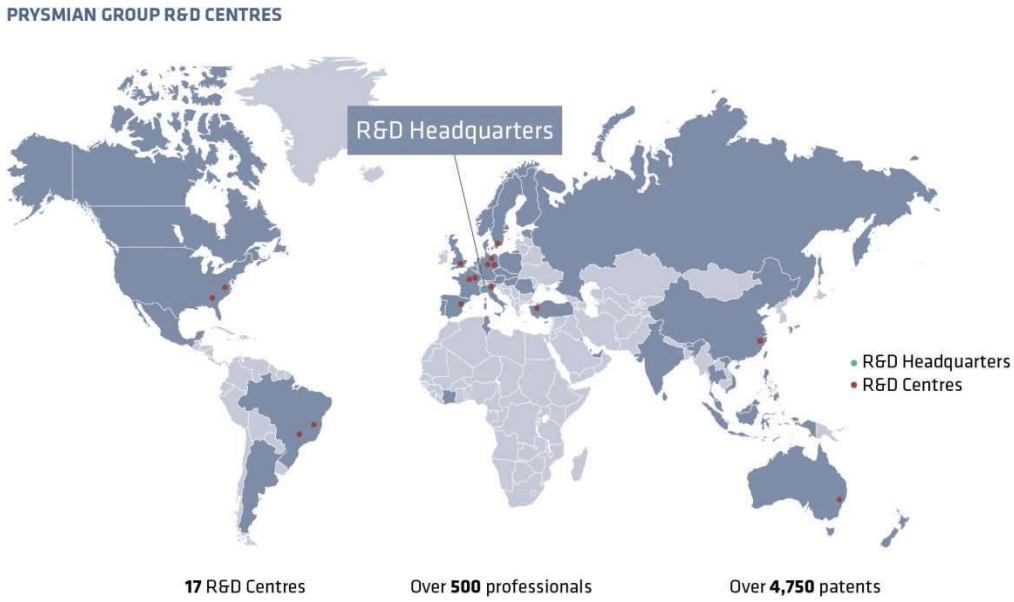
RESEARCH AND DEVELOPMENT

With 17 Centres of Excellence, over 530 professionals, more than 4,750 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 aim 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 530 skilled professionals. With more than 4,750 patents granted or filed and partnerships with major universities and research centres in many countries where it is present, the Prysmian Group intends to be industry leader in R&D. The Group's spending on Research, Development and Innovation amounted to approximately Euro 73 million in 2015, broadly in line with the previous year and confirming its steadfast commitment to and focus on sustainable long-term growth.

Prysmian Group R&D Centres



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

Submarine Systems. In the area of cables for submarine systems, work continued to expand the range of three-core alternate current (AC) cables. In addition to the official qualification of the 50 Hz cable with 1200 mm² 220 kV copper conductors, two new types of three-core cables were developed with double steel-stud armouring for installation at medium-high depths of nearly 1,000 metres. Still in the AC cables area, a new single-core cable design with optical cable integrated in the armouring was developed and qualified for the submarine project in the Philippines. In addition, special repair methods, suitable for the presence of optical

cables in the armouring, were designed and qualified. New techniques of conductor diameter jointing were developed to collect large aluminium conductors together in conductor platforms and to join conductors of different cross-sections and materials. These technologies can be applied to both AC cables and direct current (DC) cables and allow a more efficient system design and significant reduction in costs. The first prototype with alternative armouring serving the development of cables for installation at great depths underwent full mechanical testing, while a second prototype was designed for installation at depths of more than 2,500 metres. The latter prototype will use non-metallic reinforcing elements that were optimised and developed during the year. In the area of MI cables (Mass Impregnated paper-insulated), work continued to improve the recovery plan for the WesternLink project and its 600 kV HVDC cables insulated using PPL technology, and research began into alternative materials and into optimising the design and manufacturing process to achieve a significant increase in operating voltage compared with the current level of 600 kV. With reference to the 525 kV extruded cable project, work on developing a flexible coupling point reported its first positive results.

