

Ethylene production

A technology leader for grassroots
plants and expansions





A market leader with a portfolio of experience

From conceptual design and licensing through construction and commissioning, TechnipFMC is a leader in the ethylene industry.

Our project portfolio includes 150 grassroots plants and a large number of modernization projects, all designed to add capacity using our proprietary technologies.

Our experience stems from two basic technology offerings:

- ▶ TechnipFMC ethylene technology backed by 50 years of experience
- ▶ Legacy Stone & Webster process technology backed by 75 years of expertise

Since 2000, we have licensed about 50% of the world's total added capacity.

Ethylene in our daily life

Ethylene, the simplest of olefins, is used as a base product for many syntheses in the petrochemical industry including plastics, solvents, cosmetics, pneumatics, paints and packaging.

Today, the demand for ethylene is over 150 million tons per year with a growth rate of 3.5% per year. The average capacity of production plants, known as steam crackers, has risen from 300 KTA in the 1980s to more than 1,500 KTA today.

Centers of excellence

Our ethylene technology experience and resources stem from six centers of excellence: U.S. (California and Texas), the Netherlands, Italy, England and France. These centers, together with our established global engineering, procurement and construction network, have a long history of working together to provide the leadership, experience and resources for our customer's projects.

Mega-challenges for mega-crackers

Since the late 1990s, we have strengthened our leading position in the market for mega-crackers used for ethylene production.

Recent achievements include:

Sadara, KSA: the world's largest mixed feedstock cracker (ethane, LPG, naphtha) designed for 1,500 KTA ethylene and 500 KTA propylene. The plant started up in 2016.

Jamnagar, India: the world's largest cracker based on refinery off-gases, under design to produce 1,400 KTA ethylene. The plant is expected to start up in 2017.

CP Chem, USA: design of a grassroots ethylene plant located in Baytown, Texas, producing 1.5 million tons per year of ethylene. The plant incorporates TechnipFMC's proprietary Ultra Selective Cracking furnaces. Our scope of work included development of the Process Design Package and Front-End Engineering Design (FEED), as well as procurement of key long-lead equipment items and detailed design of the furnaces.

Sasol Chemicals, USA: technology license and FEED for a 1,500 KTA grassroots ethane cracker based on feedstock derived from shale gas. Location is the Louisiana Gulf Coast and plant is under construction.

Dow Chemical Co. LHC-9, USA: technology license, FEED and cracking furnaces engineering and procurement for a 1,500 KTA ethane cracker. Location is the Texas Gulf Coast.

The world's largest cracking furnaces: 250 KTA ethylene based on ethane feedstock and over 200 KTA ethylene based on liquid feedstocks, designed and built by TechnipFMC.

Proprietary furnace technologies

Thanks to a variety of associated proprietary technologies, TechnipFMC offers ethylene producers the ability to meet tough production challenges, reduce capital costs of new furnaces and improve operational efficiency of existing furnaces.

The furnace technologies contain a wide range of design options for reliable, flexible and highly selective solutions to meet stringent environmental regulations and the operational needs of our customers. Standard design features include radiant coils, combustion systems, quench exchangers and multi-level shutdown features. Today the largest gas cracking furnace is over 250 KTA and the largest liquids cracking furnace is over 200 KTA.

Gas cracking

SMK™ and Ultra Selective Conversion (USC®) M-coils are preferred for high-capacity and low-cost.

In the last 10 years, more than 180 furnaces have been installed based on these technologies, which are designed to achieve very large capacities and enable selectivity optimization.

Liquids cracking

GK6® and USC® U-coils are designed for short-residence time

These technologies, which can be applied in new furnaces or used to modernize existing furnaces, have been applied in nearly 200 furnaces in the last 10 years.

Recent developments

A unique linear quench exchanger arrangement eliminates the need for offline cleaning and reduces waste. This arrangement can be applied for all coil types.

