



Civil engineering
services applied
to wind energy

solute



About **solute**

SOLUTE is a multidisciplinary technical engineering consultancy with over 15 years of experience, headquartered in Madrid, with branches in Barcelona, Badajoz, and Toledo.

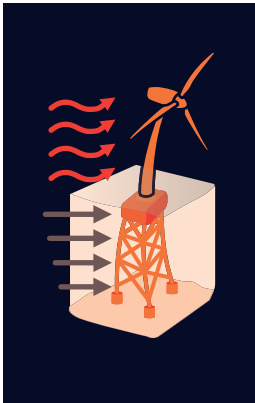
Throughout our history, we have primarily specialized in the renewable energy sector, particularly in the wind industry, where our capabilities cover all phases of wind farm development. Other sectors in which we specialize include automotive, solar energy, software development, weather forecasting services, and virtual reality, among others. This, along with the development of projects in more than 20 countries and for some of the most important clients in the sectors in which we operate, endorses us as one of the leading engineering consultancies in our country.

Our mission is to provide multidisciplinary solutions on a global scale, through the technical rigor and expertise of our engineers. Combined with SOLUTE's portfolio, this enables us to guarantee the quality and excellence of our work in every project.

We emphasize R+D+I as one of SOLUTE's main drivers, as since the company's inception, we have launched several in-house developed tools, which are now offered as products to our clients. Some of these include Furow, a comprehensive wind resource software; Aphelion, a platform for meteorological and energy forecasting services applied to the wind sector; and EVE, our suite of virtualization services in industrial environments.

SOLUTE'S technical areas applied to wind industry

AEROELASTIC LOADS

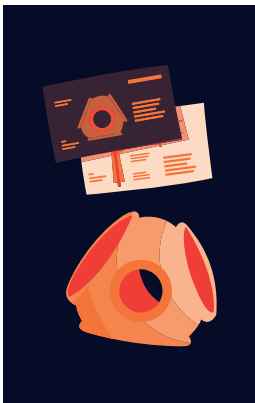


Through aeroelastic models that define the wind turbine from a structural and aerodynamic perspective, load calculations allow us to quantify the stresses experienced by the structure during its exposure to all environmental and operational conditions throughout the turbine's lifespan.

SOLUTE has extensive experience in aeroelastic load simulations, both for the development of new wind turbine models and for the validation of existing models.

Our engineering teams work on developing new configurations with the aim of adapting them to increasingly demanding operational scenarios, including feasibility studies prior to the installation of a wind farm under specific site conditions, both onshore and offshore. Additionally, we conduct reanalyses during the operation and maintenance phases to improve the wind turbine's performance.

STRUCTURAL MECHANICS

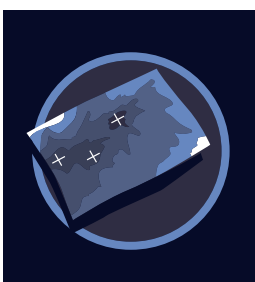


The wind industry continuously designs and develops new machines in the pursuit of greater energy and economic efficiency to drive the growth of this type of energy. Ensuring the structural integrity of a new wind turbine, both as a whole and for each of its parts and mechanical joints, is vital in its development, as it is a rotating machine subjected to considerable loads. The certification process by accredited entities, to which each new machine must be subjected, ensures this integrity and establishes precise guidelines for the analysis prior to prototype experimentation to verify the results.

The analysis methodology requires an advanced level of mathematical modeling and a high degree of detail to provide valid results. SOLUTE performs these analyses, ensuring the structural lifespan of wind turbine components, from the blade to the foundation structure.

SOLUTE frequently collaborates and engages directly with leading international OEMs (Original Equipment Manufacturers) in new developments. Additionally, SOLUTE works with wind farm owners who, without owning the technology, wish to gain knowledge of structural behavior to manage O&M actions and life extension.

ENERGY RESOURCE



The analysis of the wind resource aims to optimize the energy resources of a site through the proper selection and placement of available technology to maximize energy utilization and production, specifically the LCOE (Levelized Cost of Energy) or the units of energy per investment in the project. This means producing more for less by placing the machine where it is most profitable.

SOLUTE has extensive experience and technical capability in wind resource assessment (WRA) studies, which allow for the proper definition of a project at any stage of its development, based on the available information to reduce uncertainty at any stage and provide the client with the necessary technical and economic aspects.

