

03.2 Industrial capital



Projects in which the company works

As a result of the restructuring, Abengoa will henceforth focus on its specialist EPC role (Engineering, Procurement and Construction) or turnkey projects, viz., the engineering, procurement and construction of plants for third parties in four key areas: energy, water, transmission and infrastructures and, finally, services.

Abengoa will thus be focused on sectors and products with high growth potential, in which it is not only internationally recognised, but from which a wide portfolio of projects and commercial opportunities will emerge. To carry out these opportunities, Abengoa needs a smaller organization, adapted to the new reality, to accompany operations in the same sector and activity, but on a smaller scale, in line with the new strategy and the availability of resources.

Abengoa's activity by areas is as follows:

Energy

G4-4

Through its Energy vertical, Abengoa integrates the activities of business development, promotion, bids, engineering, technology and project performance, referring to the generation business, both conventional and renewable, covering the entire value chain of turnkey projects or EPC, from the commercial phase, design and basic and detail engineering through to construction and start-up.

Looking ahead to 2017, the energy vertical is tasked with becoming a benchmark in the EPC electricity generation market, concentrating its efforts on those products and markets that allow it to comply with the bases established in the organisation's new strategic plan.

From its energy vertical, Abengoa is developing the following products:

Generation of conventional energy

- › **Combined cycles:** electricity production plants that combine the direct potential of gas combustion and the steam produced as a consequence of re-utilisation of the combustion gases. Abengoa has delivered over 2,000 MW in recent years and is in the process of completing projects for an additional 640 MW.
- › **Cogeneration:** plants producing electricity and steam from the combustion of natural gas or other fuels such as biomass. Located in industrial environments with major self-consumption needs, it allows the surplus to be fed into the grid for sale. In recent years, Abengoa has built and delivered more than 320 MW.

Generation of renewable energy

- › **Thermosolar power tower:** allows the production of electricity by concentrating the solar energy captured, through a field of heliostats, into a receiver located at the top of a tower. Abengoa is a pioneer in the construction of tower plants for commercial operation, with more than 80 MW in operation.

Also, thanks to the combination of this technology and the salt storage, it guarantees the plant production during lengthy periods without solar radiation or even during the night.

- › **Thermosolar parabolic trough plants (STEP):** these base their operation on the collection of solar energy through parabolic trough technology that allows the heating of a heat transfer fluid for the use of heat in a conventional thermal cycle. Abengoa is a pioneer in the construction of these types of plants, with more than 2,000 MW in operation and 500 MW under construction.

Likewise, the company has been the first to integrate a solar field into a conventional generation plant using combined cycle.

Water

G4-4

Abengoa, as a global technological operator in the water sector, provides solutions both to the scarcity of water resources, generating drinking water and transporting it, as well as protecting the environment, with the treatment of urban and industrial discharges.

The activity in the water sector is carried out for industrial clients and public institutions, in the areas of:

- › **Desalination:** Abengoa is one of the world leaders in the design and construction of this type of plant, with more than 20 large desalination plants in Spain, Africa, Latin America, Middle East and Asia, for the production of drinking water or industrial water from seawater or brackish water, using conventional and advanced membrane processes, which account for more than 1.5 Mm³/day of installed desalination capacity.
- › **Water treatment:** Abengoa has an extensive track record with more than 120 plants built in Spain, Africa and Latin America, for the potabilization of water and also for treatment and reuse of wastewater of urban or industrial origin through physical-chemical and biological processes, including treatments for digestion and recovery of sludge.
- › **Hydraulic infrastructures:** throughout its more than 70 years of history, Abengoa has always been at the forefront of hydraulic initiatives, collaborating with public and private institutions in the implementation, improvement and operation of infrastructures for regulation, transportation (more than 40 pumping stations), distribution (more than 4 million people served), irrigation (more than 500,000 ha) and hydroelectric plants (350 MW installed in more than 30 activities –plant construction, improvement, upgrading, etc.).

During 2016, Abengoa has continued to build desalination plants, urban and industrial water treatment plants; hydraulic infrastructures for the transport, storage and distribution of water for supply and sanitation grids, either under concession or through construction contracts for the public or private sectors.

