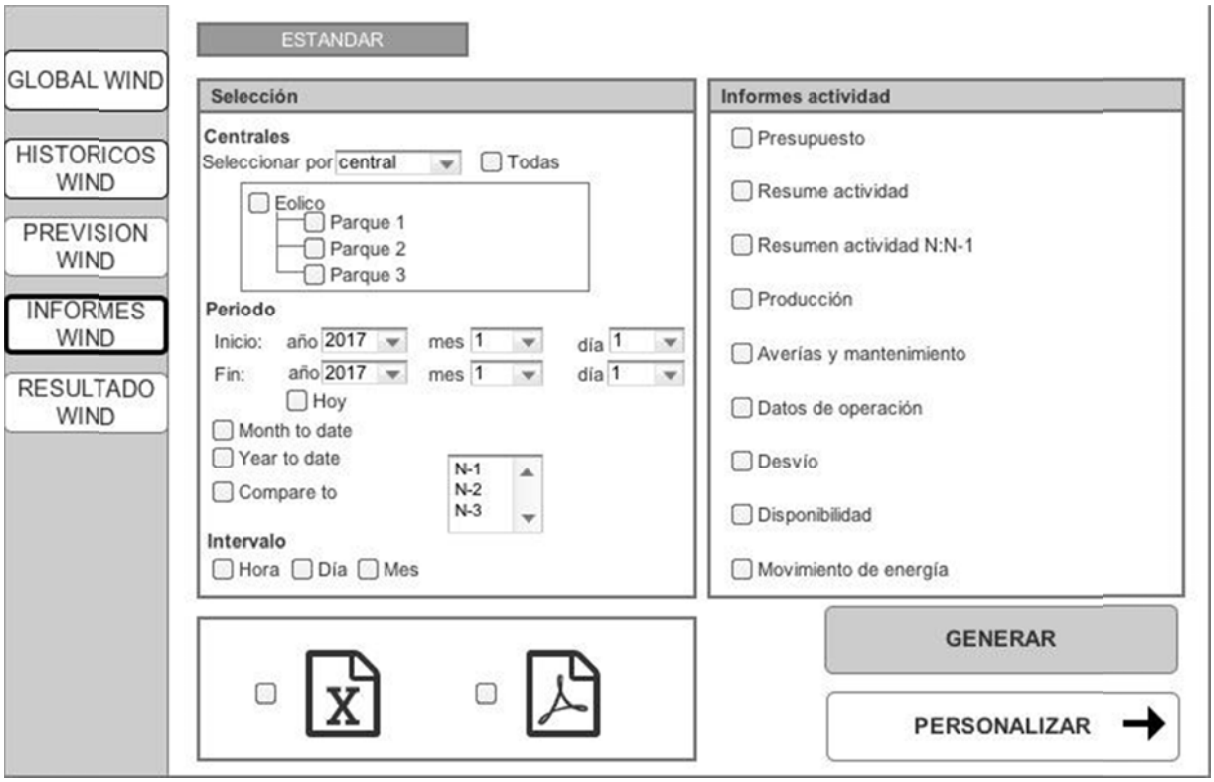


Figure 41: Wind technology Manager Reports Interface- Homepage

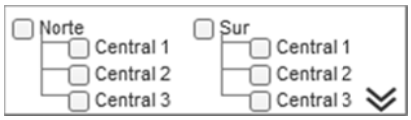
-SELECTION

a. Plant

First of all the User has to choose the plants he wants to include in his Reports. He can either choose all of them, or according to a subgroup. The subgroups are: Technology, Geographic Location, Market Agent or Plant

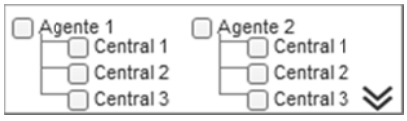
i) Geographical Location

If the marked option is Geographical Location, the plants will be displayed grouped by Geographical Location. The User has the option to choose the whole set of plants of each specific zone, or to choose only some of the plants within them.



iii) Market Agent

If the marked option is Market Agent, the plants will be displayed grouped by their corresponding Market Agent.



iv)Plant

If the marked option is Central, the whole list of plants will be displayed.

The aim of this selection method is to simplify the searching process for the user and to optimize the "path" that the searching algorithm must follow in order to create the report.

b. Period

Once the object of study has been chosen, the User has to specify the time interval the control centre must collect the data from. To do so he has to fix the starting and final date.

If the User doesn´t want to limit the interval in the traditional way he can also choose the Month to date and the Year to date option. These options are compatibles and can be marked at the same time.

To conclude, after having chosen the time interval, the user can demand to compare the period with the analogous period of a previous year. To do so he has to select the option "compare to" and the year affected knowing that N is the year at the time of consultation.

The constraints tied to the period selection are:

- The time period has to be a multiple of a fortnight. Otherwise, the remaining days will be filled with a hyphen.
- The longest time period is 365 days.
- The user could ask for information of years N, N-1, N-2. Older information won't be able on the database.

c. Time-grouping unit

The time grouping unit alludes to the frequency in which the data will be grouped and displayed. There are four possibilities: FORTNIGHT, MONTH, TRIMESTER OR YEAR.

The constraints tied to the time grouping unit selection are:

- There is no possibility to choose a time grouping unit bigger than the period itself.
- If the time interval is between 1-31 days, the possibilities of time grouping unit are FORTNIGHT OR MONTH.
- If the time interval is between 31-93 days, the possibilities of time unit are FORTNIGHT or MONTH.
- If the time interval is between 93-365 days, the possibilities of time unit are MONTH or TRIMESTER

-REPORTS

In this box, the user can choose between seven different reports that, although they are standardised, provide specific information about key topics of the management of the wind farm. As said before the standard reports are those described on the Wind Farm Manager Reports. *(See i-5.1-3 Reports)*

However, as in this section the reports may include more than one variable the structure presents some variants. Before the resulting reports, the following columns are added:

- Geographical Zone
- Market Agent
- Plant

As the plants from the same geographical zone normally have a similar behaviour, the default configuration to display the data is Geographical Zone-Market Agent-Plant.

To conclude, the graphical output of these reports, based on the graphs included on the wind farm standard reports, must display cumulative charts representing each geographical zone as well as global charts representing the whole technology's activity.

Having said that, if the user doesn't want one of the standard reports (If none of them are marked as selected), he can create personalised reports by pressing the personalise button. (See 4.2 PERSONALISATION). Otherwise, if the user actually wants to generate a standard report, he won't be able to press the GENERATE button unless at least one report is selected.

1. File

Finally the user has to choose if the report has to be generated into an excel file or pdf.

4.2 PERSONALISATION.

Once the Personalization button is selected, different screens will appear on the user interface that will allow him choose and manipulate the data in order to maximize the utility of the future report.

A. SELECTION

The first page of the Personalisation series is the selection page.

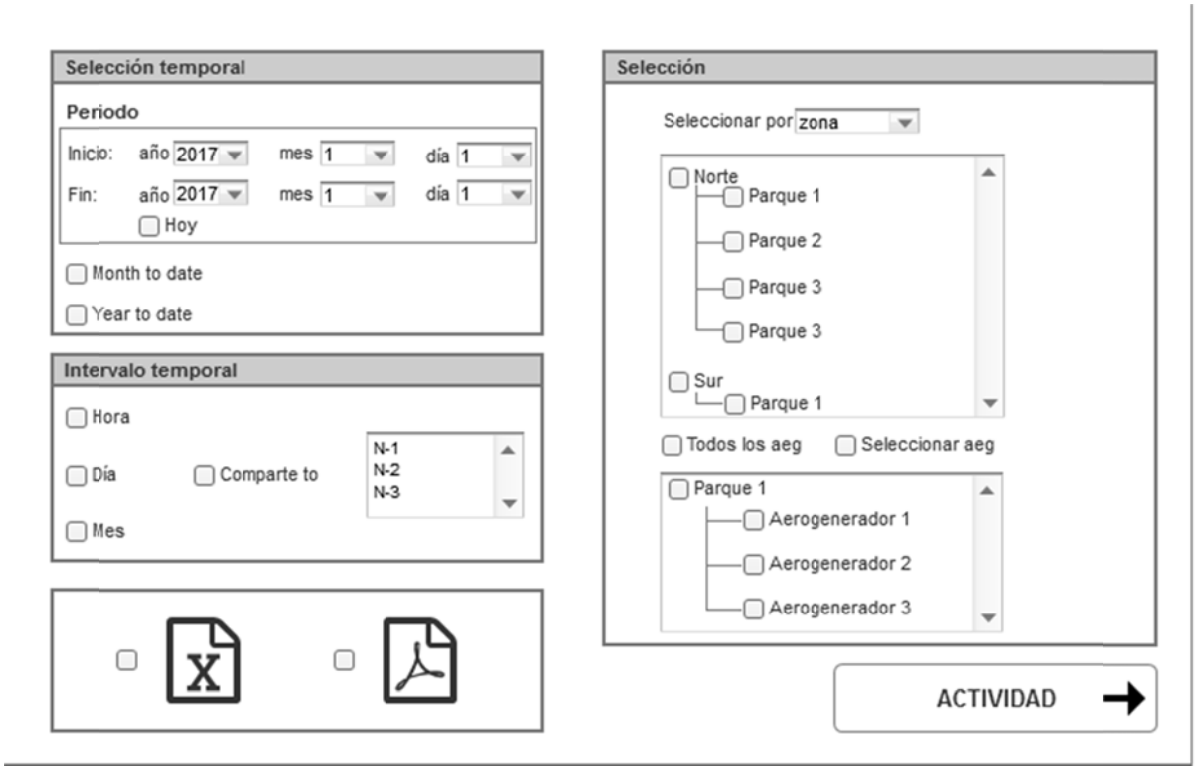


Figure 42: Wind technology Manager Reports Interface- Personalisation-Selection

On the left side of the page we find *the period selection box, the time unit selection box and the files selection box.* . These Boxes are the same that the ones explained hereinabove on the reports homepage.

On the right side, we find the Selection Box which allows the user to choose the plants and the wind turbines of those plants to be included on the reports. The process to fill out this box goes as follows:

First of all the user has to select the wind farms following the same trend that the one explained above in the homepage: choose the subgroup (seleccionar por) and then the plant.

Once the plants have been selected, the user can either include all the wind turbines on the report or to pick only some of them. To easily include all the turbines (for example for reports regarding the activity and performance of the whole plant) he/she must mark the "Todos los aeg" button. Otherwise, he/she has to mark the "seleccionar Aeg" one.

If the button marked is the "seleccionar Aeg" on the lower window they will appear the selected wind farms with all their wind turbines displayed.

B. PERSONALISATION PAGES

Once this page is correctly filled in, by pressing the ACTIVIDAD button the User accesses the different personalisation pages which coincide with those described on the Wind Farm Management Personalisation Reports: Activity, Production, Maintenance, Scada, Deviations, Availability and Energy Movement *(See i-5.2 PERSONALISATION PAGES)*

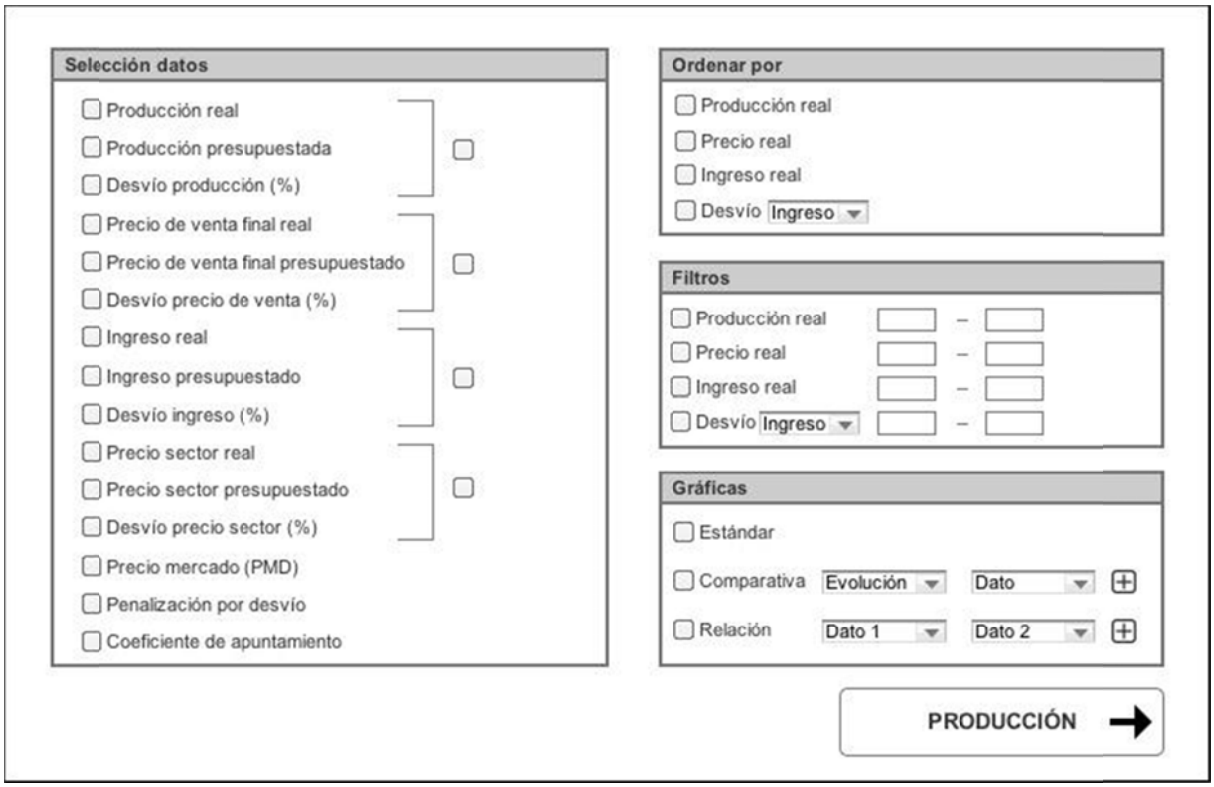


Figure 43: Wind technology Manager Reports Interface- Personalisation-Activity

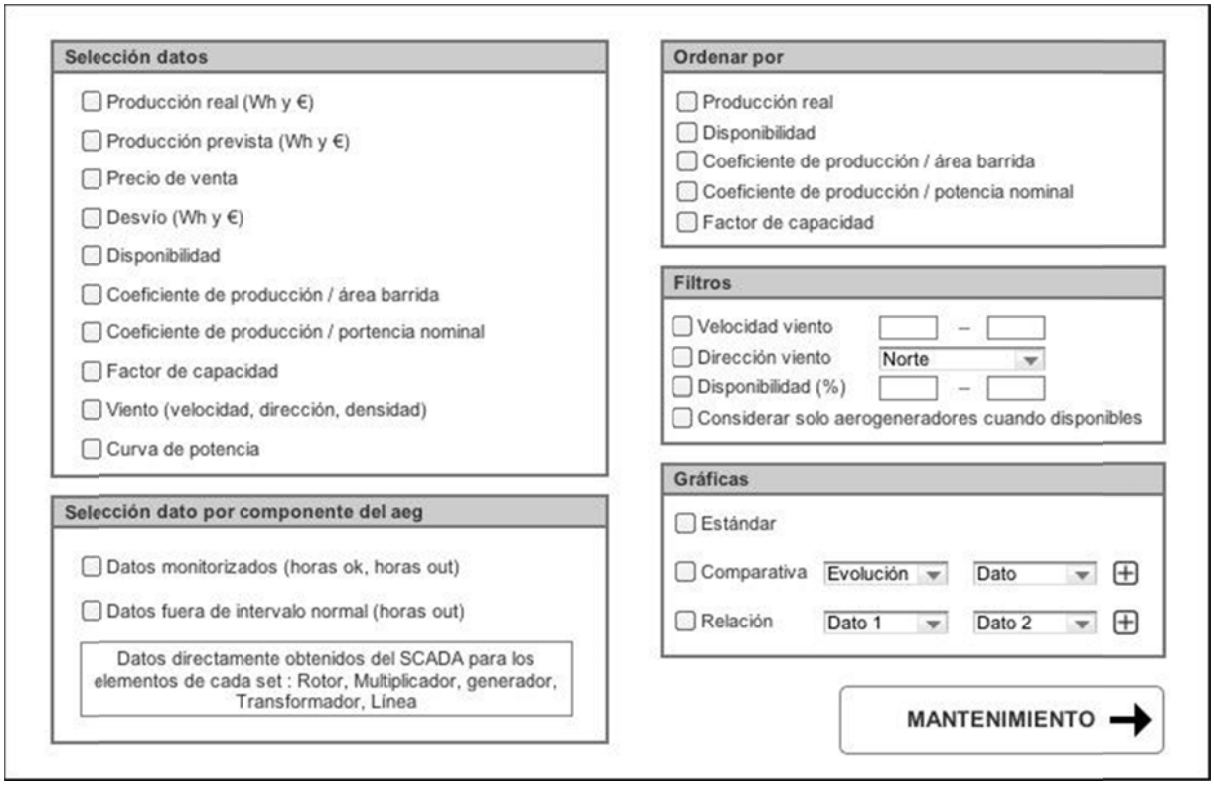


Figure 44: Wind technology Manager Reports Interface- Personalisation-Production

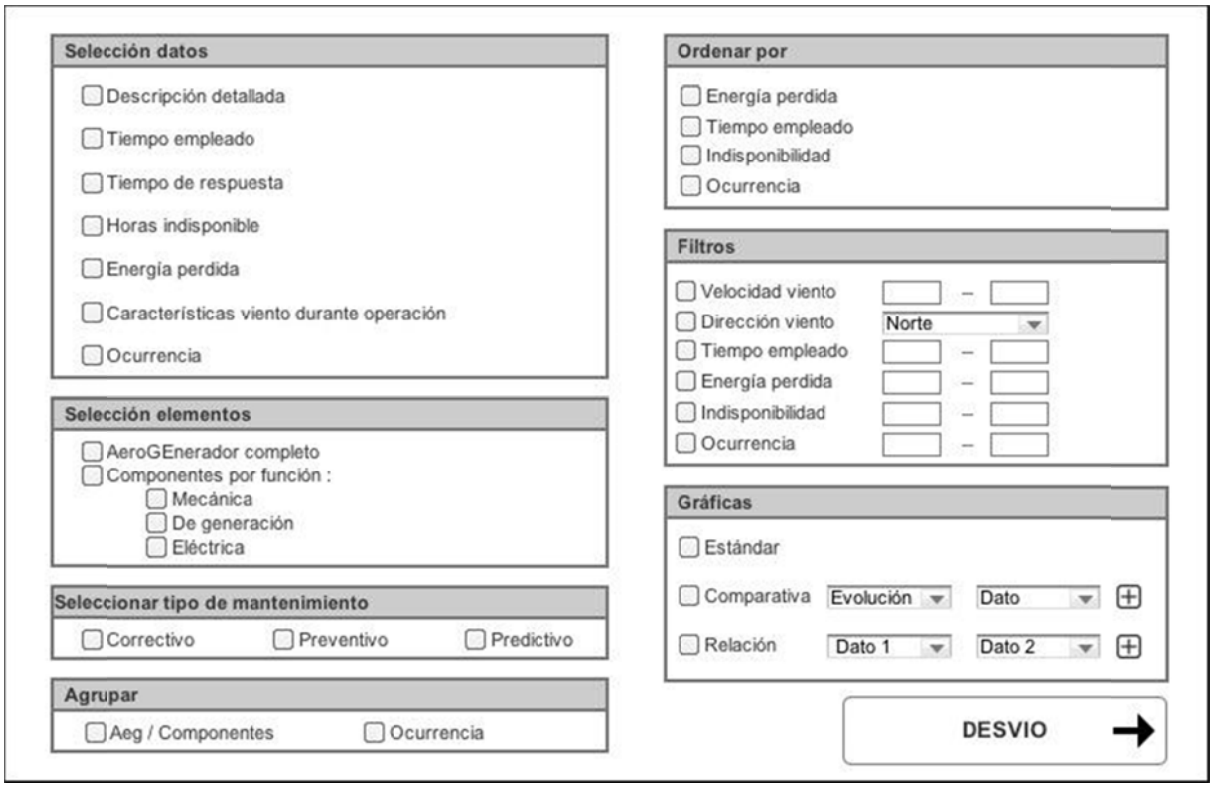


Figure 45: Wind technology Manager Reports Interface- Personalisation-Maintenance

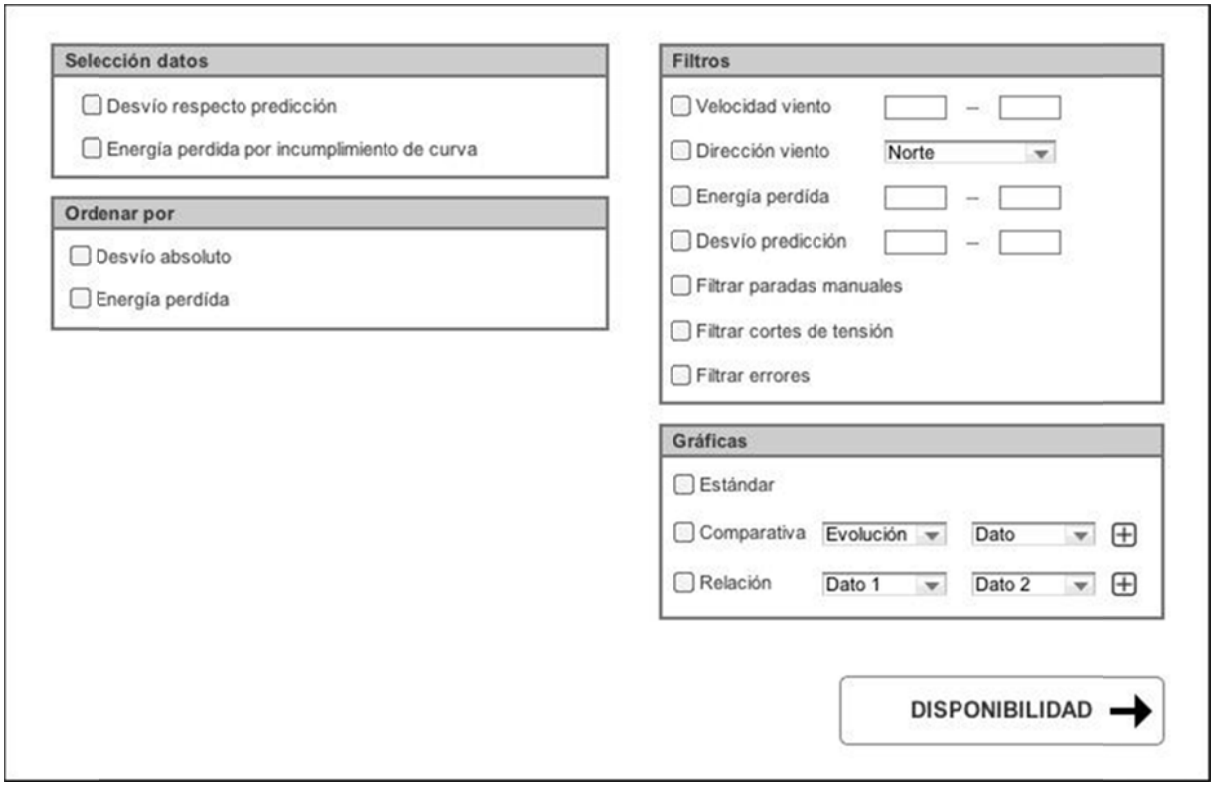


Figure 46: Wind technology Manager Reports Interface- Personalisation-Deviations

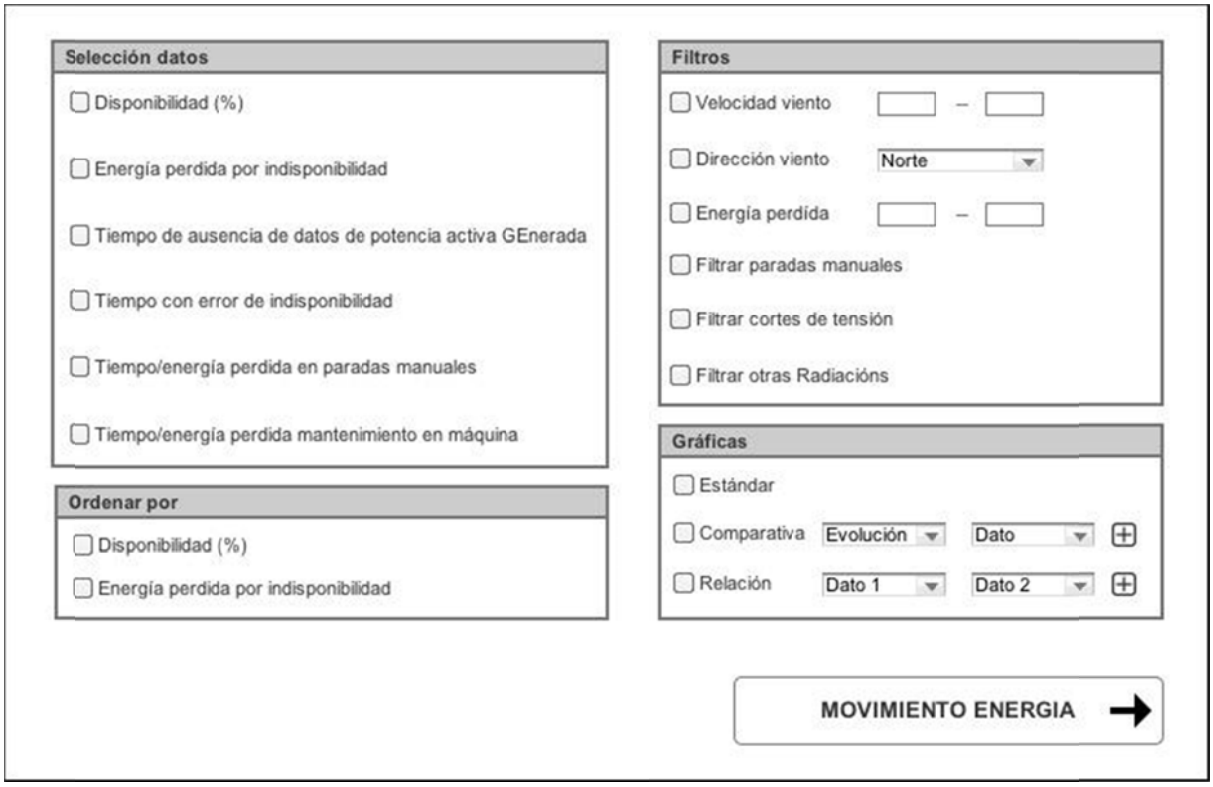


Figure 47: Wind technology Manager Reports Interface- Personalisation-Availability

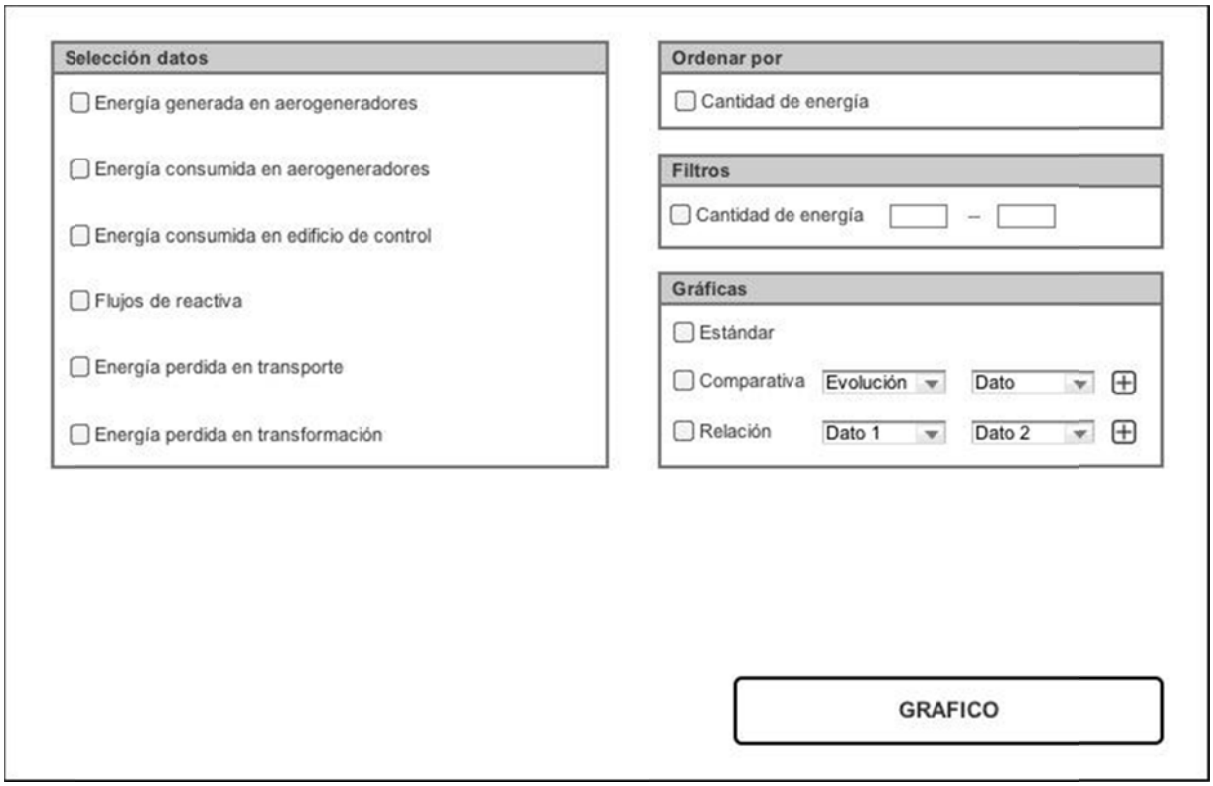


Figure 48: Wind technology Manager Reports Interface- Personalisation-Energy Movement

4.3 GRAPHICS

To conclude with the Personalised Reports section the User has to choose the graphical output to be included on the report.