The processes carried out by SOLUTE include measuring the wind conditions at the site, estimating the wind resource in the park, defining and optimizing the layout, calculating energy and uncertainties for preliminary studies and/or financing phases, as well as assessing the wind conditions on the machine to evaluate the loads and ensure the lifespan of the site.

METEOROLOGY

The main objective is to improve the quality of predictions in small geographic areas through the study and analysis of local atmospheric phenomena, which influence the meteorological behavior of these areas by increasing the accuracy of deterministic predictions and extending the temporal range of probabilistic predictions.

Within the framework of its R&D&I initiatives, SOLUTE has designed and optimized an energy and meteorological forecasting service tailored to the needs of wind farm operators. Among the implemented tools, the energy load forecasting algorithms for intraday, daily, and balancing markets stand out, providing valuable information for optimizing energy sales strategies.

Additionally, to complete the service, SOLUTE provides its meteorological models and post-processed information so operators can schedule their routine O&M actions in wind farms.

Furthermore, the meteorology team works in conjunction with the energy resource area to develop strategies specific to Dynamical Downscaling, with the aim of offering a full range of historical meteorological data of various natures. This includes "wind and radiation atlases," typically with horizontal resolutions of 3 to 1 km, as well as tabular data and long time series generated with LES (Large Eddy Simulation) models, with resolutions up to 10 meters.

Thanks to this diverse data, it is possible to configure specific services such as the estimation of extreme wind regimes, specific data for wind and solar resource projects, average icing conditions of turbines at a particular site, etc.



MECHANICAL-ROTATING MACHINERY ENGINEERING

The components of the transmission shaft of a wind turbine are systems in themselves of various types and applications, primarily used for power transmission while allowing rotational movement with minimal friction. They basically consist of two rings between which rolling elements are housed, with one of the rings fixed to a housing and the other to the shaft, so that the rolling elements rotate between the rings, separating the movement of the shaft.

Through analytical and detailed calculation, SOLUTE conducts analyses of all the technical specifications necessary to meet the requirements of the application in which the components will be used. This includes selecting the correct type, determining the expected theoretical life, arranging the components, adjusting assembly, ensuring proper lubrication, and sealing. Additionally, it is also possible to analyze and evaluate existing designs to identify inefficiencies, propose design improvements, and perform root cause analyses of failures.



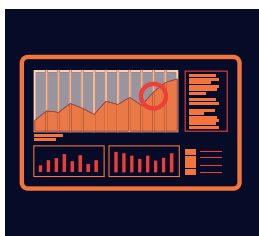
ENERGY SYSTEMS



For every electrical system, it's essential to develop a set of blueprints detailing all its components. This includes designing electrical plans for all sectors of the industry, ranging from low-voltage to high-voltage systems. To achieve this, it's necessary to identify the technical characteristics of the system, the requirements, and the components needed to design and develop the connection maps and diagrams.

When implementing an electrical network project in any sector, SOLUTE focuses on designing electrical blueprints for low, medium, and high-voltage networks. This includes collector substations and high-voltage overhead lines for onshore wind farms. Additionally, SOLUTE has experience in designing electrical blueprints and integrating renewable energy into industrial, commercial, residential, and agricultural sectors. This also extends to designing direct current electrical networks for solar parks.

AUTOMATIZATION AND CONTROL



The implementation of SCADA (Supervisory Control and Data Acquisition) and Condition Monitoring Systems (CMS) in the industry allows us to monitor and control various production processes and determine critical parameters, enabling us to operate under optimal safety conditions. These systems enable data acquisition for planning and intelligent, efficient resource management, making the process more efficient and resolving one of the major industry challenges: production downtime due to machinery failures.

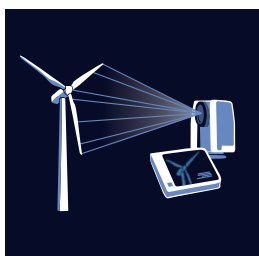
SOLUTE is capable of installing SCADA and CMS systems in wind turbines, solar plants, factories, commercial buildings, and more. To carry out these installations, SOLUTE leverages its knowledge and experience in equipment selection, blueprint design, scheduling, calibration, and commissioning, among other processes.

SOFTWARE DEVELOPMENT

Technology is omnipresent in our world, and the greatest advances have come hand in hand with computing, essentially comprised of the hardware and the software that governs it. Nowadays, virtually every work process involves the use of software applications, and the productivity of these processes largely depends on the adequate development of Ad-Hoc tools capable of automating tasks and facilitating the execution of user projects.

SOLUTE has a long history and great technical capacity to address software development of various types. This ranges from industrial automation systems to applications focused on professional use in specific sectors, and even mobile apps suitable for field use.