SFT® (Swirl Flow Tube) technology: this technology, which uses helical tubes that enable improved thermal exchange coefficients, can be used in all furnaces to further improve performance (selectivity, capacity and run-length).

SPYRO®: our furnace design and optimization software tool

SPYRO® is TechnipFMC's proprietary model for steam-cracking yield prediction and complete furnace simulation of either gas or liquid feedstocks. Since its introduction in 1978, the tool has been adopted by 80% of ethylene producers worldwide.

The tool simulates pyrolysis reactions of the cracking process inside the radiant coil of an ethylene furnace together with the complete furnace model. It is applied for feedstock selection, process scheduling and production optimization. SPYRO® allows accurate prediction of yield patterns for feedstocks ranging from gases to heavy (or treated) gas oils at all current operating conditions.

Many ethylene plants run on-line control and optimization systems with our program embedded in their system software. The tool can also be applied for stand-alone simulation.

A determining factor in plant configuration and revamp scenarios

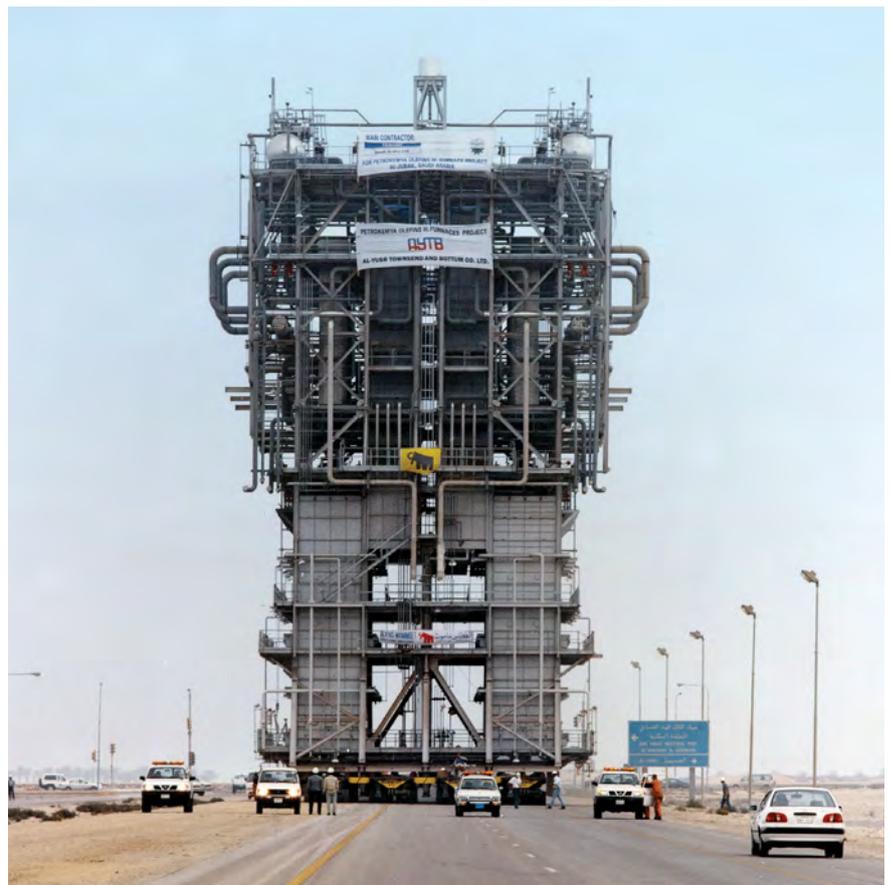
The data on yields and furnace availability provided by SPYRO® can also be used to set up revamp scenarios for the furnace and downstream sections of a plant.

For optimum design of large capacity gas or liquid furnaces, we apply SPYRO® linked with CFD (Computational Fluid Dynamics), enabling the best design of burner arrangement, cracking coil layout and flue gas ducting.