Extra High Voltage (EHV) Underground Systems. In the field of product development of EHV underground cables, development and type tests were completed for the new 525 kV HVDC system and certified according to CIGRE TB496. This important achievement is a milestone for cable power transmission, allowing a single circuit to carry over 2.6 GW in power, according to the type of installation, which is more than twice as much as can be carried by 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 submarine interconnectors like the 200 kV 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 continue with the development of a totally new system comprising solid-insulated cable and pre-printed accessories, as well as the development of non-conventional jointing technology. Also in the area of EHV product development, three extruded cable prototypes were completed with Milliken copper conductors with 2500 and 3500 mm² cross sections and a longitudinally welded aluminium sheath. 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 in the process of being initiated. Development of EHV cables with large cross-section aluminium conductors (3000 and 3500 mm²) was also completed and the prototypes are now undergoing official qualification tests according to the IEC62067 standard. Optical fibre has been inserted in these prototypes, with longitudinally welded aluminium sheaths, for on-line measurement of cable operating temperature.

*Technology Development and Transfer***.** In the area of technology development and improvement, a project is in progress to optimise medium and high voltage conductors, by reducing cable weight and diameter in accordance with regulatory requirements for direct current resistance. Weight savings of around 2-3% have been achieved for the conductor cross-sections modified to date. Still in this area, some new large cross-

section Milliken copper conductors have been developed with an improved AC resistance coefficient thanks to a reduction in the "skin effect", achieved by same-direction stranding of the sectors and oxidation of the wires.
With reference to technology transfer, prototype EHV cables went into production at the Rybinsk plant (Russia) with the manufacture of 330 kV 2500 mm² copper cables, while industrial production started for 110 kV 1200 mm² and 1600 mm² copper cable. Work continued on starting up and qualifying the factory in Slatina (Romania) for the production of 110 kV 630 mm² copper prototypes and 150 kV 1000 mm² aluminium prototypes. Qualification tests according to VDE standards are in progress for the first prototype and according to IEC standards for the second. The VCV2 line at the Abbeville plant started operating with the production of two 245 kV 2500 mm² copper prototypes. The type tests are in progress. The HV business unit started a Best Practices HV project to share, through technical visits and technological assistance, the best practices used by the Group for selecting raw materials, design and technology.
As regards technology transfer involving special and low voltage cables, NEK606 technology was successfully transferred to operating companies in China and Brazil, while work was started on the project to standardise raw materials and technologies. LSOH (Low Smoke Zero Halogen) technology was upgraded at the plants in Melaka (Malaysia) and Schwerin (Germany).

*P-Laser Technology***.** Development of Energy cable P-Laser technology has continued with particular intensity for HVDC applications; the thermoplastic nature of P-Laser insulation significantly improves performance by such applications thanks to greater chemical stability and the absence in HPTE (High-performance Polypropylene Thermoplastic Elastomers) insulation of cross-linking by-products. The 320 kV DC system successfully completed its qualification process. The complete loop of terminals and joints for underground installation passed pre-qualification tests according to the requirements of CIGRE TB 496 for VSC systems with a 90°C conductor temperature, 20°C above the temperature at which standard XLPE (Cross-Linked Poly-Ethylene) insulated systems are normally qualified. Furthermore, the same cable was subjected to a narrow but particularly significant series of tests (defined with an important TSO that operates in the HVDC field), designed to evaluate the system at a 350 kV voltage with polarity reversals, typical of LCC systems. The tests, conducted in this case at a conductor temperature of 70°C, demonstrated the HPTE insulated system's excellent performance even with rapid polarity reversals, when the system is required to rapidly remove the locally accumulated space charges; this situation is considered to be particularly critical for standard XLPE insulated systems, given the presence of the cross-linking by-products that act as traps for the space charges. Based on the promising results described above, work has started on developing and applying P-Laser materials to the 525 kV load class, which will be the next technological frontier for long distance DC connections. With reference to distribution systems, P-Laser cable has been qualified for certain utilities operating in Northern Europe (Finland), a region in which overhead lines are actively being replaced with buried lines. The superior performance of the P-Laser system in terms of reliability and thermal rating, allow local operators to significantly improve the quality of service provided. The P-Laser cable design for application in Finland has been adapted to the requirements of local utilities, in particular its defensive properties against the passage of water through the cable's various constituent parts.

