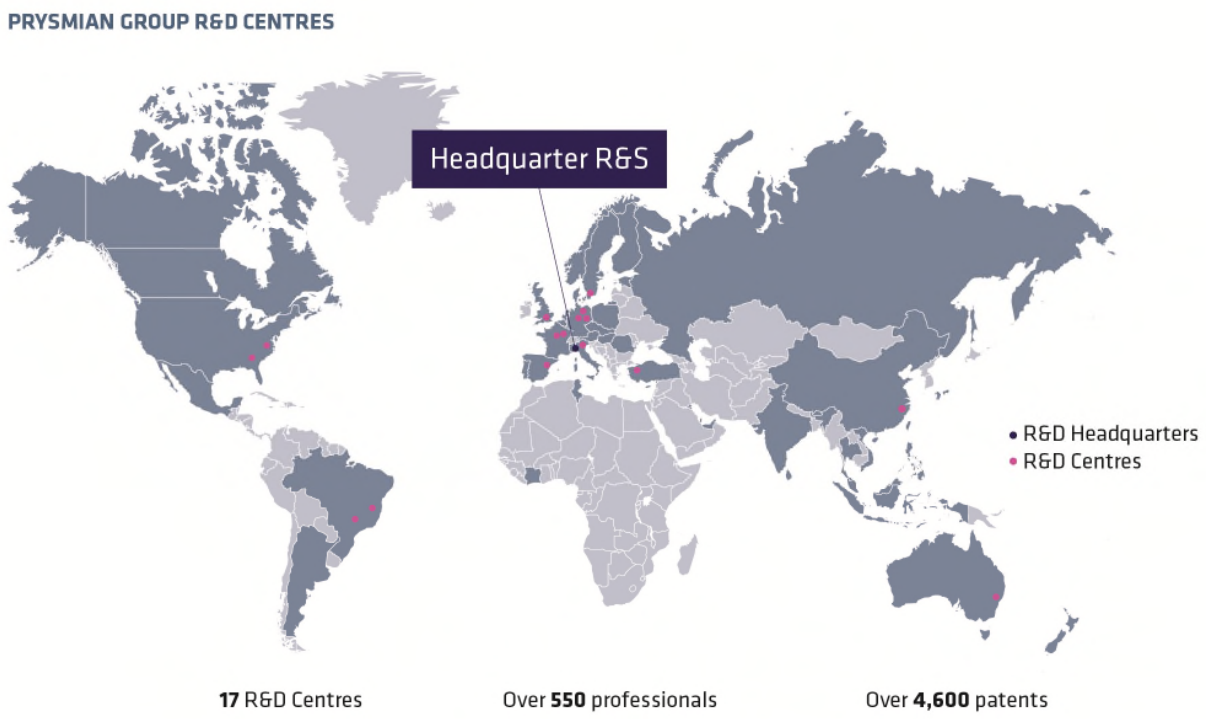
RESEARCH AND DEVELOPMENT

With 17 Centres of Excellence, over 550 professionals, more than 4,600 patents and partnerships with universities and research centres in many countries, the Prysmian Group intends to be an innovation leader.



Prysmian Group has always given key strategic importance to Research & Development to maintain its market leadership, with the intent of differentiating itself and of providing its customers with technologically innovative solutions at increasingly competitive costs. The Group currently has 17 Centres of Excellence, with headquarters in Milan, and over 550 qualified professionals. The Prysmian Group intends to be industry leader in R&D, with more than 4,600 patents granted or filed and partnerships with major universities and research centres in many countries where it is present, like:

- Politecnico di Milano (MIP) - Italy
- 'Giulio Natta' Department of Chemistry, Materials and Chemical Engineering, MIP - Italy
- University of Milano-Bicocca - Italy
- Department of Information Engineering, University of Padua - Italy
- Electrical, Electronics and Telecommunication Engineering and Naval Architecture Department, University of Genoa - Italy
- National Electrical Energy Research & Application Center (NEETRAC) of the Georgia Institute of Technology - USA

- University of South Carolina - USA
- Centro di Pesquisa e Desenvolvimento em Telecomunicacoes (CPqD) - Brazil
- University of São Paulo (USP) - Brazil
- Universitat Politecnica de Catalunya - Spain
- Shanghai TICW - China

Resources amounting to approximately Euro 84 million were employed Research, Development and Innovation in 2016, broadly in line with the previous year and confirming the Group's steadfast commitment to and focus on sustainable long-term growth.

