Where energies make tomorrow

Ethylene Decarbonization

Reducing CO_2 emissions of ethylene plants, by energy efficiency, electrification, use of hydrogen and carbon capture

T.EN TECHNIP ENERGIES

A long history of innovating to improve ethylene plant performance

For over 50 years, Technip Energies has been a leading provider in the licensing, design and Engineering, Procurement and Construction (EPC) of ethylene plants. Our teams have designed and built some of the largest and most complex ethylene crackers in the world.

Over the years, through innovations in the design of the technologies and equipment, we have transformed our ethylene plants to improve their energy efficiency, lower their costs and reduce their emissions, including CO_2 and NOx.

Improved energy efficiency and reducing emissions

With regulatory changes pushing to decrease CO_2 emissions for crackers, (e.g., Europe's goal calls for a 55 percent decrease by 2030), Technip Energies has been looking at a range of options to reduce CO_2 emissions from ethylene plants, applicable to both new and existing plants.

We offer our clients designs of plants that decrease steam generation and increase the use of electric motors as drivers for machinery. This electrification of plants works hand in hand with new furnace designs to minimize the fuel fired and CO_2 production.

T.EN's past achievements in energy efficiency and CO_2 reduction provide a sound platform for future decarbonization

Decarbonization of ethylene production

Technip Energies now offers a number of technologies to reduce the CO_2 emissions from steam crackers – from mature technologies such as electrification, use of hydrogen and Carbon Capture Utilization & Storage (CCUS) to new technology developments not yet commercialized, such as electric furnaces and Rotating Olefins Cracker (ROC).

Hydrogen firing

One of the most straightforward ways of reducing cracker CO_2 emissions is by replacing the methane fuel with hydrogen rich fuel.

Burning pure hydrogen does not generate CO_2, so this is a relatively easy way of reducing the CO_2 emitted from the cracker. Hydrogen can either be generated from the fuel gas generated in the cracker by reforming or imported from outside the cracker.

Hydrogen from outside the cracker is typically generated by electrolysis. Electrolysis technology is evolving and currently has high capital and operating costs when compared to reforming. The electricity consumed by electrolysis can have a higher CO_2 footprint than the cracker.

Technip Energies believes a better way forward is to convert the cracker fuel gas to a high hydrogen stream, by steam methane reforming (SMR) or auto thermal reforming (ATR). Our proprietary BlueH$_2$ By T.EN™ minimizes the energy consumed in the reformer, generates no additional steam, and includes capturing the CO_2.

Blue H_2 reforming of fuel gas to H_2

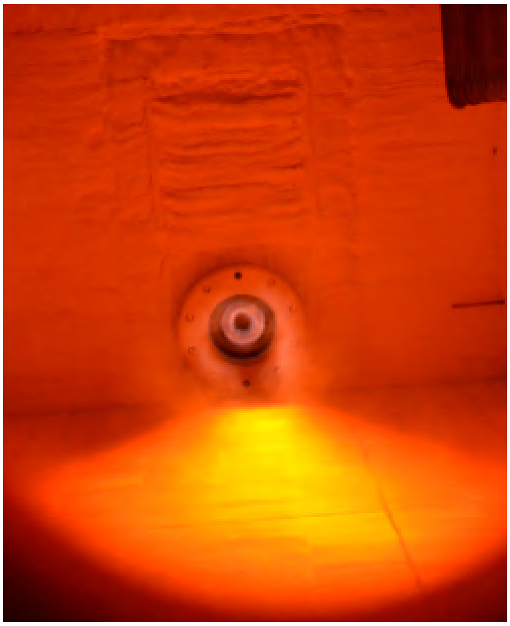
"Blue" hydrogen, with substantially reduced CO_2 emissions, is produced through minimization of the primary footprint and deliberate capture of the co-produced CO_2. Technip Energies is a pioneer in this rapidly expanding market and a global leader in low-carbon hydrogen solutions through:

- Portfolio of enhanced reforming technologies
- Company-developed recuperative reforming technologies: Technip Parallel Reformer "TPR®" and Enhanced Annular Reforming Tube for Hydrogen "EARTH®"
- In-house combustion and burner technology, and experience utilizing a wide range of fuels (heavy to carbon-free)
- 50+ hydrogen/syngas references already utilizing CO_2 capture solutions.