Recent technology developments

- ▶ Cracking furnace intensification
- ▶ Improved cryogenic schemes with associated equipment advances
- ▶ Anti-fouling quench systems
- ▶ Spent caustic pre-treatment/oxidation process for plant optimization, investment cost, HSE, energy efficiency and emission reduction
- ▶ Ongoing flow scheme evolution/simplification and significant alternative approaches to cracking technology are under development.

Petrokemya
Kingdom of
Saudi Arabia



Proprietary equipment

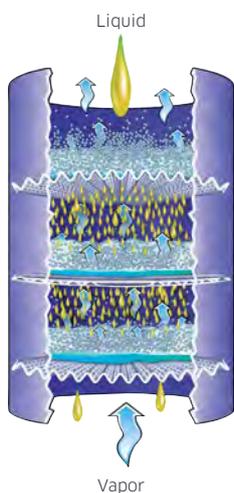
Transfer Line Exchanger (TLE)

This exchanger safely recovers heat from furnace outlets without fouling to produce very high pressure steam. We developed our design and manufacture the equipment in our fabrication shop. This allows for better integration and a shorter delivery schedule.

Burners

Our burner designs for low NOx emission, developed in-house, are also manufactured in our shop:

- ▶ Large Scale Vortex (LSV[®]) burners for bottom burners
- ▶ Side wall burners



Ripple Tray™ technology

- ▶ Our high-capacity trays are used in fouling services and/or to increase production capacity. In the past 50 years, the trays have been applied in nearly 500 applications worldwide.

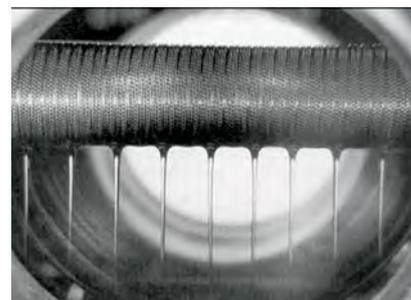
Vapor Flute™

This proprietary device is an important component of many Quench Oil and/or Quench Water tower grassroots and revamp projects. The device increases operational efficiency by improving distribution and acting as a first line of defense against liquids and coke that enters the tower.



Quench Fitting

This unique device provides high-efficiency, direct-contact quenching of furnace effluent gas with a process hydrocarbon liquid stream to obtain the desired mix, quickly and completely.



Anti-Coking Heavy Feed Mixer™

The mixer vaporizes heavy hydrocarbon feedstocks. It uses a unique patented anti-coking design that minimizes the coking tendency and required length of the mixing chamber. In turn, this reduces capital costs and maintenance of the furnace convection section.

High performance exchangers

Our agreement with Wieland to jointly market innovative enhanced heat exchangers for ethylene plants allows further reduction of energy consumption as well as CO₂ emissions. These exchangers can be used either for boiling or condensing applications.

Proprietary separation technologies

Our progressive separation technologies, which reduce energy consumption and lower CO₂ emissions, are available for all types of acetylene separation processes.

Acetylene elimination

Ethylene plant operators aim at a very pure output from steam crackers: 99.95% ethylene, with a very low content (below 1 ppm) of extremely reactive molecules such as acetylene. To achieve this, we developed a sophisticated sequence of processes to separate and purify high value products in the steam cracker.

Three methods are available:

- ▶ **Front-end hydrogenation**, coupled with either front-end deethanizer or front-end depropanizer, is available for gas or liquids crackers. The technology is applied in many plants in operation such as Petro Rabigh and Sadara projects in the Kingdom of Saudi Arabia.
- ▶ **Back-end hydrogenation**, coupled with front-end demethanizer, is applied for either gas or liquids crackers. The technology is applied in many plants in operation such as Yansab in the Kingdom of Saudi Arabia.
- ▶ **Acetylene extraction** can also be provided. We have installed acetylene extraction in four plants based on dimethylformamide (DMF) absorption technology.



