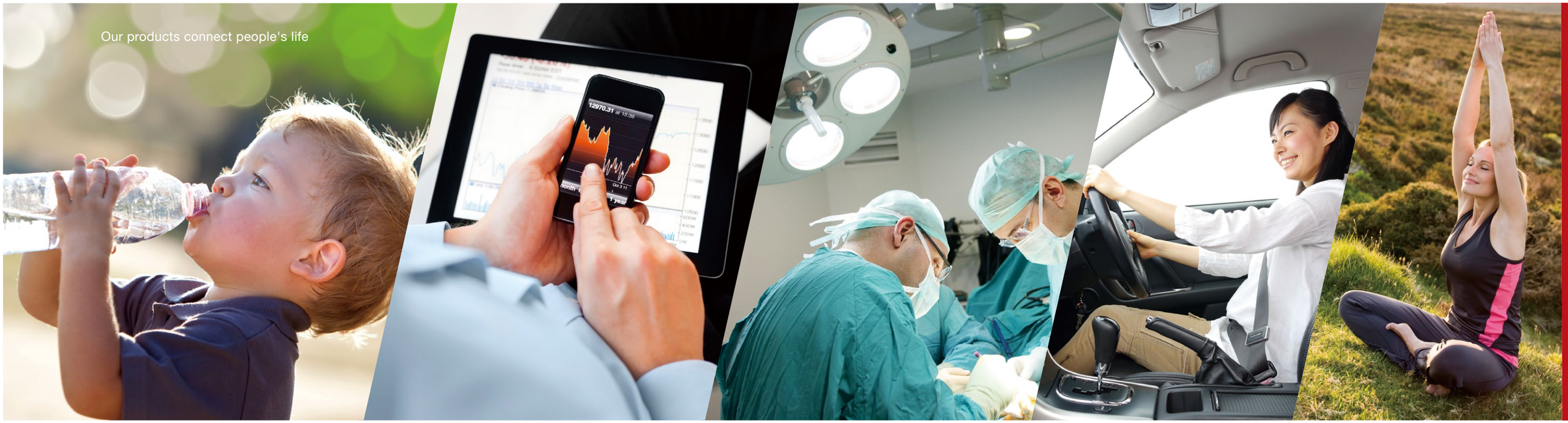
Innovation and R&D

The Energy to Innovate

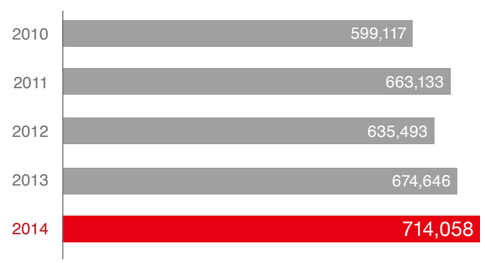


The Far Eastern Group R&D Center (hereinafter referred to as “R&D Center”) was founded by Far Eastern New Century in 2001 with the goal of accelerating development of new core-technology peripheral products with high added value and strengthening our competitive edge, as well as creating new value through constant breakthroughs, innovations, and active research and development.

Short-term R&D goals are centered in polyesters, environmental protection, energy conservation, and carbon reduction segments of our operation, all in keeping with global trends and demands. FENC core in PET (polyethylene terephthalate) synthesis is utilized to enhance our R&D efforts. PET-based feedstock and products are constantly developed to contribute to more applications of PET towards higher value products and markets. Long-term goals look to integrate resources and core competencies of the affiliated enterprises within Far Eastern Group so as to focus on green energy, biomass industry, PET feedstock and new materials. FENC has a clear direction with confidence to continuously improve on these segments that have significant potential in growth.