VIRTUALIZATION



A common problem among companies with separate industrial facilities and technical offices is the complex and costly procedures that lead to a lack of access to operational data of assets. The use of advanced digital tools makes this solution possible, currently partially addressed through costly site visits, searching through outdated and unclear information archives, or even making decisions without the necessary information.

SOLUTE's digitization services provide solutions such as 3D scanning of spaces and components, followed by the generation of virtual tours, detailed digital replicas, and simulated action procedures for training or field support.

CIVIL ENGINEERING



Civil engineering plays a crucial role in the development of wind and photovoltaic parks, contributing to various disciplines.

The design and calculation of wind turbine towers and foundations are undoubtedly one of the most important and challenging aspects, aimed at ensuring their structural integrity against the various actions throughout their lifespan.

Another fundamental aspect is the planning and design of roads and accesses that enable the passage of vehicles and heavy equipment, both during the construction phase and for maintenance purposes.

Additionally, water management in the vicinity of the park allows for anticipating the risk of exposure of its elements to water masses.

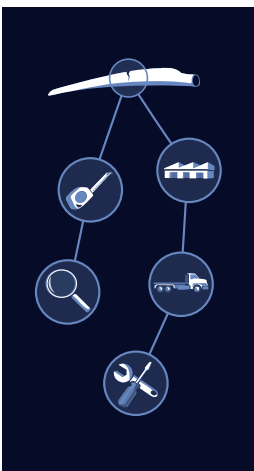
SOLUTE has extensive experience in the design of towers, wind turbine foundations, as well as roads and accesses for wind farms. They have participated in numerous projects for different development phases, from preliminary designs to final design calculations, and production of construction drawings and documentation for certification.

This experience has led SOLUTE to participate in projects for various tower technologies, including hybrid, full concrete, and metallic towers, as well as various types of foundations, such as piled, ribbed, with bolt cage connections, sleeves, or post-tensioned boxes. They have also been involved in the development of innovative solutions such as the design of prefabricated foundations.

The significant value of SOLUTE's civil department applied to wind turbines lies in their deep knowledge of state-of-the-art industrial solutions for supporting structures and in the industry's reference codes and regulations.

Furthermore, SOLUTE offers flood studies services using two-dimensional hydrodynamic models, allowing for the anticipation of the site's viability against these phenomena.

O&M



The reduction in O&M costs, along with improved asset reliability, has become a top priority in wind turbine maintenance strategies. The market trend is moving towards larger wind turbine designs, which increases the number of components, the probability of failure, and consequently, the maintenance costs. Therefore, research in the wind energy field is increasingly focused on improving techniques to extend the lifespan of assets while minimizing O&M costs.

Historically, park developers would contract a comprehensive maintenance service with turbine manufacturers, even after the warranty period. However, nowadays, more park owners realize that they are losing knowledge and control over their assets due to the lack of information and transparency in service contracts with technology providers, along with increasing costs.

This is why there is a growing demand for operational and maintenance support services from independent engineering companies like SOLUTE. The O&M support team carries out activities for the operations departments, including mechanical rotation, high and low voltage support, operational reliability, and root cause analyses (RCAs).

Wind turbine towers and foundations

Tools

- ANSYS
- SAP2000 (CSI)
- FAGUS (CUBUS)
- Diana
- Microsoft Excel y VBA
- AutoCAD

Normative

- IEC 61400-1 Design requirements
- IEC 61400-6 Tower and foundation design requirements
- Eurocódigos: EN1990, EN1992, EN1993 y EN 1997
- DNVGL-ST-0126 Support structures for wind turbines
- DNVGL-ST-0262 Lifetime extension of wind turbines
- GL Guideline for the Certification of Wind Turbines, Edition 2010
- CEB-FIP Model Code 1990 & 2010

SOLUTE has extensive experience in developing structural projects for wind turbines, including:

- Design and certification of wind turbine towers and foundations
- Peer review and RCA of wind turbine tower and foundation design
- Assessment of the life extension of towers and foundations

To this end, SOLUTE has a specialized civil engineering team experienced in structural analysis and the study of wind turbines. They actively develop their calculation methodologies, enabling them to perform the requested analyses of both general and specific elements within the timeframes demanded by the industry.

1. Design and certification of tower and foundations

Both for the construction of a wind farm and for the sale of new technologies for towers and foundations, their design and, in some cases, the certification of said design are necessary.