The main achievements in the Energy business during the year are described below.

- Submarine Systems
  In the area of cables for submarine systems, the 220 kV cable with 1200 mm² copper conductors for the 50 Hz project has obtained approval and most of its production has been successfully completed. In the AC cables area, a new-design single-core cable with fibre optics integrated in the armouring has been installed and commissioned for the submarine project in the Philippines. Work has continued to develop new techniques for conductor diameter splicing to allow large aluminium conductors to be gathered together in conductor platforms and to splice conductors with different cross-sections and different metallic materials for DC systems operating at 320 kV and AC systems at 220 kV. The development activities also include long-term trials that will end in the next few years. The development of systems for deep water installation has seen a prototype with optimised double armouring completed and tested internally, confirming the feasibility of installation at depths of up to 3000 metres. In the area of MI cables (Mass Impregnated paper-insulated), besides work to improve the remediation plan for the WesternLink project and its 600 kV HVDC cables insulated using PPL technology, the first phase of research has been completed into alternative materials and optimisation of the design and manufacturing process, achieving internal qualification at 700 kV. With reference to the 600 kV extruded cable project, the first positive results have been obtained using XLPE and P-Laser technologies. Feasibility studies have been performed for the development of long-distance EHV AC submarine systems (up to 200 Km), and for the monitoring of partial discharges by long-distance EHV, AC or DC submarine systems using Prycam Gate technology. A project has been approved and initiated to implement and manufacture leadless submarine systems, using welded copper sheaths, at the Pikkala plant in Finland. This product will go into production at the end of 2017.

- Extra High Voltage (EHV) Underground Systems)
  In the field of product development of EHV underground cables, development and type tests have been completed for the new 600 kV HVDC system and certified according to CIGRE TB496. This important achievement is a milestone for cable power transmission and allows a single circuit to carry over 2.6 GW in power, according to the type of installation, which is more than twice the capability of the 320 kV

systems currently in service. The Prysmian Group's know-how in materials, technology and electrical testing has been decisive in achieving this result. HVDC systems are the preferred choice for carrying high voltage power over long distances via insulated cable. Prysmian precedents in the field of HVDC transmission using extruded cables include 200 kV submarine interconnectors like the Transbay cable, the 320 kV power lines in the North Sea and the 320 kV underground interconnectors between France and Spain, and between France and Italy. The EHVDC project will now move on to the development of a totally new solid-insulated cable system and pre-printed accessories, as well as to the development of non-conventional splicing technology. Still in the area of EHV, development has been completed of three extruded cable prototypes containing 2500 and 3500 mm² cross-section Milliken copper conductors and longitudinally welded aluminium sheaths. The two 2500 mm² prototypes have been insulated with alternative materials to those currently in use. The test circuits have been mounted at the IPH laboratories (CESI) in Berlin and the qualification tests according to the IEC62067 standard are about to start. Development of EHV cables with large cross-section aluminium conductors (3000 and 3500 mm²) has also been completed and the prototypes are now undergoing official qualification tests according to the IEC62067 standard. The prototypes with longitudinally welded aluminium sheaths also contain optical fibre for on-line measurement of cable operating temperature.