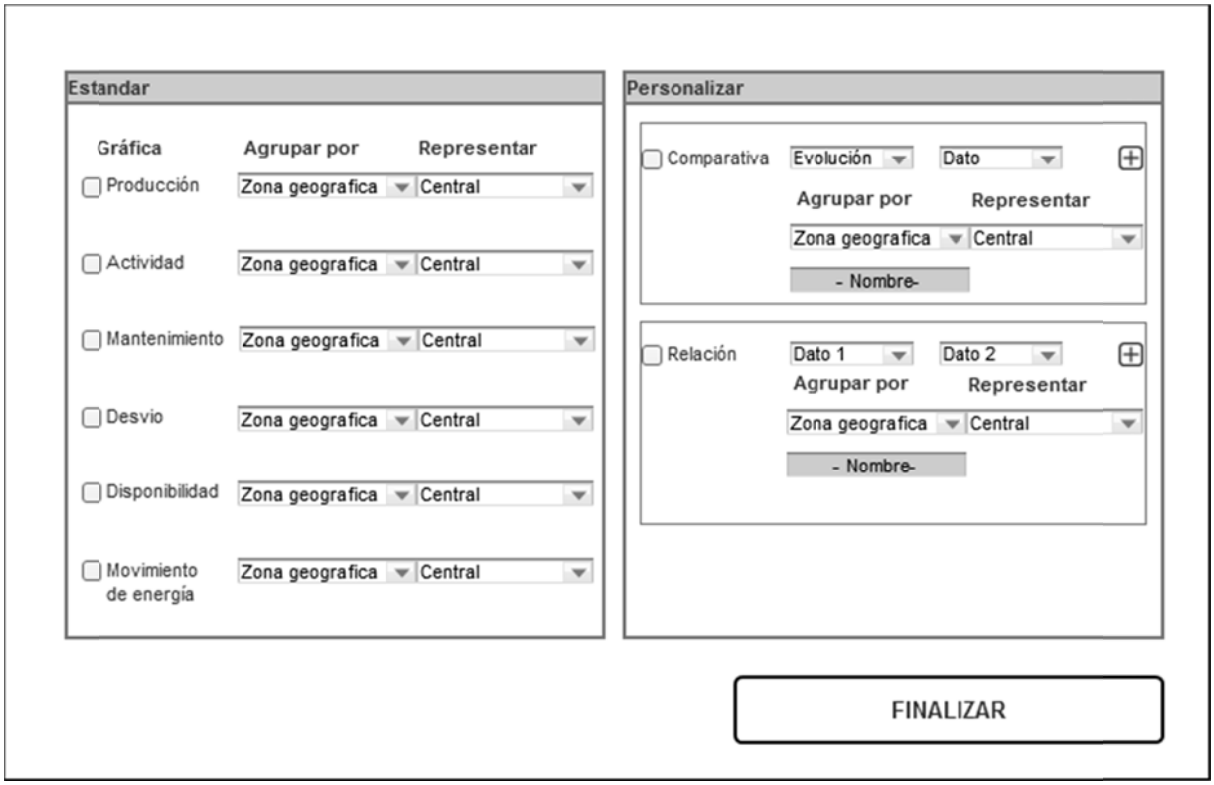


Figure 49: Wind technology Manager Reports Interface- Personalisation-Graphics

As there are many variables to be taken into account (some of them affecting the wind turbines, others the production plants...) and there are many ways to analyse them (separately, by plant, by geographical zone..) this page enables the user to fix the charts and schemes to be produced. This step also facilitates the work to the proper control centers. Due to a vast amount of data, creating a lot of automatised charts may end up causing a huge computational complexity that could be dispensable.

The page is divided in two sections: The standard graphics and the personalised graphics.

On the left side of the page we find the *standard graphics.* In this section the user can directly choose the graphics already desing for the standard reports. However he can determine the actual content of the graphic by selecting on one hand, the subgroup that each

graphic should represent for example, one graphic per geographical zone, per Market agent or per wind farm or just on only chart for the whole selection); and on the other, the actual object of the graph (one curve per plant or one piece of pie chart per geographical zone ..)

For further undersating, here there are some examples:

EXAMPLE 1: If the user had chosen N geographical zones and J production plants per geographical zone and he marks the Production Set, he ask to group them by geographical zone and to represent each wind farm, inter alia, he will be provided of N production evolution charts with J curves plotted on each of them.

EXAMPLE 2. If the user had chosen N geographical zones and J production plants per geographical zone and he marks the Production Set, he ask to group them by geographical zone and to represent each geographical zone, inter alia, he will be provided of N production evolution charts with one only curve plotted on each of them. (a cumulative curve resulting of the production of the J wind farms of the zone).

On the right side of the page the User has the possibility to create from scratch the charts. To do so, he firstly has to determine the type of chart to be produced: Comparative chart or relation chart.

- The comparative charts are those which enable the user to compare one single variable either throughout the selected period of time or in total in comparison to another object of study. Thus within this type, the user can choose between Evolutive or Total charts. Once the chart type is determined, the user must select the data to be plotted and the subgroup and the objects to be represented. The possible variables to be included are only those ones that had been selected throughout the previous pages. The Subgroup and Object selections follow the same trend that the one described for the standard graphics.

- The Relation charts are those which enable the user to determine if there is any correlation between two variables (for example the increase of temperature and the frequency of maintenance work in a wind turbine). If the User wants to create a relation chart he has two choose to variables between those previously marked, and fix the subgroup and object selection.

The User can add as many charts as desired by pressing the "Plus button" located on the right upper corner of each chart type window. Once the report personalisation is finished, the User can generate it by pressing the FINALIZAR button.

5. INCOME STATEMENT.

This page of the Wind Technology Responsible package reports the user about accountability situation of the wind farms as it gives access to all the profit and loss statements.

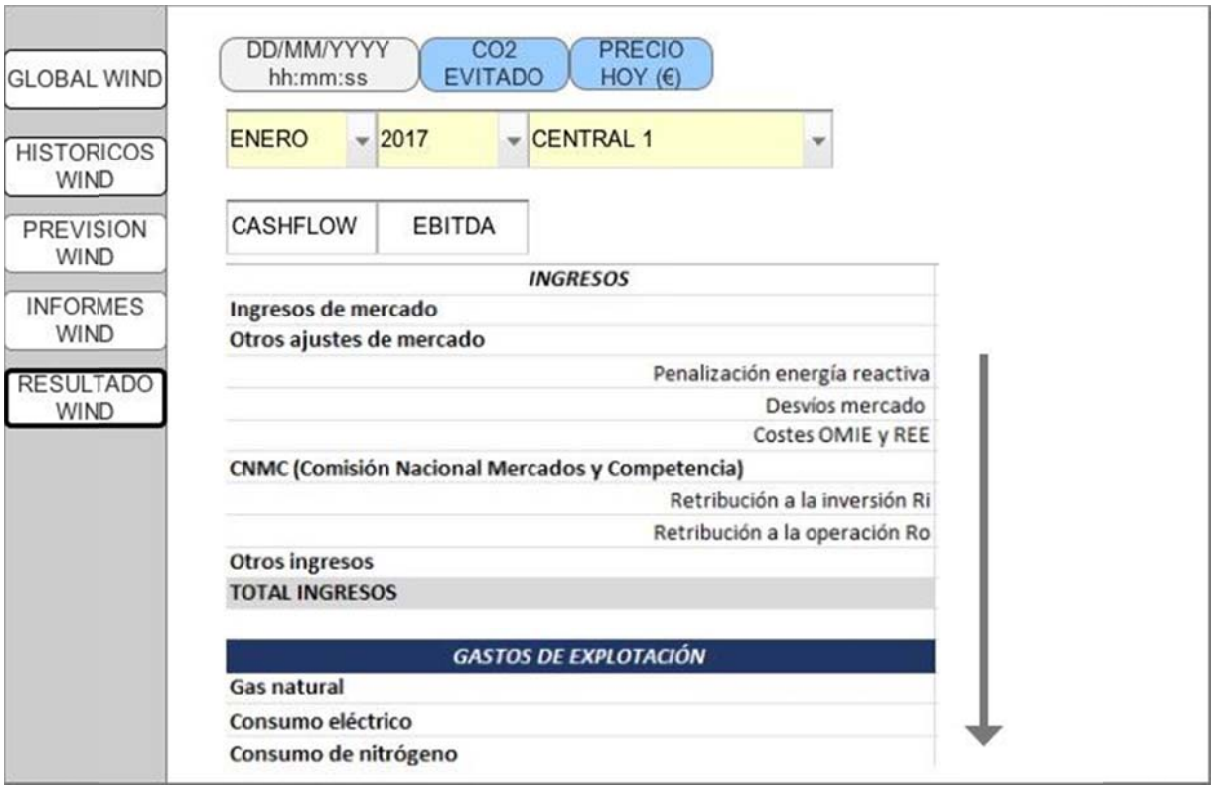


Figure 50: Wind technology Manager Income Statement Interface

As shown on the image above, by selecting the MONTH, YEAR and INSTALLATION, the User accesses to the income statement of the concerning plant during the month chosen.

The Income statements are available on the **management database** and can be downloading into excel or pdf sheet. Similarly to the Forecast Page, **this page does not have an automatised refresh frequency. In only refreshes if a new selection is commanded.**

iv) CSP Technology Manager

This package is only accessible for the user accredited as "CSP Technology Manager" or for those who are higher in the company's hierarchy such as the COO or the CEO.

CSP technology Manager is in charge of the supervision and optimization of the activity of the company's CSP Production plants. Thus, in order to assure an optimal management of the farm, he has to be able to access to all the real-time information of the plants, as well as to all their historical data. He wants to know how much we are producing, how much we have produced, how much we are going to produce and why. In addition, he has to keep an eye in the economic (incomes) and mechanical (maintenance) issues of the plant, as well as the role they are playing on the electricity market.

That said, the package consists of 5 pages: Global, Historicals, Forecast, Reports and Income Statement. Once logged in, the default home page displayed is the Global Page. By pressing the buttons of the left main menu, the user is able to move from one page to another.

1. GLOBAL.

It's the main page of the package and it's the first one the user will see when he accesses the control center.It shows a photograph of the real-time status of the CSP activity.

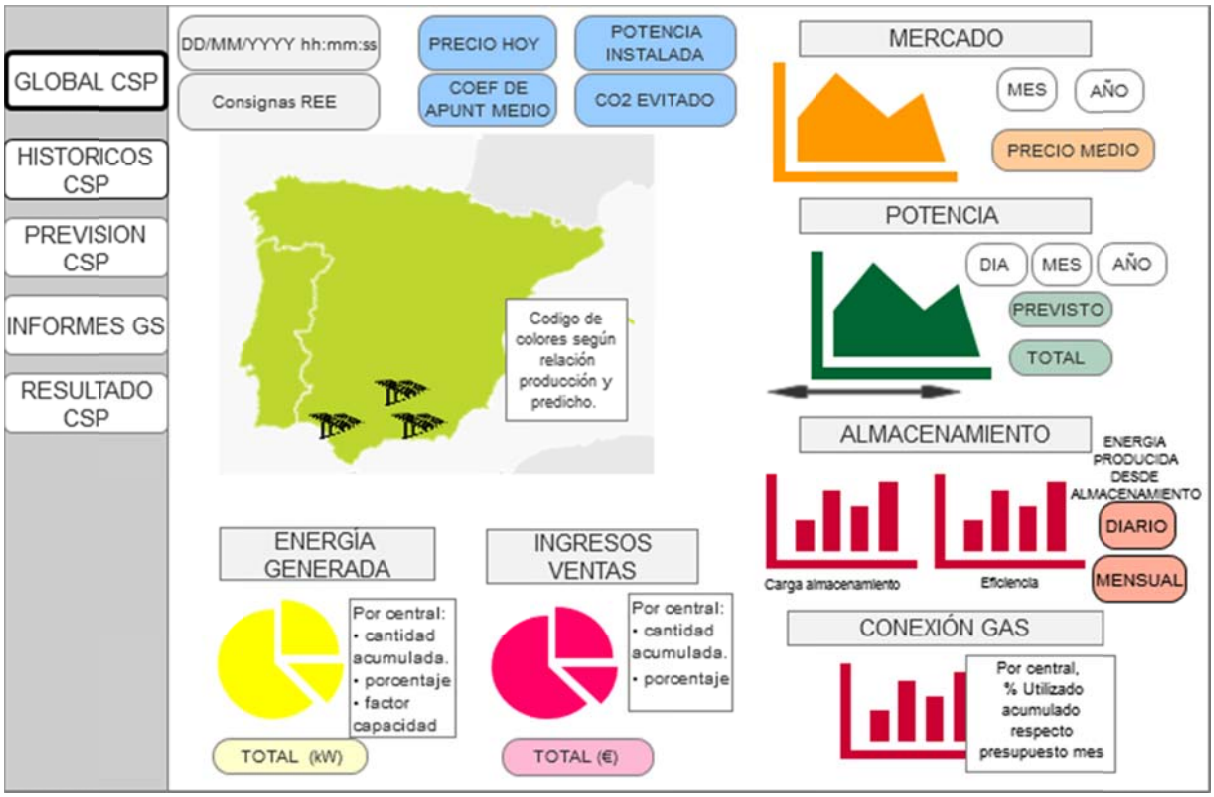


Figure 51: CSP Technology Manager Global Interface

-DAILY DATA (Blue)

In the upper left of the Global page we find the date and hour at the time of consultation of the control center as well as the REE alarms checkbox that will pop-up if new alarms linked to the operation of the CSP parks have been received. Next to it, we find, first of all, the actual electricity sale price or Pool price which is **extracted from OMIE's platform each hour**. Secondly, the Solar parks theoretical capacity and the peak coefficient, which are stored in the management **database and remains unchangeable.** Thirdly, there is the Company's peak coefficient. **This coefficient is calculated and stored in the control center's data base.** To conclude, there is the CO2 avoided, a figure calculated by the company and used to evaluate how sustainable is the company's activity.

- LOCATION MAP.

The plant location's map is on the left side of the screen. It displays the geographic and production status of the solar parks. The icon used to identify the CSP production plant is composed of two CSP panels. Depending on the rapport of the real production and the expected production, the icon will be coloured differently.

	If the difference between the farm's real production and the expected production is in a range of of 0 - 10%
	If the difference between the farm's real production and the expected production is in a range of of 10 - 20%
	If the difference between the farm's real production and the expected production is over 20%

The colours of the icons are **updated after every market pool based on the data available on the control center's database regarding forecast and real production.**

To conclude, **the icons also act as buttons that enable the user to access to the package of the responsible of each CSP park** to know more in detail about the plant's activity.

- MARKET.

The aim of the line chart is to reproduce the evolution of the market price and the company's final selling price and compare it to the budget price. Thus, the Y axis measures price in €/MW while the X axis represents the time. The time scale varies according to the option chosen: days if the option is MONTH and months if the option is YEAR. The default option is MONTH. In both cases the chart includes three curves.

If the selected option is month, the data corresponding to each curve is:

- CSP PMD curve: the daily **price is collected from the markets operator website and it is corrected by the law's CSP peak coefficient, available on the management data base.**
- CSP Budget curve: **the monthly budget price is available in the management database.**
- Company's CSP mean final selling price curve: the daily final real price **is extracted from the sale agents' fortnight reports which are stored in the database**.

Concerning the three curves, the values displayed correspond to the mean of the sector. Thus, to display the budget curve, the control center must calculate the mean of the budget price of all the CSP parks. By the same token, the final selling price curve results of the mean of the final prices of each Market Agent.

As the Market Agents reports are sent every two weeks, the data refreshes once the new report is received. Therefore the user doesn't have the information of the current day until this period is finished.

To conclude, if the selected option is MONTH, the numerical value of the company's CSP energy mean real price for the last 30 days is plotted too. Likewise, the average value of the year is displayed if the selected option is YEAR.

- PRODUCTION.

Likewise the Wind technology's globals page production chart, this chart reports the user about the CSP production through time. There are three versions of it: DAY, MONTH and YEAR. Depending on the the period chosen, the chart presents some variations. However, in the three cases the the Y axis represents power while the X axis represents the

timeline. That said, the default chart is the MONTH.

The DAY's line chart displays in three curves the following information.

- The real production
- The forecast sent to the dairy market (with percentile 10 and percentile 90)
- The corrected forecast

The real production curve is based on the data collected from the meters and the Scada. This information is taken every 10 secs and but **it is recorded aggregated on the database every 10 minutes. Thus, the curve will refresh once new data is stored.**

The other curves derive from the forecasts sent to the intraday market and the dairy market. **The corrected forecast curve is plotted while the production is recalculated and sent to the intradaily market and so it refresh after each intradaily market forecast.** (17.00, 21.00, 01.00, 08.00, 12.00) while the dairy market forecast curve **is updated every day.**

The MONTH's and YEAR chart displays in three curves the following information:

- The real production
- The Forecast production
- The Production of year N-1.

The data used to create the real production and the production from year N-1 come from the scada and is **available on the historical database.** The **MONTH chart datum correspond to the sum** of the concerning day's real production of all the CSP parks. Thus, the MONTH chart **refreshes every day** at the end of it**.** T**he YEAR chart datum corresponds to the cumulative** of the daily productions of all the CSP production plants each month. Thus, the YEAR Chart **refreshes every month.** The last datum, the one corresponding to the current month, shows the production of that month up to date**.** The information used to create the forecast production comes from the past data provided by the forecast agent that are available on the historical data base. As happens with the real and year N-a production, the forecast production curve also corresponds to the cumulative of the daily (or monthly) forecasts of all the CSP parks.

- GENERATED ENERGY. (ENERGÍA GENERADA)

The Generated Energy chart is a pie chart whose aim is to illustrate the contribution of each CSP Plant to the company's production during that month.

The whole pie represents the total solar production and each piece of it, a CSP Plant. The size of the piece depends on the portion of the total production produced by the corresponding plant. By, clicking on each piece, it must be shown:

- The aggregate amount of energy produced by the plant during that month in KW.
- The percentage that it represents of the total solar production.
- The average capacity factor of the plant during that month.

Added to that, beside the chart, the total amount of aggregated energy that has been produced by the CSP Plants during that month is displayed too.

All this values can be calculated with the information available on the Data Base concerning the daily productions (SCADA) and the daily capacity factor (Management data).

Once the final daily aggregate production per plant has been calculated and stored on the historical data base, the pie chart is updated. **Thus the pie chart and the values concerned refresh everyday.**

- REVENUES (INGRESOS VENTAS)

The revenues chart is a pie chart that illustrates the contribution of each solar plant on the CSP company's market revenues during that month.

The whole pie represents the CSP total revenue and each piece of it, a solar plant. The size of the piece depends on the portion of the total revenue produced by the corresponding plant. By, clicking on each piece, it must be shown:

- The aggregate revenue produced by the plant during that month in €.
- The percentage that it represents of the total CSP production.
- The average selling price of the plant.

Added to that, beside the chart, the total aggregate revenue produced by the CSP technology is displayed too.

The pie chart and the values are calculated with the data provided by the market agents report. Once new report is received, the revenues and the prices of each plant are extracted and added to the current values. **In this chart, the revenue is calculated as the product of the amount of energy sold and the real final price.**

That said, taking into account that the reports are received every two weeks, **the revenue pie chart must refresh every two weeks**[6] too.

- STORAGE

Regarding the storage of energy there are two charts and two numerical pieces of information displayed.

On one hand we find the *storage status chart*. The storage status can be interpreted as the plant's capacity to face future production problems related to the solar panels, the sun radiation etc. Each column of the bar chart represents a CSP farm and its height, the percentage of storage used of the tanks.

The information of the tanks status is recorded in real time by the SCADA and stored on the data base. Thus, the chart must refresh every 10 minutes when the info is updated.

On the other hand there is the *Efficiency chart.* Each column of the efficiency chart represents a CSP farm and its height is proportional to the plant's efficiency. The efficiency is calculated comparing the quantity of energy given to it and the energy produced from those thermal reserves. **Both data are measured are recorded by the SCADA. Similarly to the storage status chart, the Efficiency chart refreshes every 10 minutes.**

To conclude there are two numerical data to be included: the energy produced that month using the stored energy and the the energy produced that year using the stored energy. Even if **the intermediate information is recorded from the data in real time but it is updated on the screen daily.**

That said, **the value of the plant efficiency once calculated must be stored on the data base respecting the same time grouping than the data recorded by the SCADA.**

[6] *The fact that the information concerning the revenues is received two weeks later, leads to a fortnight delay on the update. Thus, from day 1 to day 15 of month M the pie chart displayed will be showing the information concerning the end of month M-1.*

-ENERGY AND AUXILIARIES CONSUMPTION DATA (Grey).

Unlike the wind farms, the production of electricity frequently is assured with the energy and other auxiliaries. The two auxiliares are Water and natural gas. The status of the consumption of these two components is very useful as they set up in opposition to the generated power.

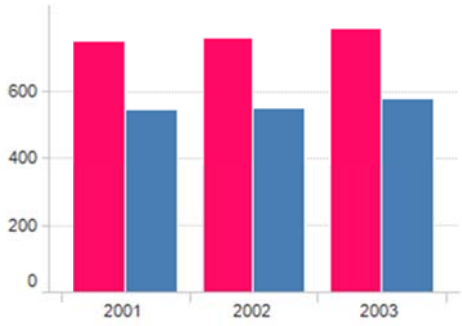


Figure 52: Format of the Auxiliary Consumption Diagram

The bar chart is composed of a set of two columns. Each set represents a CSP park and each of the columns corresponds to one auxiliar (water and natural gas). The height of the columns is proportional to the percentage consumed of the budgeted quantities.

As the budget consumption is measured in euros the real consumption must be measured economical terms too. To do so, the control center must take the daily natural gas price and the quantity injected. The water consumed is calculated similarly.

All the data used to create the chart is **obtained in from the SCADA of the installation every 10 minutes and from the management database (budgets)**.

2. HISTORICAL

This page allows the Manager to access to the historical data that reflects the performance of the solar park during a past period of time. It is accessible from the left column of the control center interface. More specifically, the historicals page gives the user an idea of the global page of a past period of time, with the advantage that the solar parks concerned can be filtered.

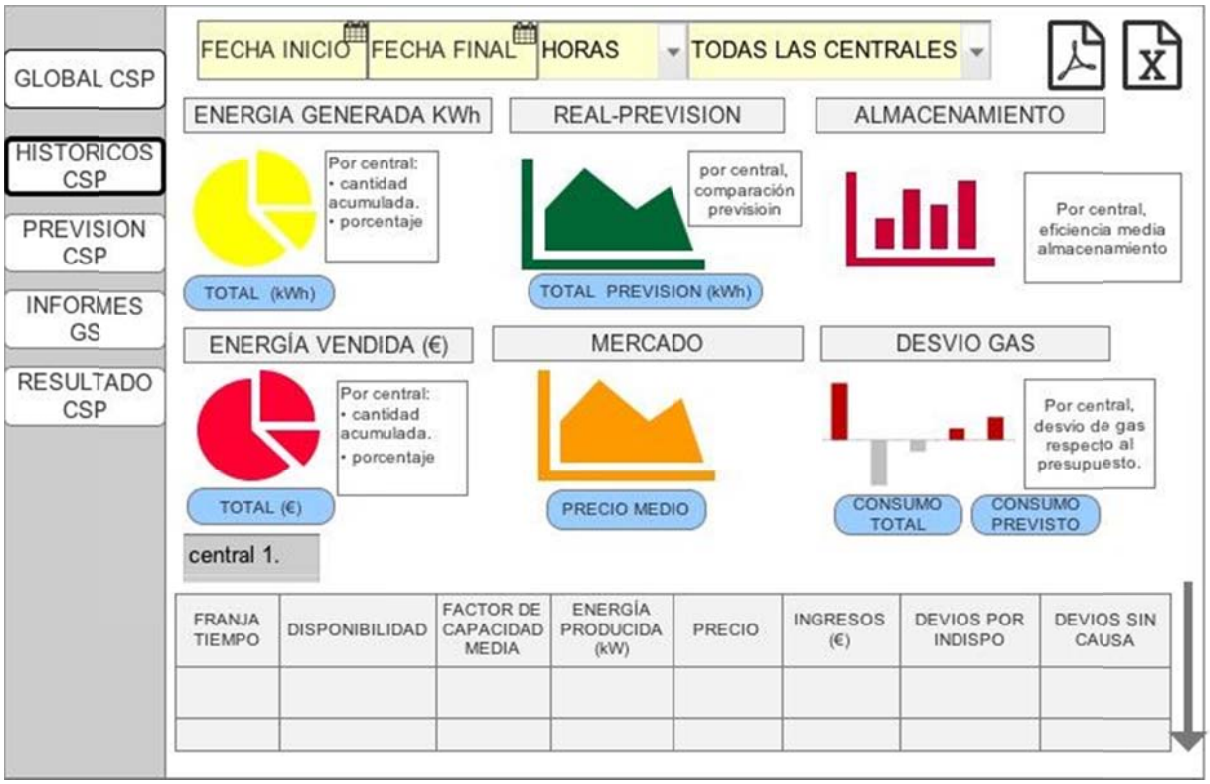


Figure 53: CSP Technology Manager Historical Interface

The page is divided in three sections: Selection, Charts and schemes and Data table. The Historical page doesn't have an automatic refresh frequency. Indeed once a command has even executed, the screen freezes keeping the outputs until a new command is carried out.