► R&D Expenses

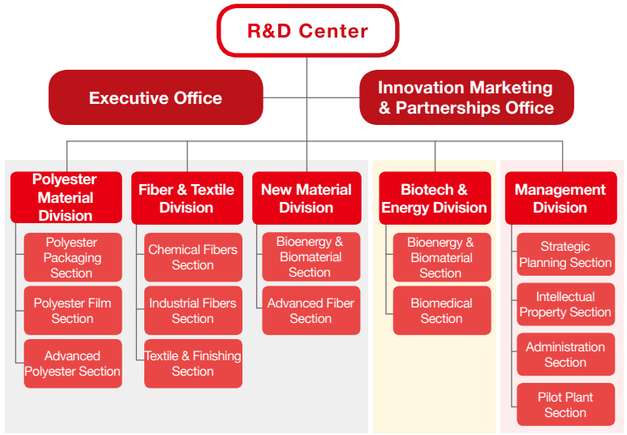
Unit: NT$ thousand



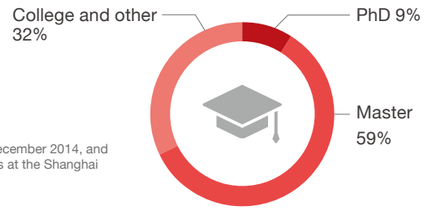
Restructuring and Reorganization

The R&D Center courses are divided into two main categories: 70% of activities are directly related to strategic business units (SBU) with the remaining 30% on future-oriented research. The R&D Center plans commissioned by SBUs cover the optimization of existing products and responding to special customer needs. An average of six new projects per year were submitted between 2008 and 2012. This figure significantly increased to 43 per year between 2013 and 2014, clearly indicating an increasing collaboration in research between SBUs and the R&D Center.

In June 2014, the R&D Center went through significant structural reorganization, increasing the original five R&D divisions to a total of ten. Human resources increased from 195 in December 2014 to 237 in December 2015 (approximately 20% increment). In addition to the existing Bioenergy & Biomaterial Section and Biomedical Section, the R&D sections for polyester and textile operations have been greatly expanded (Polyester Packaging Section, Polyester Film Section, Chemical Fibers Section, Textile & Finishing Section, and Industrial Fibers Section). FENC has also made a firm commitment to the development of new strategic materials and technologies so as to satisfy the needs of SBUs. We have thus embarked on the development and utilization of new materials through the newly established Polyester Feedstock, Advanced Fiber, and Advanced Polyester Sections. Our R&D capabilities in new materials and fibers are expected to further facilitate and accelerate the integration of upstream raw materials and downstream applications. These newly developed platform technologies will enable FENC to maintain our lead in the industry.



► Educational Background of the R&D Team

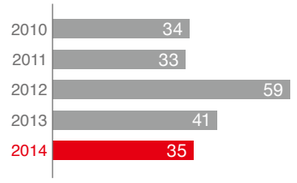


Total **195**

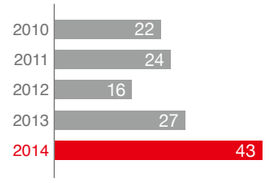
Note: Data shown are from December 2014, and include the 12 members at the Shanghai branch

► Patent

Number of patent applications



Number of awarded patents



Educational Training

The R&D Center contracts renowned academic experts to provide educational training and seminars on functional textiles, specialty chemicals, medical equipment, nanotechnology, and other related technologies so as to allow a firm grasp of cutting edge trends in global academia, industry and markets among employees of the Center. Individuals are encouraged to actively engage in external seminars and workshops, participate in technical discussions, and training courses, thus acculturating norms of incorporating sustainable material and economic development concepts in the R&D operations.

Sustainable Development-related Training

- The development of textile products in global climate change
- Development of international environmental protection trends--Analysis of the latest requirements of Oeko-Tex® Standard 100 & STeP® Certification
- Analysis criteria for product water footprint inventories
- Functionalized Mesoporous Silica Nanoparticles as Efficient Solid Catalysts for Biofuel ProductionGreen technologies and productivity
- Development and application of bioplastics
- Bioenergy
- Eco-friendly flame retardant technology and future trends
- Sustainability of core technologies, key materials, and industries

Training Type	2013		2014	
	Courses	Trainees	Courses	Trainees
Internal training courses	11	385	4	115
External seminars	48	89	47	74

Awards and Recognitions

- In 2013, the Company was recognized for achievements in the field of industrial innovation by the Ministry of Economic Affairs for its “Polyester Shrinkage Film.”
- In 2013, the Company received 6 major awards at the Taipei International Invention Show (including 2 Platinums, 1 Gold, 2 Silvers, and 1 Bronze) for its inventions: dyeable PP fibers, bone graft, polyester shrinkage film, heat retaining fabric, 3D display functionality film, and antibacterial polymer materials.
- In 2014, Bio-TopCool⁺ was selected and recommended as the “ISPO selection” in the 2015 ISPO Textrends Conference (International Sporting Goods Trade Show in Germany, Munich). The international review panel made selections in eight product categories based on functions, sensual experience, innovation, originality, environmental protection, multi-functionality, and health.