- T&I. The focus of R&D for the T&I business has concentrated on the following areas:
  - SAFETY: CPR - Construction Products Regulation is entering a decisive phase. The harmonised European standard EN 50575 became effective on 10 June 2016, followed by a one-year transition period before this standard becomes mandatory throughout the European Union (on 1 July 2017). During this transition period both old products, complying with current national legislation, and new ones, complying with the new European directive, can be sold but from 1 July 2017, only the latter will be authorised for sale. The Prysmian companies that operate in European countries affected by the new regulation are making huge efforts to make sure the characteristics of its product portfolio (cables intended for permanent indoor installation) comply with the performance classes adopted by each individual nation. On top of development activities are certification ones, since the new regulation lays down very strict criteria for testing and approval of CPR compliant cables. The results achieved in 2016 are encouraging as far as the deadline of 1 July 2017 is concerned when the CPR will become effective throughout the European Union.
  - SUSTAINABILITY: CFP - Work has started to develop and apply a tool that will allow the environmental impact of Prysmian products to be assessed, albeit partially, in terms of their carbon footprint (CO2 equivalent) and recyclability. These parameters will be assessed on the basis of standard design data for each product (BOM and routing) just for the phase of the cable's life when it is under the manufacturer's control, or subject to the latter's influence. The intention is for widespread application of this tool to the Group's products. A pilot project is planned for 2017 and across-the-board application in 2018.
  - NEW PRODUCT INDICATOR: a computer model has been developed to monitor and quantify the impact of new product development in all of Prysmian's operating units. This model, which classifies

new products in three categories (Innovation, Product Development and Technology Transfer), is used to assess economic performance, sales and contribution margin over a three-year lifespan commencing with the new product's first sale.

- Oil & Gas
- The O&G business has focused on two main areas this year. The first is the development of solutions to increase the safety of cables used in Gas projects (ex LNG). Extensive work has been done on evaluating and improving resistance to gas flow of cables used to connect potentially explosive areas (Zone 0) with lower risk areas (Zone 1 and 2), or with the outside world. Prysmian Group offers customers not just technical solutions, but also support in how to understand and evaluate the impact of the cables and of the overall system (including accessories) used in these applications.
- The other area in which development activities have been concentrated is that of cables for Electrical Submersible Pumps (ESP). Prysmian Group is currently developing a new generation of products to cover a wide range of applications (for more or less severe operating conditions), with associated test procedures accelerated and on a real scale, as well as hybrid Downhole Technology high corrosion-resistant solutions for high temperatures, a totally new concept in this market sector.

- OEM

  In the area of cables for special OEM (Original Equipment Manufacturer) applications, the multitude of applications and the breadth of the product portfolio implies a large number of development projects for the various markets and customers. Among these the most important in the different fields of application have been:
  - CRANE - Protolon high-speed reeling cables able to withstand high mechanical stress, developed using Airbag technology. Spreaderflex cables (for winding drums) for arctic temperatures (-40°C).
  - MINING - Continued work to develop and produce SHD-GC and GGC cables for the North American market.
  - ROLLING STOCK - Approval of cable product families for Cat 5e and Databus 120 Ω and 105 Ω transmission, in accordance with the strict European installation standard EN45545.
  - RAILWAY - Flexible power cables for air-conditioning in stationary carriages. Cables for axle counters in accordance with the specifications of the Australian and American markets. Copper and steel conductors on heavy cables are becoming more frequent in this sector to limit the phenomenon of line theft.
  - NUCLEAR – Completion of internal approvals to extend the useful life of VVER cables to 60 years, as required by the latest updated specifications in this industry.
  - WIND POWER - Development of Medium Voltage twist-resistant cables with reduced diameter (-16%) for the customer Vestas.
  - DEFENCE - 36-fibre cables for military ships in the North American market.

- INFRASTRUCTURE - Development of products for airport runway lighting according to the American standard FAA L-824, but for the Chinese market. In addition, 400 Hz connectorised cables have been developed for aircraft ground power supply.