- SELECTION

On the top of the page we find the selection boxes. The selection boxes include: the starting date, the final date, the time unit of time and the production plants to be included.

Regarding the time selections there are the following constraints:

- The final date is limited by the current date.
- If the time interval is a day, the only possibility of time grouping unit is HOURS.
- If the time interval is between 1-31 days, the possibilities of time grouping unit are DAY and WEEK.
- If the time interval is between 31-92 days, the possibilities of time unit are DAY, WEEK and MONTH.
- If the time interval is between 92-365 days, the possibilities of time unit are

WEEK, MONTH and trimester

- If the time interval is bigger than 365, the possibilities of time unit are MONTH, trimester and YEAR.

-CHARTS AND SCHEMES

This section includes ¡six charts: two of them are evolution charts (The Market Evolution Chart and The Production Evolution Chart) and the other four, cumulative (The Generated Energy Pie-chart, The Revenues Pie-chart and the Storage Bar-chart and the Natural Gas Bar-chart). Depending on the time interval, there are some elements that may be modified or not be available.

The generated energy pie chart follows the same philosophy that the" iv-1 *generated energy"* but framed by the conditions set on the selection boxes.

The revenues pie chart follows the same philosophy that the*"iv-1. Revenues"* but framed by the conditions set on the selection boxes.

The storage barchart reports of tf the plant's mean efficiency when producing with the storage tanks. Each bar represents one of the selected solar parks and its height is proportional to the plants' mean efficiency during the chosen period. **The mean efficiency represents the relation between the injected energy into the storage tanks and the energy produced with it. Both pieces of information are recorded by the SCADA.**

The natural gas bar chart displays the difference between the plants gas consummation and the budget consummation. **Both pieces of information extracted from the budget and expenses reports available on the management database**. Thus, each bar represents one CSP park and its height is proportional to the deviation between both quantities. The deviation is expressed in terms of percentage and it can be negative or positive (overuse). The natural gas is normally used in "emergency cases" as a heat source to produce electricity. Therefore, an overuse may indicate a sub-optimal activity of the production plants.

The *production evolution graph* is composed of two curves: The forecast production curve and the real production curve.

The forecast production curve is base**d on the data sent by the weather forecast**

agent the eve of the day concerned. The real production curve is based on the data recorded by the scada.

If the chosen interval is a day, as the time unit is an hour, this chart will only be available if the day falls under the last month. Otherwise, the value per hour will not be exist on the control center's data base.

The Market evolution chart is composed of two curves: The Company's final selling price curve and the market's selling price curve.

The company's final selling price is based on **the data extracted from the market's agent reports. The Market's selling price curve is based on the data extracted from the OMIE's website.**

3. FORECAST

This screen allows the Responsible of CSP to access to the forecast of the solar plants activity in terms of production and market. It is accessible from the user's main menu located on the left side of the screen.

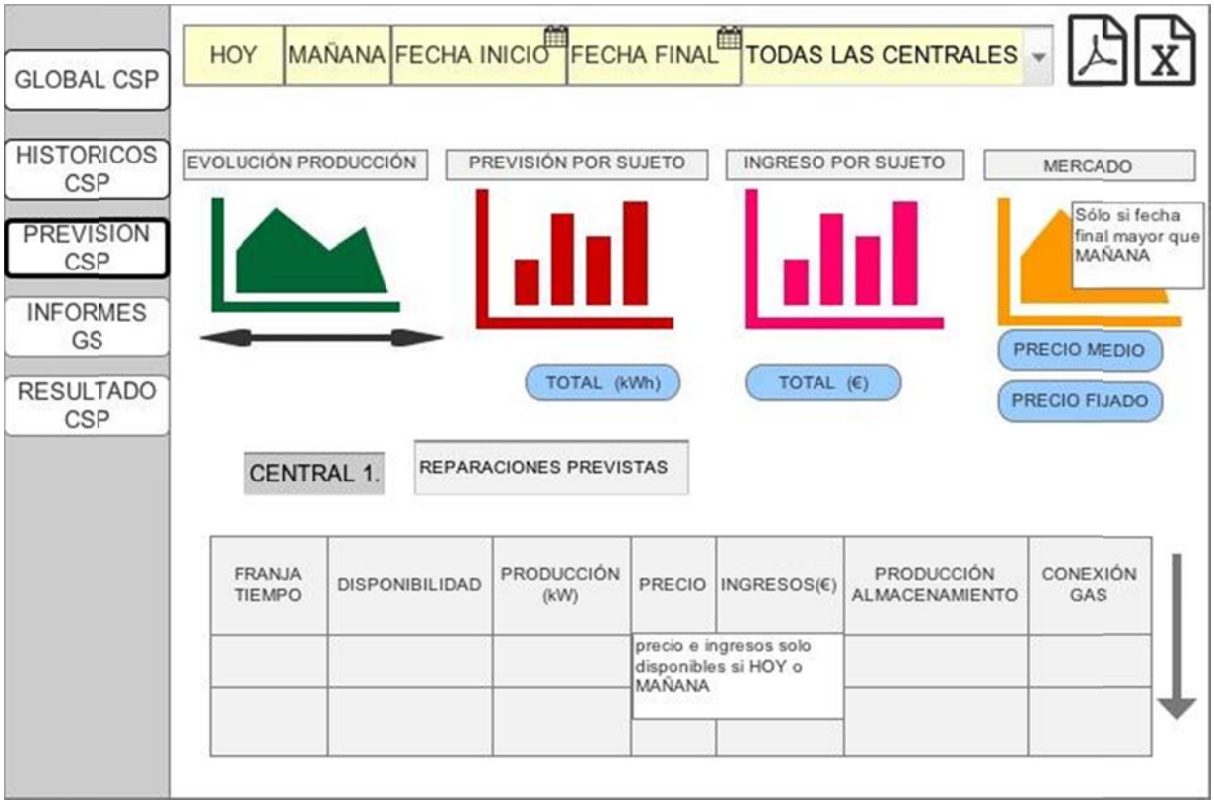


Figure 54: CSP Technology Manager Forecast Interface

The page is divided into three sections: selection, charts and schemes and data table.

- SELECTION

On the top of the page we find the selection boxes. The selection boxes include: the starting date, the final date, and the wind farms to be included. Added to that, the user has also the option to choose just that day's forecast or the following day's forecast by selecting "HOY" or "MAÑANA".

Regarding the Time selections there are the following constraints:

- The final date cannot be earlier than the starting date.
- The final date must fall under the following three subsequent months.

- CHARTS AND SCHEMES

This section displays four charts concerning the behaviour of the production, the revenues and the market throughout the selected period of time.

The production evolution curve is displayed in different versions depending on the selected period of time.

If the selected period of time is *TODAY* the time axe is divided into intervals of one hour and the chart includes three curves. First of all we find the real production curve with the information available up to the time of consultation. **The data used to plot this curve comes from the information recorded by the scada**. Secondly, we have the market's offer forecast curve, **which is based on the forecast sent by the weather forecast agent the day before.** Finally, to conclude we have the updated forecast curve. The data used to plot this curve **comes from the intraday forecast that the weather forecast agent estimates for each intraday market pool.**

If the selected period of time is *TOMORROW* there are two possible scenarios. **If the report with the forecast for the following day is available on the data base, the production curve will be based on the data extracted from that report.** Otherwise, if the company hasn't been provided of that report yet, the curve will result from the **data available on the most recent fortnight forecast report available on the control center's data base.** That said, in both cases, the time axe is also divided into intervals of one hour.

If the selected period of time falls under the dates included in the most recent fortnight report provided by the weather forecast agent, **the product evolution curve will be based on the data extracted from it.**

To conclude, If the selected period of time doesn't fall under the dates included in the most recent fortnight report available on the control center data base, **the control center will use the production of year N-1 during that period of time to plot the forecast curve.** In this case the unit of the time axe depends on the duration of the period. If the period is shorter than 48 hour, it will be aggregated into hours. Otherwise, it will be aggregated into days.

That said, as the curve must include the forecast of all the solar plants marked on the selection box, data source used to plot the curve must be the same for all of them. I.e the source of information must be the most updated one from which we can extract information of all the desired CSP parks

The production barchart reports the user the contribution per plant to the forecast production. The sources of information used to create this chart follow the same trend that the one described above. However, in this case, instead of aggregating the values of all the plants for each time unit, **the value to be calculated is the sum of the production per plant during the given period of time.** Thus, each column of the barchart will represent the total production of each plant through the period selected by the user.

The revenues barchart informs the user about the revenues to come during the desired period of time. The height of each bar represents the revenue that each wind farm will produce.T**he value result of the sum of the multiplication of the forecast production and the forecast price of the market at each instant**. The values of the production are extracted following the trend described above for the production evolution curve. The price is extracted from the data provided by OMIE's website. If the end date does not fall under the 48 next hours, as there is no hourly or daily information about the price, this char is not displayed.

The *market evolution curve* represents the expected behaviour of the market's price during the chosen period of time. Depending on the period chosen, the graph presents some variations. If the chosen period is today or tomorrow, the graph will display the hourly data. If the chosen period doesn't fall under the next 48h, the chart will not be displayed. Instead, **it will be displayed the value provided by the OMIE's website concerning the selected time period.**

To conclude, there is a pop up box with the number of maintenance work planned for the chosen period of time. If the user clicks this bottom, he will access to their description (wind farm affected, elements affected, duration…). **This information available from the control center's data base and is extracted from the maintenance reports.**

- DATA TABLE.

Finally, at the bottom of the page we find a table corresponding to each solar plant which includes the intermediate numerical values used to create the charts. The table contains the following columns:

- Instance
- Availability
- Production
- Price
- Revenues
- Production from stored energy.[7]
- Gas conexion[8]

Similarly to the charts regarding price and revenues, the information will only be available if the period of time falls under the subsequent 48 hours.

To conclude, the user can download the output displayed for his request into a an excel sheet or a pdf file by pressing the corresponding button.

4. REPORTS

This section is the one that actually allows the user to manage and interact with all the data generated by the whole wind technology activity. It is where the added value of the control center lies in as it gives the opportunity to manipulate all the elements from different points of views and personalise reports. It is accessible from the left side menu.

[7] *The Energy produced using stored heat is based on the maintenance reports and the "storage connection planning" made by the park's manager.*
[8] *The Gas conexion is based on the maintenance reports and the gas connection planning" made by the park's manager.*

4.1 REPORT'S HOME PAGE

The reports Home Page is the first screen the user sees when clicking on the corresponding button.

This Homepage enables the user to easily generate standard reports. These reports are the same that those described on the Solar Park Manager reports section. *(See ii-5.1-Reports)* That said, the page is divided into three sections: Selection, Reports and Files.

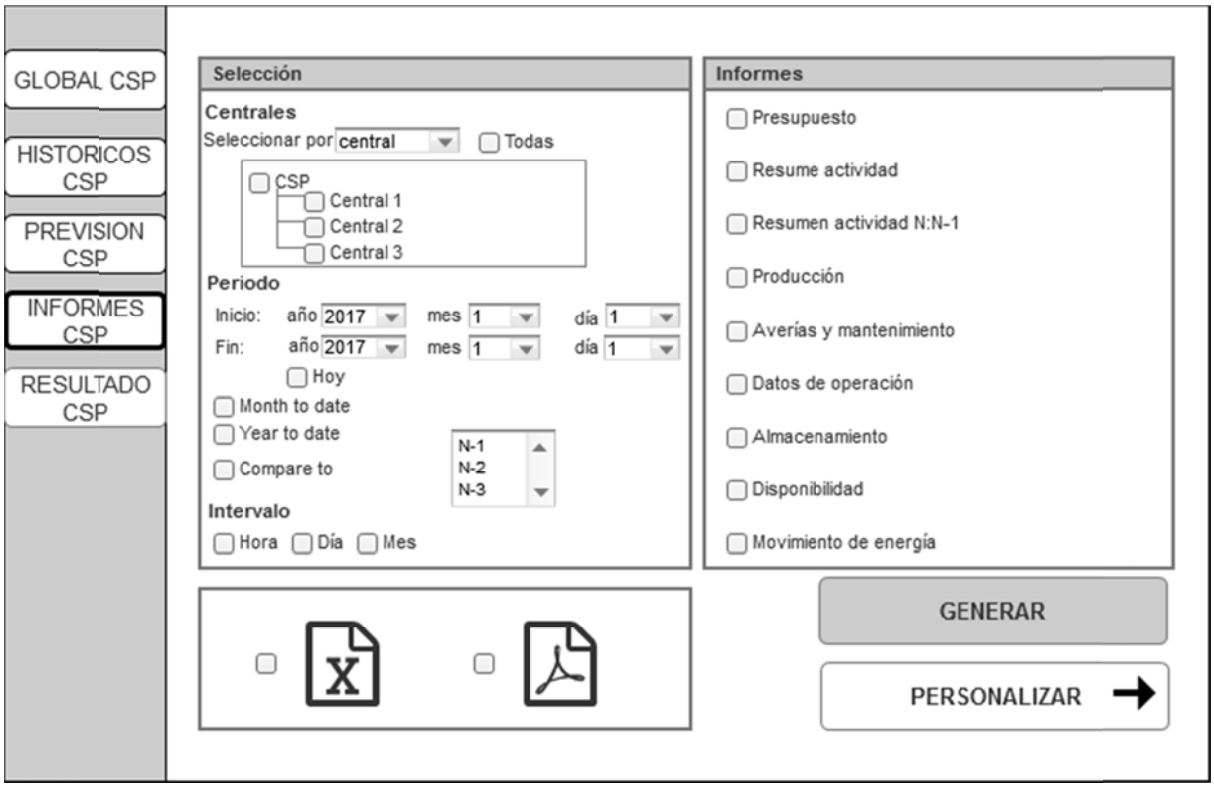


Figure 55: CSP Technology Manager Reports Interface-Homepage

-SELECTION

a. Plant

First of all the User has to choose the plants he wants to include in his Reports. He can either choose all of them, or according to a subgroup. The subgroups are: Geographic Location, Market Agent or Plant

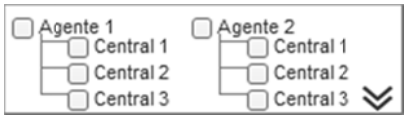
i) Geographical Location

If the marked option is Geographical Location, the plants will be displayed grouped by Geographical Location. The User has the option to choose the

whole set of plants of each specific zone, or to choose only some of the plants within them.

iii) Market Agent

If the marked option is Market Agent, the plants will be displayed grouped by their corresponding Market Agent.



iv)Plant

If the marked option is Central, the whole list of plants will be displayed.

The aim of this selection method is to simplify the searching process for the user and to optimize the "path" that the searching algorithm must follow in order to create the report.

b. Period

Once the object of study has been chosen, the User has to specify the time interval the control centre must collect the data from. To do so he must fix the starting and final date.

If the User doesn´t want to limit the interval in the traditional way he can also choose the Month to date and the Year to date option. These options are compatibles and can be marked at the same time.

To conclude, after having chosen the time interval, the user can demand to compare the period with the analogous period of a previous year. To do so he has to select the option "compare to" and the year affected knowing that N is the year at the time of consultation.

The constraints tied to the period selection are:

- The time period has to be a multiple of a fortnight. Otherwise, the remaining days will be filled with a hyphen.
- The longest time period is 365 days.
- The user could ask for information of years N, N-1, N-2. Older information won't be able on the database.

c. Time-grouping unit

The time grouping unit alludes to the frequency in which the data will be grouped and displayed. There are four possibilities: FORTNIGHT, MONTH, TRIMESTER OR YEAR.

The constraints tied to the time grouping unit selection are:

- There is no possibility to choose a time grouping unit bigger than the period itself.
- If the time interval is between 1-31 days, the possibilities of time grouping unit are FORTNIGHT OR MONTH.
- If the time interval is between 31-93 days, the possibilities of time unit are FORTNIGHT or MONTH.
- If the time interval is between 93-365 days, the possibilities of time unit are MONTH or TRIMESTER

-REPORTS

In this box, the user can choose between seven different reports that, although they are standardised, provide specific information about key topics of the management of the wind farm. As said before the standard reports are those described on the Solar Park Manager Reports.

However, as in this section the reports may include more than one variable the structure presents some variants. Before the resulting reports, the following columns are added:

- Geographical Zone
- Market Agent
- Plant

As the solar parks from the same geographical zone normally have a similar behaviour, the default configuration to display the data is Geographical Zone-Market Agent-Plant.

To conclude, the graphical output of these reports, based on the graphs included on the Solar Parks Standard Reports, must display cumulative charts representing each geographical zone as well as global charts representing the whole technology's activity.

Having said that, if the user doesn't want one of the standard reports (If none of them are marked as selected), he can create personalised reports by pressing the personalise button. (See 4.2 PERSONALISATION). Otherwise, if the user actually wants to generate a standard report, he won't be able to press the GENERATE button unless at least one report is selected.

-FILE

Finally the user has to choose if the report is to be generated into an excel file or pdf file.

4.2 PERSONALISATION.

Once the Personalisation button is selected, different screens will appear on the user interface that will allow him choose and manipulate the data in order to maximize the utility of the future report.

A. SELECTION

The first page of the Personalisation series is the selection page.

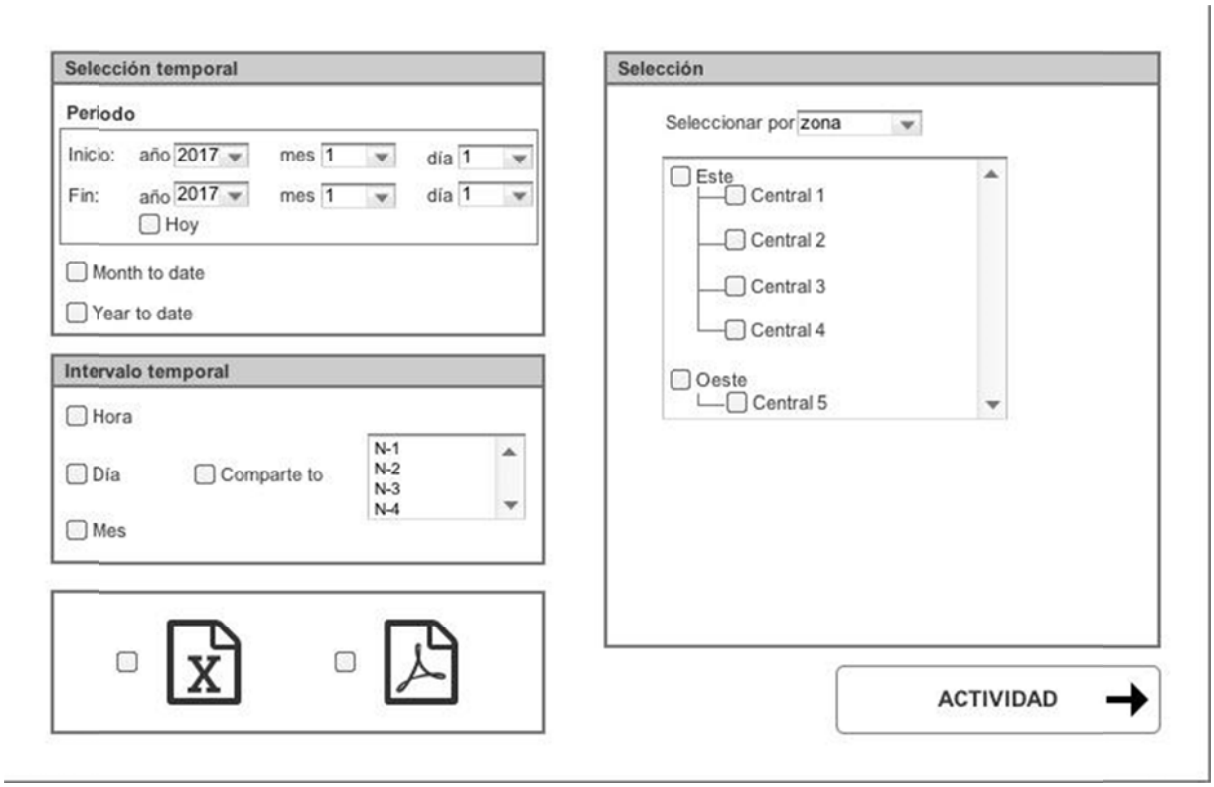


Figure 56: CSP Technology Manager Reports Interface-Personalisation-Selection

On the left side of the page we find *the period selection box, the time unit selection box and the files selection box.* . These Boxes are the same that the ones explained hereinabove on the reports homepage. On the right side, we find the plant *selection box* which allows the user to choose the solar plants to be included on the reports. As for the standard reports, he/she can either choose all of them, or according to a subgroup. The subgroups are: Geographic Location, Market Agent or Plant.

B. PERSONALISATION PAGES.

Once this page is correctly filled in, by pressing the ACTIVIDAD button the User accesses the different personalisation pages which coincide with those described on the Solar Park Management personalisation pages: Activity, Production, Maintenance, Storage, Availability and Energy Movement (*See ii-5.2 PERSONALISATION*)

