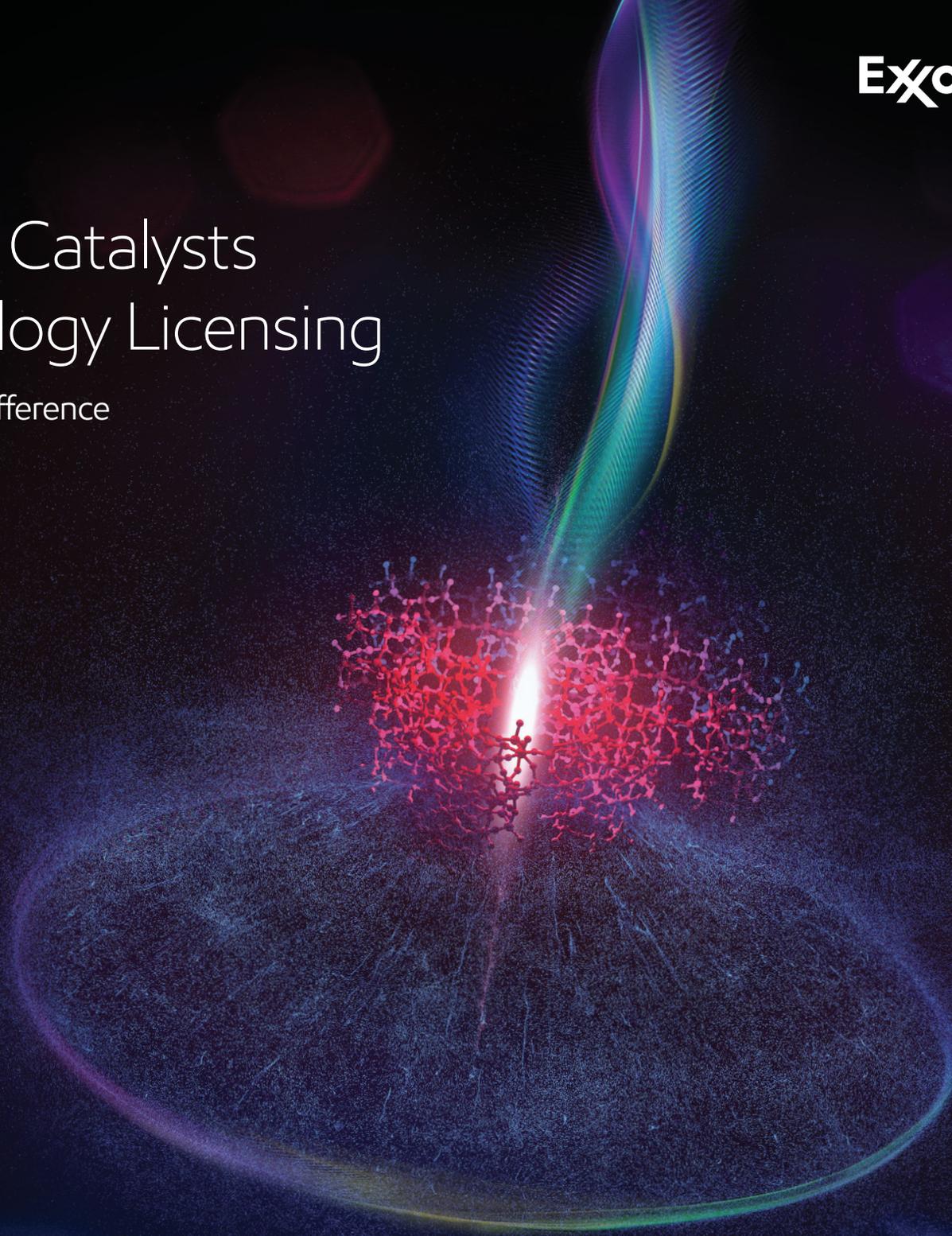


# ExxonMobil Catalysts and Technology Licensing

Creating a particle of difference



Catalysts and Technology Licensing offers its customers a portfolio of high-performing catalysts and advanced process technologies backed by a legacy of continuous innovation and a commitment to maintaining strong customer relationships. ExxonMobil offers decades of operational expertise to ensure that our customers have access to the industry's best solutions: The same world-class innovations and technologies we use in our own facilities. Our role as an owner operator uniquely positions us as experts in this area. From planning and installation to plant startup and beyond, we continue to offer our services and know-how to customers well after implementation. Whether it's for producing paraxylene, lubricants, fuels or other products, ExxonMobil would like to partner with you on your success.