In the Netherlands the P-Laser system completed its qualification for the 50 kV load class, representing a significant portion of the country's power transmission network.

T&I. The focus of R&D for the T&I business is concentrated on 4 main strategic drivers:

1. SAFETY: CPR (Construction Products Regulation), with intensive testing activities for the market launch of CE marked products from July 2017; the introduction of the new Afumex+ cable in Argentina with improved design and performance; the extension of the portfolio and certifications of fire-resistant low-smoke cables for the Middle East, ASEAN and Nordics;
2. QUALITY: extension of the "Attention! All cables are not the same" initiatives to improve product safety and usage through continuous benchmarking with competitors, direct contact with installers and extended educational campaigns. This includes the new initiative by Prysmian Turkey focused on cables for renewables, new demonstration equipment and the start of the testing of competitor cables in preparation for the campaign's 2015/16 launch in Australia, Spain, UK, Italy and the Netherlands;
3. SUSTAINABILITY: application of Brazil's Afumex Green technology to 1 kV cables and launch of the new "building wire Green Dream" in China;
4. TIME SAVING: expansion of the range of "Easy-to-Install" products in France with the new BW 4fil and countrywide activities to improve flexibility and ease of peeling that have already received a strong market response.

*Oil & Gas***.** One of the key R & D initiatives for the Oil & Gas business has been the harmonisation of the more important products for the principal business segments (upstream topside & downstream). In the case of upstream topside applications (drilling platforms), some countries, especially China and Brazil, have significantly increased their demands for localisation. This is why we are developing a comprehensive harmonised portfolio of offshore cables that meet NEK606 standards. The resulting global product line will be able to simplify framework agreements, make the management of production more flexible and improve inventory management including through the use of distribution centres. Product harmonisation for the Onshore Downstream business (refining and petrochemical plants) also continued in 2015, with the design and implementation of a comprehensive approach to managing macro projects using centralised designs, but based on a multi-sourcing method of production. This approach has required the transfer of high-end technology between the various production units and the development of new high-performance products. The most significant examples are the "Arctic Onshore" low-temperature technology used in the Yamal LNG project, and the series of advanced solutions for medium and low voltage fire-resistant cables, as well as instrumentation and control cables, tailored to the specifications of each project.
With reference to market niches for highly specialised products, new-generation advanced materials and designs have been launched for the Motor Lead and Flat ESP cables which are extra resistant to corrosion from aggressive chemicals and high temperatures. In addition, the area of onshore and offshore drilling systems has seen continued development of customised high performance solutions using relevant procedures and specific testing apparatus to ensure their reliability. The Prysmian Group owns the BOSTDRIVE™ high-end technology specially developed for these systems.

Products have also been developed for TADS (Tender Assisted Drilling Units), used in shallow water. These consist of an optimised package of cables, stations and mechanical subsystems for both static and dynamic applications for power, instrumentation, control and telecommunication connections between the tender barge and drilling equipment set. This subsystem is called Bridle.
Lastly, the portfolio of high-performance fire-resistant products has been extended with the addition of a new and unique design developed to resist jet fires (as required for offshore applications).The new family of products called BFOU JF (Jet Fire) has passed ISO 22899-1 testing and has been certified by DNV for a 250 kW/m² jet fire with temperatures exceeding 1200° C for 30 minutes (time needed to complete all the safety procedures in the event of fire).