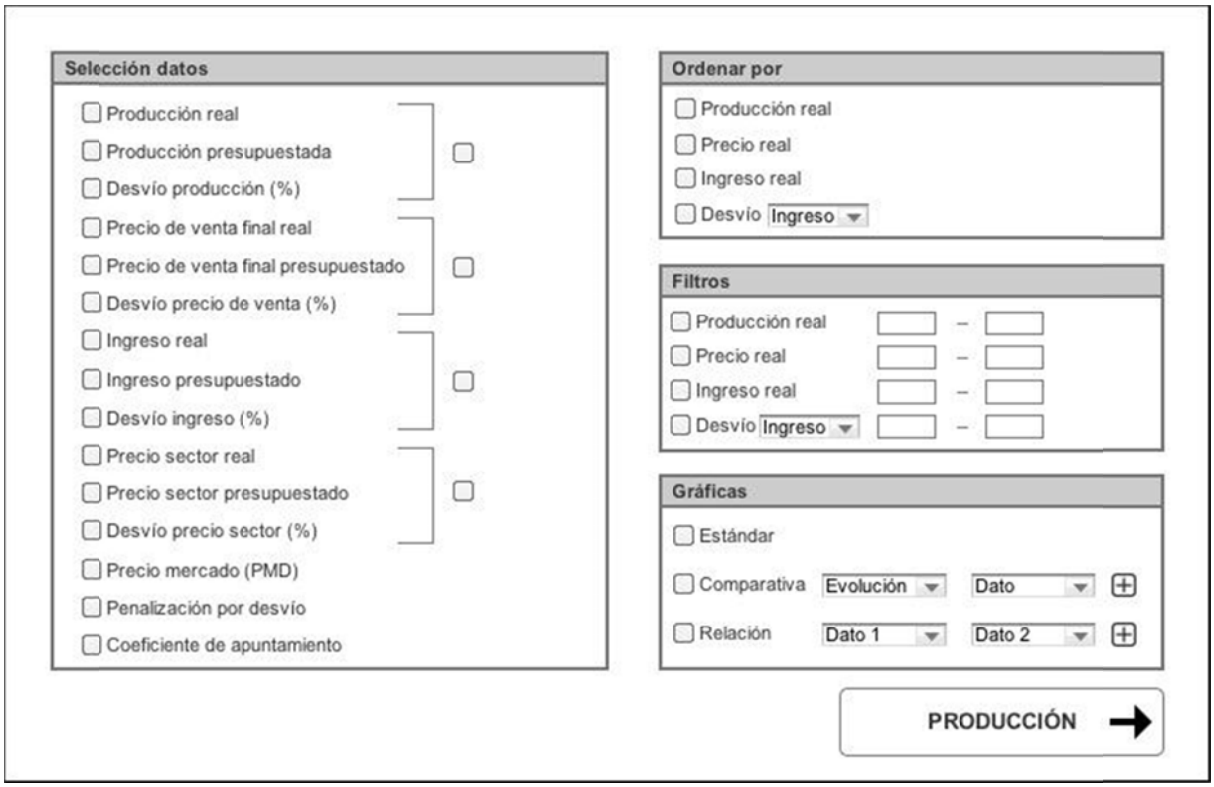


Figure 57: CSP Technology Manager Reports Interface-Personalisation-Activity

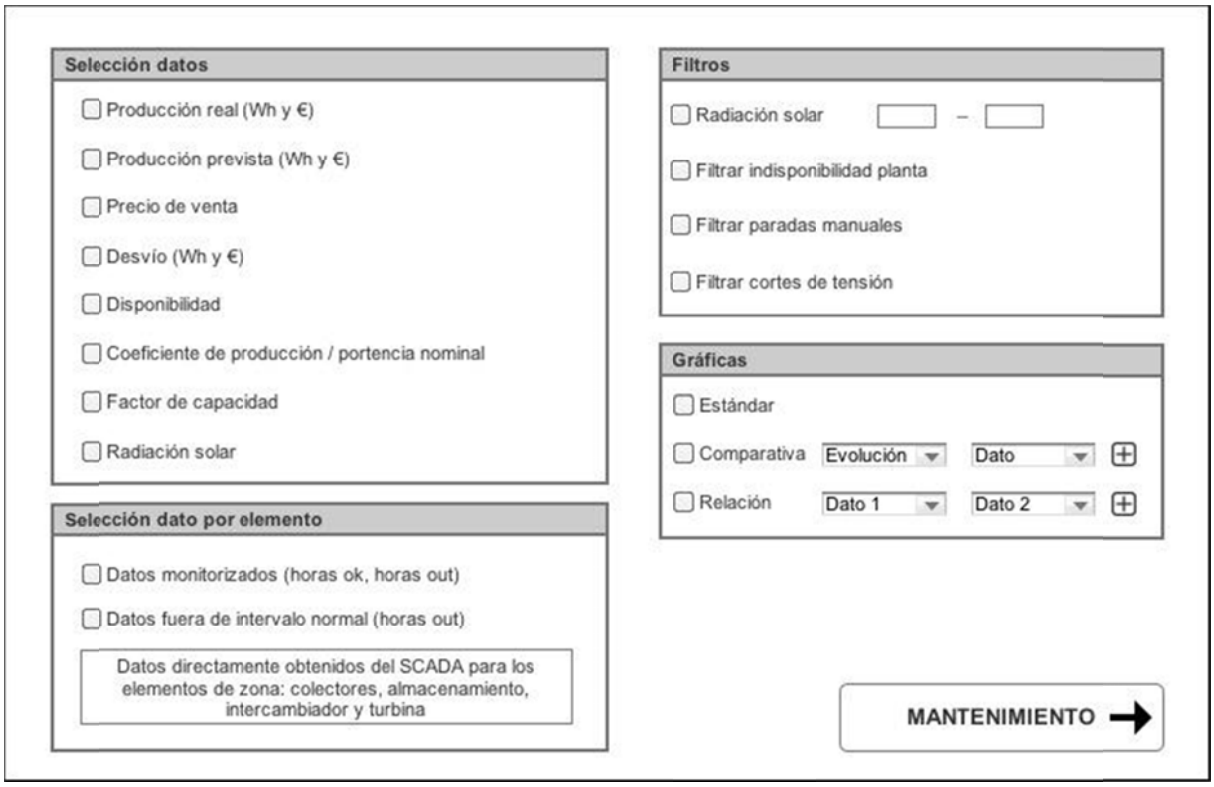


Figure 58: CSP Technology Manager Reports Interface-Personalisation-Production

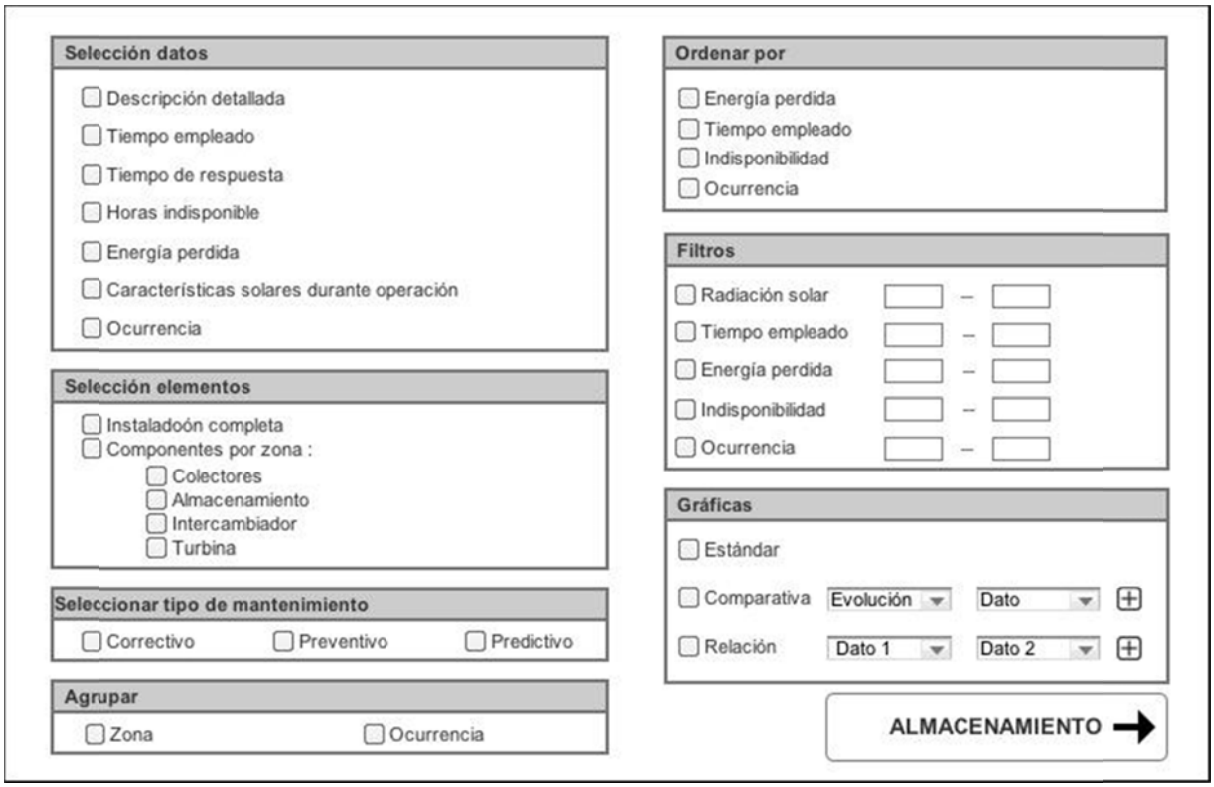


Figure 59: CSP Technology Manager Reports Interface-Personalisation-Maintenance

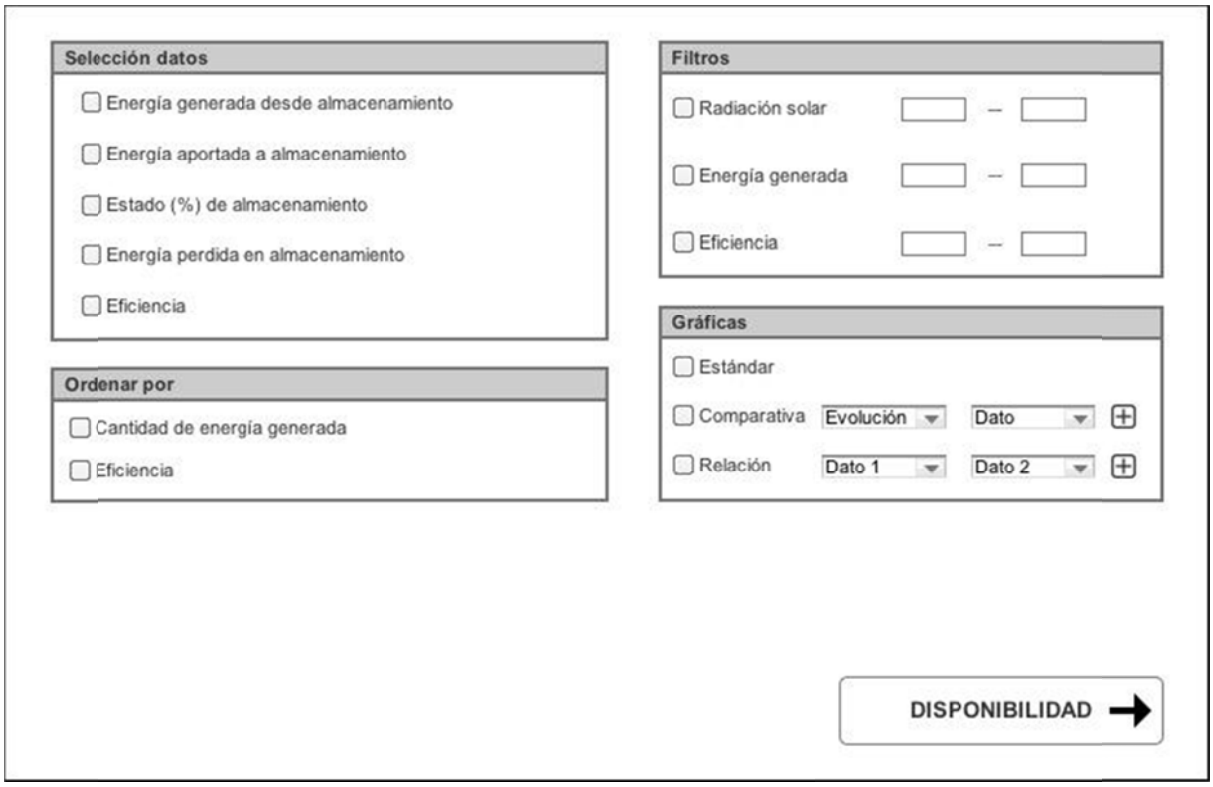


Figure 60: CSP Technology Manager Reports Interface-Personalisation-Storage

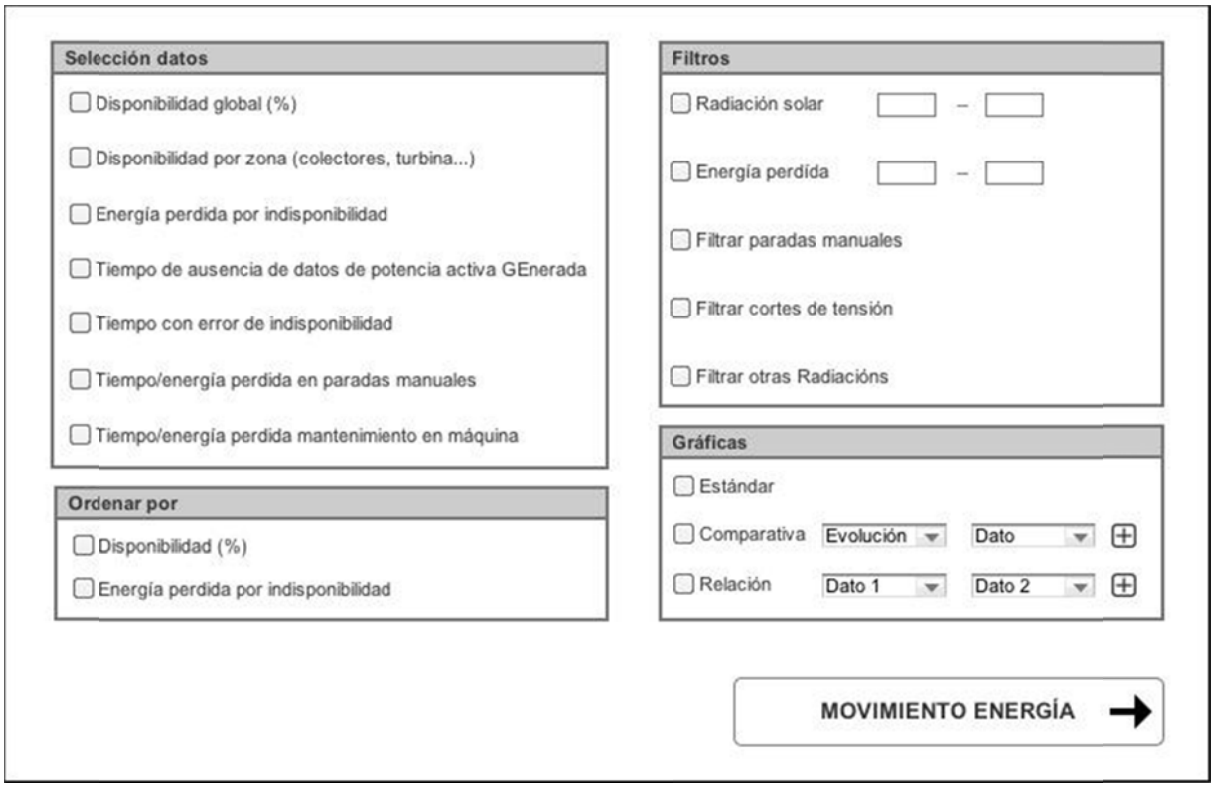


Figure 61: CSP Technology Manager Reports Interface-Personalisation-Availability

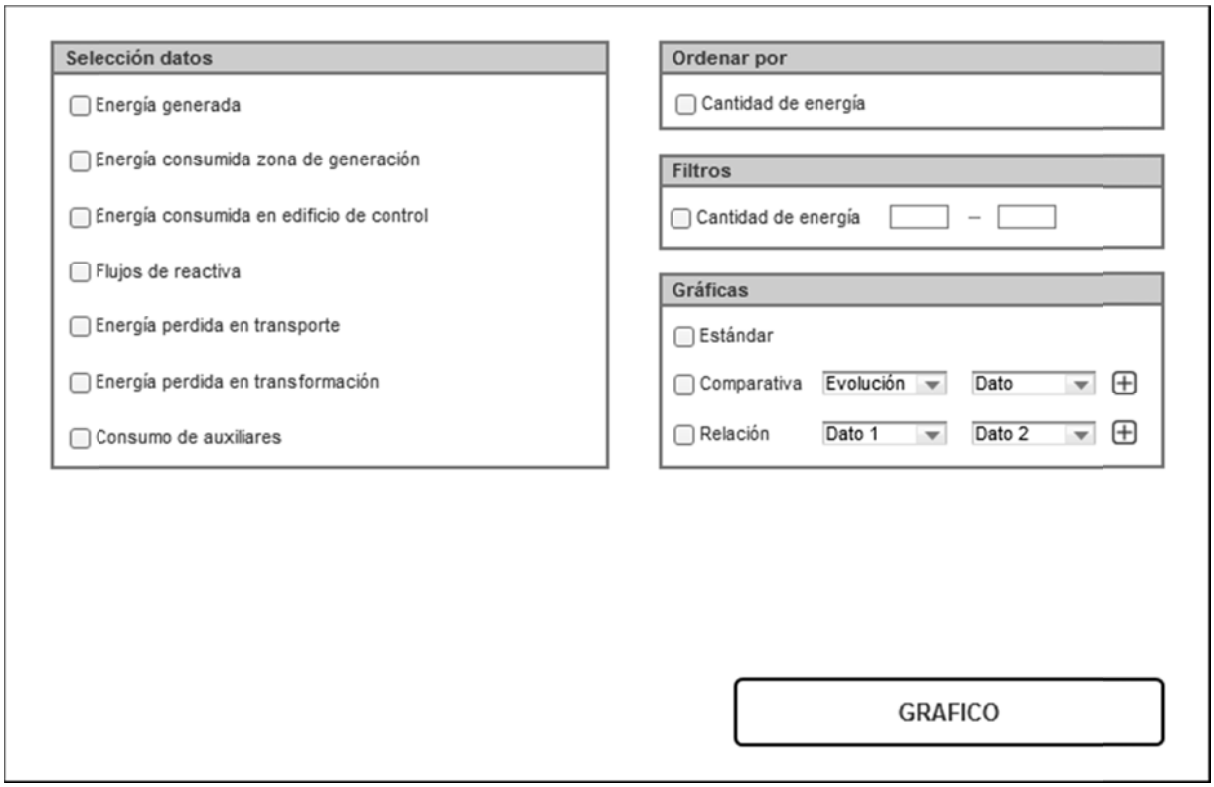


Figure 62: CSP Technology Manager Reports Interface-Personalisation- Energy Movement

4.3 GRAPHICS

To conclude with the Personalised Reports section the User has to choose the graphical output to be included on the report.

As there are many variables to be taken into account (some of them affecting the panels, others the storage section, others the production plants...), and there are many ways to analyse them (separately, by plant, by geographical zone...), this page enables the user to fix the charts and schemes to be generated and displayed. This step also facilitates the work to the control centers itself. Due to a vast amount of data, creating a lot of automatised charts may end up causing a huge computational complexity that could be dispensable.

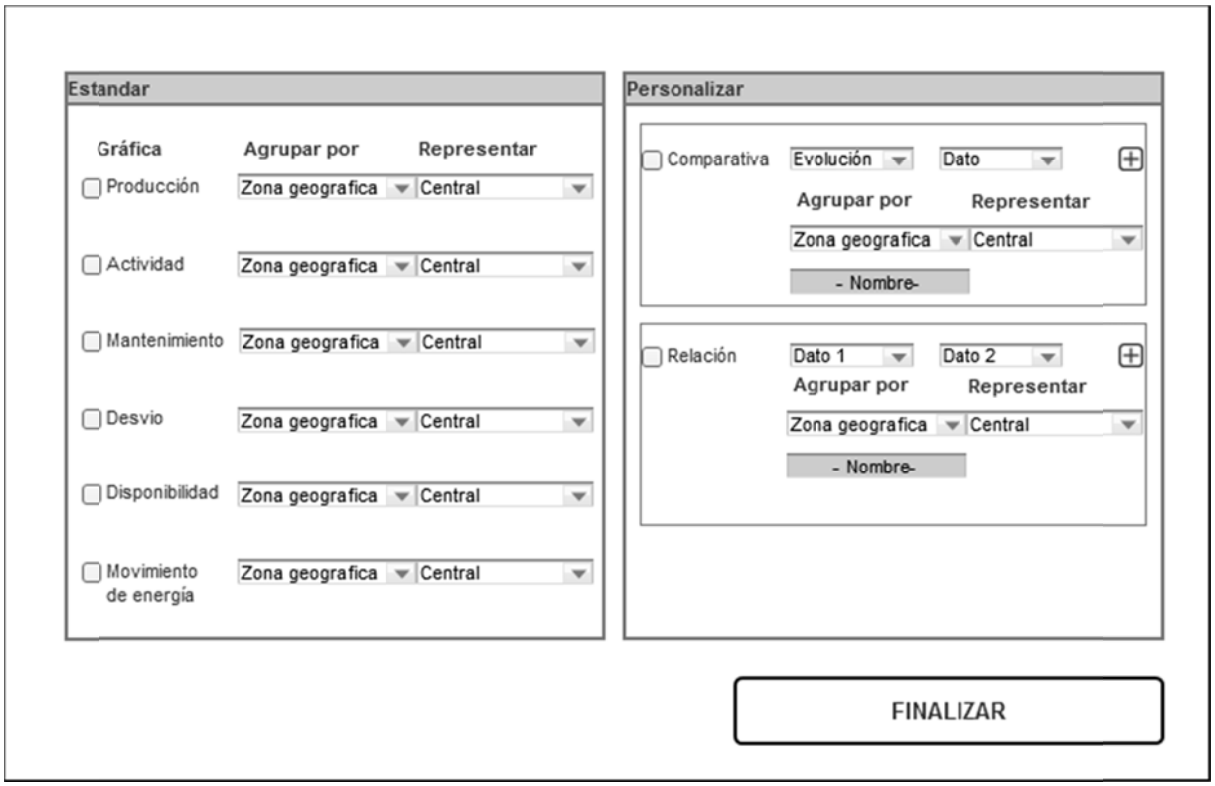


Figure 63: CSP Technology Manager Reports Interface-Graphics

The page is divided in two sections: The standard graphics and the personalised graphics.

On the left side of the page we find the *standard graphics*. In this section the user can directly choose the graphics already desing for the standard reports. However he can determine the actual content of the graphic by selecting on one hand, the subgroup that each

graphic should represent (for example, one graphic per geographical zone, per Market agent or per wind farm or just on only chart for the whole selection); and on the other, the actual object of the graph (one curve per plant or one piece of pie chart per geographical zone ..) [9]

On the right side of the page the User has the possibility to create from scratch the charts. To do so, firstly he has to determine the type of chart to be produced: Comparative chart or relation chart.

- The comparative charts are those which enable the user to compare one single variable either throughout the selected period of time or in total in comparison to another object of study. Thus within this type, the user can choose between Evolutive or Total charts. Once the chart type is determined, the user must select the data to be plotted and the subgroup and the objects to be represented. The possible variables to be included are only those ones that had been selected throughout the previous pages. The Subgroup and Object selections follow the same trend that the one described for the standard graphics.

- The Relation charts are those which enable the user to determine if there is any correlation between two variables (for example the increase of temperature and the frequency of maintenance work in a wind turbine). If the User wants to create a relation chart he has to choose two variables between those previously marked, and fix the subgroup and object selection.

The User can add as many charts as desired by pressing the "Plus button" located on the right upper corner of each chart type window.

Once the report personalisation is finished, the User can generate it by pressing the FINALIZAR button.

5. INCOME STATEMENT

This page reports the user about accountability situation of the CSP parks as it gives access to all the profit and loss statements.

[9] *See the examples described on 4.3 graphical pages of the wind technology standard reports for further understanding of the manipulation of the standard charts.*

Figure 64: CSP Technology Manager Income Statement interface

As shown on the image above, by selecting the MONTH, YEAR and INSTALLATION, the User accesses to the income statement of the concerning plant during the month chosen.

The Income statements are available on the **management database** and can be downloading into excel or pdf sheet. Similarly to the Forecast Page, **this page does not have an automatised refresh frequency. In only refreshes if a new selection is commanded.**

v) Markets and Regulation Manager

This package is only accessible for the user accredited as "Market and Regulation Manager" or for those who are higher in the company hierarchy such as the COO or the CEO.

The assignment of the market and regulation manager is to supervise the company's commercial activity in the electricity market. To do so, he must track the production and market changes as well as the decisions made by the sales agent and the capacity of the plants

to meet the forecasts and budgets.

That said, the package consists of 3 pages: Global, Historicals and Reports. Once logged in, the home page displayed is the Global Page. By pressing the buttons of the main menu, the user will be able to move from one page to another.

1 GLOBAL

The Global Screen is the main page of the package and it's the first one the Responsible of Market and Regulation will see when accessing to the control center. It shows a photograph of the global real-time status of commercial activity.

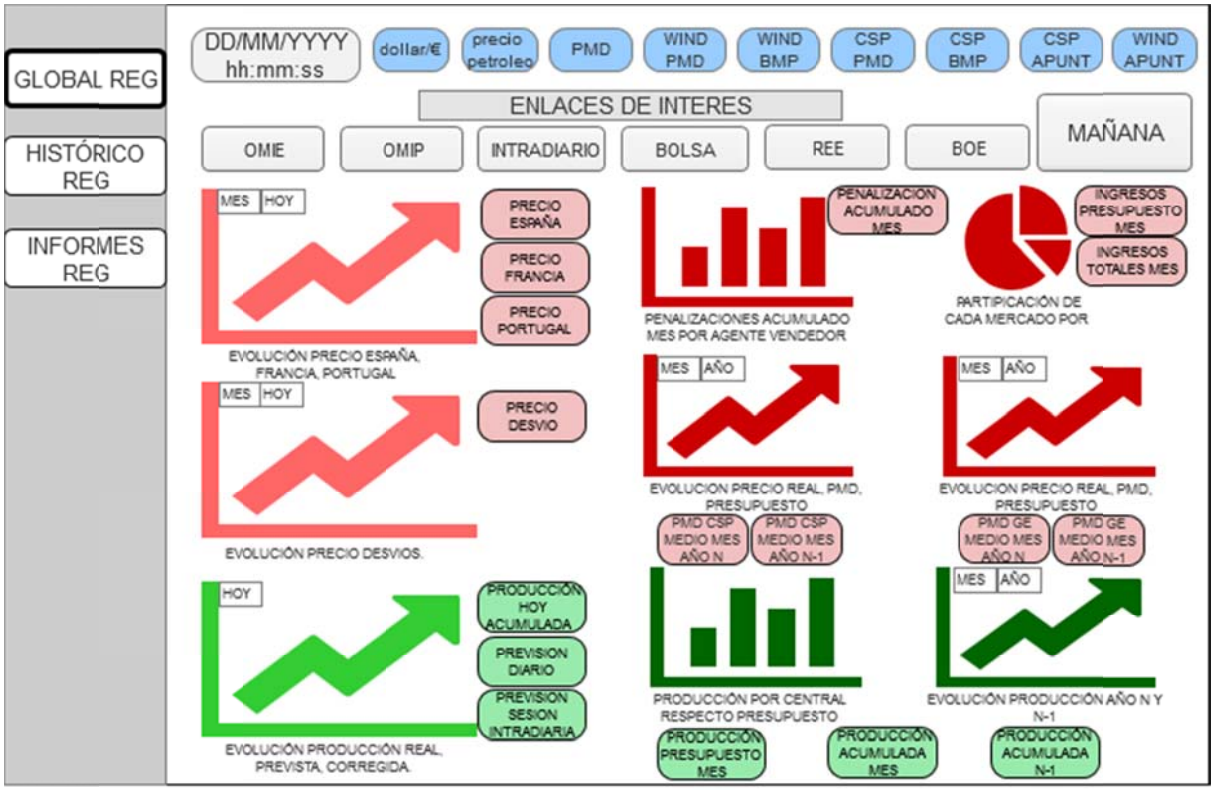


Figure 65: Market and Regulation Manager Global Interface

- DAILY DATA (BLUE)

First of all, In the upper left of this Home Page the user will find the date and time of consultation of the control center.

At the same level, the screen displays the current day's rate dollar/€, the oil's price, the markets prices, the budget price and the corresponding technological peak coefficients.

The exchange rate (Dollar-Euro) and the Oil Price are **daily pieces** of information and **they are extracted from the official website of the European Central Bank[10] and the OPEC official website [11] respectively.** The PMD of electricity (Daily Market Price or POOL), **refresh every hour and they are extracted from the OMIE and REE Official websites[12] and are subsequently stored in the database.** The BMD (Budget Market Price) is a **monthly piece** of information and it is retrieved from the budget sheets stored in the **management database**. To conclude, the technological Peak Coefficients are set by law[13] and the average technological peak coefficient. And they are **extracted from the sales agent reports and the database. The Average coefficients are refreshed every month.**

- USEFUL LINKS (GREY)

Underneath the daily Data, there will be a series of buttons linked to the OMIE's website, The Stock Market's website,[14] REE Website, Essios Website (Information System of REE) and the Ministry of Energy BOE Webpage.

-TOMORROW'S PORTFOLIO AND MARKET'S CLOSE. (GREY)

At the higher-right corner of the page it will be the Tomorrow's Button (MAÑANA). This bottom **displays in an excel sheet** the offers proposed by each sales agent and the close agreement.

If the button is pressed, the control centre will **extract the corresponding values from the reports stored on the Sale's agent database.** The information will only be available once the offers have been made and the information has been subsequently received

[10] *European Central Bank- Exchange Euro-Dollar*
https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html
[11] *Organization of the Petroleum Exporting Countries. Oil Price*
http://www.opec.org/opec_web/en/data_graphs/40.htm
[12] *PMD of electricity.*
https:// www.omie.es/inicio; https://www.esios.ree.es
[13] *For example right now the wind peak coefficient is 0,889 while the solar one is 1.0207.*
BOE Energy Ministery
https://www.boe.es/boe/dias/2017/01/13/indice_departamentos.php?d=11&e=MINISTERIO+DE+INDUSTRIA%2C+ENERG%CDA+Y+TURISMO
[14] *Stock Market*
https://www.bolsamadrid.es/esp/aspx/Portada/Portada.aspx

by the company. Otherwise, a zero will be displayed in every box.

- MARKET CHARTS AND DIAGRAMS (RED)

The Electric Market is monitored on the following charts and diagrams:

A) MARKET'S EVOLUTION (EVOLUCIÓN ESPAÑA, FRANCIA PORTUGAL)

This line chart displays the evolution over time of the electricity price of the Daily Market of Spain, France and Portugal. The user has the option to choose the period: MONTH or DAY. The Y axis features the prices scale in €/MWh whereas the X axis features the time, whose scale depends on the option selected: the monthly chart is measured in days, while the daily one is measured in hours. The default option is DAY.