Innovative Cooperation

The reorganization of the R&D Center meets our internal needs to expand business operations and enhance R&D activities. We also look forward to the application of new products we develop through strategic cooperation with renowned brands so that we could have a firm grasp of future demands in the chemical fiber and textile markets.

In the past, FENC fabrics and garments were mostly OEM products. Our R&D efforts focused more on the development of suitable products that meet the demands of brand manufacturers. Nowadays, FENC is taking the initiative in introducing internally developed new materials and technologies to brand clients with whom we establish strategic alliances that facilitate the design of revolutionary products utilizing new materials. This way, we help determine the product design activities of downstream and brand manufacturers. Today, renowned sports brand manufacturers already use new materials and fibers developed by FENC for the design of novel products. In addition, we also cooperate with the R&D departments of renowned brands to test newly developed fiber materials and initiate an exchange of views on how to adopt and apply these materials. FENC’s strategy of aggressive promotion of R&D technologies has thus created a competitive niche characterized by high profits and stronger market presence.

In terms of joint research efforts, the cooperation partners of our R&D Center are not only confined to downstream and brand clients; we also cooperate with academic institutions in future-oriented R&D programs or commission external organizations to conduct research. Some of their research partners include affiliated organizations within the group. Such an arrangement creates group synergy.

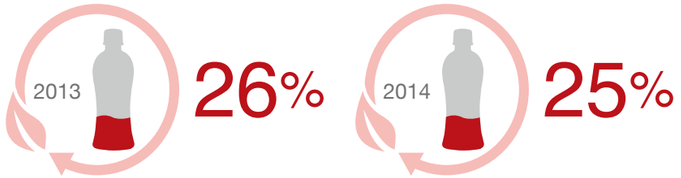
► FENC’s Joint Development and Strategic Partners

Cooperation Partner	Development Project
Timberland	Recycled PET base Breathable & Waterproof Film
Vf	Outdoor functional fabric Development of Bio-TopCool⁺ fibers and fabrics
Burberry	Fluoride-free, water-repellent fabrics
Nike	Waterless dyeing and finishing auxiliaries Bio-TopCool⁺ Eco-friendly shoe materials
Genomatica/BASF	Bio-TopCool⁺
Certain US-based company	Cellulosic ethanol Bio-PX
Patagonia	Ultra-thin film Bio-TopCool⁺
Levi's	CottonPlus
Coke, Virent	Bio-PX/PTA 100% Bio-PET
Taiwan Textile Research Institute	Joint development of outdoor sports TopCool⁺® textile products
Industrial Technology Research Institute	Hollow fiber membrane guidance program

Green Processes and Products

Green Product Sales Performance

► Revenue ratio of green products



Note: Based on sales value statistics of the manufacturing business in the consolidated financial statement. The slight drop in the sales value of green products in 2014 was due to lower product unit prices following global drops in raw material prices in 2014.

FENC features a large number of products that were developed in response to green and eco-friendly trends such as products, technologies, and processes that are eco-friendly and functional products designed for comfort in extreme weather changes. These functional products can also indirectly reduce the need for air conditioning. Technologies utilized by FENC for green processes and products include a large number of revolutionary inventions that represent key milestones in the promoting sustainable development in this industry. Several exclusive products and technologies adopted by FENC are listed below. For the effects of sublimation/heat transfer print technology and the dope-dyeing method please refer to the chapter "Creation of a Sustainable Environment."