- Innovation in 2016
  - PRYCAM - the development of Pry-cam® Gate was completed in 2016; this new patented technology automatically measures the time elapsing between two partial discharge pulses, thereby determining with absolute certainty whether an accessory, or a length of cable, is affected by partial discharges without having to use any kind of expertise or artificial intelligence algorithms. A second important innovation at an advanced stage of development is Pry-cam® Cable, a hybrid cable intended solely for sensing. In particular, the idea is to combine in a single cable an energy section to power partial discharge Pry-cam® Grids monitoring systems usually installed in joint holes, a FO section for data transmission, and two FO sections for DTS temperature monitoring and DAS acoustic monitoring. In 2017 it is planned to install around 200 km of this cable, seen as the embryo of another new generation of integrated monitoring systems being developed and due to come out in 2017.
  - An on-line short-circuit current calculation application has been made available to all the Group's engineers. After a trial period of about one year, allowing the calculation procedures to be standardised and validated within the Prysmian Group, the on-line calculation application is now being used by all designers as the official short-circuit current calculation tool (http: //psp.prysmian.gph.local/Highlights/SCC_tool.aspx).
  - Development of numerical models to simulate magnetic phenomena and calculate the related losses in the armouring and the metal sheaths of three-core armoured submarine cables in a "contralay" configuration.
  - Development of a numerical model to calculate temperature transients in long-length submarine cables, when stowed on board cable-laying ships. The model has been used for detailed design of the cable heating system, in order to keep the cable at a suitable temperature during handling and transportation even at low temperatures.
  - Integration between the RTTR Lios temperature monitoring system and Prymon cable monitoring systems. First Prysmian proprietary software project.
  - Technological Development.

  In the area of technology development and improvement, the project has continued to optimise medium and high voltage conductors, by reducing cable weight and diameter in accordance with regulatory requirements for direct current resistance. This year's work focused on aluminium, reflecting the production mix in 2016. Weight savings of around 1-1.5% were achieved and the grade of aluminium cut, from 16 to 12, with an estimated saving on purchase price and materials management of around Euro 0.7 million.

  IEC62067 qualification was completed in the first quarter of 2016 for EHV 330 kV 2500 mm² copper and aluminium cables at the Rybinsk plant (Russia). The Rybinsk plant also saw the start of production of

EHV cables with small-section copper conductors (up to 400 mm²). The longitudinal welding line for aluminium laminated sheaths was inaugurated at the Mudanya plant in Turkey and a prototype produced for qualification of the technology according to Cigré TB446. HV cables with a Solidal conductor from 630 to 1200 mm² went into production at the Pignataro plant. Type Test IEC62067 was completed for the 245 kV 2500 mm² copper prototype, manufactured on the new VCV2 line at the Abbeville plant. The HV business unit carried on a Best Practices HV project involving technical visits and technological assistance to share the best practices used by the Group for selecting raw materials, design and technology. With regard to the technological development of specialty and low voltage cables, work continued on the project to standardise materials and NEK606 technologies.

Achievements in the Telecom business are described below.

- Optical Fibre

  The fibre manufacturing process has been further developed at the factories in the US and Brazil, which can now produce optical fibres with greater autonomy. Other investments have concerned improvements in product and process quality in some factories, resulting in a significant reduction in production costs. Several factories have been equipped to produce BendBrightXS fibres, which have much better micro- and macro-bending performances than competitor products. Their bend performance, even with small diameters, means these fibres can be used in the manufacture of smaller cables used in the different layers of FTTH (Fibre To The Home) networks.

  In the area of multimode fibre, the OM5 standard has been adopted since September, confirming the Prysmian Group's leadership in this field. This fibre is capable of transmitting 4 channels of 25 Gbit/s, or even 50 Gbit/s, with a wavelength division of between 850 nm and 950 nm. This fibre, adopted by the international standard-setting committees in record time, will help reduce the number of 40, 100 and 400 Gbit/s cables used in data centres.

  Another important innovation has been "Few Mode" technology. In the same way that digital information is encoded and travels on a single mode of transmission in "Single Mode" fibres, "Few Mode" fibres use a few such modes. The first 4-mode fibres are about to be tested in academic laboratories and small companies. These have been successfully tested in some of the preliminary trials with different partners with reference to data transmission (100 Gbit/s systems with 10 Gbit/s signals transmitted at 1310 nm on each mode) and to access networks (PON, Passive Optical Networks, at 1310 nm).