*OEM***.** In the area of cables for special OEM (Original Equipment Manufacturer) applications, the project to unify marine cables with the TEMAR family was completed thanks to the creation of a global Prysmian catalogue for this sector. Certifications are in progress with the different certifying bodies for the plants concerned.
Cables for nuclear power plants have completed joint type test approval with France and Germany in connection the process to qualify the entire range with AREVA initiated in the previous year. An international technical team has been created for this field of application to manage the extension of existing approvals to new plants and to manage new product development in accordance with AP1000 standards.
In the area of renewable energy cables, products have been developed and approved in accordance with the new European standards (EN).
In the mining segment, a new solution has been devised for single point suspension cables, in response to market demand in Australia, involving modification of the cables produced in China and ASEAN and of the related self-supporting suspension system.
Research has continued into alternative materials such as CCA (Copper Clad Aluminium) for use in flexible cables. In the area of fire-resistant cables, approval has been obtained for the cabling system according to UL standards for the American market. Prysmian is the only approved manufacturer of non-metal clad traditional cables under this highly selective standard. Two international teams were also set up to optimise and unify the design of fire-resistant cables that now offer a variety of different solutions.

*PRYCAM***.** With regard to the development of Prycam technology, some important innovations were developed in 2015 that will lead to the birth of two new products: the first is the development of the *Pry-Cam® Gate* prototype; this new patented technology consists of electronics for automatically measuring the time elapsing between two partial discharge pulses. This innovation will make it possible to install a system that can determine 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. The second major innovation is the *Pry-Cam® Brain;* this system involves the creation of a "smart" search engine that, using nearly 100,000 measurements performed around the world with Prycam technology, processes the data and helps operators to produce a diagnosis as objective and reliable as possible, helping them to separate the discharge source and to identify it. This technology will also be used for automatic generation of alarms in

monitoring systems and will be included, in a simplified version, in the control software of the *Pry-Cam*® *Portable* system.

Achievements in the Telecom business are described below.

*Optical Fibre***.** In the field of single-mode optical fibre, several of the Group's factories were made ready for full production of bend-resistant BendBrightXS fibres (BBXS), which have much better micro- and macro-bending performances than competitor products. Its bending performance and small diameter allow this fibre to be used in the manufacture of smaller cables used in the different layers of FTTH (Fibre To The Home) networks. A number of improvements were also made at several factories, leading to a significant reduction in fibre production costs.
In the area of multimode fibre, WideCAP OM4 has confirmed Prysmian Group's leadership in this sector. This fibre is capable of supporting four 25Gb channels or even four 50Gb channels with wavelength-division multiplexing from 850 nm to 950 nm. The international standard-setting committees have adopted this fibre in a record time, which will help reduce the number of 40, 100 and 400 Gb/s cables used within data centres.
Another important innovation was made using "Few Mode" fibre technology. In the same way that digital information is encoded and travels on a single mode of light with single-mode technology, with "Few Mode" technology several individual light modes are able to transmit the digital information. The first 4-LP-Mode fibres are now being tested by academic laboratories and small companies. Preliminary transmission trials with different partners have been successful in the fields of Datacom (100Gb systems with 10G signals transmitted at a 1310 nm wavelength for each single mode) and access networks (PON, Passive Optical Network, at 1310 nm).

*Optical Cables***.** In the field of optical cables, the technology used in the Flextube cable family has proved the most efficient for optimising and reducing the size of high-fibre-count cables. In addition to Flextube micro-module technology, another success factor has been BendBrightXS 200 micron fibre. The 23 mm 1728-fibre cable with 4.2 fibres per mm² already in this family has been joined by a new 2112-fibre version. These products are an excellent solution for use in ducts congested with other cables. A typical field of application is for connections between mega data centres. New types of "nano cables" have also been developed using "micropipe" technology and BendBrightXS 200 micron fibre. A record density of more than 5 fibres per mm² has been achieved in the 96 to 288 fibre cable range. This allows a considerable reduction in the diameter of ducts in which cables are installed using blown technology, resulting in a considerable reduction in space occupied.
Our platform for dry/dry technology has been further expanded with the development of reduced diameter ribbon cables specially for the Australian market, of new series of dry/dry Flextube cables and bufferless pipe cables in South America, of a new 864-fibre central pipe cable based on a 36-fibre ribbon in North America, and 1728-fibre applications for data centres.
These developments reflect the need for ever shorter installation times, thus reducing overall installation costs.

