



Process catalysts –

Partnerships on new technologies and licensing that makes our partners love technology.

 **BASF**

We create chemistry

BASF Catalysts Business

BASF Catalysts Production Capabilities

Comprehensive Catalyst Solutions

The value of your catalyst solution is measured by more than just its price tag. At BASF, we understand that it must also include commercial and technical support, global supply, and responsive customer service. That's why we've built a commercial and technical group that collectively has many decades of experience in the development and application of catalyst technologies across the entire range of chemical processes. This expertise is further strengthened by a global team of customer service providers, global centers of manufacturing excellence, and the capability of the global BASF supply chain.

Worldwide Resources

As part of BASF, the Catalysts division offers global assets for the entire value chain. Our ability to deploy BASF's international resources improves response time for technical support and decreases the lead times for product manufacturing and delivery, while maintaining high quality and flexibility. BASF has a network of plants, research units, and site communities in regions where technologies can effectively and efficiently be dispensed.

Committed to Customer Success

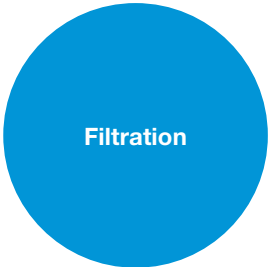
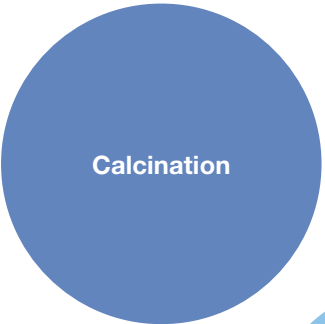
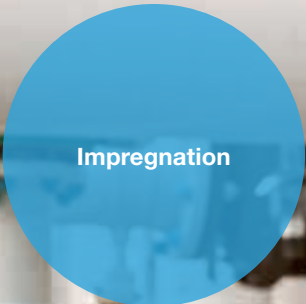
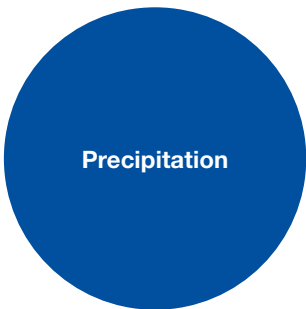
Assisting our customers in attaining their financial and manufacturing goals is important to BASF. Our creative scientists, skilled engineers, and best-in-class technologies make BASF the global leader in catalysis.

Award Winning Innovations

Through research and extensive experience, our portfolio of catalysts and adsorbents was specifically engineered to meet the requirements of a broad range of applications in a variety of industries. Over 650 BASF catalyst specialists are dedicated to creating innovations that raise performance levels to exceed expectations.

Scale-up capabilities

The scale-up of catalysts from lab-scale to industrial scale requires precise control on a complex chain of operations. BASF can look back to more than 100 years of experience in the field of catalysis, extensive knowhow and expertise in its global production operations as well as its R&D network.



BASF Catalysts Research & Development and manufacturing sites

Privileged access to **high-throughput screening** capabilities (hte)