SOLUTE's civil engineering team has extensive experience in the design of wind turbine towers and foundations, carrying out the required stability and structural analyses. Regarding certification, SOLUTE has developed a methodology for obtaining certifications, which has been agreed upon in each case with both the client and the certifying body. This ensures a comprehensive range of standardized processes and documentation that facilitate the certification process, allowing it to be completed within the established timeframes.

This approach addresses the two main requests from clients: a valid and efficient design and the acquisition of a certificate that serves as a guarantee when offering the designs to third parties.

The primary clients interested in these types of studies are construction companies that have acquired wind turbine technology and need support in defining the tower or foundation, or small engineering firms that have developed new typologies and need a certificate to gain greater visibility in the market.

In both cases, SOLUTE has recently completed projects where the required design for construction or certification was defined within the specified time and deadlines.

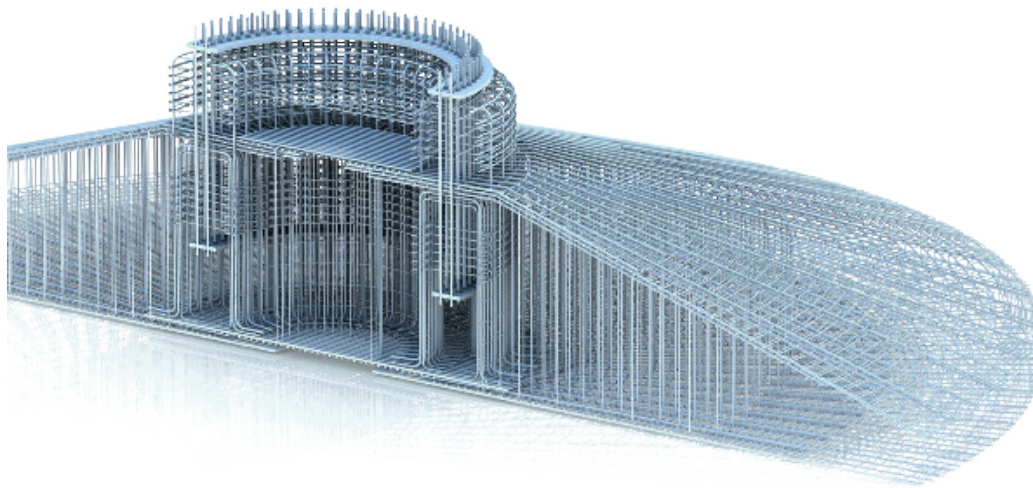
Foundations

The portfolio of works carried out by SOLUTE includes direct and deep foundations, ring foundations for concrete towers or circular foundations with anchor cages or embedded flange for steel towers, as well as ribs foundations manufactured in situ and prefabricated.

The methodology followed for the calculation process includes the stability study of the structure, taking into account the geotechnical conditions of the terrain and the loads coming from the wind turbine; the ultimate limit state, serviceability, and fatigue analysis of the general elements of the structure, as well as the definition and structural analysis of the singular elements such as the connection with the wind turbine tower.

Regarding studies of existing foundations where some type of failure has been found (such as concrete cracking or bolt failure) or on which modifications are intended, the procedure followed focuses on simulating the existing conditions (geometry, loads, and geotechnics) through detailed FEM models, followed by processing the results and performing reinforcement evaluation, concrete sections, and checks related to the connection (anchor cage, flange, or post-tensioning tendons).

As a result, SOLUTE provides an optimal definition of all foundation elements through appropriate documentation and plans, facilitating certification by the accredited body. Depending on the client's needs, they offer post-delivery advisory services through the creation of execution manuals, solution adaptations, and follow-up on possible modifications during construction.