Welcome to a world of opportunity!

Building on more than 125 years of experience, ExxonMobil operates in three core businesses:



### Chemical

Our decades of expertise in chemical production allow us to offer innovation and expertise to the chemical industry. Our high-quality catalysts and process technologies offer methods to upgrade low-value chemicals into high-value products in innovative and cost-effective ways. They can be used to manufacture chemicals and polymers used in creating polyethylene, nylon, styrene and other high-performance materials.



### Gas

ExxonMobil Catalysts and Technology Licensing also bring our experience in innovation to offer cost-effective, low-risk solutions for H<sub>2</sub>S cleanup and syngas production. Gas-treating technology can enable customers to meet stringent emissions standards. Our technologies can also assist in the production of high-quality synthetic fuels from methanol derived from natural gas.



### Refining

Our high-performance catalysts and advanced process technologies can bring big benefits to refining companies. We can offer industry-leading advantages in fuel production, resid conversion and lubes production. Our technologies can offer higher product yields, convert low-value products to higher-value end products and enable the production of high-quality base stocks for engine oil production. They can also help to meet regulatory requirements for sulfur and benzene removal.

We're committed to delivering industry-leading, innovative process technologies, specialty catalysts and expertise that exceeds customer expectations and provides differentiated value. Our main goal is to help customers increase production capacity, decrease operating costs and lower emissions, so they can achieve greater operational success. Most importantly, we collaborate with our customers as long-term partners — taking on challenges, finding solutions together and providing guidance on best practices that help achieve customer goals.



# Shaping the future

As a technology innovator and manufacturer with close relationships to its customers, ExxonMobil has developed fundamental insights that optimize and improve customers' operations through technology development.

## **Solving shared challenges through our experience**

ExxonMobil is committed to its customers' operational success, focusing on increasing the value generated by our customers' processes and plants. Used in over 150 commercial facilities around the world, ExxonMobil catalysts and technologies offer a number of potential advantages, over a range of technology categories.

ExxonMobil catalysts are used in over 150 commercial facilities worldwide.

## **Toluene alkylation with methanol (EMTAM™ process technology)**

ExxonMobil's EMTAM process uses inexpensive methanol to upgrade toluene to paraxylene. It's a breakthrough technology that maximizes production of valuable paraxylene product while lowering feed and energy costs. The highly paraxylene-selective process is built from commercially proven technologies. Unlike other toluene conversion processes, there is no benzene co-product and no hydrogen co-feed. It is the only process that can tune the methyl-to-ring ratio based on market conditions and allows unlimited benzene co-feeding to produce paraxylene.

## **Heavy aromatics transalkylation (TransPlus™ 5 process technology)**

ExxonMobil's TransPlus 5 process is the low-cost, high-conversion solution to upgrade C9+ heavy aromatics and toluene into higher-value mixed xylenes and high-purity benzene products. The TransPlus 5 process — which is based on

a proprietary high-activity, co-extruded dual zeolite catalyst with low precious metal content — offers superior yields, longer cycles, lower operating costs and increased profitability.

## **Selective toluene disproportionation (PxMax™ process technology)**

ExxonMobil's PxMax process technology is the industry benchmark for selective toluene disproportionation. Based on an ex-situ selectivated catalyst, the PxMax process offers unmatched paraxylene selectivity and product yields (superior xylenes-to-benzene ratio), which improve over an exceptionally long and stable catalyst cycle.

## **Xylene isomerization (XyMax™ -2 process technology, LPI process technology)**

ExxonMobil's XyMax-2, and LPI processes isomerize para-depleted xylenes effluents from the paraxylene recovery section into equilibrium mixed xylenes, thereby upgrading lower-value isomers to



higher-value paraxylene product. The XyMax™-2 process provides unmatched performance, stable yields and catalyst cycles. The ultra-low xylenes losses, high ethylbenzene conversion, higher benzene purity and high WHSV allow customers to reduce capital costs, inexpensively debottleneck existing facilities and reliably increase profitability over the extremely long catalyst cycle.