Figure 66: Example of the Countries price evolution chart. Source: essios.ree.

The data plotted on the Day Chart corresponds to the markets hourly real prices. **It refreshes every hour and it comes from the OMIE's website.** The data plotted on the Month Chart corresponds to the average daily price. **It refreshes every day and it comes from the database.**

Both charts are followed by the corresponding numerical values at the time of consultation.

B) DEVIATION COST EVOLUTION (EVOLUCIÓN PRECIO DESVÍOS)

This line chart displays the evolution over time of the price of deviation penalties. The user has the option to choose the period: MONTH or DAY. The Y axis features the prices scale in €/MWh whereas the X axis features the time, whose scale depends on the option

selected: the monthly chart is measured in days, while the daily one is measured in hours. The default option is DAY.

The daily chart includes:

- The selling price in upper deviations (curve)
- The penalties payment price for lower deviations (curve)
- The percentage of deviations against the market. (barchart)

The data plotted on this chart **comes from the Essios webpage and it refreshes every hour.**

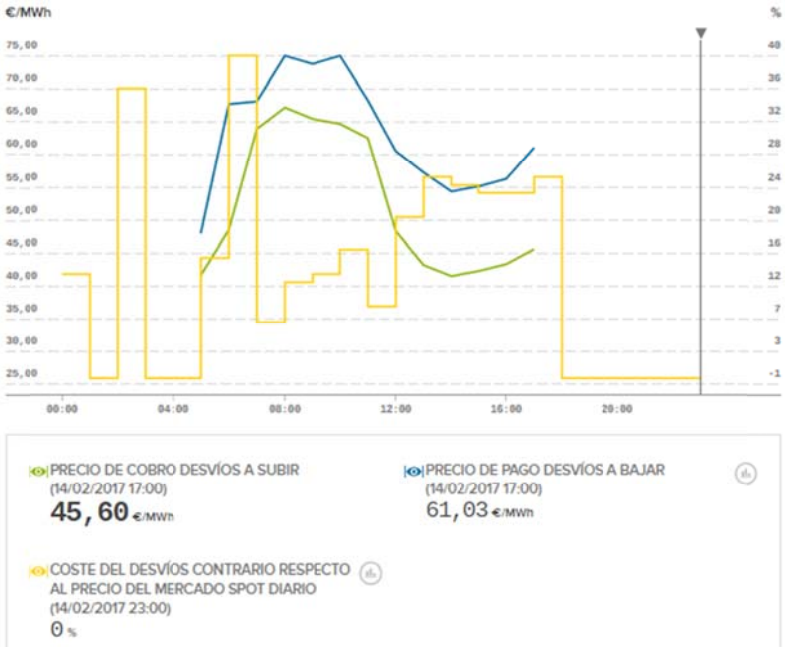


Figure 67: Example of deviations' costs evolution chart. Source: essios.ree.

The monthly chart includes, on one hand, the three graphs resulting of the market activity and in the other one, two graphs corresponding to the company's activity.

The data plotted on the three market graphs correspond to the daily average prices. **It refreshes every day and it is extracted from the database.**

The graphs corresponding to the company's activity are.

- Curve of the company's price of penalties payment.
- The percentage of deviations against the market. performed by the company (bar chart)

The data plotted on these two cases comes from the fortnight reports sent by the sales agent and stored in the management database. **Therefore the chart will be refreshed every two weeks, with the information of the corresponding days.**

C) ACCRUED PENALTIES PER SALES AGENT (PENALIZACIONES ACUMULADAS POR AGENTE VENDEDOR)

One of the main roles of the sales agents is to shield the production deviations of the each plant by leveraging the individual surplus and deficits as well as seizing the opportunities of the intraday market to reduce penalties.

Therefore, under the name of "penalizaciones acumuladas por agente vendedor" there is a bar chart displayed. Each bar represents a sales agent, and its height determines the accrued penalties of the current month for each of them.

Beside the chart, the numeric value of the total of accrued penalties of the current month is displayed.

The values used to plot this graph are extracted from the sales agents' fortnight reports. Therefore the information will be refreshed every two weeks.

D) WIND MARKET EVOLUTION (EVOLUCIÓN MERCADO WIND)

The aim of the line chart is to reproduce the evolution of the Wind PMD, the Wind Budget price and the company's final selling price. Thus, the Y axis measures price in €/MW while the X axis represents the time. The time scale varies according to the option chosen: days if the option is MONTH and months if the option is YEAR. The default option is MONTH.

In both cases the chart includes three curves.

If the selected option is month, the data corresponding to each curve is:

- Wind PMD curve: the daily **price is collected from the markets operator website and it is corrected by the law's wind peak coefficient, available on the management data base.**
- Wind Budget curve: **the monthly budget price is available in the management database.**

- Company's wind final selling price curve: the daily final price **collected from the sale agents' fortnight reports which are stored in the database**.

Concerning the three curves, the values displayed correspond to the mean of the sector. Thus, to display the wind budget curve, the control center must calculate the mean of the budget prices of all the wind plants. By the same token, the final selling price curve results of the mean of the final prices of each sales agent.

As the sales agents reports are sent every two weeks, the data refreshes once the new report is received.. Therefore the user doesn't have the information of the current day until the week is finished.

To conclude, the average final prices of the month for years N and N-1 are displayed beside the chart. **This information is extracted from the database.**

E) SOLAR MARKET EVOLUTION (EVOLUCIÓN MERCADO CSP)

This Set of data is analogous to the Wind Market Evolution one but with the corresponding values of the CSP activity.

F) MARKET SHARE

The market share is featured via a pie chart. Each piece represents a market: Mercado Diario, Mercado Intradiario and Forward contracts.

The data used to generate this chart comes **from the fortnight sales agents' reports and which are available on the database.** The chart displays the accrued values for the current month and **refreshes every two weeks.**

To conclude, the User has the possibility to see the numerical information correspond to volume of energy (MWh) and the revenues (€) deriving from each market share.

- PRODUCTION (GREEN)

The production set consists of the following numerical data and charts:

A) TODAY'S PRODUCTION LINE CHART

The aim of this line chart is to get to know the evolution of the current day's global production compared to what was forecast by the weather forecasting agent. Thus, the Y axis represents power while the X axis represents the timeline. The timescale can be an Hour or 10 Minutes, depending on the option chosen by the user. The default option is Hour

The today's line chart displays in three curves the following information.

- The real production
- The forecast sent to the dairy market (with percentile 10 and percentile 90)
- The corrected forecast

The real production curve is based on the data collected from the meters and the Scada. This information is taken every 10 secs and but **it is recorded aggregated on the database every 10 minutes. Thus, the curve will refresh once new data is stored.**

The other curves derive from the forecasts sent to the intraday market and the dairy market. **The corrected forecast curve is plotted while the production is recalculated and sent to the intradaily market and so it refresh after each intradaily market forecast.** (17.00, 21.00, 01.00, 08.00, 12.00) while the dairy market forecast curve **is updated every day.**

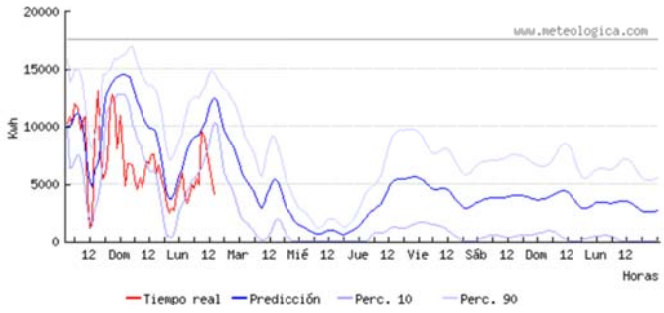


Figure 68: Example of production deviations chart format

Added to that, the chart goes together with the numerical data corresponding to the current day's accumulated production (MWh) and the current day's corrected forecast total production (MWh).

B) COMPARAISON REAL PRODUCTION AND BUDGET

The comparison between year N and budget is displayed using a bar chart. The aim of this chart is to know the performance of each central regarding the compliance with the

budget. Therefore, each bar corresponds to a central and its height represents the percentage achieved of the production budget. To this effect, the percentage result of the comparison of the month's accrued production **(recorded by the scada and available on the database)** and the budgeted production **(available on the management database)**. The chart refreshes **at the end of the days once the daily activity is closed** and goes together with the numerical data corresponding to the percentages, accrued productions and budgets

To conclude, the chart is complemented with the global production anticipated in the budgets. This numerical data result of the sum of all the productions anticipated in the budgets.

C) COMPARAISON YEAR N AND N-1

The aim of this chat is to compare the production of the current year (Year N) and the previous one (Year N-1).Therefore, Y axis the power, measured in MWh; and the X axis the time line measured in months or days depending on the option chosen (YEAR or MONTH). The default option YEAR

That said, the chart includes two curves. One curve corresponds to the production of year N up to the time of consultation while the other one corresponds to the production of year N-1. The marks of each graph represent the accrued production of the month or day (Depending on the option). The data used to create the graph comes from the scada and is **available on the database.**

The MONTH chart **refreshes every day** at the end of it**.** The YEAR Chart **refreshes every month.** The last datum, the one corresponding to the current month, shows the production of that month up to date**. The information corresponding to year N-1 is displayed with the same frequency than the one from year N.**

The chart is followed by two numerical pieces of information of the accrued production of the current month up to date of year N and the production of year N-1.

2. HISTORICALS

The historical screen allows the User to evaluate the graphs shown up on the Global Screen during another past period of time.

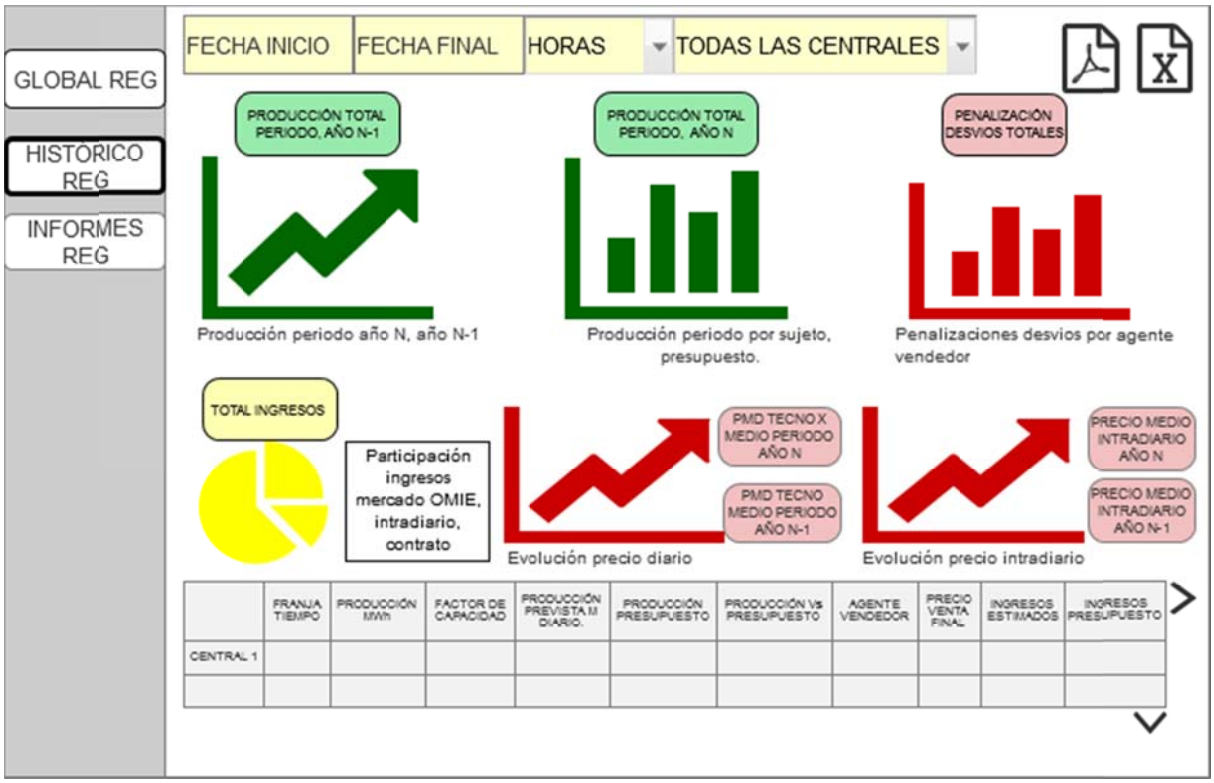


Figure 69: Market and Regulation Manager Historical Interface

- SELECTION

At the top of the page, in yellow, the User is able to define his selection. The boxes to fill in are: The information to be studied[15], the starting date, the final date and the time grouping unit and the "object" of study. This last box is only available if the chosen graph belongs to the production set. In that case, the user can choose between GLOBAL, WIND or CSP.

Regarding the Time selections there are the following constraints:

- The final date is limited by the current date.
- If the time interval is a day, the only possibility of time grouping unit is HOURS.
- If the time interval is between 1-31 days, the possibilities of time grouping unit are DAY and WEEK.
- If the time interval is between 31-92 days, the possibilities of time unit are

[15] *The information to be studied has to be part of the global screen.*

DAY, WEEK and MONTH.

- If the time interval is between 92-365 days, the possibilities of time unit are WEEK, MONTH and trimester
- If the time interval is bigger than 365, the possibilities of time unit are MONTH, trimester and YEAR.

- CHARTS AND TABLES.

Once the selection has been defined, the control center displays the corresponding graph and a table with the numerical information used to create it.

All the information is available in the **control centre's databases.** If the piece of information selected can not be displayed within the desired grouping time, the control centre will automatically display it using the closest option.

At the bottom of the page, the User can export the information into Excel.

3. REPORTS

The Reports section is the user's proper business intelligence tool. This section is accessible from the left-side menu by clicking on the button "INFORMES REG". Based on the roles and mission of the Responsible of Market and regulation, the functional design for this section goes as follows.

3.1 REPORTS HOME PAGE.

The reports Home Page is the first screen the user sees when clicking on the corresponding button.

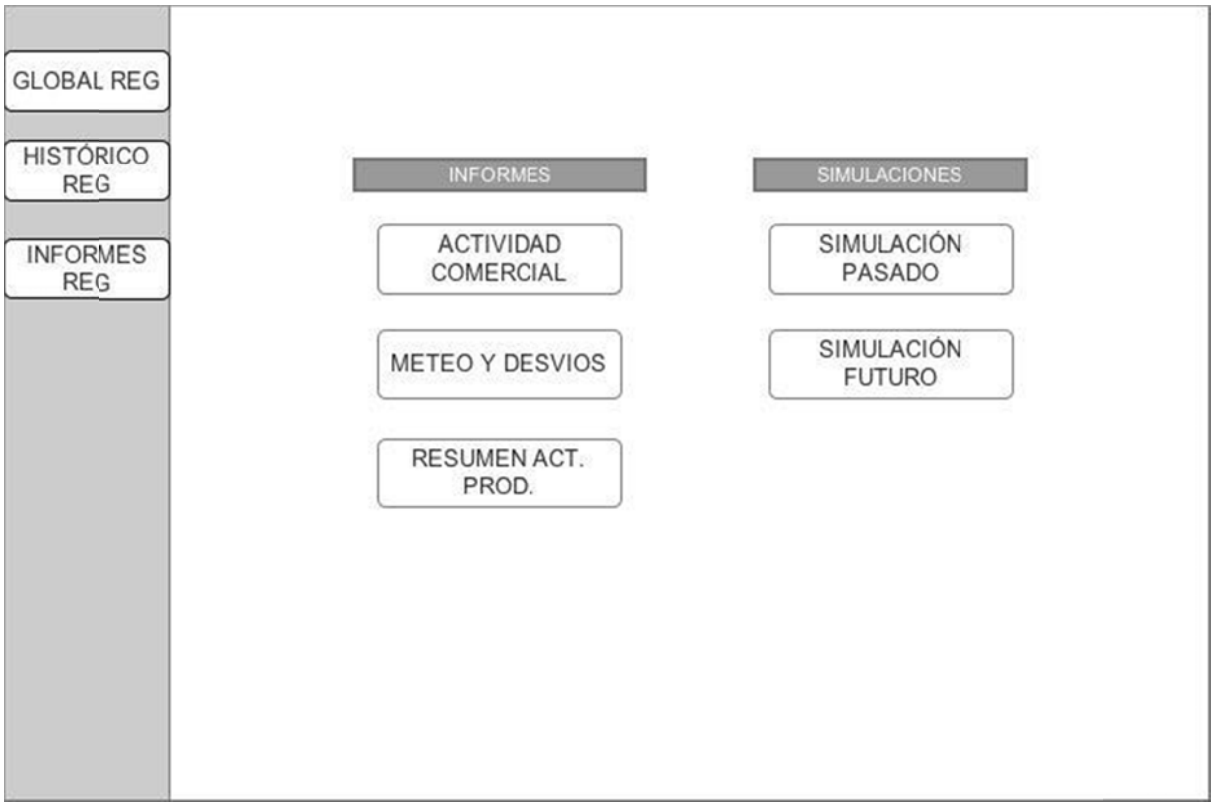


Figure 70: Market and Regulation Manager Reports Interface-Homepage

On this page there are no numerical or graphical data displayed. Indeed, it only acts as the static submenu of the reports section. To this end, the page layout goes as follows.

The menu is divided in two columns, each of them headed by one text box: INFORMES and SIMULACIONES.

The left-side column headed by INFORMES includes three buttons: Commercial Activity Summary (Actividad Comercial) Weather forecast and Deviations (Meteo y desvios) and Productive Activity Summary. (Resumen Act. Prod). The right-side column headed by SIMULACIONES includes two buttons: Past Simulation (Simulación Pasado) and Future Simulation (Simulación Futuro).

Each button opens a different window that will permit the User to create the corresponding report.

3.2 COMMERCIAL ACTIVITY REPORT.

The aim of this report is to know in detail the commercial activity of different objects of study (market agents, a technology, a geographic zones or plants).

By clicking the "Actividad Comercial" Button, the Reports Search Window is opened. After having filled the different boxes and clicked on the button "GENERAR", the Control Centre creates and opens the corresponding file.

A. SEARCH WINDOW.

The Search Window consists on four sections: Selection, Output, Filters and File.

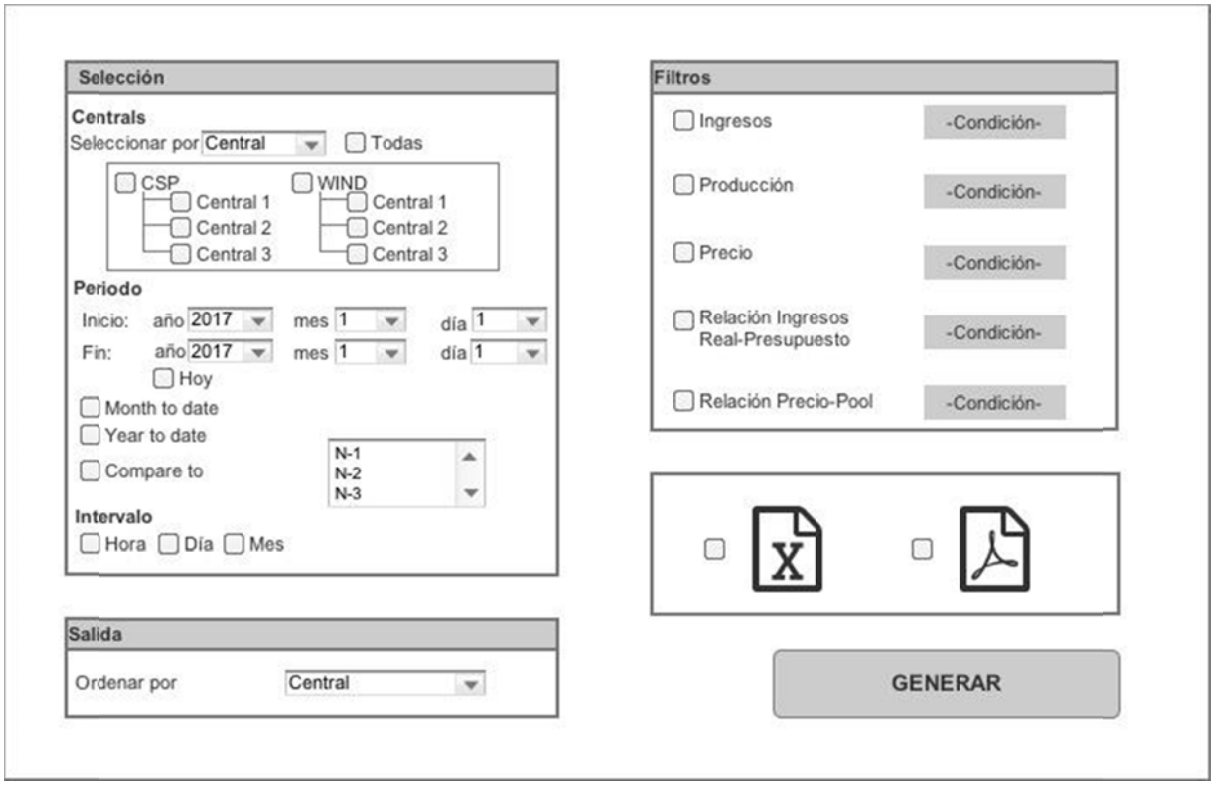


Figure 71: CSP Technology Manager Reports Interface- Commercial Activity Report

-SELECTION (SELECCIÓN)

In the Selection Box the User has to fill out different request concerning the object and period of studying. The Selection process goes as follow:

a. Central

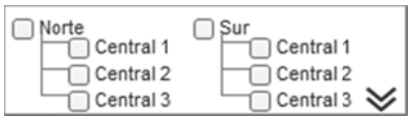
First of all the User has to choose the plants he wants to include in his Reports. He can either choose all of them, or according to a subgroup. The subgroups are: Technology, Geographic Location, Sales Agent or Plant

i) Technology (Sector)

As shown in the window example, if the Technology option is marked the plants will be displayed grouped by technology. The user has the option either to choose the whole technology (Wind and CSP) or to choose only some specific plants within the technology.

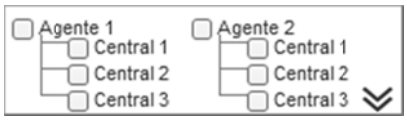
ii) Geographical Location

If the marked option is Geographical Location, the plants will be displayed grouped by Geographical Location. The User has the option to choose the whole set of plants of specific zones, or to choose only some of the plants within them.



iii) Sales

If the marked option is Sales Agent, the plants will be displayed grouped by is corresponding Sales Agent.



iv)Plant

If the marked option is Central, the whole list of plants will be displayed.

The aim of this selection method is to simplify the searching process for the user and to optimize the "path" that the searching algorithm must follow in order to create the report.

b. Period

Once the Object of study has been chosen, the User has to specify the time interval the control centre must collect the data from. To do so he has to fix the starting and final date.

If the User doesn´t want to limit the interval in the traditional way he can also choose the Month to date and the Year to date option. These options are compatibles and can be marked at the same time.

To conclude, after having chosen the time interval, the user can demand to compare the period with the analogous period of another year. To do so he has to select the option "compare to" and the year affected knowing that N is the year at the time of consultation.

The constraints tied to the period selection are:

- The time period has to be a multiple of a fortnight. Otherwise, the remaining days will be filled with a hyphen.
- The longest time period is 365 days.
- The user could ask for information of years N, N-1, N-2. Older information won't be able on the database.

Time-grouping unit

The time grouping unit alludes to the frequency in which the data will be grouped and displayed. There are four possibilities: FORTNIGHT, MONTH, TRIMESTER OR YEAR.

The constraints tied to the time grouping unit selection are:

- There is no possibility to choose a time grouping unit bigger than the period

itself.

- If the time interval is between 1-31 days, the possibilities of time grouping unit are FORTNIGHT OR MONTH.
- If the time interval is between 31-93 days, the possibilities of time unit are FORTNIGHT or MONTH.
- If the time interval is between 93-365 days, the possibilities of time unit are MONTH or TRIMESTER

- OUTPUT (SALIDA)

In the Output Box the user has the option to select how he wants to regroup the information. There are three possibilities: CENTRAL, TECHNOLOGY or MARKET AGENT.

-FILTRES (FILTROS)

This box allows the user to filter the objects to be included in the report by fixing conditions tied to some variables. The conditions must be in equations. The possible variables are:

- Revenues
- Production
- Price
- Relation Real Price and Pool price

The variables Revenues (Ingresos), Production (Producción) and Price (Precio) are natural numbers, while Ration Pool-Real Price (Relación Precio-Pool) is measured using percentage. The variables “Ingresos” and “Production” refer to the absolute quantities for the period chosen.

-FILES

Finally the user has to choose if the report has to be generated in an excel file or pdf.

B. REPORT

Once the selection Box is fulfilled[16], the commercial activity report will include:

a) Concept:
- Installation
- Sales agent
- Period of time
- Revenue Production's Market Settlement
- Revenue Production's Server Settlement
- Total Revenue per Installation (€)
- Production per installation (MWh)
- Average Selling price per installation (€/MWh)

b) Production's Market Settlement:
- Price (€/MWh)
- Production (MWh)
- Revenues (€)

i) Daily Market Component Prod
- Price (€/MWh)
- Production (MWh)
- Revenues (€)

ii) Intraday Market Component:
- Price (€/MWh)
- Production (MWh)
- Revenues (€)

c) Production's Server Settlement (SCDES guaranteed)
- Price (€/MWh)
- Production (MWh)
- Revenues (€)

[16] *All the boxes but the Filters one must be fulfilled in order to generate the report.*

i) Program Production Ajustement
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

ii) Intraday Technical Restrictions (RT4)
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

iii) Real time Technical Restrictions (RT5)
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

iv) Breach of Power Factor Control.(CFP)
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

v) Technical Restrictions Stage 1(RTF1)
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

vi) Real time Technical Restrictions(I) (RT5X)
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

vii) Breach GDV y TER (BALX)
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

d) IA REE/OMIE
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

i) Daily Market Component
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

ii) Intraday Market Component
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

iii) Daily Market Prod Component
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

iv) Intraday Market Prod Component
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

v) Program Adjustment
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

vi) Prod Program Adjustment
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

vii) Secondary Band (B) (BS1)
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

viii) Secondary Band (VCF) (BS2)
   - Price (€/MWh)
   - Production (MWh)
   - Revenues (€)

ix) Secondary Regulation(SEC)

- Price (€/MWh)
- Production (MWh)
- Revenues (€)

x) Deviations Management REE- UP (GDV)
- Price (€/MWh)
- Production (MWh)
- Revenues (€)

xi) Tertiary REE UP (TER)
- Price (€/MWh)
- Production (MWh)
- Revenues (€)

If the grouping element isn't "Central", at the beginning of the report there will be a concept summary of the commercial activity of each group unit (technology, geographical zone or market agent)

- Group unit name
- Components of the group
- Period of time
- Revenue Production's Market Settlement per group
- Revenue Production's Server Settlement per group
- Total Revenue per group (€)
- Production per group MWh)
- Average Selling price per group (€/MWh)

All the information is extracted from the sales agent's fortnightly reports which are stored in the management database.