Towers

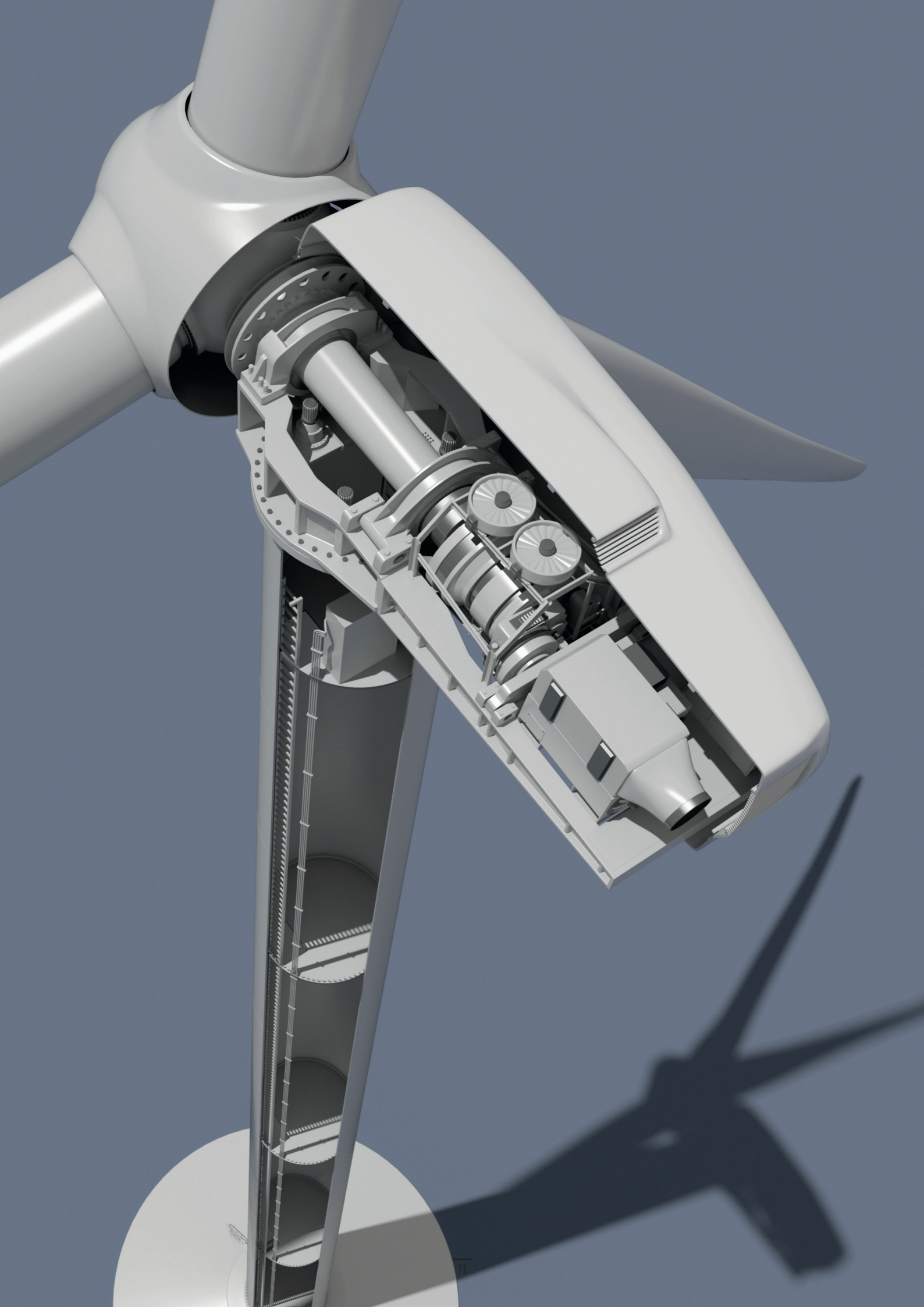
The tower is one of the most critical elements of a wind turbine, as its main function is to transmit the loads generated by the rotor to the foundation. It is particularly sensitive to fatigue, where constant turbine oscillations can dynamically excite the fundamental modes of this element, potentially leading to undesirable phenomena.

SOLUTE can tackle specialized civil engineering for structural calculation thanks to its experience in designing wind turbine towers of various types: concrete, steel, or hybrid.

The methodology focuses on verifying the overall performance of the structure and defining the specific elements to ensure realistic behavior, based on applying wind turbine industry standards and structural calculations, both nationally and internationally.

The steps followed can be grouped into the ultimate limit state, service, and fatigue analysis of the general structure elements, the definition and structural analysis of specific elements such as cable holes or doors, and the verification of different connections between tower elements, whether through flanges or mortars.

The process involves preparing documentation that meets the requirements of the certifying body, mainly consisting of documents supporting the calculations and plans defining the geometry, reinforcement, and other elements of the structure.