The LPI process also isomerizes para-depleted xylenes effluents from the paraxylene recovery section into equilibrium mixed xylenes, but the reactions take place in the liquid phase — offering a number of unique benefits, including significant energy savings, low temperature operation and ultra-low xylenes losses. These unique benefits allow customers to reduce capital costs, inexpensively debottleneck existing facilities and reliably increase profitability over the long catalyst cycle.

#### **Aromatics treatment (Olgone™ process technology)**

ExxonMobil Olgone process technology is designed to extend cycles of existing aromatic streams treaters to reduce or eliminate the amount of solid waste generated from an aromatics complex. At the heart of this high-performance technology is a highly stable and reusable catalyst. The outstanding performance of the Olgone process can lead to significant operating-cost savings, better protection of downstream units, fewer treater changeouts, as well as debottlenecking opportunities.

#### **Ethylbenzene alkylation (EBMax™ process technology)**

The EBMax process was designed by Badger Licensing LLC to upgrade ethylene and benzene to ethylbenzene for use in the styrenics (polystyrene) value chain. It has been commercially deployed over 35 times and represents ~45% of all the ethylbenzene

manufactured today. The process is built upon ExxonMobil's proprietary zeolite catalyst that drives a very high selectivity to ethylbenzene and enables a low-capital, highly energy-efficient design that is applicable to grassroot, expansion and retrofit opportunities. The EBMax process produces ethylbenzene with exceptional product purity for the manufacture of styrene.

#### **Cumene alkylation (Cumene process technology)**

The Badger cumene process was designed by Badger Licensing LLC to upgrade propylene and benzene to cumene for use in the phenolics/bisphenol-A value chain. It has been commercially deployed over 29 times and represents ~55% of all the cumene manufactured today. The process is built upon ExxonMobil's proprietary zeolite catalyst that drives a very high selectivity to cumene and enables a low-capital, highly energy-efficient design that is applicable to grassroot, expansion and retrofit opportunities. The Badger cumene process produces cumene with exceptional product purity for the manufacture of phenol, acetone and subsequently bisphenol-A.

#### **Gas treating (FLEXSORB™ technology)**

ExxonMobil's FLEXSORB technology enables customers to process increasingly sour gas streams while helping to meet stringent emission regulations and sulfur recovery objectives. The highly selective H<sub>2</sub>S removal process has also been used in tail gas treating (TGT), acid gas enrichment (AGE) and high-pressure acid gas removal (AGR) units. The technology provides a cost-effective way to meet low H<sub>2</sub>S specifications while minimizing CO<sub>2</sub> co-absorption.

#### **Synthetic fuels (Methanol to gasoline technology)**

ExxonMobil's methanol-to-gasoline technology converts methanol to gasoline that minimizes offsite and logistic complexity. MTG creates a single, fungible liquid product with virtually no sulfur and low benzene, which can be sold as-is or blended with ethanol, methanol, conventional gasoline or gasoline components.

#### **Lube dewaxing (MSDW™ technology, MWI™ technology, MAXSAT™ technology)**

ExxonMobil's MSDW, MWI and MAXSAT catalyst technologies are ideal solutions for producing base stocks for high-quality engine oils. These high-performance catalytic technologies offer premier lube catalytic dewaxing and hydrofinishing benefits capable of processing a very wide range of feedstocks — from hydrotreated VGOs and DAOs to hydrotreated raffinates and slack waxes.

#### **Diesel dewaxing (MIDW™ technology)**

ExxonMobil's MIDW catalyst technology enables higher yields of low cloud-point diesel. Through isomerizing paraffins instead of cracking them, this diesel dewaxing technology may also enhance cetane and volume swell compared to other technologies that rely only on cracking.

## Mogas production (BenzOUT™ technology)

ExxonMobil's BenzOUT technology is a commercially proven process technology for the reduction of benzene in gasoline. Developed by ExxonMobil and licensed by Badger Licensing LLC, BenzOUT can operate as a grassroots unit or can be retrofitted into existing equipment, such as polygas units. This unique process advantage helps refiners meet benzene regulations, while maximizing their return on investment.

## Hydroprocessing (SCANfining™ technology)

ExxonMobil's SCANfining technology is a cost-effective solution for meeting the low-sulfur requirements of gasoline. Jointly developed by ExxonMobil and Albemarle, this hydroprocessing technology removes sulfur, lowers hydrogen consumption and minimizes octane loss.