3.3 FORECAST AND DEVIATIONS.

The aim of this report is to analyse the accuracy of the forecasting and the production of the plants.

By clicking the "Meteo y desvios" Button, the Report's corresponding Search Window is opened. Once the user has filled the different boxes and clicked on the button "GENERAR", the Control Centre generates the corresponding file.

A. SEARCH WINDOW.

The Search Window consists of four sections: Selection, Output, Filters and File.

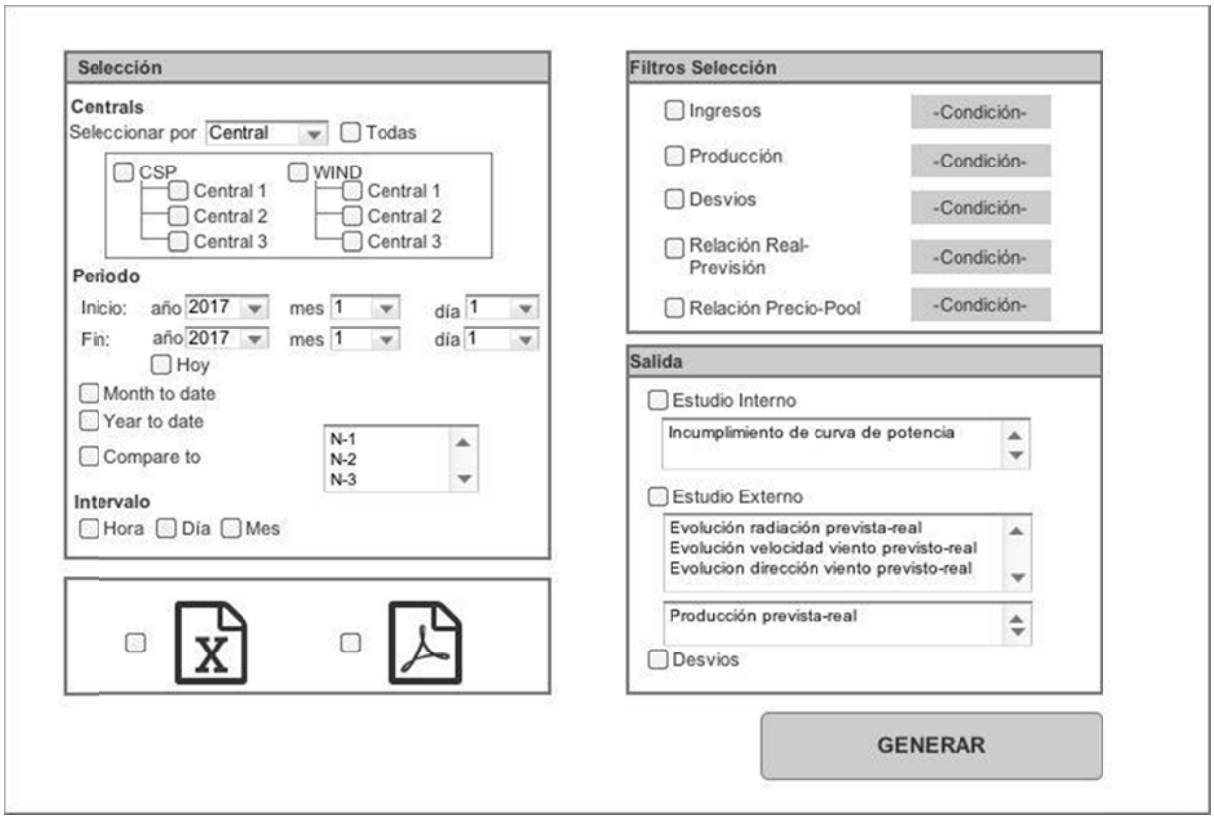


Figure 72: Market and Regulation Manager Reports interface-Forecast and Deviations

-SELECTION (SELECCIÓN)

The Selection box is similar to the Commercial Activity Report's Selection Box.

-FILTRES (FILTROS DE SELECCIÓN)

The Filters box is similar to the Commercial Activity Report's filters Box.

-OUTPUT (SALIDA)

The output box is adapted to the report. Thus, the report can include three areas of study.

- Internal Study
- External Study
- Deviations

That said, the three options can be selected at the same time. In that case, they would be displayed in the following order: Deviations, Internal Study and External Study.

-FILE

Finally the user has to choose if the report has to be generated in an excel file or pdf.

B. REPORT

Once the selection Box is fulfilled[17], the report is generated displaying the charts and the numerical data marked in the Output box.

- Internal Study.

The aim of this option is to see if the problem of the production forecasting relies on the wind turbines or the solar panels by displaying their theoretical and real power curves.

The calculus is made using **with the information from the SCADA (taking into account only the windturbines or braches of the solar park whose switch is not in maintenance or off mode) stored in each installation's database.**

Therefore, the report will present for each installation, for each grouping time unit, the energy lost in the periods where the machine was disponible (due to the non respect of the power curve) of the components where the deviation is over the critical value. The numerical table will come with visual charts.

- External Study.

The aim of this option is to see if the problem of the production forecasting relies on the fact that the weather forecasting wasn't reliable.

[17] *All the boxes but the Filters one must be fulfilled in order to generate the report.*

To do so the user can analyses the different characteristics of the weather conditions and compare them to the ones forecasted. **The forecasted information is available in the management database and the real ones are calculated using the information collected by the meters.**

The report will plot the name of the "group" whose forecasting agent's deviation overpases the critical value as well as the numerical and graphical grouped by the time unit selected.

- Deviations:

The aim of this option is to plot the forecasted production, the corrected forecasts and the real production.

The information of the forecast production comes from the weather forecasting agent's reports which are stored in the database while the real production data is obtained from the scada.

If the three options are marked, they would be displayed in the following order: Deviations, Internal Study and External Study.

3.4 PRODUCTION'S ACTIVITY REPORT.

The aim of this report is to display the the economic data from the electric market and the electricity production of the desired plants.

When the "Resumen Act. Prod" Button is clicked; its corresponding Search Window is opened. Once the user has filled the different boxes and clicked on the button "GENERAR", the Control Centre generates the corresponding file.

A. SEARCH WINDOW

The Search Window consists of four sections: Selection, Output, Filters and File.

-SELECTION

The Selection box is similar to the Commercial Activity Report's Selection Box (3.2.1 Search Box -> Selection).The only difference relies on the time constraints. In this case the minimum time unit is month as it includes the budget data.

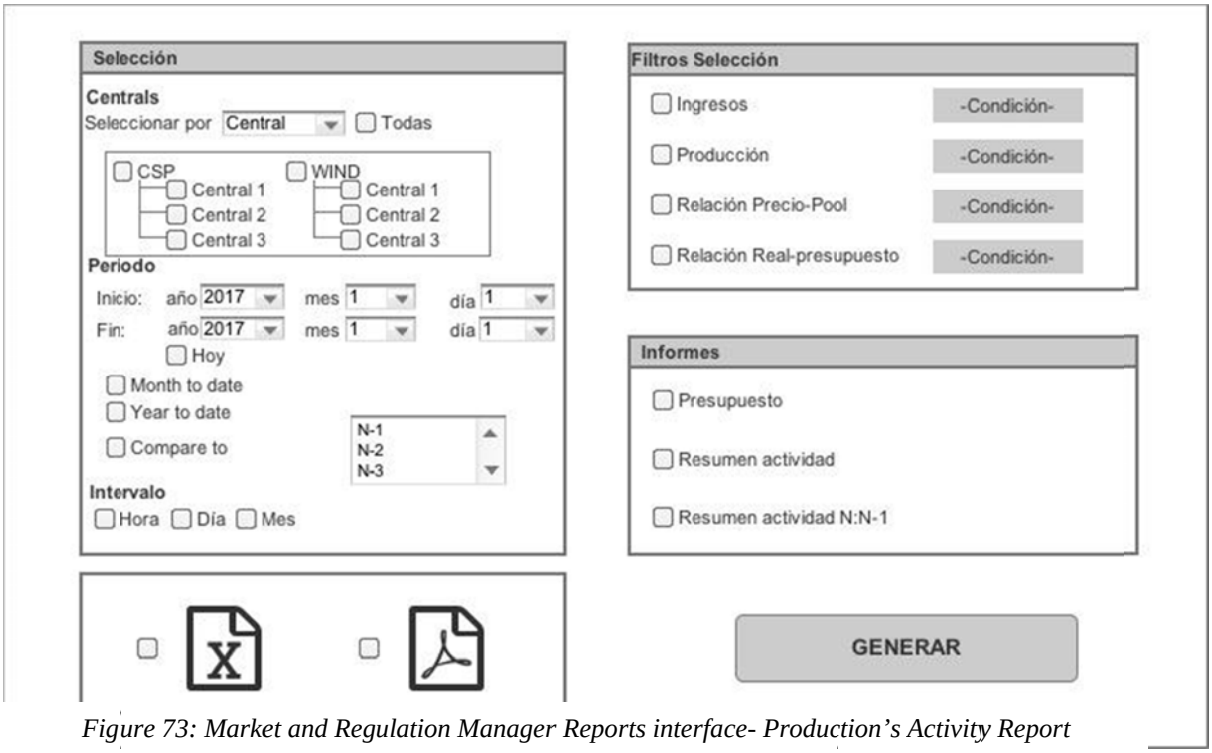


Figure 73: Market and Regulation Manager Reports interface- Production's Activity Report

-FILTRES

The Filters box is similar to the Commercial Activity Report's filters Box (3.2.1 Search Box -> Filters)

- OUTPUT

The output box determines the report. Thus, it can include three f study.

- Budget (Presupuesto)
- Activity Summary (Resumen Actividad)
- Activity Summary N:N-1 (Resumen Actividad N:N-1)

The Activity Summary option can be selected separately However, the Budget and the Activity Summary N:N-1 options imply the selection of the ACtivity Summary automatically.

-FILE

Finally the user has to choose if the report has to be generated in an excel file or pdf.

B. REPORT

Depending on the options marked on the searching box, the report will include different pieces of information.

First of all the Activity Summary report includes a table with the following data for each time grouping unit:

- Real final selling price,
- Real production
- Real final income,
- Market pool (PMD), Sector pool, Deviation penalty, Kurtosis coefficient.

By clicking the Budget option, the report includes:

- Real final selling price, budgeted selling price and the variation between them.
- Real production, budgeted production and the variation between them.
- Real final income, budgeted income and the variation between them.
- Market pool (PMD), Sector pool, Deviation penalty, Kurtosis coefficient.

Finally, the Activity Summary N:N-1 includes:

- Year N Real final selling price, Year N-1 selling price and the variation between them.
- Year N Real production, Year N-1 production and the variation between them.
- Year N Real final income, Year N-1 income and the variation between them.
- Market pool (PMD), Sector pool, Deviation penalty, Kurtosis coefficient.

In addition, the three first points are accompanied by a double line chart that shows

the evolution of the values (real and budgeted and/or year N-1) throughout the selected time period.

All the information is obtained from the plant's database, the management database and from the OMIE online website.

3.5 PAST SIMULATION.

The past simulation enables the user to compare the real activity of a past period of time with another scenario.

When the "Simulacion pasado" Button is clicked, its corresponding Search Window is opened. Once the user has filled the different boxes and clicked on the button "GENERAR", the Control Centre generates the corresponding file.

A. SEARCH WINDOW:

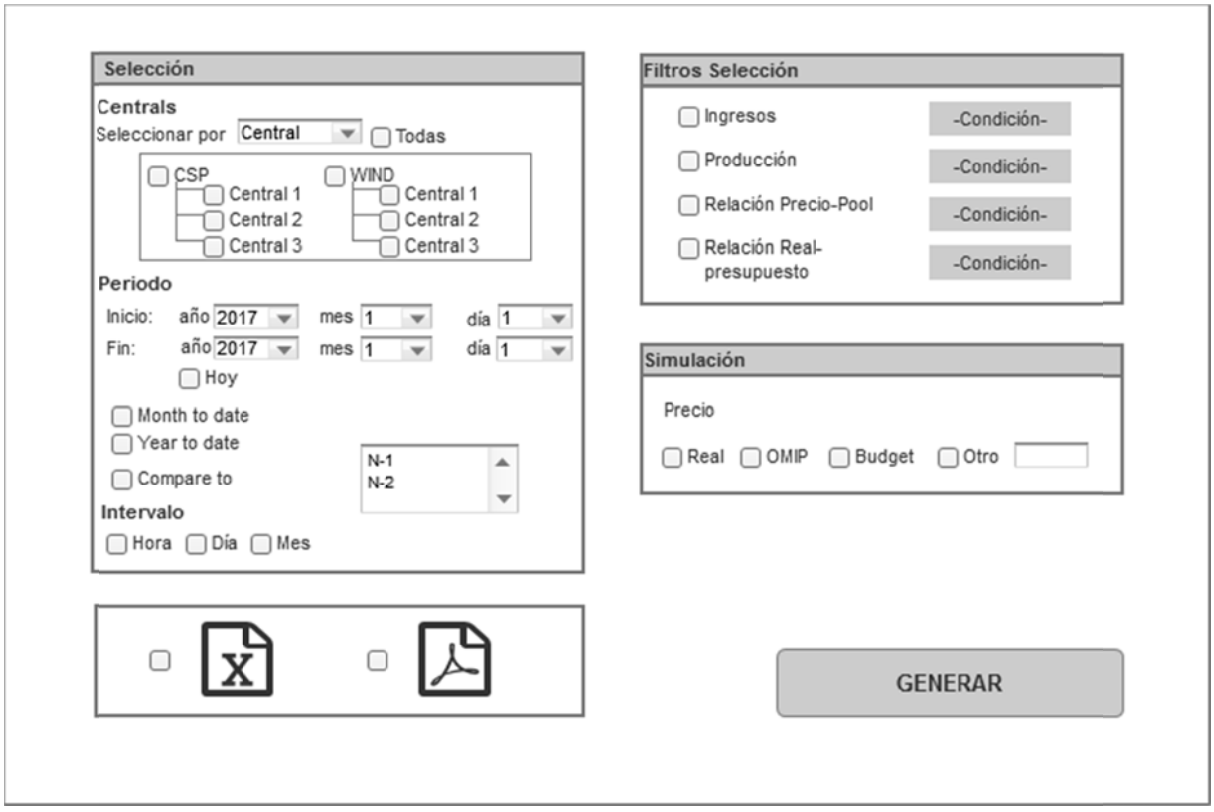


Figure 74: Market and Regulation Manager Reports Interface- Past Simulation

The Search Window consists of four sections: Selection, Simulation, Filters and File.

-SELECTION

The Selection box is similar to the Commercial Activity Report's Selection Box (3.2.1 Search Box -> Selection)

-FILTERS

The Filters box is similar to the Commercial Activity Report's filters Box (3.2.1 Search Box -> Filters)

-SIMULATION

The Simulation Bow allows the user to define the imaginary scenario to be recreated.

The options for the selling price are:

- Real Price
- OMIP (Ideal if the user wants to evaluate the sales agent's performance)
- Budget (Ideal if the user wants to evaluate the reliability of the budgets).
- Other prices: This box only admits numerical value.

  In this box, all the options can be selected at the same time.

-FILES

Finally the user has to choose if the report has to be generated in an excel file or pdf.

B) REPORT

Depending on the options marked on the searching box, the report will display different scenarios. However the report's table will always include:

- The real production
- The real price
- The total income

- The simulated price
- The simulated income
- The comparison between both incomes in percentage.

In addition, the table is accompanied by a multiple line chart that shows the evolution of the values (price and production) throughout the selected time period for the different scenarios.

If the price chosen to simulate is the budget price, the report will also include the budget's production and the corresponding income (the budget income). In this case, the smallest time grouping will be automatically month. Added to that, a line chart displaying the evolution of the production will be included.

The data related to real production, real price, budget production and budget price are recorded in the plant and management data bases. The OMIE prices must be downloaded from it webpage.

3.6 FUTURE SIMULATION.

The future simulation enables the user to recreate and analyse different scenarios for a future period.More precisely, its aim is to recreate different commercial scenarios playing with bilateral contracts. .

By clicking the "Simulación futuro" Button, the simulation's corresponding Search Window is opened. Once the user has filled the different boxes and clicked on the button "GENERAR", the Control Centre generates the corresponding file.

A. SEARCH WINDOW

The Search Window consists of four sections: Selection, Forecast, Simulation, Output and File.

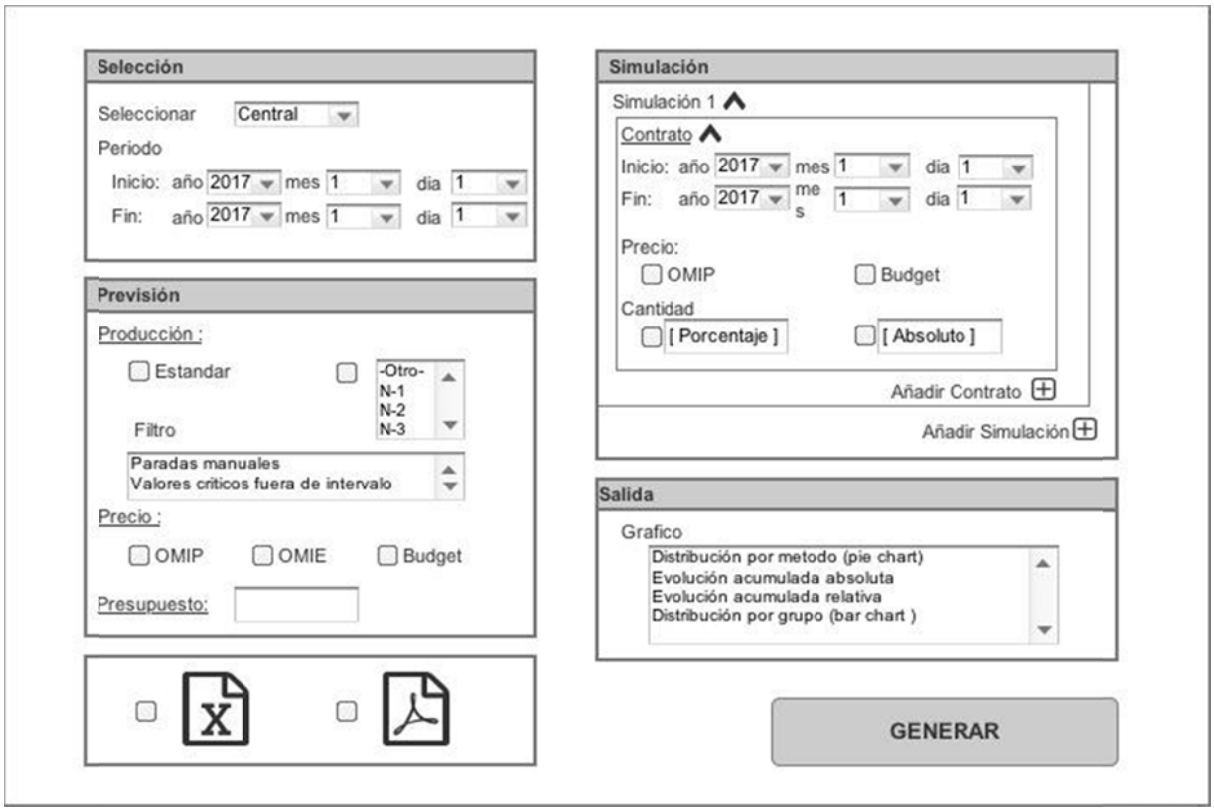


Figure 75: Market and Regulation Manager Reports Interface- Future Simulation

- SELECTION (SELECCIÓN)

In the selection box the user has to choose the plant and the forthcoming period. The final date can not overpass the year time from the time of consultation.

-FORECAST (PREVISION)

In order to establish a reference situation without contracts, the user has to select the production and the price expected.

a) Production

Regarding the production, the responsible can choose between two options. On one hand, the standard option uses the production data provided by the weather forecasting agent. If this one is not available, it will use the production included in the budget. On the other hand, the production of another year can be used as reference. (Year N-1, N-2 or N-3). In order to make this last one more real, he can

filter and soften the pics of production by disregarding, the manual stops or eliminating and converting the critical values.

b) Price

Regarding the price, the user can choose between the budgeted price, or the market price. If the period's price is early enough to have been defined by OMIE, he could be able to choose OMIE. If the time interval is further, he could only choose OMIP. Added to that, he can fix another value of his desire.

-SIMULATION

Once the plant and the scenario of reference are selected, the user can establish the different simulations to be analysed by filling this box.

Each simulation can have as many contracts as the user wants as far as they are compatibles i.e. the total quantity attributed during a same period of time cannot overpass the 100%.

To "define" a contract the user has to choose the time period, the selling price and the quantity of production affected. On hand hand, the price can take the values given by OMIE for that period of time, the budget price for that period of time, or any other value of the user's desire. On the other hand, the production can be determined either by specifying the absolute amount of energy to be sell or ascribing the percentage of the production to be include.

-OUTPUT

After having established the different scenarios the User can choose the graphs and chart to be included. The options are:

a) Pie chart by commercial method.
b) Simulations comparative bar chart.
c) Absolute aggregated evolution
d) Relative aggregate evolution

-FILES.

Finally the user has to choose if the report has to be generated in an excel file or pdf.

B REPORT

First of all the report will include a table with the numerical values of price, production and income for each scenario. Subsequently, the charts chosen in the search box will be displayed.

a) Pie chart by commercial method.
   For each simulation, there will be a pie chart illustrating income gained by each commercial activity (reference and contracts).

b) Simulations comparative bar chart.
   In this chart, each bar represents the income of a different simulation the bar will be display as the aggregation of each commercial activity.

c) Absolute aggregated evolution
   This chart displays the evolution of the total income (in €) throughout the time interval. Each simulation is represented by a curve.
   - If the time interval is the following day, the time unit will be hours.
   - If the time interval is shorter than a month, the time unit will be days.
   - If the time interval is between month and trimester, the time unit will be weeks.
   - If the time interval is between a trimester and a year, the time unit will be months.

d) Relative aggregate evolution
   This chart displays the evolution of income of each scenario compared to the budgeted income of the company throughout the time interval chosen. As in the absolute graph, each simulation is represented by a curve and the time unit varies depending on the time interval's duration.

All the information concerning budget or historicals is available on the plant's database. However the price data deriving from OMIE and OMIP need to be downloaded from the corresponding page at the time of consulting.

vi) Chief Operating Officer (COO)

This package is only accessible for the user accredited as "COO" or for the CEO who is ranked higher in the company scheme.

The COO is the direct responsible of all the operations of the company, including the wind and solar production and the sale of the energy in the national market. Thus, in order to assure an optimal management of the company, the user has to be able to access to all the real-time information of the plants, as well as to all their historical data. He wants to know how much we are producing, how much we have produced, how much we are going to produce and why. He has to keep an eye in the economic and mechanical issues of the plant farms as well as in the market changes and the external agent's performance.

This package is the tool that allows the COO to monitor all the different components of the production chain as well as all the different external events that happen in the day-to-day.

That said, the package structure is divided into seven main pages that cover the information management function of the control center. Those screens are: Home Page, Wind, CSP, Forecast, Market and Regulation, Reports and Income statement. The historical screen is not necessary as it is redundant compared to the reports the user is able to generate. Moreover, displaying all the historical information of the different installations in one screen does not bring added value as it saturates the user who is unable to extract useful information.

Once logged in, the home page displayed is the Global Page. By pressing the buttons of the left main menu, the user is able to move from one page to another. In each page the user will find the following pieces of information and features.

1. GLOBAL

It's the main page of the package and it's the first one the COO will see when he accesses the control center, it is the home page of his user interface. It shows a global picture of the real-time productive and economic status of different sites of the company as well as the the comparison with the budgeted performance. It displays the following information:

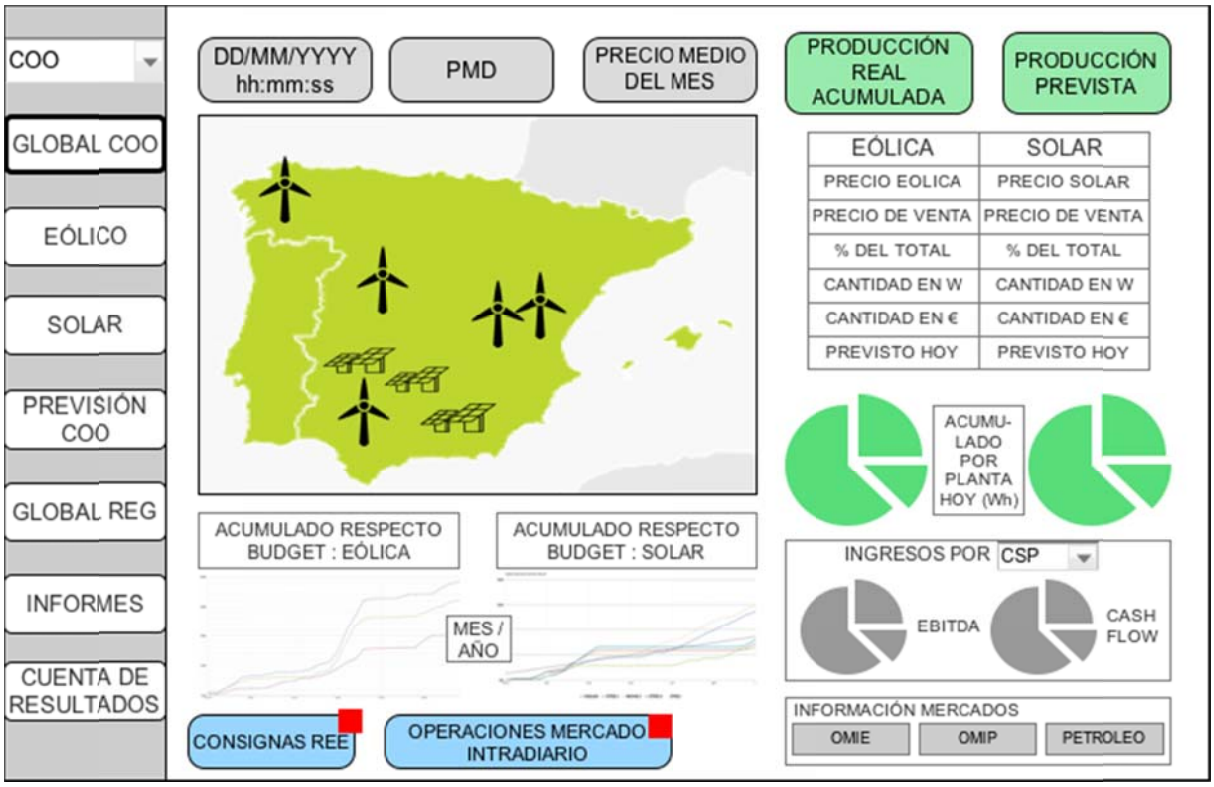


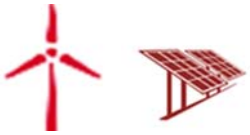
Figure 76: COO Global Interface

-DAILY DATA

On the upper left side of the Global page, in the grey boxes, we find the date and hour at the time of consultation of the control center as well as the actual electricity sale price (PMD) or Pool price that is **extracted from OMIE's platform each hour**, and the average real sale price of the month, that is actualised **each day and comes from our Management database,** in order to compare them.