- Optical Cables.

  In the field of optical cables, work has focused on increasing fibre density, by producing high-fibre-count cables, on reducing cable sections, on making them easier to use and on reducing total cost of ownership. This applies to the various types of Flextube, Loose and Ribbon cables:

  - FLEXTUBE: The offer of Flextube cables has been extended to different markets, and their manufacture to several factories. An overhead version (ADSS), able to operate in tough environmental conditions, has also gone into production. The compactness of its structure is particularly suited to the development of high-fibre-count cables. Cables containing 2112 fibres

have been successfully developed and installed, and work is continuing with the goal of achieving 4000-fibre cables.

- MULTILOOSE: development work is mainly focused on reducing cable diameter to maximise the amount of fibre that can be blown into the designated underground ducts. A complete range of products from 12 to 144 fibres, with 1.35 mm tube diameter, is now available. In these cases, the high level of stress to which the fibres are subjected requires them to be selected from higher performance ones within our product portfolio. In the future we expect, by working with appropriate materials, to achieve a higher fibre density of 6 fibres/mm^2.
- RIBBON: The data centre product portfolio has been expanded with the addition of 864 fibre and 1728 fibre products (UL Riser Rated Indoor Outdoor cables), which reduce costs and complexity within hyperscale data centres. The Group's "dry" cable technology has also been certified for high-salinity environments.

Listed below are some examples of initiatives to simplify the use and installation of cables:

- Retractanet cables: this family has been expanded with the introduction of cables with limited "extractability" (up to 30 m). Specific versions of these cables are available with different fibre capacities for short lengths such as 1–2 metres.
- "Dry" cable technology has also been extended to Multiloose cables with tube diameters greater than 1.9 mm. Work is continuing to extend this technology to Flextube cables as well.
- A "dry" version (Dry ADSS) overhead cable has been introduced, with lower installation costs but the same high standard of reliability.
- Also very promising is the "overblowing" technology used in the UK, where ducts are extremely congested; the technology allows cables to be installed, by blowing, in the free space between the existing cable and the duct walls. The solution has received considerable interest and could be very attractive for many markets, also because of the ability to offer correctly sized cables and related joints.
- New lines of hybrid products have been presented, like the Power Fibre Cables for Small Cell 4G/5G antenna applications, or Super Radiation Resistance Fibre Cables for applications in the nuclear industry.

- As far as rationalisation of production is concerned, the development of Flextube technology has been completed at the Slatina factory. It is now possible to manufacture Microcables in most of the Group's factories. The main focus of attention has been on increasing production capacity at the Romanian factory in Slatina. This has involved the introduction of new machinery and development of products able to cover the majority of European markets. The product range includes Loosetube, standard and nano cables, Flextube and overhead (ADSS) cables.

- Connectivity

  In terms of connectivity, Prysmian has continued to develop new accessories for FTTH use (ultra broadband access networks). The focus has been on cabinets, with the development of optical distribution frames (MDFs), joints for splicing cables and termination solutions involving wall-mounted cabinets with pre-terminated cables for homes and modular solutions at the point of building access. The LMJ (Large Multi-Function Joint), originally developed for BT in 2015, was launched globally in April 2016. A number of new components have been designed to complement the range of multi–function joints (Compact Joint - CMJ, Medium Joint - MMJ and LMJ) and to be suitable for global markets. The new components include cable lead-in units, to expand the cable range from 20 to 23 mm, multiple lead-in units, for a maximum of 8 cables, new splice trays to accommodate the shrinkable 2.2 mm joint caps (common in many markets), new components to house optical splitters, and splice holders for up to 36 fibres. A small splice has been designed and launched for small repairs involving a limited number of fibres (up to 24 fibres).

  A new range of termination boxes (Customer Termination Box - CTB) has been developed for the French market - CTB MK3 (4FO), CTB hybrid (optical/copper) and DTIO (for installation within electrical panels) - in particular for Orange France. The products are generally supplied to the customer with a length of pre-installed cable. This is why these products have been produced in Tunisia at the connectorisation factory in Menzel.