## Sulfuric acid alkylation

ExxonMobil's proven sulfuric acid alkylation technology helps refiners increase their crude barrel value. By reacting isobutene with propylene, butylene and pentylene, this process forms alkylate — a superior gasoline blendstock that offers high octane and low vapor pressure.

## Resid conversion (FLEXICOKING™ technology)

ExxonMobil's FLEXICOKING technology converts a range of heavy, low-value feeds to higher-value products in a competitive, cost-effective, flexible and environmentally friendly solution with virtually no coke. ExxonMobil's operations experience, low-cost design and continuous innovation enable significant long-term economic value.

## Our portfolio

Group	Technology category	Brand	Application
Chemical	Xylenes	EMTAM™	Paraxylene production
		TransPlus™ 5	Heavy aromatics transalkylation
		PxMax™	Selective toluene disproportionation
		MTDP-3	Toluene disproportionation
		XyMax™ -2	Xylenes isomerization
		LPI	Liquid phase xylene isomerization
	Benzene alkylation	EBMax™ (ethylbenzene)	Benzene alkylation
		Cumene	Benzene alkylation
Gas	Gas treating	FLEXSORB™*	Gas treating
	Synthetic fuels	MTG	Synthetic fuels
Refining	Lubes	MSDW™	Lube base stock dewaxing
		MAXSAT™	Lube base stock hydrofinishing
		MWI™	Wax dewaxing
		Nebula	Specialty hydrotreating
		RHC/RHT	Specialty hydrotreating
	Fuels	MIDW™	Diesel dewaxing
		BenzOUT™	Fuel production
		SCANfining™	Hydroprocessing
		Sulfuric Acid Alkylation	Sulfuric acid alkylation
		Nebula®	Specialty hydrotreating
		Celestia™	Specialty hydrotreating
	Resid conversion	FLEXICOKING™*	Resid conversion

\* All EM technologies use a catalyst except for FLEXICOKING and FLEXSORB

## Specialty Hydrotreating (Nebula® and Celestia™ catalysts)

Nebula is a commercially proven bulk-metal catalyst that provides high-activity hydrotreating. Jointly developed by ExxonMobil and Albemarle, the Nebula catalyst has been successfully applied in many hydroprocessing applications, from naphtha hydrotreating to hydrocracking pretreatment since 2001.

Celestia is a second-generation bulk-metal catalyst. It has the highest activity of any catalyst in the hydroprocessing industry. Through unprecedented hydrodesulfurization, hydrodenitrogenation and aromatic saturation activity, Celestia™ catalyst can provide step-out performance and operational flexibility.

The higher activity of the Celestia catalyst allows refiners to simultaneously benefit from

opportunities such as increased feed rate, cycle length and improved product quality.

The Nebula and Celestia catalysts are often deployed together in stacked configurations, which can lead to significant performance improvement over other supported catalysts.

## Technology leadership in catalyst discovery and commercialization

ExxonMobil has a long history of innovation in catalyst development and process technologies, and proven track record for converting its inventions into commercial reality. From its early pioneering work on fluid catalyst cracking units and zeolite technology through numerous advanced technologies, ExxonMobil continues to demonstrate its leadership in innovation and commercialization.

1950

1960

1970

1980

1990

2000

2010

2020

1958

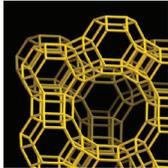
### Sulfuric Acid Alkylation

Process that primarily reacts butylene with iso-butane to form high octane alkylate for gasoline blending

1962

### Zeolite catalytic cracking

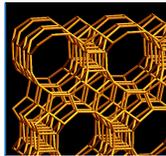
Selective cracking of gas oils greatly improves the octane value of gasoline



1967

### Zeolite beta discovery

The second zeolite catalyst in the ZSM series of catalysts with a three-dimensional structure of 12-ring pores



1975

### Alkylaromatics synthesis

Nickel-containing zeolite catalysts enable production of alkylaromatic compounds

1979

### Vapor phase ethylbenzene

ZSM-5 catalyst enables the alkylation of benzene to ethylbenzene, and allows the production of styrene and styrene derivatives



1983

### FLEXSORB™

Gas treating technology utilizing proprietary hindered amines for selective removal of H<sub>2</sub>S in the presence of CO<sub>2</sub>