Likewise, it has also continued the O&M of two desalination plants whose concession Abengoa owns, located in Ghana and Algeria, as well as five other plants built by Abengoa and with which it has long-term O&M contracts.

The aggregate drinking water production capacity of these plants in operation is more than 775,000 m³/day, which would be able to supply more than 3.5 million people.

For 2017, Abengoa has set itself the challenge of finalising the concession divestment plan and consolidating its activity, accelerating ongoing projects and culminating in the contract awards for new water projects, especially in the Middle East.

Transmission and infrastructures

G4-4

The Transmission and Infrastructure vertical of Abengoa has four areas of activity:

- › **Electrical transmission and distribution**, with more than 27,000 km of transmission lines developed worldwide and more than 330 substations built in the last 15 years.
- › **Railway:** we have exceeded 2,300 km of railway lines and 80 traction substations.
- › Over 70 years' experience in **installations and infrastructures**.
- › Auxiliary manufacture of **electrical and electronic equipment**, with own design capabilities.

In 2016, as part of its divestment plan, Abengoa sold the assets and liabilities of Abengoa's Production Centre in Seville to the company Cuadros Eléctricos Nazarenos (CEN). The production centre in Seville engaged in the design, manufacture, testing and logistics of electrical equipment for the electricity generation, transmission and distribution markets.

Electricity transmission and distribution

Abengoa offers a wide range of technical solutions in transmission and distribution. It includes electric lines and substations of all types and sizes: alternating current and direct current; all voltage levels (low, medium, high and very high); overhead and underground lines; cable laying and live work, transmission grids (HV), distribution grids (MV) in primary and secondary substations, evacuation of thermosolar plants in booster and collector substations, air, oil, gas and hybrid-insulated substations.

It also has capabilities to carry out the integral management of projects, from feasibility studies, design and engineering and supply to construction, assembly, commissioning, operation and maintenance.

Railway

Abengoa is an international benchmark in the development of turnkey projects for catenary, traction substations, communications, signalling, electrical installations in high voltage and low voltage (LV), lighting and ventilation associated with both conventional and high speed railways, metro, tram and monorail.

From the area of railway engineering, Abengoa covers any technical needs of its projects, regardless of the geographical area where they are located.

It also has one of the most advanced railway machinery ranges in the sector, highly sophisticated and with maximum functionality.

Installations and infrastructures

Abengoa has over 70 years' experience in the industrial and infrastructure facilities, carrying out the construction of facilities at all types of plants (conventional and renewable generation, oil&gas, food and paper) and singular buildings (hospitals, prisons, cultural, educational and administrative centres), covering the design, supply, manufacture, assembly and testing of systems as well as operation and maintenance.

Auxiliary manufacturing

Manufacture of electronics with own design capability, software and hardware and equipment with integrated electronics, as well as the supply of control racks, ticketing and access control, X-ray machines and power supplies.

Services

G4-4

Abengoa provides comprehensive predictive, preventive and corrective maintenance and operation services for renewable, conventional and water treatment plants, with the objective of optimising their reliability, performance and uptime, minimising the consumption of fuels, chemicals and consumables, as well as the emission of GreenHouse Gases (GHG) and maximising their production.

In the same way, the company manages its own assets in operation. To do this, the asset management lifecycle is conceived as an important source of cost savings, regulatory compliance, improvements in uptime and competitive advantages. Through the application of asset management systems throughout their life cycle, Abengoa is able to manage the work and maximise the fixed or physical performance or capital goods that have a direct and significant impact on achieving the economic, environmental and social objectives, always maintaining a high commitment to the prevention of occupational risks.

The Abengoa Services vertical focuses on four main areas:

- › Operation and maintenance
- › Asset management
- › Factories for metal structures
- › Commercialisers

Operation and maintenance

Abengoa offers Operation and Maintenance (O&M) services in the field of energy, water and the environment. With more than 15 years' experience in this activity, it performs corrective, preventive and predictive maintenance, as well as computer-assisted maintenance at thermal, renewable and conventional plants, hydraulic and environmental infrastructures.