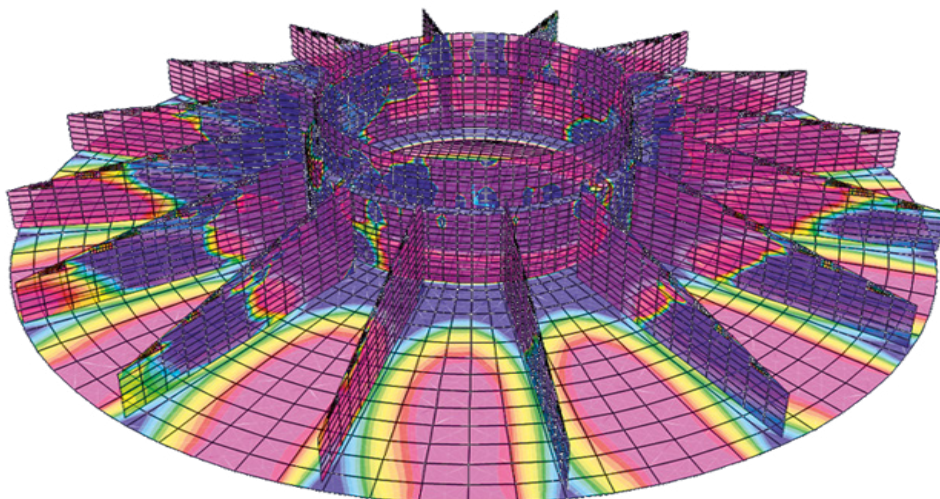
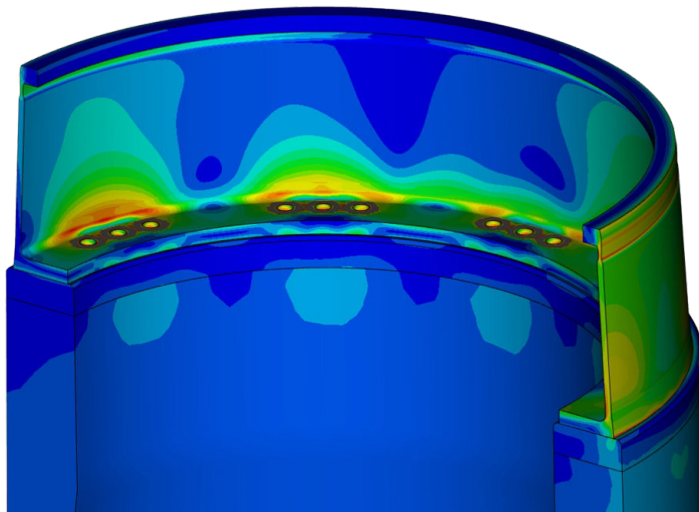


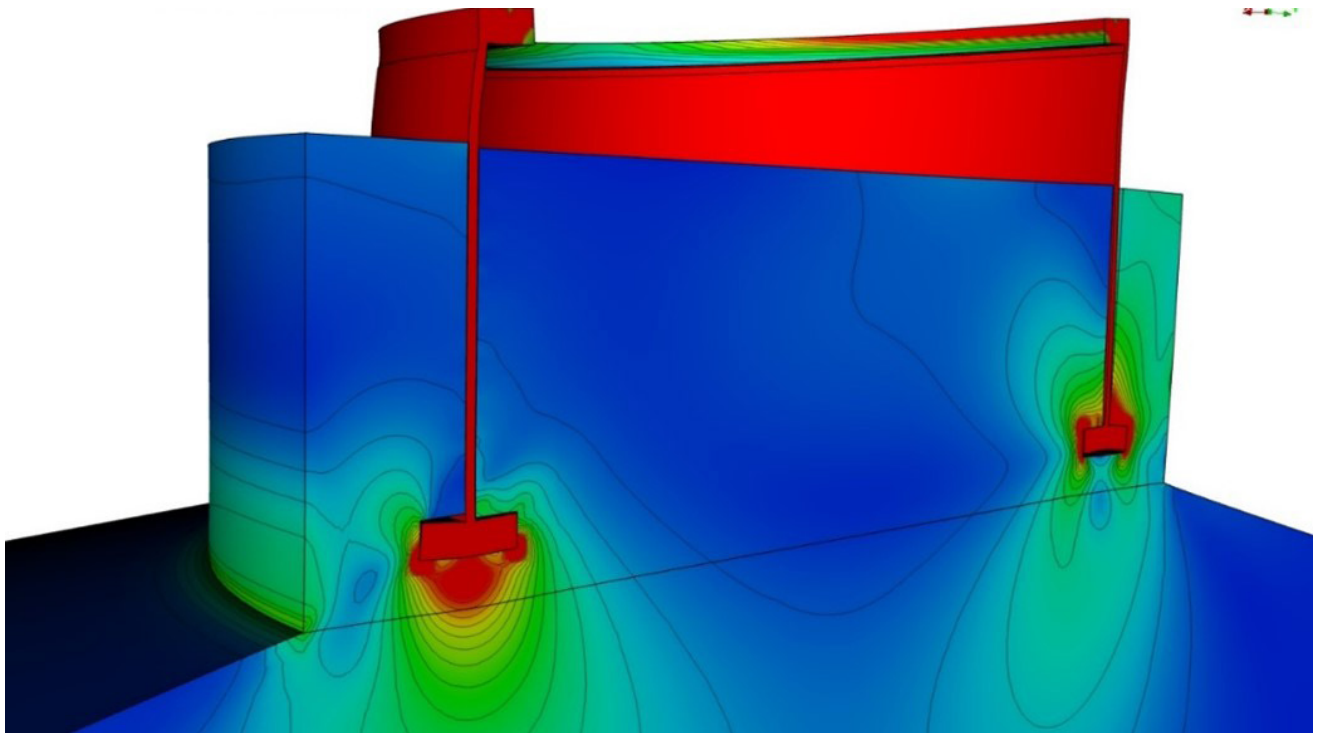
2. Peer review and RCA of wind turbine tower and foundation design