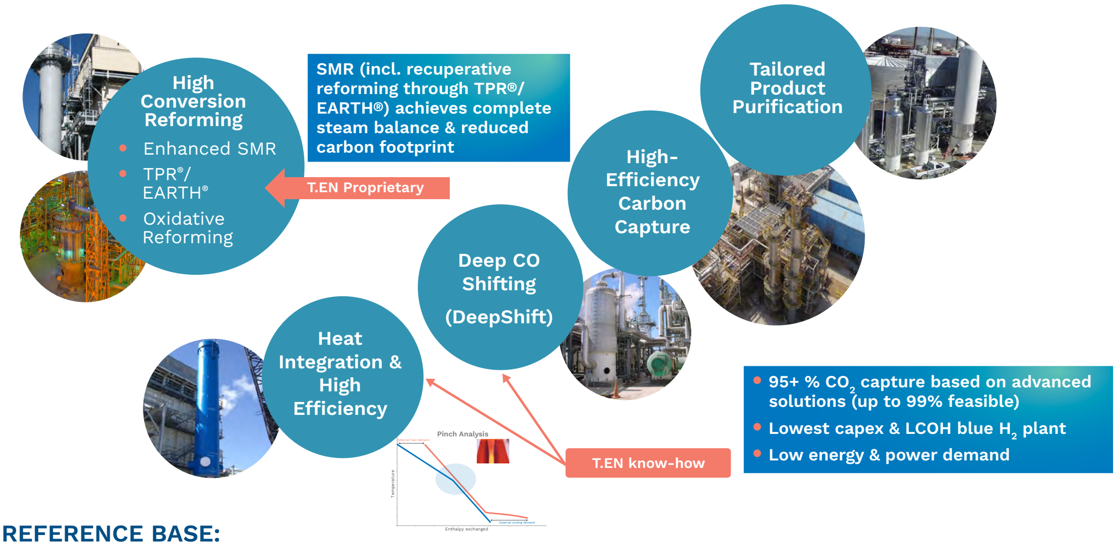
Technip Energies' BlueH_2 by T.EN™ solutions offer many advantages:

- Up to 99 percent reduction in the carbon footprint compared to the traditional hydrogen process – from ~10 down to 0.1 kilogram CO_2 per kilogram H_2, while maintaining flexibility to be tailored to each individual application.
- Maximum hydrogen yield, minimum energy demand (fuel + power), and highly efficient carbon avoidance and carbon capture utilization and storage (CCUS) techniques, to arrive at the lowest cost of blue hydrogen (LCOH).
- Comprised of "flight proven", Company-developed and owned technologies and equipment, available to customers today.

Technip Energies has its own burner designs in development and tested for firing up 100 percent hydrogen fuel. This photo shows a burner firing hydrogen in the Technip Energies test furnace.



Building blocks for low-carbon solutions



REFERENCE BASE:

- > 50 H_2 with carbon capture
- > 30 H_2 with deep CO shift
- > 14 H_2 with recuperative reforming

Carbon capture and storage/Carbon capture and utilization (CCS/CCU)

Apart from the use of high hydrogen content fuels, carbon capture is the only currently commercially proven technology to effectively reduce the majority of CO_2 emissions from steam crackers.

Carbon capture can achieve 90 to 95 percent CO_2 removal. The CO_2 would be removed from the furnaces and, if required, the auxiliary boilers. Carbon capture can be added to an existing steam cracker without significant disruption to the plant. We can also design new steam crackers with a future provision for installing carbon capture. The main requirements are:

- Provision of tie-in connections on furnace and boiler stacks
- Provision of plot space for the CC plant, as close as possible to the furnaces and boilers, to minimize the length of the flue gas ducting
- Provision of space for the flue gas ducting and support on furnace and boiler structures
- Assessment of the impact on utility systems

Captured carbon is often utilized for oilfield recovery or is stored. These routes are normally only accessible to plants located close to the sea, onshore oilfields, or unused oil pipelines. An alternative use for the captured CO_2 is to convert it into marketable products, such as methanol and ethanol. These can be converted into olefins.

> “Technip Energies has been awarded the EPC phase of the new Borouge 4 steam cracker in Abu Dhabi. This plant will be the first cracker in the world to be constructed which is designed to accommodate a CCS unit.”

Low CO_2 furnace

Technip Energies' proprietary low-emission cracking furnace is designed to improve the fuel efficiency of the cracker and thereby reduce the CO_2 emissions. In developing the technology, our research showed that the heat recovery scheme of the conventional furnace configuration was limiting the extent to which the fuel efficiency can be improved. We developed a patented new heat recovery scheme to overcome this limitation.

The benefits of this design include:

- Proven techniques to reduce CO_2 emissions by 20-30 percent
- May be used in conjunction with other techniques, for example to reduce hydrogen demand or CO_2 captured and exported

Electrification of cracker

The use of electric motor drivers for the compressors is known as the electrification of the cracker. This is not new technology. Technip Energies has four reference plants (three grassroots, one revamped) where electric motors are used to drive at least two of the three main compressors. These plants were designed to take advantage of the low cost electricity then available in certain countries.

When electricity from renewable sources is available, the CO_2 emission reductions are fully realized.

Electrification of crackers is combined with reduced fuel consumption and steam generation from the furnaces. The extent of electrification is determined by matching the steam balance which arises from minimizing the fuel fired in the furnaces.

Electric furnaces

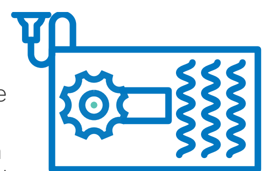
Technip Energies is currently developing the technology to use electricity in furnaces to provide the heat of reaction instead of firing fuel. The main concerns with the use of electric furnace technology are focused on the amount of electricity required, the CO_2 footprint of the electricity, and the effect on the electricity grid of start-up and shutdown of the cracker.

e.Furnace™ by T.EN

The CO_2 footprint for electricity should decrease over time, with the phasing out of coal firing and increased use of renewables. But, to substantially reduce the CO_2 emissions for the complete cracker footprint, it is necessary to source electricity with a very low CO_2 footprint.