*Connectivity***.** In the connectivity field, Prysmian has continued to develop new accessories for use in FTTH (Fibre to the Home) applications. Of particular importance has been the development of the LMJ (Large Multi-Function Joint) which can connect up to 2688 fibres and uses 24-element trays each. Solutions with pre-terminated cables are now available from our new factory in Tunisia, as well as a new, extremely robust connector for outdoor use.
The extractability of optical elements in solutions such as Verticasa or Retractanet allow shorter installation times thanks to the smaller number of joints and connectors required. The RetractaNet solution has been further developed for aerial applications, and supplemented with different cable and connectivity solutions.

*MMS***.** 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 Power over Ethernet (PoE) technology, with the launch of a family of cables optimised for long connections based on Category type cable to provide both power and data to the connected device. Residential wiring is supported with the new reduced section Cat.7A cables. In the area of internal wiring, a complete range of optical cables based on Flextubes has also been developed.
Cabling solutions using combined copper and optical fibre cables have been further developed for data centres. The first full Cat.8.2 connection offering a 40 Gb/s solution over copper on a 30m channel has been qualified in partnership with an industrial partner and is now available for sale. Multimode optical fibre cables have been developed for high data speeds (40/100 Gb/s); these cables are based on 12-fibre modules terminated with multi-fibre MPO connectors. The optical modules used can be of the micro-module Flextube type or 3 mm micro-cables which are 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.

As regards 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:

- Better performing materials have been found than those at present for the construction of laminates used in EHV submarine cables. The research into these materials has led to the development of new lab methods to evaluate their performance.
- A recipe for a compound with variable resistivity according to the electric field applied has been researched for use in the manufacture of a new type of HVDC joint.
- Basic research has been started to understand the crystallisation of PBT (Poly-Butylen-Terephtalate), with the aim of improving its processability and performance in optical cables.
- Tests on aluminium clad steel armouring for Oil & Gas applications have been successful. This will make it possible to develop a new highly corrosion resistant product.
- Research is being conducted into the possible use of graphene and carbon nanotubes in partnership with many universities and research institutes. In particular, experiments have started on graphene in collaboration with a manufacturer.

- A partnership has been started with an American organisation to define new composite armouring systems for submarine cables, umbilicals and flexible pipes.
- Research has been started to find substances able to absorb water in a stable way without release. The purpose of this research is to construct new barriers in place of metal in telecom and submarine cable production.
- Research has begun to develop oil-resistant polymers, starting with both thermoplastic and cross-linkable materials: this development could bring significant benefits especially for Oil & Gas applications.
- New Afumex compounds have been introduced to replace the previous versions. Work is currently in progress to develop and optimise new high performance recipes for the top CPR classification levels.
- There has been continued research into new recipes for compounds that leave a particularly small volume of ash in the event of fire.
- Research continues into alternative materials for diversifying the supplier base and reducing sole supplier risk as much as possible, especially in the case of key materials in both commercial and technical terms. In some cases, this requires long laboratory experimentation and collaboration with suppliers.

Lastly, work on cost optimisation continued throughout the year. The package of DTC (Design to Cost) projects, of which there are now 1,200, made it possible to make progress in the process of rationalising compounds and optimising cable design. All these R&D activities resulted in a saving of some Euro 29 million in 2015, helping to enhance the competitiveness of our products.

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 and Telecom operating segments, have allowed it to continue to add to its patent portfolio, 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 2015, the Prysmian Group had 4,785 patents and pending patent applications throughout the world, covering 771 inventions (of which 228 in the Energy Projects and Energy Products segments and 543 in the Telecom segment). During 2015, 45 new patent applications were filed, of which 20 in the Telecom area and 9 in the Energy area, and 164 patents were granted after examination, of which 17 by the European Patent Office (EPO) and 34 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 2015, the Prysmian Group owned 589 trademarks, corresponding to 2,762 trademark

registrations in its countries of operation, covering the names and identifying symbols of its companies, activities, products and product lines.