SOLUTE has significant experience in peer review of wind turbine tower and foundation design, as well as in root cause analysis (RCA) of already constructed structural elements.

To carry out both tasks, a thorough study of the information provided by the client is conducted. This verifies, on one hand, that the structural element has been designed according to current regulations and, on the other, that the component has been correctly calculated and manufactured following industry best practices.

These competencies, therefore, require a multidisciplinary team with a deep understanding of current regulations, the behavior of structures, common practices in the design and calculation methodologies of these components, and manufacturing techniques.





3. Extension life assessment of towers and foundations.

During the design stage of a wind turbine, components are defined for a specific service life. In the case of foundations and towers, this life span is usually 20 or 25 years. The objective of the life extension study is to assess the remaining fatigue life of each component according to current regulations.

The analysis of the life extension of certain components of a wind turbine is highly demanded nowadays, as many existing turbines are very close to reaching the end of their designed service life. The main clients interested in this type of study are component manufacturers, wind farm developers, government authorities, and private companies, aiming to achieve higher performance from installed wind turbines.

In this field, SOLUTE emerges as a solution for conducting life extension studies, boasting a structural engineering team that carries out an assessment of the turbine's conditions, applying them to finite element models for subsequent fatigue analysis.

The methodology employed focuses on studying all available inputs of the wind turbine, which involves analyzing the actual fatigue loads on the turbine based on the winds it has been subjected to during its service life and their directionality. Through the fatigue analysis performed, it will be determined whether the wind turbine components are capable of withstanding the obtained loads for a certain additional service life. Depending on the scope of the study, it could simply focus on the structural validity or on checking the validity and proposing solutions in case of failure.

Design of roadways and accesses

Tools

- Civil3D
- AutoCAD
- Infraworks

Wind and photovoltaic parks are often located in remote areas that need to connect with the general road network to facilitate the transportation of each of the components comprising these installations. This transportation is not ordinary, as the different elements that need to be moved are of large dimensions, and often it's the size of the components that determine the characteristics of the overall layout.

For accessing wind and photovoltaic parks, preliminary development of internal road layouts is necessary, minimizing earth movements. Therefore, the development of site plans, longitudinal profiles, cross-section profiles, and platform definition is carried out, in addition to earthwork measurements. Additionally, simulations of maneuvers of the vehicles transporting blades, cranes, and tower sections over the internal roads of the wind park may be required.



For the development of the project, the localization of wind turbines and client restrictions, including geographical, parcel-related, or other types of constraints, will be carried out. This will generate a layout of access roads connecting the main roads with the wind turbines and photovoltaic park. The type of section to be used will also be defined, and the alignment of the road layout will be planned according to criteria established by wind turbine manufacturers regarding slopes, curvature radii, widths, platforms, etc. Drainage, location, and design of related actions are also studied.

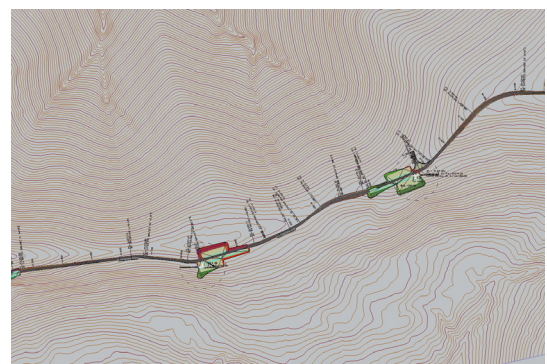
Alongside road development, after analysis by an electrical engineer, the location of different power lines, whether overhead or underground, will be arranged and displayed on the plans.