ROC

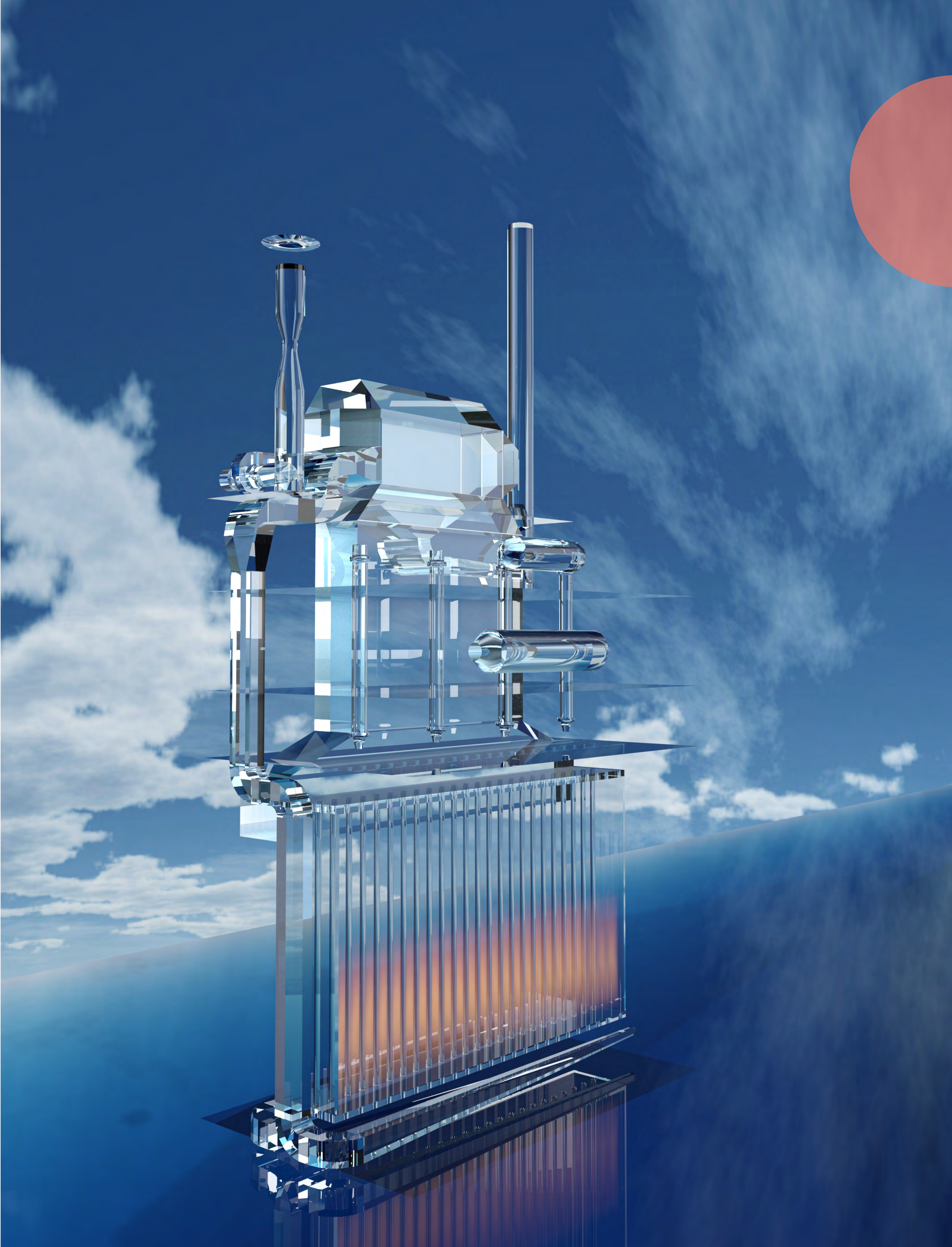
Technip Energies and Siemens Energy have recently announced an exclusive agreement to jointly develop, commercialize, and license the Rotating Olefins Cracker (ROC) technology to decarbonize olefin production processes. The ROC technology employs a dynamic reactor system that replaces conventional furnaces used for pyrolysis when manufacturing light olefins.



The ROC technology offers driver flexibility, and when driven by electric-powered motors or hydrogen-fired gas turbines, the technology leads the path to decarbonize the process. The decarbonization impact is even more significant when the electric power or hydrogen fuel is derived from renewable sources. The ROC process is also expected to have better first pass olefins yields with similar operating costs compared to the currently commercially available technologies.

Technip Energies and Siemens Energy are now working on plans for a demonstration unit utilizing the ROC technology in a plant.

T.EN's low emission cracking furnace



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