The operation and maintenance ensures that the assets work correctly throughout their useful life. Designing and building with an operator's vision is a competitive advantage for Abengoa, which has established itself as a leader in the O&M of solar plants. It has an installed capacity of 1,603 MW in commercial operation of thermosolar plants (tower -a technology in which Abengoa is a pioneer-, parabolic troughs and hybrids integrated with conventional cycles) and photovoltaic, which place it as the company with highest amount of installed thermosolar capacity in the world.

Thanks to this know-how and the technological development it entails, the company has made it possible for the plants it operates to achieve high levels of production and uptime. In addition, Abengoa assumes responsibility for the upkeep and operation of machines and equipment to obtain maximum productivity, profitability and safety at the plants.

Asset management

The Services vertical manages its assets in a safe, reliable, efficient, profitable and sustainable way in the fields of energy, water and the environment.

With extensive experience in electrical, renewable and conventional power plants, hydraulic and environmental infrastructures, the objectives of the company are:

- › Apply the most modern management techniques that guarantee the generation of value and the sustainability of assets throughout their useful life, in line with the company's vision of safe, reliable, efficient, cost-effective and focused on sustainable development.
- › Provide a professional service with a highly qualified team with a high commitment to the safety of people and facilities.

Factories for metal structures

In its seven decades of experience, Abengoa has manufactured more than 1.5 Mt of metal structures for its own and third-party projects worldwide. Abengoa thus offers an integrated service, covering the entire value chain, from engineering to manufacturing, including full scale load testing of structures. In the test station in the factory of Spain, towers up to 72 metres in height can be tested by applying loads equal to those that will be supported in service in their real enclave once installed.

The Services vertical has three production centres, located in Spain, Mexico and India, which have a common form of work and add up to a global production capacity of 15,000 t of metal structures per year.

- › **Eucomsa**, located in Utrera, Seville (Spain): a factory with high quality standards, as leading electricity companies are required to have. It has an excellent structural engineering capability, which gives it additional value for problem-solving and optimisation of designs (some of them under patent).
- › **Comemsa**, in Querétaro (Mexico), is the largest and most modern structures factory of Abengoa. It has two independent Galvanising and Railway Spur plants, all in the same location and serving both Latin America and North America.

- › **APS India**, located in Haloi Gujarat, to the west of the country, manufacturing structures with huge economic competitiveness and representing an important gateway to the Asia and Middle East markets.

Commercialisers

Abengoa carries out its commercial activity in the Services area through Abencor and Nicsa. These companies specialise in the distribution of electrical equipment (power and distribution transformers, insulated low-, medium- and high-voltage cables, bare and submarine cables, UPS, etc.) and with more than 70 years' experience. The core activity of Abencor and Nicsa is focused on supplying equipment and spare parts during construction and operation stages, both for internal and external clients.

The main supplies for Abengoa have been developed in the Chile Metro project and in the Xina Solar One Thermosolar plant project in South Africa.

Presence of Abengoa G4-8

Abengoa's activity during 2016 was carried out mainly in the following geographies:

South America

Abengoa has been present in South America for more than 50 years. In fact, the first international projects were carried out in Colombia, Venezuela and Guatemala, creating the first international office in Argentina. Since then, South America has become one of Abengoa's most important regions, with a presence mainly in:

- › **Peru**: present in this country for more than two decades, Abengoa offers comprehensive solutions to its clients in the sectors of mining, energy, water, industry, oil&gas and infrastructure, with a particular focus on civil, hydraulic and electromechanical projects. It also operates and maintains high-voltage transmission systems.
- › **Argentina**: Abengoa has specialised in turnkey energy projects (conventional and renewable generation and transmission and distribution); water and sanitation (infrastructure and sewage) and industrial plants (cement).

- › **Uruguay:** established in the country since 1980, Abengoa continues here by participating in its main infrastructure projects. It has performed around 400 projects, including approximately 450,000 m² built, more than 100 hydraulic works, 70 electrical projects, including the development of several wind energy projects and numerous industrial projects.