Containers and Packaging Materials

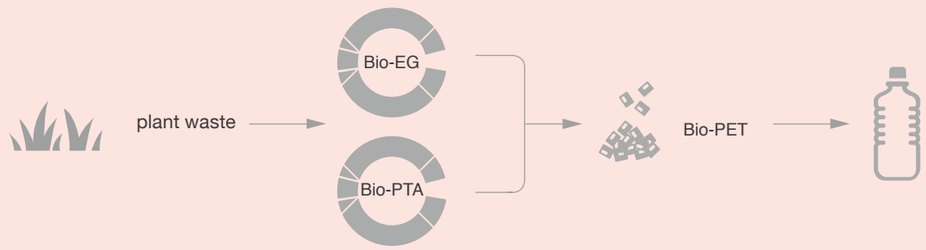
Anti-scratch PET Sheet	Anti-scratch PET sheet is mainly used for packaging. As the scratch resistance of standard PET window-class sheets is low, a PE (polyethylene) coating is usually added as protection. As this PE coating must be removed again before processing, there is no permanent anti-scratch protection. This new product has greatly enhanced scratch resistance properties and does not require the use of traditional PE coating films while also maintaining its transparency. Due to these unique properties, there is no need for clients to remove any coating films. This offers great savings on required energy, materials, and manpower.
Printable PET Sheet	PET sheets are not easily for printing. Although additives may help improve printability, they tend to decrease transparency, are prone to damage and lead to breakage during cutting. This new product is characterized by excellent transparency, printability, cutting yield, and scratch resistance properties. It not only increases the marketability of the product but also effectively reduces the amount of products discarded due to cutting or scratch damage, thus increasing the resource usage efficiency. In addition, printable PET may be used as a substitute for other traditional printing materials that are hard to recycle and reuse such as polystyrene (PS), thereby greatly enhancing the recyclability of materials. This product has been certified by a large number of customers in Japan and Taiwan.
Polyester Shrinkage Film	FENC is the first company in Taiwan to pioneer and mass produce this innovative shrinkage film. This film replaces dioxin-generating PVC shrinkage labeling materials that have been regularly used for years. FENC started to mass produce this film in 2010 and currently enjoys a market share of over 70% in Taiwan. Two production lines were added in 2014 to gain a better foothold in China and Southeast Asian markets.
Food-Grade Recycled (PETPro-green®)	Bottle chips made from recycled PET bottles (rPET) can serve as a substitute for bottle chips made from petrochemical raw materials. Due to astringent hygienic requirements, generic recycled chips may not be used for food containers. However, FENC's Pro-green® has passed the challenge-test regulated by FDA and has obtained approval from USFDA. Compared to generic bottle chips, Pro-green® generates only 50% of their carbon emissions.
Biodegradable Polyester Materials (FEPOL®)	FEPOL® is a new biodegradable plastic materials. The R&D Center utilizes an innovative polymer control technology to allow FEPOL® to degrade completely into water and carbon dioxide within a short period outdoors without polluting the environment.