  Some new solutions - using PBO - are being developed to simplify the range of reinforced connectors. Currently the use of reinforced connectors is growing, but they are expensive and are covered by patents. The purpose of the PBO is to have a standard connection on the end of a drop cable, with a component that seals and blocks it on the junction box. A number of solutions have been designed and are currently being evaluated for production in 2017.

  In addition, again for the French market, Prysmian is currently supplying a range of modular metal trays for splicing/termination. Constant pressure on costs means that the Group is transitioning to plastic versions, currently in the design stage.

  Further developments for the range of optical splitter building termination boxes have been completed for the Italian market. Mould construction is underway for ROE16 and ROE32 wall-mounted and post-mounted versions. The boxes can be used internally or externally, to connect customers in multi-dwelling units, with or without optical splitters (GPON or Point to Point). These products will enter production early in 2017, and are expected to be available to the market in about May 2017.

  Other developments include a new SRS (Subrack System) modular tray that will increase splice/termination capacity from 48 to 144 fibres in the same space (1U). The module designs have been completed and mould construction was started in December 2016. The product should be available to the market in May 2017.

- OPGW, special optical and submarine cables

  In terms of OPGW cables, research has concentrated on developing the product portfolio of steel tubes for the high-fibre-count segment: central tube structures (1 x 96 fibres), and multi-loose structures (3 x 48 fibres). New steel tubes for OPGW applications have also been developed and qualified.

In the area of submarine cables, Prysmian has taken an important step towards returning to this market, by developing and qualifying a single-armoured cable with up to 48 fibres.

- MMS - Multimedia Solutions
  Improvements have been made to the discontinuous metal ribbon-based Cat.6A U/UTP solution for structured cabling with copper cables.
  Interesting developments have taken place in remote-powering technology (eg. Power over Ethernet, PoE), with the launch of a family of cables optimised for longer connections than standard in the cat. 7 family of cables, which supply both power and data, to connect devices such as wireless access points or surveillance cameras. Cat. 7 residential cables are now available in a reduced diameter version suitable for installation in small spaces.
  In the area of building wiring, a complete family of optical cables using Flextube technology has also been developed.
  Additional hybrid optical/copper cabling solutions have been developed for data centres. In collaboration with an industrial partner, the first fully cat 8.2 connection has been qualified, allowing 40 Gbit/s transmission over a 30 m long copper channel, now available on the market.
  High speed MM fibre cables have also been developed (40/100 Gb/s); these cables are based on 12-fibre modules, to which multi-fibre MPO connectors are applied. These modules can either be of a Flextube kind, or 3 mm micro-cables, assembled to cover the 72 to 144 fibre range. These cable families are available in a version with low smoke and toxic gas emissions and in a Plenum/Riser version.
  Considerable energy is being devoted to the adoption of the Construction Products Regulation (CPR). Most existing products will be classified according to the new fire-performance classes. New solutions are also being studied and developed for classification in the very highest categories.
  As part of steps to rationalise production, the new factory in Prešov (Slovakia) has been further expanded. Production capacity has also been boosted with the acquisition of a data cables factory in Neustadt (Germany).

As for materials, Prysmian is intensifying exploratory research in this area due to the strategic role they play in cable and accessories technology. The main achievements in the year are described below:

- Joints created in labs using compounds with variable resistivity have performed well. Full-size joints have now been made for testing electrically in a circuit, with these tests due to take place next year.
- New high permittivity compounds have been made for both joints and terminations, resulting in the qualification of new accessories in class 36kV.
- Prysmian is evaluating the use of graphene and nanotubes in polyethylene sheaths to improve water resistance and conductivity respectively.
- Substances have been identified that can absorb water without releasing it. Long-term testing is in progress to identify all the parameters of water absorption of these substances dispersed in polyethylene. These two studies could identify substances capable of replacing metallic sheaths.