Also in Uruguay, through the company Consorcio Ambiental del Plata (CAP), Abengoa carries out waste management and the development of urban sanitation services. Work is also carried out on the collection of waste from containers both with trucks and by hand, and the sweeping of roadways, washing of avenues, squares and esplanades, cleaning and washing of fairs, removal of debris and special services.

It also has a forestry business area, in which it carries out 100 % mechanized harvesting and extracting activities; supply of biomass for industries –at all stages of the supply chain, from the field to the boiler –and operation of stockyards. For this last item, it works jointly with the company Schandy SA.

Moreover, in Uruguay Abengoa performs the operation, maintenance and management of wind farms, treatment plants and unique buildings, as well as providing technical advisory services, start-up of electrical installations, electrical tests and thermography in the industrial, electrical area and wind areas, among others.

- › **Chile:** Abengoa opened for business in Chile in 1987. Since then, the organisation has developed engineering and construction activities and infrastructure concessions for the electric, mining and consumer industries. Of particular note are the development of power lines and substations, civil engineering, railway works, electromechanical assemblies, sanitary and waste treatment works, desalination plants and renewable energy.

United States and Mexico

Abengoa has achieved a leading position within the construction, technology and water sectors in the United States, where it has carried out major projects such as Solana, the world's largest thermosolar plant for parabolic trough technology at the time of its construction. Abengoa is currently responsible for its operation and maintenance.

Meanwhile, in Mexico, the company carries out infrastructure projects for renewable energy (solar and wind), conventional energy (combined cycle), environmental infrastructure (aqueducts), transmission lines and electrical substations.

It has been present in the country for more than 25 years, it has its own resources and capabilities to capitalize on market opportunities and overcome environmental threats.

Europe

Throughout its history, Abengoa has performed a wide variety of projects throughout Europe (Spain, France, UK, Holland, Ukraine, Poland, Denmark, etc.). Special mention should be made of the projects for the generation of conventional and renewable energy, transmission, desalination, treatment and hydraulic infrastructures and one-off buildings. In addition, the company has the largest solar R&D centre in the world, a pioneer in this technology and a global reference, which has allowed the company to develop new technologies, services and systems of operation and maintenance, as well as maximize capacity and production of plants.

North Africa and South Africa

Abengoa currently carries out EPC and O&M activities for large thermosolar power projects in South Africa. Specifically, the company has been present in this country since 2011. And this is because South Africa, as well as being the southern region of the continent, offers great opportunities for Abengoa to expand its commercial base in the energy and water sectors in the near future.

Through this activity and the development of generation and transmission projects throughout the continent, as well as the construction of desalination plants and water treatment plants, Abengoa stands as one of the key companies in the development of the energy and water sectors in Africa.

Middle East

Abengoa is present in the Middle East, a high growth market, in countries such as Saudi Arabia, Kuwait, United Arab Emirates (UAE), Oman, Qatar, Bahrain, Jordan and Egypt, where the company has a large portfolio of projects and opportunities, as well as offices in various locations.

Innovation ID1, ID2, ID3_4

Technological development remains the main competitive advantage of Abengoa to carry out projects of high value-added in any part of the world. Today's society values technological solutions that contribute to sustainable development and the number of countries that consider it indispensable is increasing.

Throughout 2016, and as part of its restructuring process, Abengoa has also restructured the R&D and innovation area, integrating the various innovation activities that are taking place in the new verticals that make up the company. However, in the case of certain projects, a portfolio of technology packages has been created, and with them, what we call the "Technological Incubator".

The aim of the incubator is to showcase these packages not aligned with Abengoa's strategy (in the areas of bioenergy, catalysis, thermosolar, photovoltaic solar and water) and, thus, continue with the development of these technologies. To this end, the incubator is considering preserving knowledge through different formulas, such as collaboration schemes with third parties, joint ventures, spin-offs, licences or even through the complete transfer of technology.

Investment made in 2016 amounted to € 4.72 M, a decrease of 98.6 %, due to the situation experienced by the company during 2016, when it was focused on the development of its financial restructuring. Nonetheless, R&D and innovation activity continued, reaching 294 priority patents applied for up to the year of the report, with a total of 232 employees dedicated to R&D and innovation.