Fibers and Fabrics

Thermal/Moisture Management Fiber (Topcool+® and Topheat+® Fiber)	These advanced fiber materials have excellent moisture absorption and release capabilities while effectively regulating the micro-climate between the skin and the fabric. Their excellent properties exceed those of polyester, nylon, and cotton, making them ideal for cooling/heating garments, sports and outdoor clothes, shoes, and quilts.
Cooling and Quick-Dry Bio-Fiber (Bio-TopCool+)	The R&D Center exclusively developed the cooling and quick-dry fiber Bio-TopCool+ by utilizing Bio-BDO (Bio-based 1, 4 Butanediol) marketed by Genomatica®. The fiber has a bio-based content of 30% and is the first ever cooling and quick-dry fiber with such a high bio-based material content. Bio-TopCool+ possesses constant cooling functions and moisture absorption, sweat discharge, and anti-static properties. The product has passed the certification of the Taiwan Textile Research Institute and met the Specified Requirements for Certification of Instant Cooling Fabrics formulated by the Taiwan Textile Federation. This fiber is suitable for summer shirts and casual sportswear. It reduces the use of air conditioning.
Hot Melt PolyUrethane Reactive Adhesive	This product, which employs solvent-free, eco-friendly materials and solvent residual-free technologies, is widely applied in fabric-to-fabric laminates, fabric-to-breathable & waterproof film laminates, shoe materials, 3C panel assemblies, and industrial adhesives for wood planks and automobiles.
Fabric Coating Technology	This unique ultra-thin, lightweight coating technology can be combined with various self-developed functional polymers and gives knitted fabrics windproof, air-permeable, cooling, quick-dry, and deodorizing properties. Production lines for various functional fabrics have been established.
Fabric-to-Fabric	Fabric recycling is the main direction of environmental protection efforts of every major brand. The physical decolorization and chemical recycling technologies provided by the R&D Center are the only technologies capable of achieving the goal of fabric recycling. Renowned international brands believe that these technologies have the greatest commercial potential.
Recycled Polyester Fibers （TopGreen®）	Regenerated fibers produced from recycled PET bottles can serve as a substitute for current polyester fibers made from petrochemical raw materials.
Breathable & Waterproof TPEE Films Made from Recycled PET Bottles (rTPEE Green)	This breathable and waterproof rTPEE film, based on green and eco-friendly concepts, was developed in cooperation with renowned international manufacturers using recycled PET bottles as raw materials. This film may be used in combination with polyester fabric laminates, resulting in a streamlined recycling and reuse process that utilizes eco-friendly materials containing no heavy metals or halogens. The product has wide applications in snow jackets, windbreakers, casual jackets, gloves, hats, and shoes. rTPEE film has anti-mold properties, thus can also be used for isolation and protective clothing.
Waterless Dyeing by SCF CO_2	This innovative process developed in cooperation with Nike, DyeCoo, and other dye companies, eliminates the need for water or chemical during fabric dyeing processes.

100% Bio-PET

FENC has developed the first 100% Bio PET bottle in cooperation with Virent® and Coca-Cola to reduce the carbon footprint of PET bottles and minimize reliance on petrochemical raw materials. The research team presented the recyclable 100% Bio PET bottle at the 2014 Green Chemistry Conference organized by the American Chemical Society. The research team successfully converted biomaterials into chemical monomers and produced plant-based bottle chips for the manufacture of 100% Bio-based PET bottles. This project marks an important milestone in the development of green materials by FENC.



Anti-scratch PET Sheet

Anti-scratch PET Sheet is mainly used for packaging and its transparency is extremely important for aesthetic reasons. However, the scratch resistance of standard PET sheet is low. These surfaces therefore have to be protected with a PE (polyethylene) coating film during processing. The PE coating film, which covers every sheet received by the client, must be removed during follow-up operations at the client side. It therefore does not provide permanent anti-scratch protection for the window box and requires a lot of manpower.

To solve this problem, the R&D Center develops window-class, scratch resistant PET sheet that makes the PE coating film unnecessary and provide permanent anti-scratch protection for window boxes. By investing a lot of time and effort, the R&D Center was able to develop a product with superior transparency, anti-scratch, and folding and processing properties. This product does not sustain any scratches during the manufacturing and transportation process and fully satisfies customer needs. The costs are comparable to products with PE coating film. This product also reduces the use of raw materials, helps the client to save manpower and resources required for the complicated removal of PE coating film, and provides permanent anti-scratch protection for window boxes. This PET sheet has already passed certifications of major brands and can be manufactured with recycled PET (rPET) that helps achieve energy conservation and carbon reduction.

Bottle to Bottle (food-grade recycled PET, Pro-green®)