Once the layout meets the manufacturers' requirements, a study of vehicle maneuvers will be conducted if necessary for special access studies of certain vehicles. Similarly, visibility and signage studies will be developed for access to the main roads, if required.

With all the work completed, the access for the assembly and maintenance of the different components of the parks would be defined and resolved. Finally, the report, plans, and measurements are prepared.

The development of all these steps requires knowledge and use of Autodesk tools such as InRoads for park localization and preliminary layout design, or Civil 3D for road design, plan generation, and measurements.

SOLUTE provides a comprehensive descriptive report of the work done, containing site plans, elevations, profiles, etc. This way, by using the appropriate tools, the park can be accurately defined, and real measurements of earth movement or overhead lines can be obtained.



Hydrological and flood studies

Tools

- Iber
- QGIS
- AutoCAD

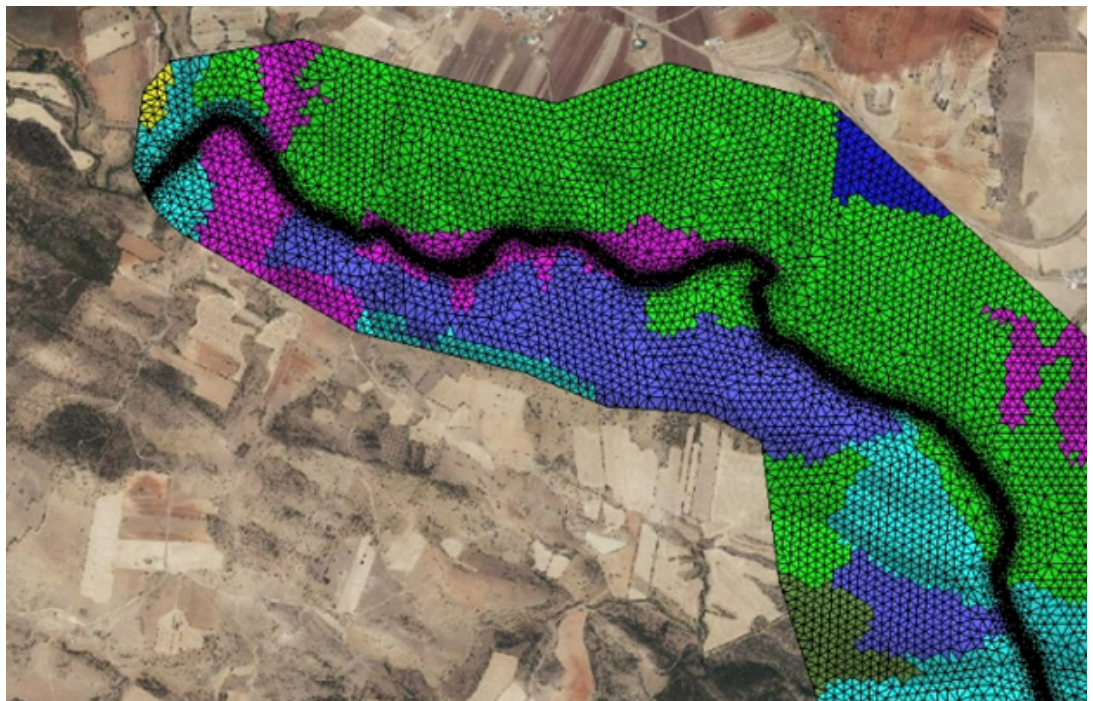
Hydrological and flood studies play a crucial role in the design and planning of wind and photovoltaic parks, as they allow for the identification and mitigation of associated risks by analyzing the environment in which they will be located. This ensures the safety of the installations and their compatibility with the natural surroundings, thus ensuring their long-term viability.

To carry out these studies, SOLUTE develops two-dimensional hydrodynamic models that anticipate the feasibility of the site in the face of these phenomena. Through specialized tools such as IBER, specifically developed for hydrological modeling and flood risk assessment, complex scenarios are simulated based on terrain topography, basin drainage capacity, and precipitation intensity, among other factors.

These studies enable the definition of the Public Hydraulic Domain, police zone, and the flooded area for streams near the installations based on the different studied return periods. This delineates the geometric definition of the plant on the lands under study, avoiding occupancy of these areas. Additionally, the study is capable of evaluating runoff flows generated within the site if required.

As a result, a descriptive hydrological report accompanied by plans reflecting floodplains and

interior plant drainage is obtained, analyzing the hazard of the location against these phenomena.





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