Main figures	2016	2015	2014
Investment in R&D and innovation (€M)	4.76	345.2	597.7
Personnel	232	797	882
Cumulative priority patents applied for	294	332	312

Main lines of technological development

R&D and innovation in the thermosolar area

In the development of thermosolar plants, Abengoa remains a world leader. To carry out these high value-added projects, it continues to develop R&D and innovation projects, with the conviction that it will be able to keep ahead in the future. This will help it identify new lines of business and acquire new skills that will keep it positioned in the market as a consolidated brand.

In the solar area, we have targeted optimization of all electric power generation technologies, promoting the renewable energy and allowing manageable generation that adapts to the new demand models. To this end, the company has worked on projects in partnership with the most important national and European centres in the field of energy generation and storage.

Thus, thanks to the work performed in the area of technology, 2016 has been a year in which Abengoa achieved the following technological milestones:

- › The consolidation of the **first commercial superheated steam receiver** at the Khi Solar One plant in South Africa, where more than eleven patents have been fully developed by Abengoa personnel.
- › The **central receiver technology** remains the most promising in solar power generation. Abengoa continues to maintain a strong commitment to the optimization of its components, especially the use of molten salts as heat transfer fluid. Solar salt, a blend of sodium nitrate and potassium nitrate, is presented as the fluid with the greatest potential for energy transfer and storage. The optimization of its use, the development of solar components for salts and the compatibility with building materials have represented a constant development throughout 2016. Also this year, different projects have been carried out for the experimental evaluation of salts at high temperatures, which will allow us to optimise the design of key equipment materials, both in solar receiver technology as well as parabolic troughs.
- › In thermosolar tower plants, the **ongoing improvement in the efficiency of thermal energy capture** is critical and therefore in 2016 we worked on three lines simultaneously:
 - I. The design of absorbent paints for the receiver tubes to improve the capture of the energy at high temperatures and the durability of the same.
 - II. The development of new coatings for mirrors, which will improve efficiency in the concentration of the energy.

- III. The development of a closed-loop control of heliostats system, which will allow the calibration of a solar field focus of up to thousands of concentrators automatically, quickly and easily.
- › Likewise, Abengoa continues to participate in European projects where it encourages the creation of **international partnerships** and focuses on new developments of **high temperature technology**.

In fact, in 2016, two FP-7 (Restructure and Storre) projects aimed at validating high temperature solar technology that fed into advanced power cycles were successfully closed. Abengoa also actively participates in the StageSte project, a consortium subsidised by the FP7 European programme, in which 40 partners participate, including the most important research centres, universities and companies in the solar field at European and international level. This alliance aims to ensure European excellence in concentrated solar energy including solar fuels, solar process heat and solar desalination of water.

In line with the strategy and developments discussed, 2017 reveals new objectives:

- › **Technological support to the development of commercial plants**, in the design phase as well as construction and operation. There are different working groups specialized in the most critical systems of each technology, providing technical support in the design, purchase and manufacture of the main equipment. For plants in operation, an exhaustive analysis of the production and self-consumption is carried out, in order to increase the overall efficiency of the plant.

Moreover, there are experts focused on the control and monitoring of other critical systems such as corrosion of materials and the degradation of storage and heat transfer fluids at future thermoelectric solar plants with molten salt technology.

In the medium term, one of the most important steps in reducing costs for thermosolar plants with tower technology that use molten salts is the increase in operating temperature. This will improve the efficiency of the cycle and thus significantly reduce the costs of electricity produced. For this reason, Abengoa will develop a small-scale pilot loop in 2017 in order to determine the impact of an increase in the maximum operating temperature in the salts.

- › As remarked upon above, the **thermal storage systems** hold the key to future competitiveness of thermoelectric solar generation plants and, therefore, R&D efforts should be largely focused on **improving their efficiency, reducing costs and optimising the components**. In this regard, and with a more long-term approach, one of the most promising lines is that of thermo-chemical storage, which allows the accumulation of energy at high temperature, with high density and the additional capacity to deliver thermal energy at a higher and more constant temperature.