-LOCATION MAP

The plant location's map is on the left side of the screen. It displays the geographic location and production status of the wind and CSP plants. The icon used to identify the farms is composed by a wind turbine for the wind technology installations or with CSP panels for the solar technology installations. Depending on the ratio between the real production and the expected production, the icon will be coloured differently.

	If the difference between the farm's real production and the expected production is in a range of of 0 - 10%
	If the difference between the farm's real production and the expected production is in a range of of 10 - 20%
	If the difference between the farm's real production and the expected production is over 20%

The colours of the icons are **updated after every market pool based on the data available on the control center's database regarding forecast and real production.**

To conclude, **the icons also act as buttons that enable the user to access to the package of the responsible of each wind or solar farm** to know more in detail about the plant's activity.

- COMPARISON WITH BUDGET

Under the location map, there are two line charts that correspond to the two types of technology of production (wind and CSP). The two graphs have the same structure, the x axis represents time and the y axis has a scale from 0 to 100. There is a line for each plant in each chart that represents the real cumulated production in percentage of the budgeted one for the selected time period, which can be the actual month or the actual year. It can be changed by the user clicking on the button between the two graphs. **The used data is extracted from the management database (budgets) and calculated from the SCADA values (real production) of the plants.** Those charts allow the user to quickly evaluate the performance of each plan individually.

- ALARMS

In the bottom left of the page we find two checkboxes that will pop-up if new alarms linked to the operation of the company and the national network, **obtained in the REE web**

platform, or linked new operations in the intraday market appear, **obtained from the sale agent reports**, appear.

- ENERGY TRADE

The data about the energy produced and sold in real-time occupies the majority of the right side of the screen. From top to bottom we have:

- The numerical value of the predicted and the real total production of the plants of the company. The quantity is shown in euros and in watts in order to provide a quick evaluation of the real today's performance of the company.
- The wind-CSP table where the the values corresponding to the following elements are displayed: technology pool, sale pool, percentage of the total production of the company, production in watts, production in euros and predicted for today.
- Two pie charts representing, for each technology of production, the percentage represented by each installation of the company with the this method of production. If the user puts the pointer on one of the sections of the pie chart, he can observe the quantity produced today in watts and euros.

All this data is obtained in the SCADAs of the plants and extracted from the management database. These elements are very important for the user as they provide at the same time an overview of the total, by technology, and individual production of the plants.

- FINANCIAL DATA AND MARKET

In the bottom of the page, in grey, we first find two pie charts that represent the cash flow and the ebitda of the selected technology of production (CSP or Wind). Each element of the pie chart represents an individual production plant and the value represented by the section can be observed if the user puts the pointer on the mentioned section. Under the pie charts we find the section dedicated to the market as we have direct links to OMIE and OMIP platform and the numerical value of the oil's price.

2. WIND (EOLICO) (See the Global Page of the Responsible of the Wind Technology)

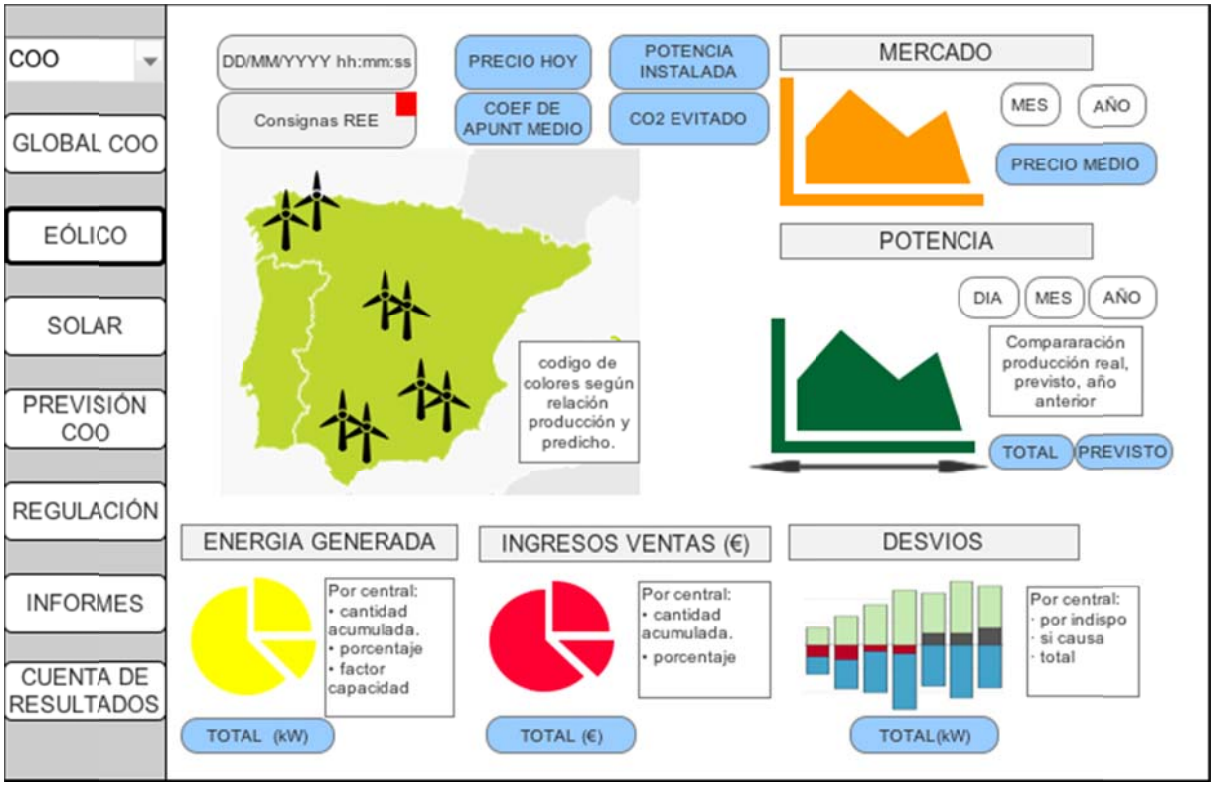


Figure 77: COO Wind Interface

3. CSP (See the Global Page of the Responsible of the CSP Technology)

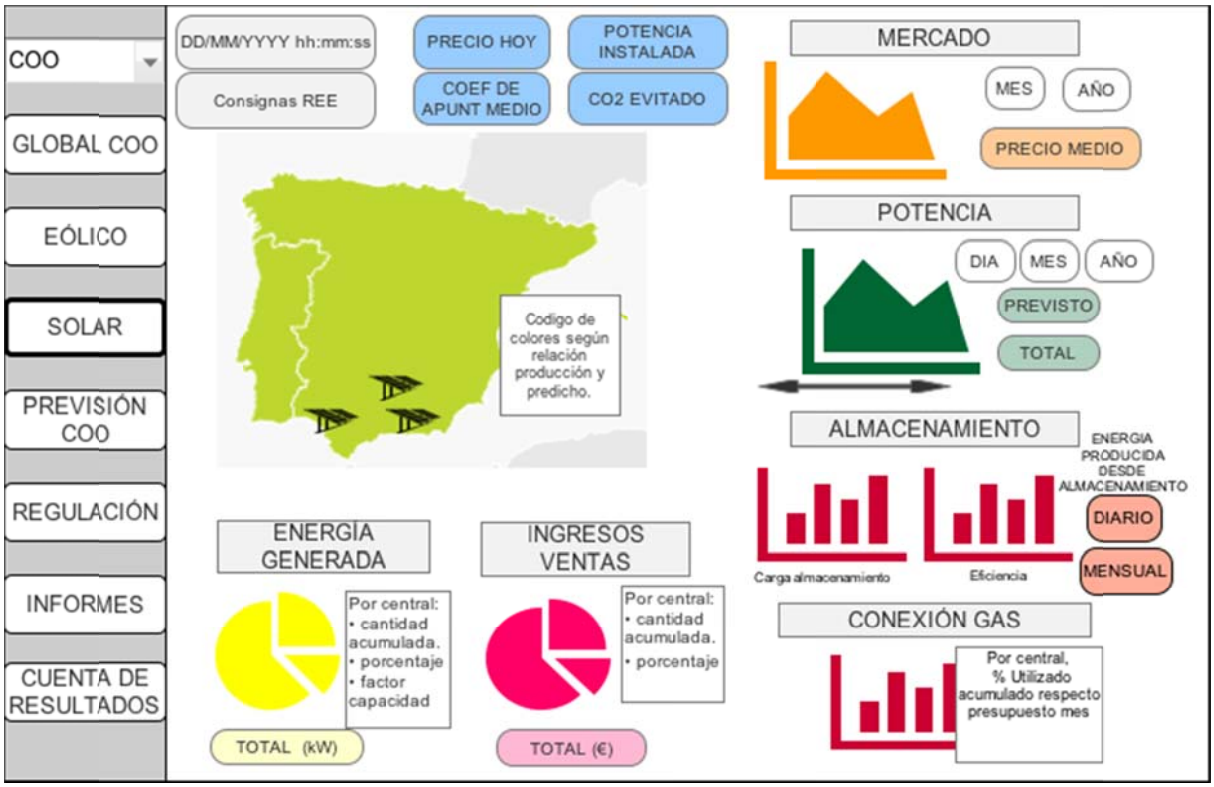


Figure 78: COO CSP Interface

4. FORECAST

This screen allows the COO to access to the predicted data that reflects the expected operational performance of the installations of the company. It is accessible from the left column of the control center interface by clicking in the corresponding button.

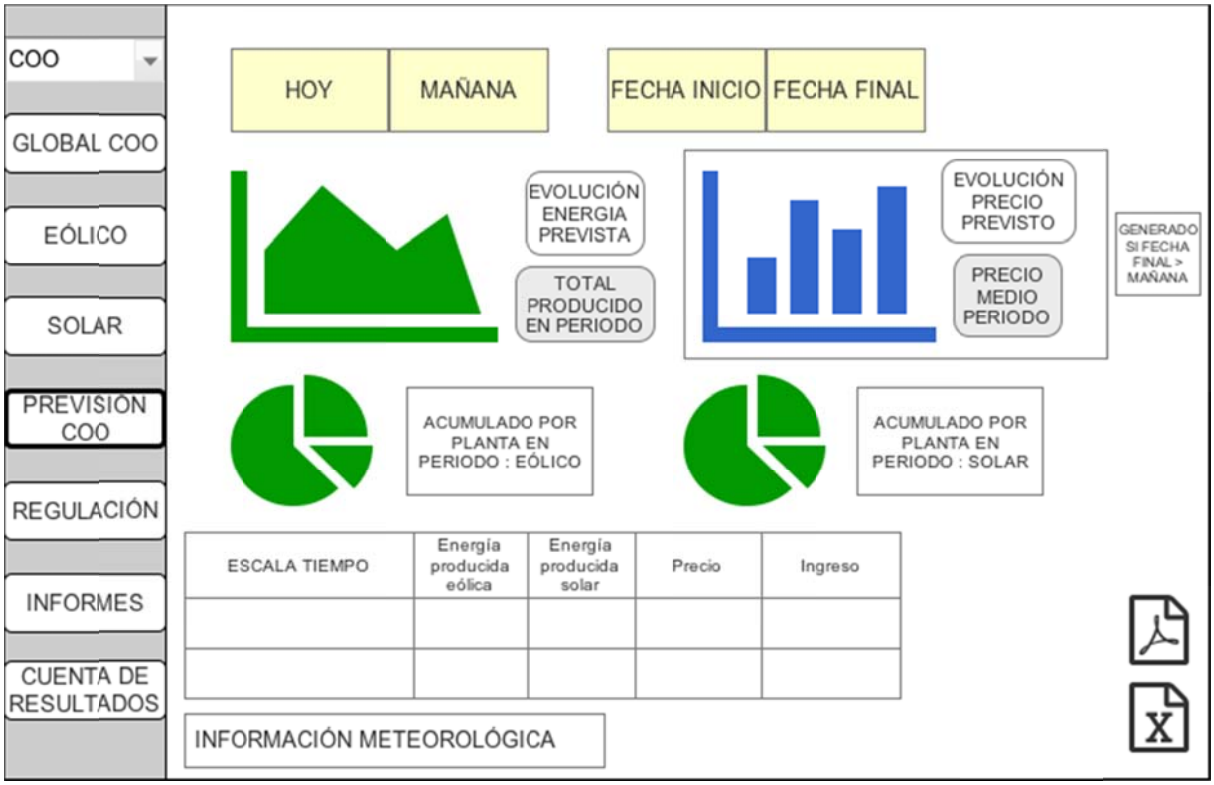


Figure 79: COO Forecast Interface

-SELECTION

In yellow, on the top of the page and horizontally displayed, the user is able to select the time interval in which data would be considered for the forecast. The interval is chosen by clicking on the "today" (the remaining hours of today are considered) or on the "tomorrow" (the 24 hours of tomorrow are considered) button. The other possibility is selecting the initial and the final date of the interval (with a maximum of ten days between today and the finish date). The data will be displayed for each hour included in the selected interval.

- CHARTS AND SCHEMES

Just under the selection elements and once the selection done, we find one line chart, one bar chart and two pie charts that are the chore of the forecast page. They synthesize all

the data presented in the table that is generated after the selection of the time interval and which we will present hereunder in the section "Data table". **As this page shows predicted data, the information comes from the crossing between the weather forecasting agent report (management database), the predicted price from OMIP (official web page) and technical information from the management database.** In order from top to bottom and right to left, we find:

The_energy production line chart (in green), with watt hours (and euros) in the y axis and hours in the x axis, gives us the evolution of the production of all the farms connecting the points that represent the predicted production for each hour. It is calculated with the predicted wind and solar radiation and the theoretical technical characteristics of the production sites. It is accompanied by the numerical value of the total cumulated during the time interval.

The price evolution bar chart (in blue), with price in the y axis and days in the x axis, that informs about the expected price of the spanish energy market in each hour of the period. It is accompanied by the numerical value of the average price of the period. Note that this graph will only appear if the time interval has a finish date greater than "tomorrow".

The production-by-plant pie chart (green) represents the the part generated by each plant during the select time period. Wind and solar have different charts in order to better compare the performance between installations with the same production conditions. For each plant it is showed the cumulated production.

- DATA TABLE

The data table includes, for each hour, the corresponding values of the graphics displayed above:

- Energy produced
- Solar energy produced
- Wind energy produced
- Market pool
- Incomes linked to the energy sale

The charts and the data table can be exported to excel or PDF by the wind farm manager clicking on the corresponding icons on the right bottom of the screen.

5. MARKET AND REGULATION

(See the Global Page of the Responsible of Market and Regulation.)

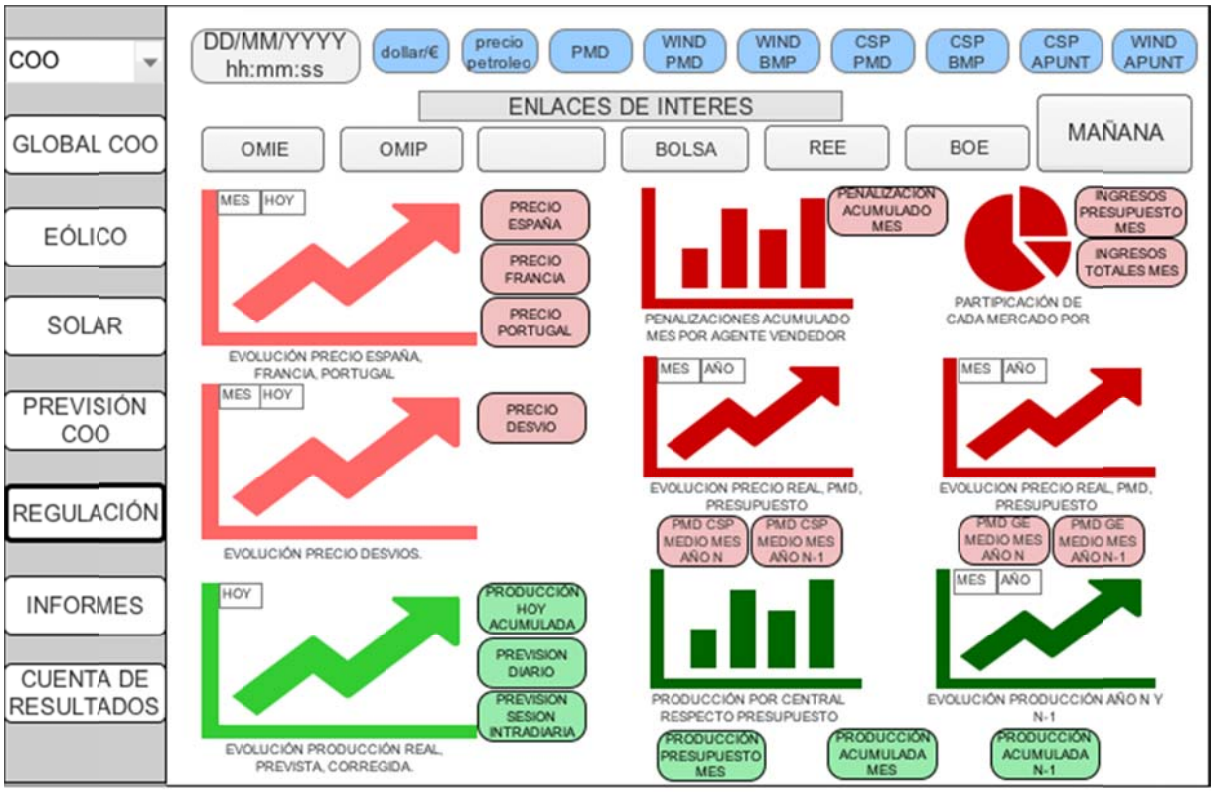


Figure 80: COO Market and Regulation Interface

6. REPORTS

This section is the one that allows the COO to directly interact with all the information generated in all the installations. It is where the added value of the control center resides as it gives the opportunity to manipulate all the elements from different points of views in order to personalise reports with a maximum of useful information for the user. It is accessible from the left column of the control center interface by clicking in the corresponding button. The COO, unlike the wind and solar farm managers and the market responsible, only has one screen that allows him to generate two different standard reports. However, he has access to the standard and personalised reports of the users mentioned before. The structure of the COO page is the following.

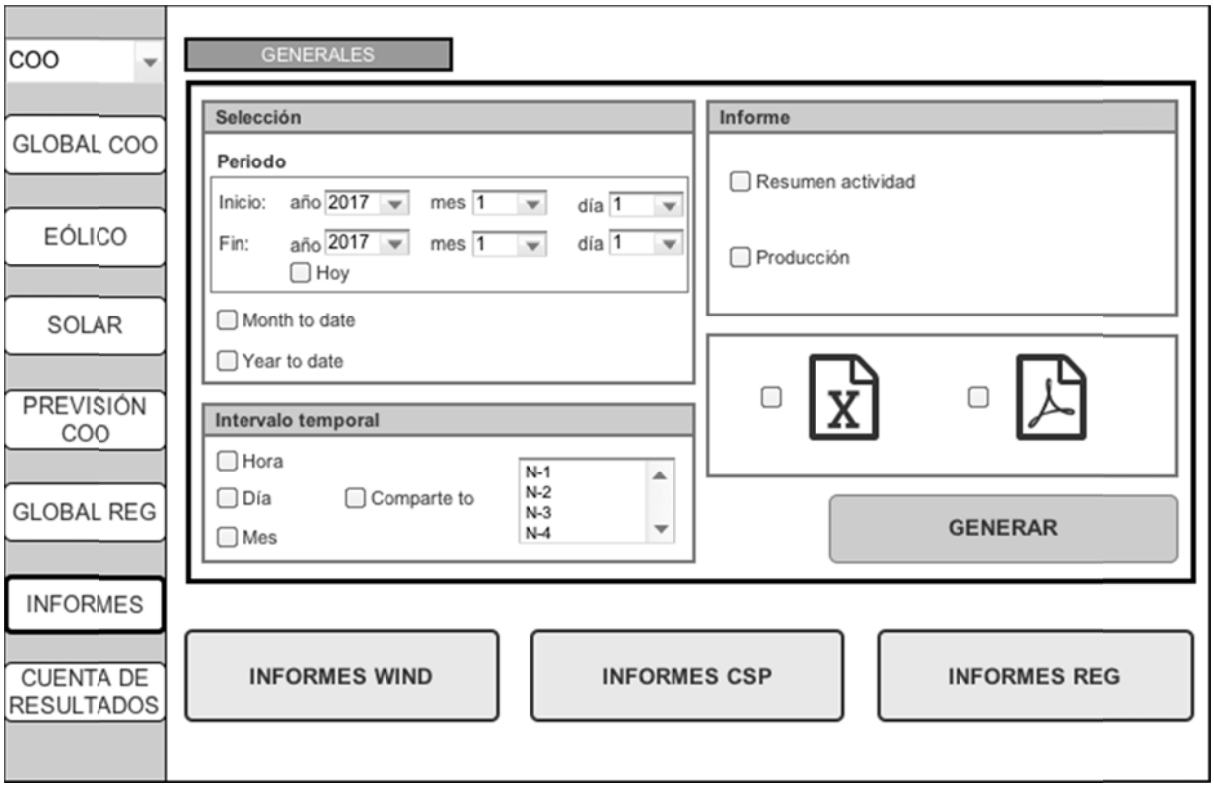


Figure 81: COO Reports Interface - Home Page

All the options that allow the user to generate the standard reports of the COO are contained in the box that occupies the majority of the screen and is called General. The content of this section of the interface is divided in four boxes.

-SELECTION

In this box, the user has to choose the time interval in which the data will be subtracted from the databases. He has three options, selecting the initial and final date (where you can select "today" for the final one thanks to a checkbox), selecting "Month to date" (all the days of the current month will be considered) or selecting "Year to date" (all the days of the current year will be considered).

-TIME GROUPING

In this box, the user has to choose **the time period which corresponds to the time grouping (the quantity of time that corresponds to an individual value)**. There are four options: **10-minute (not choosable if the time interval is greater than a week), hour (not choosable if the time interval is greater than 31 days), day and month**.

In addition, the user can choose to compare, in the "comparar a" checkbox, the values of the

selected time period with the same interval of the past years (selected by clicking on n-1, n-2 etc).

- REPORTS

In this box, the user can choose between two different reports that, although they are standardised, provide a precise global evaluation of specific the key topics that are critical on the operation's management. The reports are structured as follows:

- Activity Summary (Resumen actividad)

This report is directly linked with the asset management and is the most complete and important standard source of information for the COO. It displays the economic and the productive data, as well as the key values linked to the external agents, the market, and public regulation. **All the information is obtained in the management database and in the online oficial platforms.** It generates a table with the following data for each time grouping unit and **for each wind and solar plant:**

Production

- Total power
- Licensed power
- Energy produced
- Retained energy
- Estimated penalty due to reactive power
- Estimated deviation

Market agent

- Energy billed agent
- Retained energy billed agent
- Adjustment Daily Market / intraday market
- Incomes due to deviation (settled program)
- Power reserve to raise
- Real-time restrictions
- Billed penalty due to penalty
- Gross deviation cost
- Shielded deviation cost

Taxes

- Cumulated taxable base : 7% tax
- Quota of the tax

Weather and market

- Weather Forecast (performance)
- Market agent commission
- Compensation OMIE
- Compensation OS
- Generation toll

Financial data

- Remuneration on the operation (€) / MWh
- ROI (€) / MWh
- Specific retribution - Coverage ratio
- Total accrued
- Total collected

Retention (CNMC : Comisión Nacional de los Mercados y la Competencia)

- Cumulated energy
- Cumulated retention accrued CNMC
- Real cumulated retention CNMC
- Anual market retention
- Cumulated market retention

Market pool

- Monthly market pool OMIE (€) / MWh
- Cumulated average OMIE (€) / MWh
- Cumulated Kurtosis coefficient
- Monthly Kurtosis coefficient

- Production (Producción)

This report is a simplified version of the activity summary as it focuses on the production of energy and do not deepens the economical factor. It is focused on the installation performance and not on the electric market. **All the information initially comes from the SCADA of the wind and CSP farms and is extracted from the management**

database where it has been stored. It generates a table with the following data for each time grouping unit and for each production site:

- Total power
- Licensed power

- Real energy production
- Budgeted energy production
- Retained energy

- Real energy sold
- Budgeted senergy sold

- Estimated penalty due to reactive power
- Estimated deviation
- Weather Forecast (performance)

- GENERATION

Finally, after the time interval, the time grouping and the report selection done, the user has the possibility to choose between two document formats for the generation of the final report : excel or pdf. This selection is made on the checkboxes present in the low right corner of the general box. Once this last choice has been made, the user has to click in the button “Generation” (Generación) also in the low right corner. Once done, the selected report(s) will be generated.

- LINK BUTTONS

To conclude, at the bottom of the page, we find the only elements that are out of the general box. We observe three link buttons to the report screen of the wind farm manager, solar park manager and market and regulation responsible respectively. If the user clicks on one of them, he will be automatically redirected to the other user interface in order to generate the standard or personalised report he wants to. For more information, see the Report section on the description of the other users interface.

7. INCOME STATEMENT

This page of the COO package reports the user about accountability situation of the wind and solar farms as it gives access to all the profit and loss statements.