- The Group is evaluating the use of carbon nanotubes even in low voltage insulation to test their contribution, if any, to flame non-propagation.
- Work has been completed with an American organisation to identify new composite armouring systems for submarine cables, umbilicals and flexible pipes, resulting in the delineation of a possible new cable design. Experimentation on light armouring for submarine cables continues and optimal designs for new cable structures are being identified. A project has also been started with an external supplier for the joint development of a new tensioner.
- A particular type of polymer has been identified and synthesised that is capable of absorbing methane. The method that allows absorption efficiency and effectiveness to be assessed at both room temperature and at 70°C has been optimised. Sufficient quantities are now being made for an industrial test that will confirm the good in-lab performance.
- A number of characterisation techniques have been defined to improve the understanding of how materials behave in cables (type of ash of fire-resistant materials for cables, water resistance of paper and PPL at various temperatures, simulation of wrapping and PPL insulation impregnation, water absorption efficiency of hydro-expanding tapes).
- Research to develop oil-resistant polymers, starting with thermoplastic and cross-linkable materials, is still in progress. Associated with this research is: the development of a new cross-linking method with similar characteristics to the process using silanes but with better cross-link density.
- New Afumex compounds to achieve high CPR classifications have been put into production and entered into regular use, proving highly flame resistant as expected; one of these also shows an improvement in the processability.
- Prototypes cables have been made in Australia, UK and Italy with ceramicising compounds, whose initial evaluations have shown interesting fire-resistant properties. Testing is not yet complete: more complete results are expected during the year.
- Using a test system designed and developed by Prysmian, it has been possible to demonstrate higher resistance to corrosion in an aggressive environment (simultaneous presence of salt water, H2S and CO2) by aluminium coating than by zinc coating.
- The use of tetrazoles as aluminium corrosion inhibitors has proved a viable alternative to current methods. A quantity at least 200 g is being synthesised to allow it to be evaluated industrially. Suitable methods are also being studied for applying these inhibitors to aluminium wire.
- Rationalisations:
  - Alternative materials continue to be approved throughout the Group to eliminate sole suppliers, especially those of great commercial or technical importance. At times, this requires long laboratory experimentation and collaboration with suppliers.
  - The rationalisation of raw material codes for cables has been completed.
  - A program has been created that will show raw material specifications as soon as the material code is activated. This program will also allow the Group to have all its specifications in a single place, including for research purposes.

- The cataloguing program for compound technical specifications and associated search engine, allowing users to find compounds by entering characteristics, has been completed and is in the process of being ordered.

- DTC - Design To Cost

  Considerable attention continued to be paid this year to reducing costs. In fact, there are more than 1,100 DTC projects, which have helped continuously optimise materials and cable design. All these R&D activities have resulted in further savings of several million euros in 2016, allowing the Group to remain constantly competitive.

Intellectual property rights

Protecting its portfolio of patents and trademarks is a key part of the Group's business, particularly in view of its strategy of growth in high-tech market segments. In particular, the Group's intense R&D activities, in the Energy Projects, Energy Products, Oil & Gas and Telecom operating segments, have allowed it to continue to add to its patent portfolio during the year, especially in high-tech and higher value-added areas, in order to support its major investment in these areas in recent years and to protect the related businesses, both now and in the future.

As at 31 December 2016, the Prysmian Group had 4,651 patents and pending patent applications throughout the world, covering 749 inventions (of which 210 in the Energy Projects and Energy Products segments, 13 in the Oil&Gas segment and 526 in the Telecom segment). During 2016, 31 new patent applications were filed, of which 20 in the Telecom area and 11 in the Energy area, and 183 patents were granted after examination, of which 47 by the European Patent Office (EPO) and 33 in the United States.

The most important products, typically distinguished by particular characteristics or a specific production process, are protected by trademarks that allow them to be identified and guarantee their uniqueness. As at 31 December 2016, the Prysmian Group owned 570 trademarks, corresponding to 2,597 trademark registrations in its countries of operation, covering the names and identifying symbols of its companies, activities, products and product lines.