- › On the other hand, 2017 aims to encourage the use of solar energy for a purpose other than electricity production, focused more towards **minimising the generation of emissions in technology with high energy consumption**. In this context, Abengoa participates in two major projects funded by the European Union as part of the H2020 programme. Firstly, the Solpart project, whose objective is to demonstrate on a pilot scale the viability of the use of solar energy in cement production, one of the most energy-intensive industries today. Secondly, the Sun-to-liquid project, whose purpose is the complete validation of the production process of hydrocarbon fuels from water, CO₂ and solar energy.

With these objectives, Abengoa continues to promote the creation of a network of strategic collaborators, from national and European universities and research centres, developing specific projects and medium- and long-term partnership agreements that facilitate the exchange of researchers and the transfer of knowledge.

R&D and innovation in the bioenergy area

Abengoa's own technology has included the production of biofuels (bioethanol and biodiesel), as well as other chemical bioproducts using cereal, oilseeds and biomass (grain, sugar cane, cellulosic biomass, oilseeds and solid waste) as raw material.

More specifically, in 2016 the following developments took place:

Production of bioethanol from lignocellulosic material

During the last year, Abengoa has analysed -at the level of detail engineering- the set of improvements that make second generation biofuel technology (2G) economically profitable. In this area, the company uses an innovative approach to diversify the raw material resources used to produce not only biofuels but also bioproducts. Using enzymatic hydrolysis (EH) technology, developed by Abengoa, the biomass (agricultural waste) is transformed into renewable sugars that, after fermentation, results in bioethanol. Also the second generation sugars can be converted into butanol and cosmetic products.

Furthermore, advances in the field of EH have led to the patent protection of an enzymatic cocktail that shows the highest yields in the market, making the 2G technology from biomass more competitive and cutting edge worldwide thanks to advances in bioproducts.

Production of second generation bioethanol (2G) from Municipal Solid Waste (MSW)

The objective of the Waste-to-Biofuel (W2B-waste-to-biofuels) project is to develop a comprehensive solution for the management of municipal solid waste (MSW), which allows biofuels and energy to be converted into a larger amount of waste and reduce the quantity that goes to the landfill. This provides a **more sustainable and efficient alternative to traditional waste management**.

Thanks to a major technological effort, Abengoa has adapted and transformed the second generation pilot plant that it developed in Salamanca, which used cellulosic biomass as raw material for the production of second generation bioethanol, in a demonstration plant that uses the organic fraction of the MSW as raw material, for the production of second generation ethanol. This plant is a unique installation in Europe.

The W2B project reduces greenhouse gas emissions associated with fuel use, as well as landfill waste (at least 20 %) and, in addition to ethanol, generates a solid fuel that has been classified as level 2 by the European Community, guaranteeing its environmental quality.

Industrial production of enzymes

An extensive team of highly qualified engineers, chemists and biochemists has developed a technology for the production of an industrial enzymatic cocktail that reaches 100 grams of protein per kilo of broth. These productions are in the order of 1.5 to 2 times higher than those of other industrial systems. The demonstration plant in Salamanca (Spain) has been crucial for the development of enzyme production engineering. The work has been implemented in reactors of 500 m³, a level never seen in the industry of enzymes.

The work process established at Abengoa has led to the **reformulation and evaluation** of new enzymatic cocktails by identifying genes and encoding enzymes with a high performance profile. The development of **more effective and lower cost** enzyme combinations is of strategic interest for the competitiveness of second generation technology.

Development of bioproducts

Abengoa has developed a unique platform for the production of sugars from biomass in its first and second generation plants. The company is currently developing innovative technologies through the use of microorganisms to produce different bioproducts such as aromatic compounds for perfumery and alkanes for use in motor vehicles. Aware of the industrial value of these solutions, Abengoa is protecting these intellectual developments and industrial technologies, generating a solid portfolio of patents.