Up to 2,000 KTA of ethylene can be achieved by using any of these separation technologies, with proven equipment.



Technology designed to maximize energy efficiency and reduce emissions

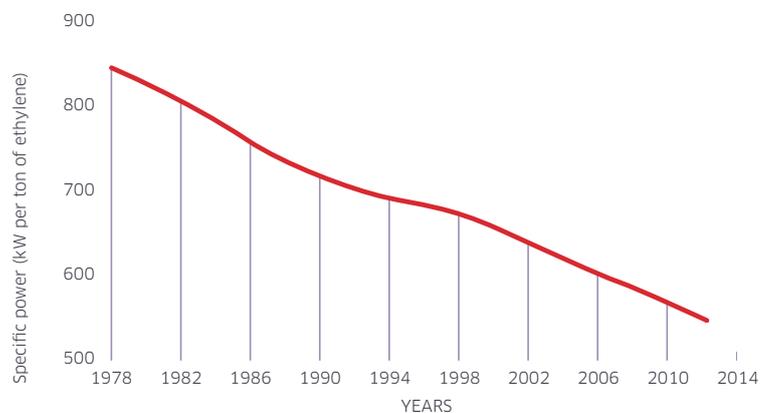


During the last 20 years, CO₂ emissions/ton of ethylene have been reduced by 30%.

Continuous improvement

Reduction of energy consumption and CO₂ emissions is obtained by:

- ▶ Improving the thermal efficiency of the furnaces, above 95%
- ▶ Reducing the compression power required per ton of ethylene



Gas cracker - Specific compression power (kW per ton of ethylene)

A full scope of project execution services



Several challenges are inherent in the execution of ethylene complexes. The ever-increasing scale of equipment, piping and structures makes it necessary to develop new concepts and work closely with suppliers.

Our offer

Through our global network of process experts, we provide a full scope of services, from licensing and studies, to full lump sum turn-key EPC projects. This includes the supply of proprietary technology and start-up services for the plant, its ancillary units and associated off-sites and utility sections.

Project services

- ▶ Financing
- ▶ Project management and consulting services
- ▶ Feasibility studies
- ▶ Conceptual design
- ▶ Licensing
- ▶ Front-End Engineering and Design (FEED)
- ▶ Detailed engineering of equipment, piping, civil, instrumentation, electrical and automation
- ▶ Cost estimating
- ▶ Project planning and scheduling
- ▶ Procurement including purchasing, expediting and inspection
- ▶ Construction
- ▶ Start-up and plant operation supporting services
- ▶ Environmental permitting and assistance in Authority Approval and Permit procedures
- ▶ HAZOP and HASAN
- ▶ Safety studies

Ethylene plant modernization

TechnipFMC has the talent and experience to modernize existing ethylene plants, including the revamp of the cracking section, compression and separation sections. We offer a unique proven approach, applied successfully in recent revamp projects.