1995

### Liquid phase alkylation

Advanced catalysts for ethylbenzene and cumene production serve over 50 applications

1985

### Methanol-to-gasoline

ZSM-5 catalyst material can play a key role in methanol-to-gasoline processes, which allow the use of natural gas from remote areas to be utilized to make liquid fuels

1990

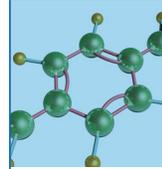
### MCM-41 invention

An advanced molecular sieve with tunable mesopore diameters

1997

### Selective toluene disproportionation

Catalysts allow high paraxylene yields and higher overall xylenes yields without the need for in-situ regeneration



1998

### Transalkylation to xylenes

Catalyst enables upgrading of C<sub>6</sub> aromatics to xylenes and benzene

1999

### MIDW™

Hydroisomerization of light distillates to produce low temperature diesel

### MSDW™

Hydroisomerization of distillates and hydro-processed oils to produce lube base stocks (Catalytic dewaxing was discovered in 1977)

2007

### Olgone™

Advanced catalyst that accomplishes the selective removal of olefins and diolefins from aromatic streams

2015

### Liquid Phase Isomerization (LPI)

Xylenes isomerization process that operates at low temperature with less xylene losses than vapor phase technology. Significant energy savings from low temperature operation and elimination of boiling and condensation operations

### EMTAM™

A breakthrough technology which maximizes production of valuable paraxylene product while lowering feed and energy costs

### Celestia™

An ultra-high activity hydroprocessing catalyst, developed in partnership with Albemarle, for increased flexibility and profitability, providing step-out performance, feed flexibility and reduced energy costs

1955

### Hydrofinishing catalyst

Using a nickel/molybdenum/alumina catalyst, hydrotreating would become a key catalytic process for the removal of sulfur and improving quality of distillates, lubes and waxes (NiMo/Al<sub>2</sub>O<sub>3</sub> catalyst)

### Fluid coking

Fluidized coking technology for resid conversion allowing for a continuous coking process and solid coke removal (Martin De Witt)



1970

### FCC

Fluid Catalyst Cracking upgrades heavy gas oils to lighter oils substantially increasing production of gasoline and diesel from crude oil

1963

### ZSM-5 discovery

ZSM-5 (Zeolite Socony Mobil) is an aluminosilicate zeolite catalyst for completing shape-selective chemistry with minimal coking – a revolutionary discovery for many refining and chemical processes

1973

### Xylene isomerization

Advanced catalysts for converting C<sub>8</sub>-rich feedstocks to orthoxylene and paraxylene

1976

### FLEXICOKING™

Combines fluid coking with air blown fluid bed coke gasification to produce high value liquids and clean burning fuel gas

1977

### Catalytic dewaxing

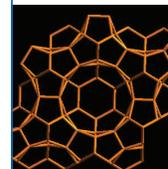
Advanced zeolite catalysts for selective dewaxing of diesel fuel can improve low-temperature performance



1986

### MCM-22 invention

Discovery of the zeolite MCM-22, with a 3-D structure featuring 12-ring surface pockets, enables highly shape-selective chemistry with minimal coking for aromatic processes



1996

### Selective lube dewaxing

Specially designed zeolite catalysts selectively isomerize long-chain paraffins, significantly increasing base stock yields

2001

### Nebula™ catalyst

Extremely high activity shaped base metal catalyst representing a great step forward since the beginning of hydroprocessing catalyst development in the 1950's. Jointly developed by ExxonMobil and Albemarle, it is especially suitable for ultra-deep desulfurization, denitrogenation and dearomatization at medium to high pressures

### SCANfining™

ExxonMobil's hydroprocessing design utilizing catalyst technology jointly developed with Albemarle allows for sulfur removal with minimum octane loss

2011

### BenzOUT™

New catalyst offerings allow selective upgrading of benzene in gasoline blend components, thus reducing benzene in gasoline





# Realizing the benefits of continuous innovation

ExxonMobil invests more than \$1 billion annually into research and development. Innovation begins at ExxonMobil's Corporate Strategic Research Center, where new catalysts and technologies are discovered and their development accelerated.