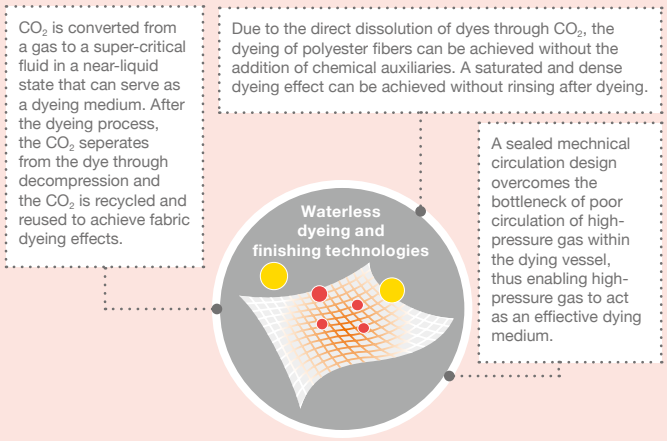
FENC recycles and reuses PET bottles through enhanced technologies and facilities to fulfill its corporate social responsibility. In 2010, the Company established the first bottle-to-bottle (BTB) production line with a capacity of 17,000 tons per year. This production line converts recycled bottles into polyester chips that are sold to large international enterprises for the manufacture of new drink bottles. In 2012, the Company gradually acquired certifications from Coca-Cola, Pepsi, Danone, and Nestle. In 2013, the Company invested around NT$ 1.2 billion in the expansion of two production lines in Taiwan and Japan. Each production line allows the processing of 50,000 tons of PET bottle bricks per year and has a production capacity of 35,000 tons of PET flakes per year. The use and promotion of post-consumer recycled (PCR) materials have increased through coordination with large international beverage companies.

Fiber recycling technologies turn discarded PET bottles into a valuable resource (recycled polyester fibers, TopGreen®)

During the 2010 FIFA World Cup, FENC proposed the adoption of TopGreen® fibers, a product manufactured from 100% recycled PET bottle materials, to Nike®. The innovative and eco-friendly soccer jersey fabric made from these fibers was used by the national soccer teams of Brazil, Australia and other countries. FENC again provided jersey fabric made from TopGreen® fibers for the national teams of Brazil, USA, Portugal, England, and Croatia for the 2014 FIFA World Cup. These light jerseys are not only eco-friendly; they also possess quick-dry and air permeability properties. This was the designated eco-friendly fabric used by Nike for FIFA World Cups, which provided global exposure to Taiwanese R&D know-how and environment-friendly concepts. Due to the leading position of FENC in the field of recycled fiber, the Company has become a formulator of rules and product categories for recycled fiber (polyester filament) in Taiwan. Please refer to the chapter “Establishment of Sound Governance” for more detail.

Replacement of valuable water resources with CO_2

Traditional textile dyeing is very water consuming and the treatment of waste water requires energy. If the treatment process is not rigorous enough, it will lead to the pollution of waterways and the environment. In early 2012, FENC therefore initiated the development of this revolutionary textile dyeing and finishing technology in cooperation with Nike and DyeCoo, the Dutch developer of waterless dyeing technologies, to make a contribution to environmental protection and sustainable development. In October 2013, FENC's waterless dyeing and finishing technology team completed the installation of the plant facilities. Pilot operations were initiated in June 2014. This production technology replaces water normally used for dyeing with recyclable CO_2. It saves large quantities of water, eliminates the generation of waste water, and reduces the consumption of petrochemical energy sources (e.g., oil, natural gas, and coal) required for the heating of water in the dyeing and finishing steps. Such a method reduces greenhouse gases emission and slows down global warming while enabling the Company to achieve the dual goal of energy conservation and preventing generation of pollutants.



Item	Traditional Dyeing	Waterless Dyeing
Water consumption (per kg of fabric)	100-180 L	No water required
Energy consumption (per kg of fabric)	Electricity: 1 kWh	Electricity: 3 kWh
	Steam: 10 kg	Steam: 5kg
Chemicals consumption (dyeing and finishing additives) (per kg of fabric)	Auxiliaries:0.2 kg	No auxiliaries required
	Dyes: 0.07 kg	Dyes: 0.02 kg
Daily production amount (same dyeing vat capacity)	1,200kg	1,500~1,700kg

This is an advanced technology that still awaits breakthroughs and process optimization. However, through the joint efforts of the Company and its cooperation partners, the production efficiency was raised from an initial 65% to 92% in 2014 with constant software innovation and hardware transformation. It is expected that this figure will reach 95% of the efficiency of traditional dyeing in 2015 while using less space for facilities. In view of the growing shortage and unstable supply of water resources, the large-scale improvement of dyeing and finishing technologies that consume less energy and water represents a revolutionary breakthrough. This reflects the determination of the industry to actively respond to changes of time in ways that transform crises into opportunities.