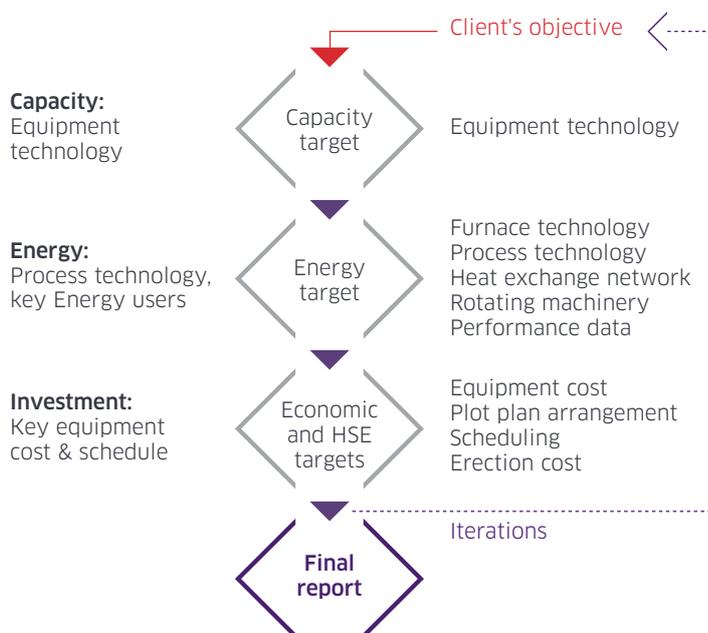
Capacity expansion and revamp projects

Existing cracking furnaces may be redesigned to increase the original capacity by 20% to more than double. At the same time, specific feed consumption is drastically reduced, contributing to an attractive low cost of production per ton of incremental ethylene.

A systematic approach to maximizing investment

In determining the most economical way to expand a plant, we evaluate technology options and review project implementation scenarios. This approach ensures that bottlenecks are identified and prioritized to ensure a maximum return on investment is achieved.

Main steps involved in the systematic approach to modernization:

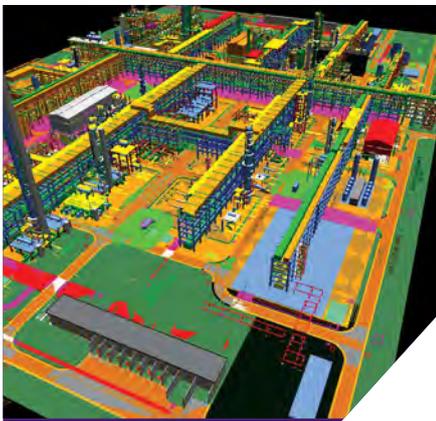




Terneuzen
The Netherlands



Successful execution of major projects reinforces our position as an ethylene leader



Reliance Jamnagar refining and petrochemical Complex - India

As part of the expansion of a world-scale refining petrochemical complex, TechnipFMC supplied the license, basic and detailed engineering as well as procurement services for a Refining Off Gases Cracker (ROGC) with 1,400 KTA ethylene production. This first-of-a-kind plant will use only refinery off gas as single feedstock. Startup is planned for 2017.



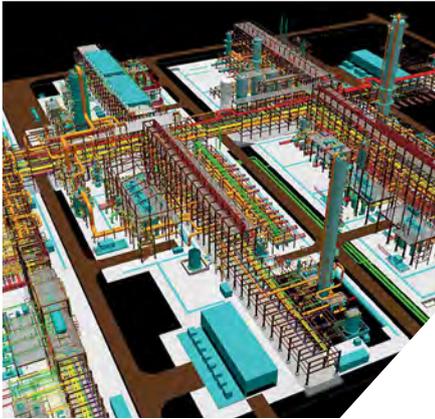
Etileno XXI - Mexico

In 2012, Braskem Idesa awarded to TechnipFMC (in a joint venture with Odebrecht and ICA Fluor) a contract for the engineering, procurement and construction (EPC) of a petrochemical complex in the Mexican state of Veracruz. The complex includes a 1,050 KTA ethane cracker, one low density polyethylene and two high density polyethylene units as well as utilities and offsites. The contract follows the FEED for the overall complex awarded in 2011. The plant started up in 2016.



Dow Chemical Co. LHC-9, USA:

We are providing the technology license, FEED and cracking furnaces engineering and procurement for a 1,500 KTA ethane cracker in Freeport, Texas. This is the fourth new grassroots plant of the Dow Chemical Company worldwide that has been awarded back-to-back to TechnipFMC in the last 10 years.