## **Continuous innovation and investment**

ExxonMobil's research and development efforts support a program of continuous improvement in performance and process optimization. Innovation begins at ExxonMobil's Corporate Strategic Research Center, where new catalysts and processes are discovered, developed and tested. ExxonMobil was one of the first companies to pioneer the use of high throughput experimentation to accelerate catalyst development. The extensive experience built by ExxonMobil researchers over many years has resulted in an efficient and effective innovation process.

## **Field-tested, insight-driven**

ExxonMobil occupies a unique position as both a developer of technology and a commercial user. Catalysts and technologies developed within ExxonMobil research laboratories are field-tested at the company's refining and chemical production facilities. Insights gained inside ExxonMobil plants regarding use and performance enable further optimization of the products and processes. ExxonMobil can then bring these catalysts and technologies to their customers.

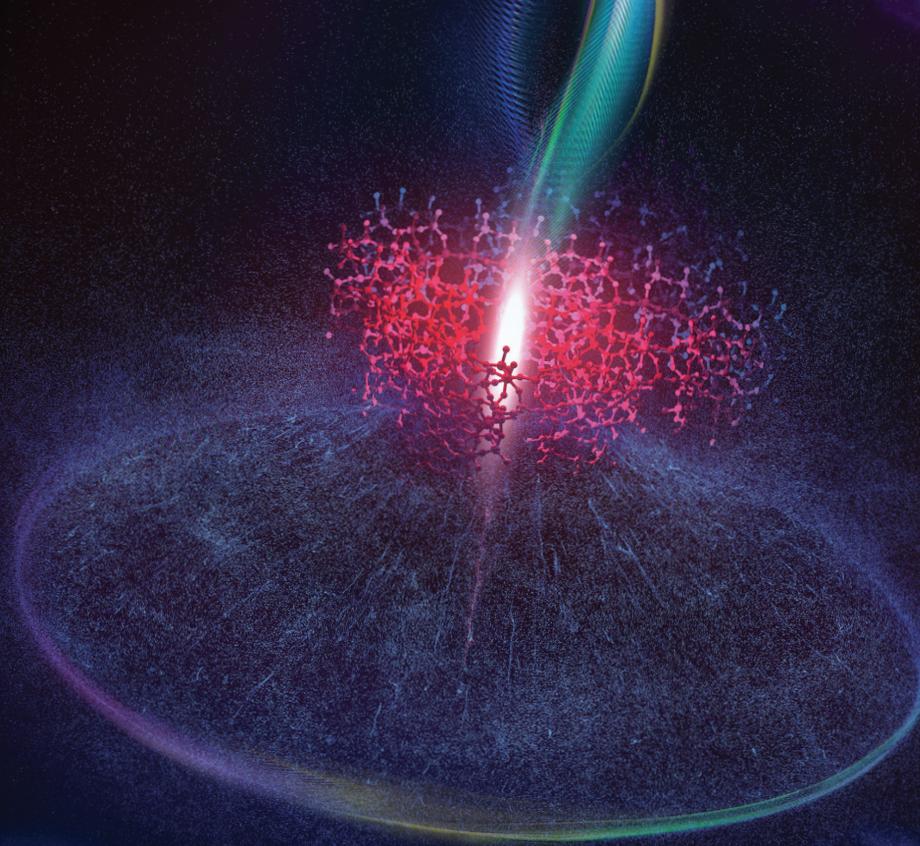
## **Successful customer relationships**

ExxonMobil highly values relationships with customers. ExxonMobil routinely meets with customers throughout the process to identify opportunities to improve operation and to discuss future expansions and needs, including the latest catalyst products and technologies. Customers can benefit from

the insights that have been developed from many years of global technical experiences, as customized to meet their specific needs. In addition, ExxonMobil and its technology licensing partners can provide combined technical and commercial solutions that assist in meeting customers' production and efficiency goals, such as process modification, expansions and new production facilities.

## **Worldwide logistics**

For many years, ExxonMobil has coordinated with its customers to reliably supply catalysts and process technologies all over the world. Using a responsive global supply chain, ExxonMobil continues to achieve operational excellence. Along with our technology licensing partners, we can provide engineering and logistics support at every step of the way.



Where common challenges meet shared solutions. Contact us to see how our experience can work for you.

**ExxonMobil**

Collaborate with us today.  
[catalysts-licensing.com](http://catalysts-licensing.com)

L1018-050E96

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