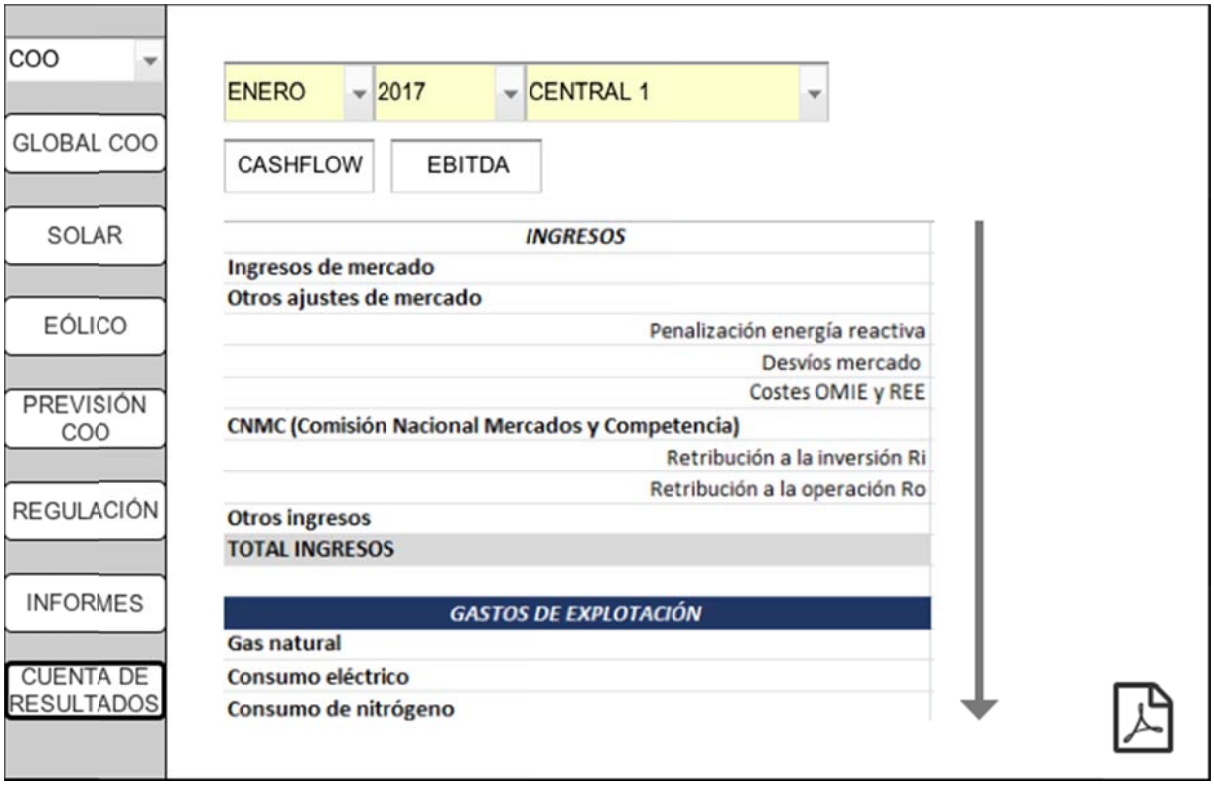


Figure 82: COO Income Statement Interface

As shown on the image above, by selecting the MONTH, YEAR and INSTALLATION, the User accesses to the income statement of the concerning plant during the month chosen.

The Income statements are available on the **management database** and can be downloaded into excel or pdf sheet clicking on the corresponding icons. Similarly to the Forecast Page, **this page does not have an automatised refresh frequency. In only refreshes if a new selection is commanded.**

CHAPTER V:

ECONOMIC EVALUATION

In this section we analyze the economic aspect of the control center. The main objective is to evaluate if the project is profitable to the client and under which conditions.

V.1 INVESTMENT AND COSTS FORECAST

The economic evaluation is based on two different studies:

- The Net Present Value and the the Internal rate of Return of four possible solutions that will be described lately.
- The sensibility of the investment's profitaibility towards the variation on the number of production plants depending on the four possible solutions.

However, before sarting the economic evaluation, the cost forecast need to be specified. This cost forecast is broken down in two parts which includes the initial investment (I) the client must assume and the annual operating expense (OPEX). That said; in order evaluate the profitability of the project the current cost of the externalized control center is set as reference.

a) Initial investment

INITIAL INVERSION IN €				
ELEMENT		**DESCRIPTION**	**AMOUNT**	
			Housing	**Hosting**
Data Center		Servers and complements (applications, antivirus, firewalls).	35000	0
Control center	Ground and Building	New needed constructions.	0	
	Hardware	6 Screens, 2 computers and a Video Wall.	6750	
	Office Furniture	Desks, chairs, shelves etc. (Amortisation 7 years)	1850	
Production Plants (x21)	Software	OPC Server	8000	
	Hardware	Computers, Screens in all the production sites.	15225	

Communication	Communication CPD - Wind	No need of additional communication hardware.	0	
	Communication CPD - Control Center	No need of additional communication hardware.	0	
	Communication CPD - REE	Activation fee.	1000	
	Communication CDP-Market Agent	The market agent is the responsible of the communication with our CPD.	0	
Engineering and Implementation	Application developpement	Development of the Business Intelligence Tool (in-house).	110000	
	Control Panel Interfaces dvp	Development of the Control Panel.	80000	
	Installation	Implementation in the control center and plants : trips, installation, last jobs.	8000	
Employee's training		Guidelines and presencial trainings.	2000	
Computer License		Licenses SCADA, servers and other programs.	10000	5000
Other investments		Estimated : 2% of the total.	5556,5	4756,5
TOTAL			**283381,5**	**242581,5**

Table 1: Initial Investement

Data center

In this first point, which takes into account the purchase of the servers and other complements that will host the control center; we confront the first operational decision as two options are possible.

The servers must be located in a very specific environment to ensure their optimal

performance. They have to be maintained in a determined range of temperatures with the correct ventilation. In addition, we need a backup power supply that allows the servers to work independently of any electrical problem. In consequence, the servers cannot be located in the company's office in Madrid without a huge investment. However, a wide range of companies offer this service in two different modalities, housing and hosting. Those options represent the first operational decision:

- Housing service is equivalent to a "colocation center" where the company that manages the installation rents the space to other business. Those facilities provide space, power, cooling and physical security for the equipment. However, the hardware and the software are not rentable, in consequence the servers, firewalls and other complements must be acquired by the clients. It is the reason why in the column of the housing option in the initial investment table has a total cost of 35000€ in the data center.

- Hosting service is a Housing service where the client also rents the servers and other softwares.It is a sort of "all-inclusive" service. The company that manages the facility looks after every physical or virtual element that is needed and the client only need to pay a single fee. It is why there is no need to make an initial investment in servers.

Control Center

It will be physically located in the already existing Madrid's office. In consequence no new construction is needed. However, new hardware and office furniture is needed as the control center would need a permanent placement with different screens and computers that would manage data every day. The values entered on the investement table are obtained with the following data:

Screen	LG-HP Media Markt 24"-28"	175
Computer	HP Business Workstation	1800
Video Wall	Pantalla TV (62")	2000
Printer	HP Laser Media Markt	100

Table 2: Cost breakdown of the office hardware investment

Table	150	Umbrella Stand	5
Chair	100	Paper Bin	5
Drawer	80	Lamp	30
Shelves	500	Sign	50
Coat Rack	15	Other	50

Table 3: Cost breakdown of the office furniture investment

The prices have been estimated based on catalogues.

Production plants

There is an initial need of adaptation of the different OPCs of the plants in order to compute them all in the data center without any problem. In addition, one computer and screen will be installed in each parc in order to have the possibility to directly access to the business intelligence application from the parc. The prices for this hardware is from this table:

Computer	550
Screen	175

Table 4: Cost breakdown of the production plants hardware investment

Communication

The communication infrastructure is already installed as the external control center that is actually operating obliges the plants to send real-time information to the national operator. However, internalising the control center obliges us to sign a new contract with a telephone company incurring a cost which correspond to the activation fee (1000€). This cost is high as the needed network is a dedicated double point to point line.

Engineering and implementation

This heading represent the majority of the initial inversion as it groups all the costs linked to the development of the software, graphic interfaces and its installation in the plants and control center. These services must be done on-demand by experts. The cost is obtained consulting real offers and professionals of the sector.

Employee's training; computer licenses and other cost complete the initial investment table. The employee's training is necessary as the business intelligence application will be something completely new. The computer licenses are more expensive in the housing option as the servers have to be acquired by the company and they will need additional softwares.

b) Operating expense (OPEX)

In the following table we will break down the OPEX considering the two options introduced before (Housing and Hosting).

In addition we will work with two different tables that represent two different scenarios depending on the method used to communicate with the national electric operator.

The first one is to internalize the communication *(100% Internalisation)*, using the data center as a switch during 24h/day and hiring the point to point network introduced before.

The second option is to use the market agent as an intermediary between us and the national operator *(Combined)*. If we give him access to the data center, he will benefit from from it as he will be able to optimize his operations. On the other hand, he will be in charge of providing the compulsory information to the transport company. This second option is called combined as we externalize one of the functions of the control center, keeping internalized the business intelligence dimension of the tool.

ANNUAL OPERATING EXPENSES (OPEX) IN € : 100% INTERNALISATION				
ELEMENT		**DESCRIPTION**	**AMOUNT**	
			Housing	**Hosting**
Data Center (CPD)		Services rental	48000	60000
Control Center	Rent and ground	The CC will be in the already established HQ.	0	
	Workforce	Responsible of the CC.	45500	
		5 Technicians. Must ensure a 24h service.	162500	
	Supplies	Electricity, air conditioner, water, office material etc.	1200	
Communication	VSat	Wind Farms - CPD	48000	
	Optical Fibre Line (sites)	CSP Parks - CPD	2475,41	
	Optical Fibre Line (Office)	CC - CPD	495,08	
	Point to Point	CPD-REE (4 leased lines)	16800	
Software maintenance		Updates, adaptation to new need etc.	14000	
Others		Hardware maintenance, travel expenses etc.	8000	5000
TOTAL			**346970,49**	**355970,49**

Table 5: OPEX of the 100% internalisation solutions

ANNUAL OPERATING EXPENSES (OPEX) IN € : COMBINED			
ELEMENT	**DESCRIPTION**	**AMOUNT**	
		Housing	**Hosting**
CPD	Data Center rental	48000	60000

Control Center	Rent and ground	The CC will be in the already established HQ.	0	
	Workforce	Responsible of the CC.	45500	
		Technician.	28600	
	Supplies	Electricity, air conditioner, water, office material etc.	1200	
Communication	VSat	Wind Farms - CPD	48000	
	Optical Fibre Line (sites)	CSP Parks - CPD	2475,41	
	Optical Fibre Line (Office)	CC - CPD	495,08	
Market Agent		Delegated Office function commission	25200	
Software maintenance		Updates, adaptation to new need etc.	14000	
Others		Hardware maintenance, travel expenses etc.	8000	5000
TOTAL			**221470,49**	**230470,49**

Table 6: OPEX of the combined solutions

CPD

This element represents the monthly rental cost of the housing or hosting service. Obviously, the hosting (5000€/month) cost is higher than the housing one (4000€/month) as the servers are installed and managed by the company and not purchased by the company. Those values have been obtained comparing real offers provided by our client.

Control Center

As it will be physically located in the company's office there won't be any extra cost linked to ground renting or construction. However, the supplies expenses will increase as

there would be more computers and employees. Having said that, the estimated amount to be expended on supplies is calculated based on the company's current invoices.

Moreover, one of the biggest costs of the OPEX are the salaries of the new employees that must be hired.

In the 100% Internalized option, the communication with the national operator is completely ensured by the company. Consequently, our control center must operate 24h/day and the needed employees are one control center responsible (35000€ of net salary) and five technicians (25000€ of net salary which take into account the night duties and weekends) that will take 8 hours shifts. The needed number of technicians is calculated with the total quotient between the total hours of a year (8760 h) and the average working time of an employee (1750 h/year). We consider that the responsible can cover the punctual sick leaves.

In the Combined option, the 24h/day communication is ensured by the Market Agent and, accordingly, the control center does not have to be permanently connected. In consequence, only two employees need to be hired, one responsible (35000€ of net salary) and one technician (22000€ of net salary) will take turns of 8 hours each day from Monday to Friday. They would focus on the technical management and performance of the asset and not on the communication with REE.

Communication

The Data Center must be accessible from every plant, the control center and REE. In consequence, every element needs a communication route towards it. The wind farms communicate via satellite (VSat - 250€/month/farm), the solar parks and the control center connects with the CPD via optical fibre (41,25€/month/park) and two dedicated double point to point lines are needed for the interaction between the Data Center and the two global control centers of the national network operator. (350€/line/month). This last one is only present in the 100% internalized OPEX as in the combined option it is done by the market agent.

The rates included in this section are provided by "Telefonica", the company's

communication operator.

Market Agent Commission

It is only present in the combined option and is estimated of 100€/month/plant and it is what the Market Agent charges us for acting as an intermediary between us and the national network operator. The amount is reasonable as he also gains some benefits.

To conclude the software maintenance and other costs represent extra expenses that the company will have to face due to the operation of the control center. They include software updates, maintenance works not covered by the service contracts etc.. Having said that, the difference between hosting and housing regarding these quantities relies on the fact that the hosting contracts include more services than the housing one where the servers are owned by the client and it is his responsibility to maintain and actualize them. The value estimation has been consulted with professionals.

VI.2 DEVELOPMENT OF THE ECONOMIC STUDIES:

a) NPV and IRR

The first economic analysis concerns the project's profitability. This study is based on the comparison of the Net Present Value (NPV) and the Internal Rate of Return (IRR) of the project in five possible scenarios for five years:

- 100% Externalisation (actual solution)
- 100 % Internalisation with Housing services
- 100% Internalisation with Hosting services
- Combined with Housing services
- Combined with Hosting services

In order to calculate the NPV and IRR, as we have already calculated the necessary investment in the "Year 0" and the OPEX of the first year, we estimate the OPEX of the following four years considering a Consumer Price Index (CPI) of 1,5% :

100& INTERNALISATION OPEX (€) ACTUALIZED WITH CPI = 1,5%							
OPEX YEAR 2		OPEX YEAR 3		OPEX YEAR 4		OPEX YEAR 5	
Housing	Hosting	Housing	Hosting	Housing	Hosting	Housing	Hosting
352175,05	361310,047	357457,68	366729,69	362819,54	372230,64	368261,83	377814,1

Table 7: Actualized OPEX of the 100% Internalisation solutions

COMBINED OPEX (€) ACTUALIZED WITH CPI = 1,5%							
OPEX YEAR 2		OPEX YEAR 3		OPEX YEAR 4		OPEX YEAR 5	
Housing	Hosting	Housing	Hosting	Housing	Hosting	Housing	Hosting
224792,54	233927,54	228164,43	237436,46	231586,9	240998,01	235060,71	244612,97

Table 8: Actualized OPEX of the combined solutions

The OPEX of the 100% externalisation option is computed with a monthly fee of 1200€ per plant in the year n. The value of the monthly fee is what the actual agreement between our client and the external control center states. The OPEX for the following four years is also affected by a CPI of 1,5%

Secondly we calculate the annual Cash Flow (Q) for each case. To do so we consider the Cash Flow as the difference between the OPEX of the actual solution (100% externalisation) and the annual OPEX for each possible option. This results from the fact that the company must have a control center, so at very least, if they were to decide not to invest on their own control center, they would surely have to pay for the externalised service. In consequence, our cash flow is not an increased income but a cost saving.

		I(N)	YEAR 1	
			OPEX	Q
100% EXTERNALISATION		0	302400	0
100% INTERNALISATION	Housing	-283381,5	346970,49	-44570,49
	Hosting	-242581,5	355970,49	-53570,49
COMBINED	Housing	-282381,5	221470,49	80929,51
	Hosting	-241581,5	230470,49	71929,51

		YEAR 2		YEAR 3	
		OPEX	Q	OPEX	Q
100% EXTERNALISATION		306936	0	311540,04	0
100% INTERNALISATION	Housing	352175,05	-45239,05	357457,6758	-45917,63575
	Hosting	361310,0474	-54374,04735	366729,6981	-55189,65806
COMBINED	Housing	224792,5474	82143,45265	228164,4356	83375,60444
	Hosting	233927,5474	73008,45265	237436,4606	74103,57944

	YEAR 4		YEAR 5	
	OPEX	Q	OPEX	Q
100% EXTERNALISATION	316213,1406	0	320956,3377	0

100% INTERNALISATION	Housing	362819,5409	-46606,40029	368261,834	-47305,49629
	Hosting	372230,6435	-56017,50293	377814,1032	-56857,76548
COMBINED	Housing	231586,9021	84626,23851	235060,7056	85895,63208
	Hosting	240998,0075	75215,13313	244612,9776	76343,36013
CASH FLOW (Q) = OPEX ANNUAL SAVING COMPARED TO 100% EXTERNALISATION					

Table 9: Cashflows of the different solutions for the following 5 years

Finally we calculate the NPV (Net present Value) and the IRR (Internal Rate of Return) for all cases. For that purpose we consider the NPV as:

$$PN = \sum_{t=1}^{5} \frac{Q}{(1+k)^t} - I$$

Where:

Q= Cash Flow (Table above)

I= Initial Investment (Table above)

k=0.05

Subsequently we calculate the IRR considering it as:

$$NPV = \sum_{t=1}^{5} \frac{Q}{(1+IRR)^t} - I = 0$$

Having said that, the values obtained are:

		NPV	
100% EXTERNALISATION		0,00 €	
100% INTERNALISATION	Housing	-458.987,06 €	
	Hosting	-458.314,35 €	**IRR**
COMBINED	Housing	74.426,12 €	14%
	Hosting	75.098,83 €	16%

Table 10: Values of the NPV and IRR of the different solutions

We observe that the only possible solutions that are economically profitable are the Combined Housing and Hosting. The 100% externalisation option, as it is the comparison value and does not require any initial investment, has a null NPV. In addition, the 100% internalisation options are found to be terrible investments with a negative NPV of nearly half a million euros. These values are logical if we compare the calculated OPEX of this option with the actual fee. The cost of the internalisation is largely superior as the necessity to communicate with REE 24h/day oblige to pay the salary of six employees.

To conclude, the NPV and the IRR of the combined options are promising as we have only evaluated them for five years, which is a short period for an operational investment like the one we are studying, and already show good values (NPV = 75000 € and IRR = 14-16%). The two options have very similar results in both values and can be considered economically equivalent. The two solutions can be recommended as good investments although the hosting solution has slightly better numbers (specially the IRR).

b) OPEX sensibility to the size of the company's portfolio.

This second economic analysis does not focus on the profitability of the investment but on the sensibility of the OPEX towards a variation of the number of plants controlled. The forecasted costs and the economic viability have been calculated with the actual number of plants owned by the company, 21. However, we can easily differentiate the fix and the variable costs of the OPEX, with the variable ones directly depending on the number of plants. In consequence, we can study what option gives the lowest operation expense if the company buys more production farms or what would have been the result if this project was raised when the company had fewer parks.

In order to answer those questions, we analyze the breakdown of the OPEX and separate the fix from the variable costs:

On one hand, the fix ones are the employee's wages and the communication costs between the Data Center and the Control Center and the National Network Operator (for the 100% Internalisation option).

On the other hand, the variable cost groups the Data Center rental (capacity of the

servers is linked with the number of parks they have to cope with), maintenance, market agent commission (for the Combined option) and other costs. We consider in this approximation that the correlation between the variable costs and the number of plants is linear.

For this economic analysis we also take into account the options considered in the NPV evaluation:

- 100% Externalisation
- 100 % Internalisation with Housing services
- 100% Internalisation with Hosting services
- Combined with Housing services
- Combined with Hosting services.

Considering all the presented elements, we obtain the following equations (being n the number of production farms) that represent the fix and variable cost of the OPEX:

OPERATIONAL OPTIONS		EQUATIONS
100% EXTERNALISATION		OPEX = (1200*12)*n
100% INTERNALISATION	Housing	OPEX = 226495,08+,5736,92*n
	Hosting	OPEX = 226495,08+6165,5*n
COMBINED	Housing	OPEX = 75795,08+6936,92*n
	Hosting	OPEX = 75795,08+7265,5*n

Table 11: OPEX variable equations depending on the number of production plants

Once the equations obtained, we use them to compute the following table that displays the OPEX in € for each option for different values of n(number of production plants):

OPERATIONAL OPTIONS		NUMBER OF PRODUCTION PLANTS					
		1	10	15	20	25	30
100% EXTERNALISATION		14400	144000	216000	288000	360000	432000
100% INTERNALISATION	Housing	232232	283864,28	312548,88	341233,48	369918,08	398602,68
	Hosting	232660,58	288150,08	318977,58	349805,08	380632,58	411460,08
COMBINED	Housing	82732	145164,28	179848,88	214533,48	249218,08	283902,68
	Hosting	83160,58	149450,08	186277,58	223105,08	259932,58	296760,08

Table 12: OPEX values depending on the number of production plants

If we compare the values of the table for each option and number of production plants, we obtain a line chart that clearly shows that the best solution depends on the number of plants that the company has:

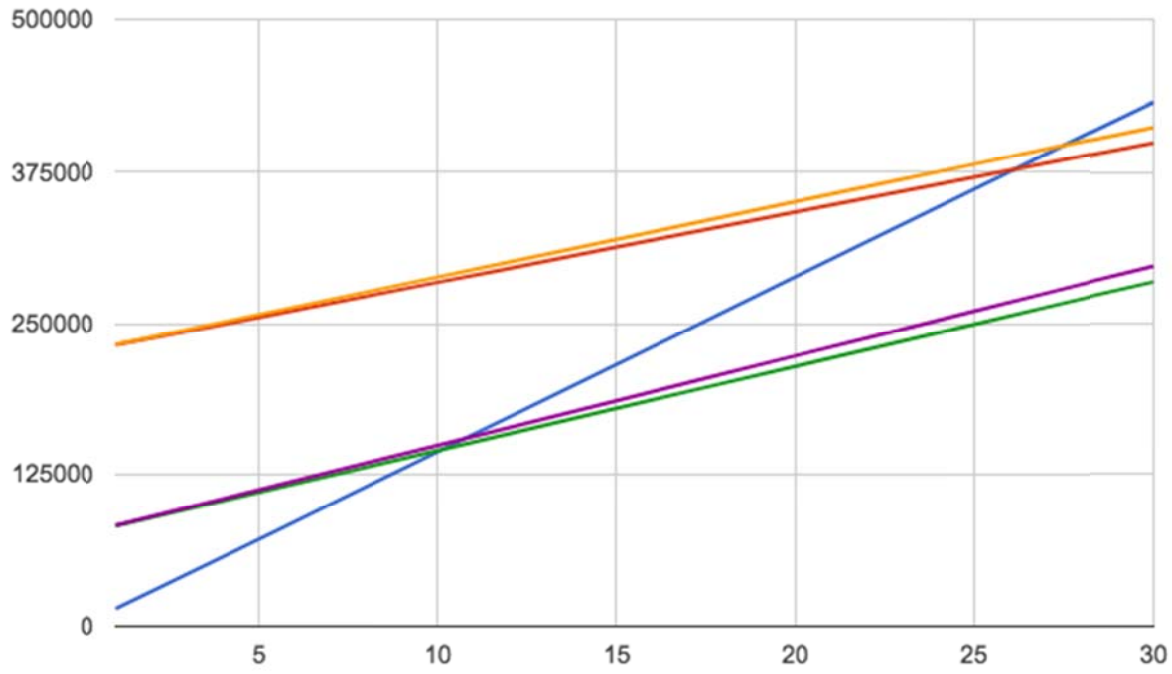


Figure 83: OPEX curves of the different solutions depending on the number of production plants

If we observe the line chart, we can clearly see that for a small company that has less than 10 production plants, the best option will be to externalize its control center as the OPEX of this option for those values of n is the lowest; in addition there is no need to do an initial investment. This situation obeys the common sense as a small company does not have the capacity to internalize all the services required in a sector where huge investments are required and the bigger companies own the majority of the market.

It can also be noted that the operational expense for the 100% internalisation option is not better than the externalized one until 26 or 27 plants owned by the company, so it corresponds to the biggest companies of the renewable sector. This result verify the one obtained in the NPV evaluation as those options were very far from being profitable with the actual number of plants (n=21). In addition, this chart does not take in account the initial inversion that has to be made and that would make this option less interesting for the company.

Finally, we easily spot that the combined solutions offer a very small OPEX compared to the other options when the number of farms is greater than 10, which validates the solution obtained in the NPV evaluation. In consequence, we can ask if this solution had to be taken by the company before as with less than 21 plants the results are also promising. In order to answer that we would have to compute the NPV for the different values of n and calculate the possible Opportunity Cost that the company has paid.

In conclusion, this second economical evaluation supports the results of the first one. With the current number of parks owned by the company, as we have observed that the optimal solution varies depending on the number of plants. In addition, the perspective is promising as the difference between the OPEX of the combined option and the other one become greater with an increasing number of plants, solution that support the expansion strategy of the company

CHAPTER VI:

CONCLUSION

VI.1 FINAL CONCLUSION AND RECOMMENDED CHOICE AFTER ECONOMIC EVALUATION

After the economic evaluation of the problem, we can state that with the current number of the production plants and the growth prospect strategies, quitting the externalised services and investing on the combined control center is the most profitable decision. Indeed, as posed above, the results of the second analysis may even raise the question whether the company should have taken the decision earlier and if it has been paying for an opportunity Cost that the company has paid.

That said, between the two combined possibilities (Hosting and Housing) we would recommend opting for the hosting services.

The housing services imply the development of an IT department of the company that has nothing to do with the core business of the company. Thus, even if the expense is not that significant, it is not worth it because it is not only unprofitable from the economical point of view but also from the strategic one, as it redirect efforts towards an activity that is not in the company's main objectives without providing added value to it.

In conclusion, beting on a control center with combined services in which the function of delegated dispatch relies on the market agent and hosting services are contracted to manage the Data Center seems to be the most profitable option In this case, the project would entail an investment of € 242581.5. This would imply an OPEX saving compare to the current situation of NPV 75.098,83 € with a 16% IRR, both evaluated for a period of five years. After five years it is estimated that a new investment would be needed for the updating of the equipment.

Thus, the company would posses a control center that would assure the respect of the regulation and increase on competitivines and autonomy; all of this with a future cost saving compared to the current situation.

VI.2 RECOMMENDATIONS FOR FUTURE STUDIES AND IMPROVEMENTS

The project approaches the technical and functional design of the fundamental elements that determine the fulfillment of the two essential functions (electric dispatch and business intelligence): the data center, the communication infrastructure (within the operation actors and with REE) and the BIA. However, in order have the control center properly developed and implemented there are some aspects that still need to be determined such as the operating protocols, the security protocols, the actuation protocols or the users accounts management. Therefore, completing the integral design of the control center and the actual technical development would represent the near-term subjects of study.

Added to that, as it can be noticed the control center proposed is based the needs and requirements of the company up to today. At present, the company only has production plants distributed throughout the Spanish territory. This means that the control must only have to deal with information of one electricity market, one regulatory framework and one network operator. Therefore, another recommended analysis could be the reassessment of the control center to face possible future strategic changes such as international expansion. Such a shift would imply introducing new markets, new actors, and new regulations that would increase considerably the quantity of data to be treated this fact would have an impact on the three main fundamentals elements: The data center, the communication infrastructure and the BIA.

Thus, depending on how the company decides to manage the foreign operations, the control center should adapt accordingly.

Furthermore, there is a huge margin of study concerning the development of the control center. Besides the algorithm modeling of the project itself, it could be interesting, for instance, to analyses if it is possible to introduce more statistical tools on the reports sections.

To conclude, the project goal is that once developed, the resulting control center had the ability to be manipulated and refined by the IT employees within the group. Thus, the design itself stays open to other possible changes and studies that may appear during the implementation or operation phases.

CHAPTER VII:

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