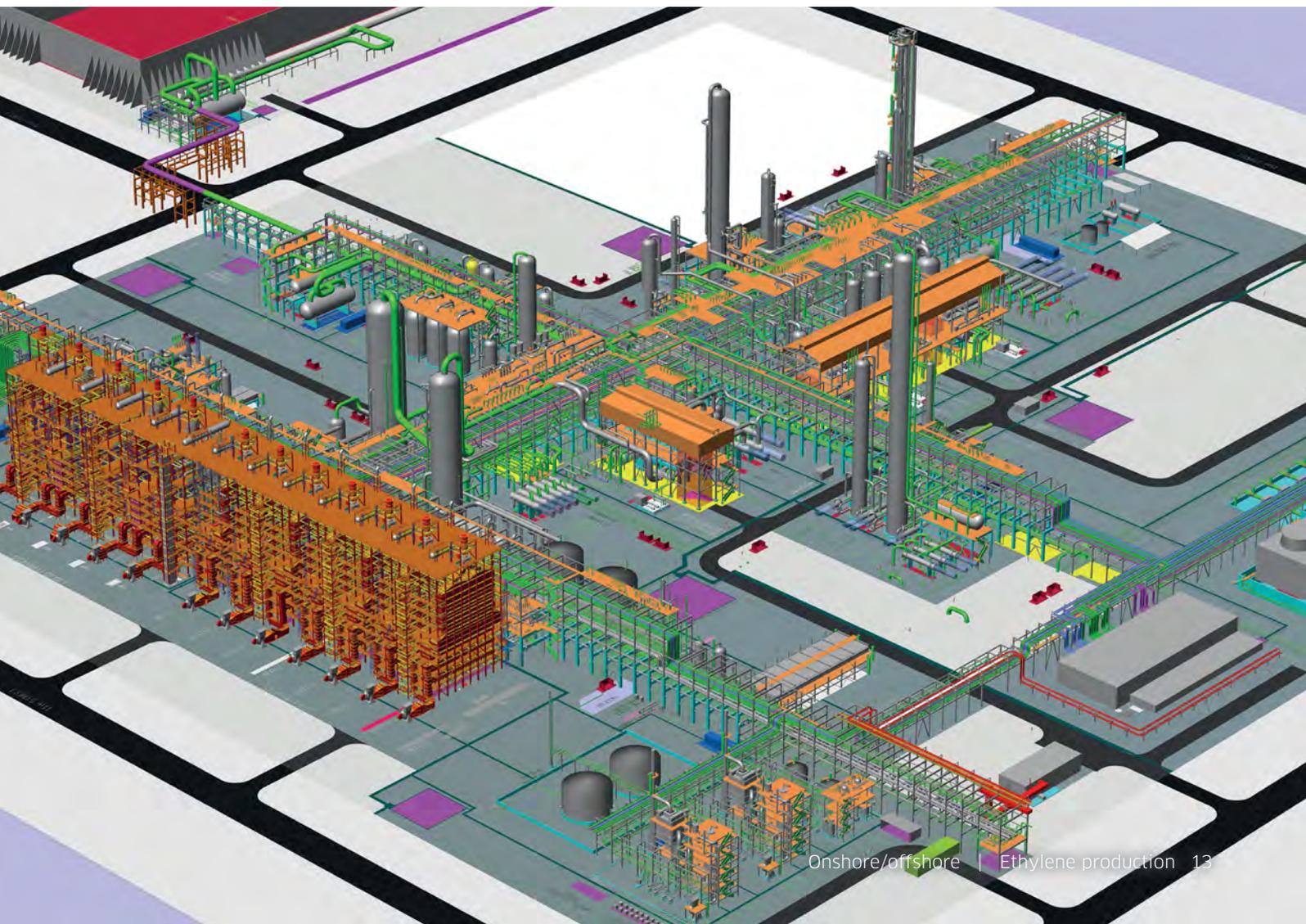


Sasol - USA

TechnipFMC, in a joint venture with Fluor, is providing engineering, procurement and construction management for Sasol's 1,500 kTA tons per year ethane cracker and derivatives complex near Lake Charles, Louisiana. During the early stage of the project's development we were awarded the license and front-end engineering design for the cracker and later, provided engineering and procurement for eight proprietary Ultra Selective Conversion furnaces.