R&D and innovation in the water area

In the water area, during 2016 Abengoa continued (and continues in 2017) with the development of the Life+ ZELDA (Zero Liquid Discharge Desalination) project. The aim of this project is the development and demonstration of a new process for the treatment of brines based on the use of electro dialysis metathesis and on the recovery of valuable compounds, with the ultimate goal of achieving a zero liquid discharge (ZLD). The project is being developed within a consortium formed by the Fundació Centro Tecnològic de Manresa (CTM), the European Water Platform (WssTP), FujiFilm and Abengoa.

During 2016, the demonstration-scale experiments campaign was carried out with rejections from a process of reverse osmosis of brackish water and in 2017 we continued the campaign of experiments with brine from the Almería desalination plant. With these types of ZLD systems, the consortium intends to prove that the technology is an **energy efficient alternative** to other thermal **processes for the concentration of saline effluents** and, at the same time, that it is **economically** and technically feasible to recover naturally occurring salts in the brine.

Thus, in the future, solutions for the management of saline effluents that are more sustainable, efficient and aligned with the new paradigm of so-called circular economy could be commercialized.

R&D and innovation in the railway area

Through its participation in numerous international projects with major technological challenges, the detection of the needs of our customers and the study of their solutions, Abengoa is at the international forefront of the development of railway innovation products and projects.

We currently specialise in the development of projects related to the study of the behaviour of facilities under extreme conditions, as well as new materials, development of sensor systems for the monitoring and protection of infrastructures, energy storage systems and the development of railway simulation software.

Abengoa has been leading the creation of a **railroad cluster in Malaga** since 2016. This cluster is organized with the intention of supporting the sector and stimulating aid in innovation at national and international level and becoming an international benchmark and a meeting or consultation point for both agencies and railway administrators or any other customer with technological needs.

Currently, Abengoa is leading this initiative in its position as vice-chairman and it comprises the companies Adif, Ferrovial, Siemens, Thales, Alstom, Vías y Construcciones, Comsa, Deimos Elecnor, Telice and Azvi.

Broken Track Project. Real-time track break detection system for high-speed trains

Between 2012-2014, Abengoa developed a track break detection system capable of real-time monitoring of the breakage of any of the dual tracks and their location.

The key outstanding features of this system are the simultaneous detection of breaks in any of the four tracks of a dual-track high-speed line (HSL) in real time. This is a **non-intrusive solution independent** of the railway line's own installation, with maximum measurement distance (from 15 km), immunity to noise typical of the railway environment, non-interference with other systems installed on track or signalling, monitoring of the condition of tracks in real time and installable on any type of railway lines.

During 2016, improvements were made to the design and development of earthing filters for this system. Recently, it has been finalized and patented internationally and is in the process of negotiation for commercialization with Adif.

Alis Project. Simulation software for the integration of electrification, safety and energy efficiency in rail systems

In 2016 Abengoa began to develop an **integral tool of complete simulation** of a railway line, unique and new in the market, comprising the following modules:

1. Electric traction simulations for DC and AC systems
2. Optimization of location, number and power of electric traction substations and auto-transformation centres
3. Simulation of pantograph-catenary interaction
4. Integration and simulation of electrical protection equipment
5. Integration of return currents by earth, drift currents, reachable, step and touch voltages
6. Study of electromagnetic disturbances, electromagnetic compatibility and effects on human beings
7. Simulations of efficient driving and energy saving
8. Integration of energy storage and renewable energy within the sector

RAIN - Railway Inspector

For 2017, the RAIN -Railway Inspector project is planned, consisting of the design, manufacture and commissioning of RAIN (Railway Inspector), an **autonomous vehicle** capable of listening to multiple elements of a railway line and its environment to guarantee safety in operation, with the ability to move at high speeds up to the auscultation zone, or at low speed for data collection.

This project also raises the possibility of leaving the track in case of an emergency and, in case of detecting any anomaly that prevents the circulation of trains in a certain section, RAIN could be sent to the risk area and record the necessary information to diagnose the problem from a remote operation centre. Likewise, it contemplates the possibility of taking image and video in real time for a quick diagnosis of the anomaly. In addition, the vehicle will be able to act as a inspection train in normal operating situations, on-site rethinking or any other functionality required to record as many parameters as necessary, reducing time and cost of these habitual measures, while also rebuilding a 3D area to develop a detailed analysis.