Sadara - KSA

The world's largest mixed feed cracker (ethane, LPG, naphta), operating at 1.500 kTA, designed by TechnipFMC.



Sustainability and innovation

TechnipFMC designs and delivers sustainable and innovative solutions to enhance the performance of the world's energy industry.



Innovation

- ▶ Mega ethylene plants (over 2,000 kTA) to ensure mechanical integrity, reliability and reduction of specific investment per ton of ethylene produced
- ▶ Proprietary equipment (Ripple trays, burners, Transfer Line Exchangers, enhanced heat exchanger surface)
- ▶ Ethylene from bio-ethanol (Hummingbird®): technology which is driven by the demand for bio-ethylene as an important intermediate in the production of sustainable plastic and polymer materials expected to grow in the long term

Environmental benefits

During the last 20 years, TechnipFMC's technological developments have improved the energy efficiency in ethylene plants, reducing CO₂ emissions by 30%:

- ▶ Thermal efficiency of cracking furnaces has been improved by almost 10%
- ▶ Specific compression power per ton of ethylene has been reduced by more than 30%

Our technology complies with the most stringent environmental regulations:

- ▶ Gas emission: limitation of greenhouse gases by reduction of NO_x
- ▶ Liquid discharge: specific technology for treatment of spent caustic by wet oxidation to minimize Chemical Oxygen Demand
- ▶ Solid emission: minimization of coke particles by routing the decoke effluents in the fire box to burn the remaining coke particles and achieve zero emission

Economic benefits

Improvement of cracking selectivity which reduces the hydrocarbons consumption per ton of ethylene produced by about 5 to 10% in the last decades.

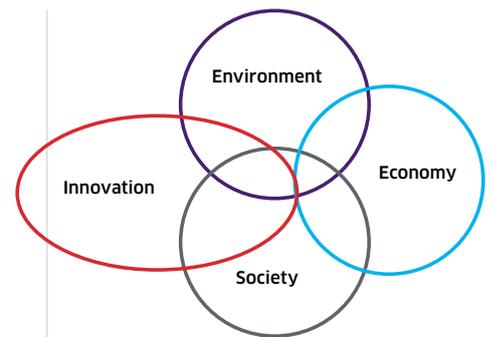
Energy efficiency: the state of the art of ethylene technology is self-supporting in energy; no import of energy (fuel gas and steam) is required for normal operation.

Social benefits

Ethylene derivatives now have higher mechanical and physical performance allowing them to be increasingly used to save lives in medicine and pharmaceuticals.

Ethylene derivatives are now widely used in transportation (vehicles, trucks and airplanes). The lighter material has replaced steel and therefore minimized fuel consumption and transportation costs.

With more than 200 ethylene technology experts worldwide, many patents have been granted to TechnipFMC contributing to the skills pool focused on improving ethylene technology.



Ethylene is the most extensively used chemical in the world. TechnipFMC has invested in technological innovations to benefit from this resource in the most responsible way. As a market leader in licensing ethylene plants, we are committed to take our leadership further by driving continuous innovation and targeting environmental, economic and social benefits.



Ras Laffan,
Qatar

France

Jean-Paul Laugier

+33 1 47 78 34 96

jean-paul.laugier@technipfmc.com

Yvon Simon

+33 1 47 78 38 61

yvon.simon@technipfmc.com

USA

Tom Pickett

+1 281-848-5216

thomas.pickett@technipfmc.com

Ravi Lal

+1 909 447 3717

ravi.lal@technipfmc.com

The Netherlands

Zain Abdin

+31 79 3293 625

Zainul.abdin@technipfmc.com

UK

Jim Middleton

+44 20 3429 4690

Jim.middleton@technipfmc.com

Italy

Enzio Viviano

+39 06 65 98 35 65

enziosavio.viviano@technipfmc.com