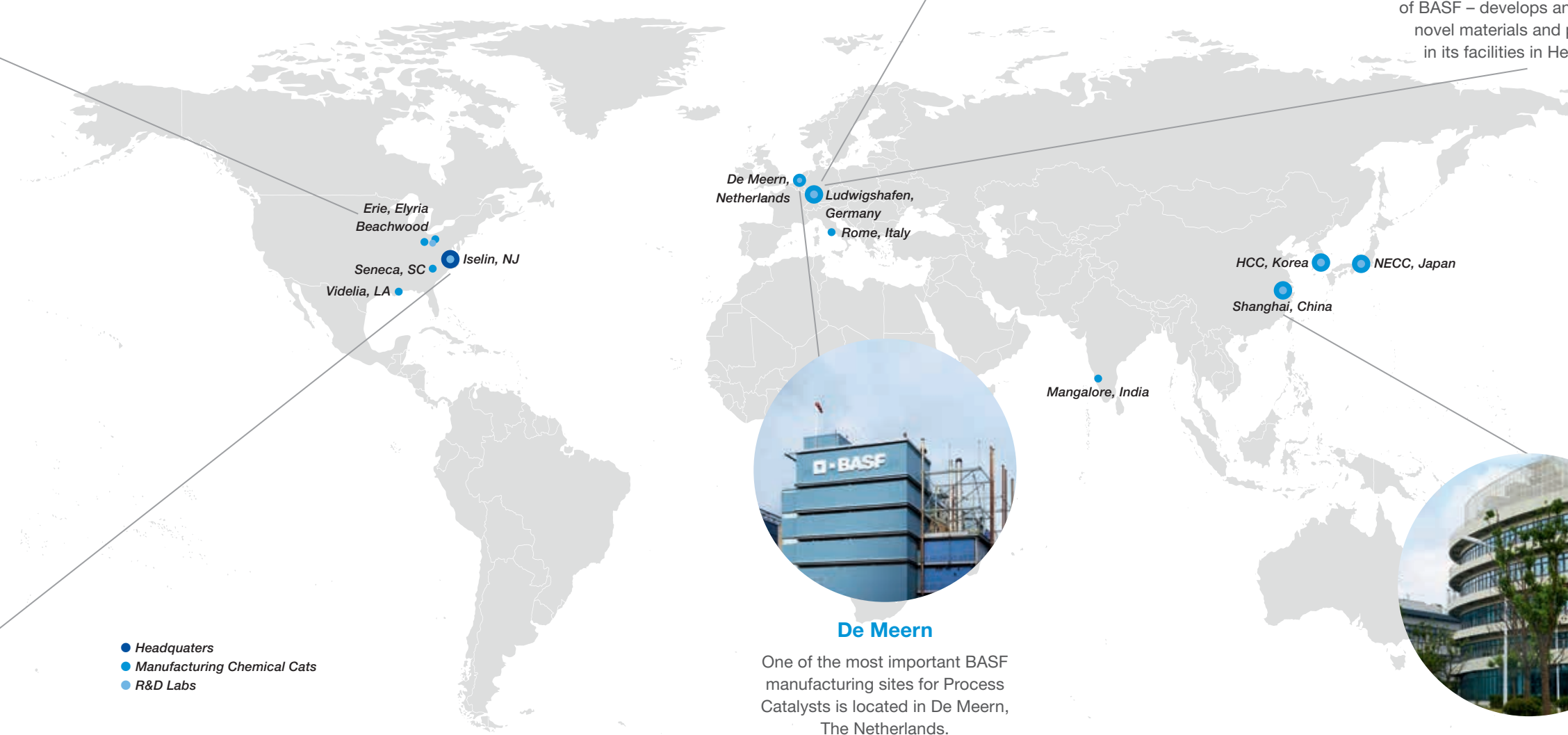
Beachwood

The BASF R&D site is the home of a team of researchers focused on chemical and process engineering.



Iselin

The headquarters of BASF's catalysts research unit are based in Iselin (USA, New Jersey).



Ludwigshafen

Ludwigshafen is the largest site within the BASF R&D Verbund, hub for the region Europe and headquarters of Process Research & Chemical Engineering platform.



hte Heidelberg

In short- and long-term R&D collaborations, hte – a subsidiary of BASF – develops and optimizes novel materials and processes in its facilities in Heidelberg.



De Meern

One of the most important BASF manufacturing sites for Process Catalysts is located in De Meern, The Netherlands.



Shanghai

In 2017, BASF opened its first Asian manufacturing site for Process Catalysts in Shanghai. The Innovation Campus is BASF's largest R&D center in the region.

>1 100 catalysts experts from
28+ nationalities globally

New Technologies and Licensing – beyond catalyst manufacturing

BASF Catalysts division creates answers to customer needs in the field of catalysis and adsorption whatever the level of implication needed.

To achieve this, BASF Catalysts proposes 4 models of interaction with our customers:

Market catalyst

A large portfolio of catalysts and purification adsorbents is already available, including top-level customer and technical service.

Custom synthesis

BASF can act as a toller or take a more active role in the successful scale-up of our customer's catalyst; the catalyst IP remaining 100 % by our customer and an internal firewall guarantees protection of customer's IP.

Process licensing

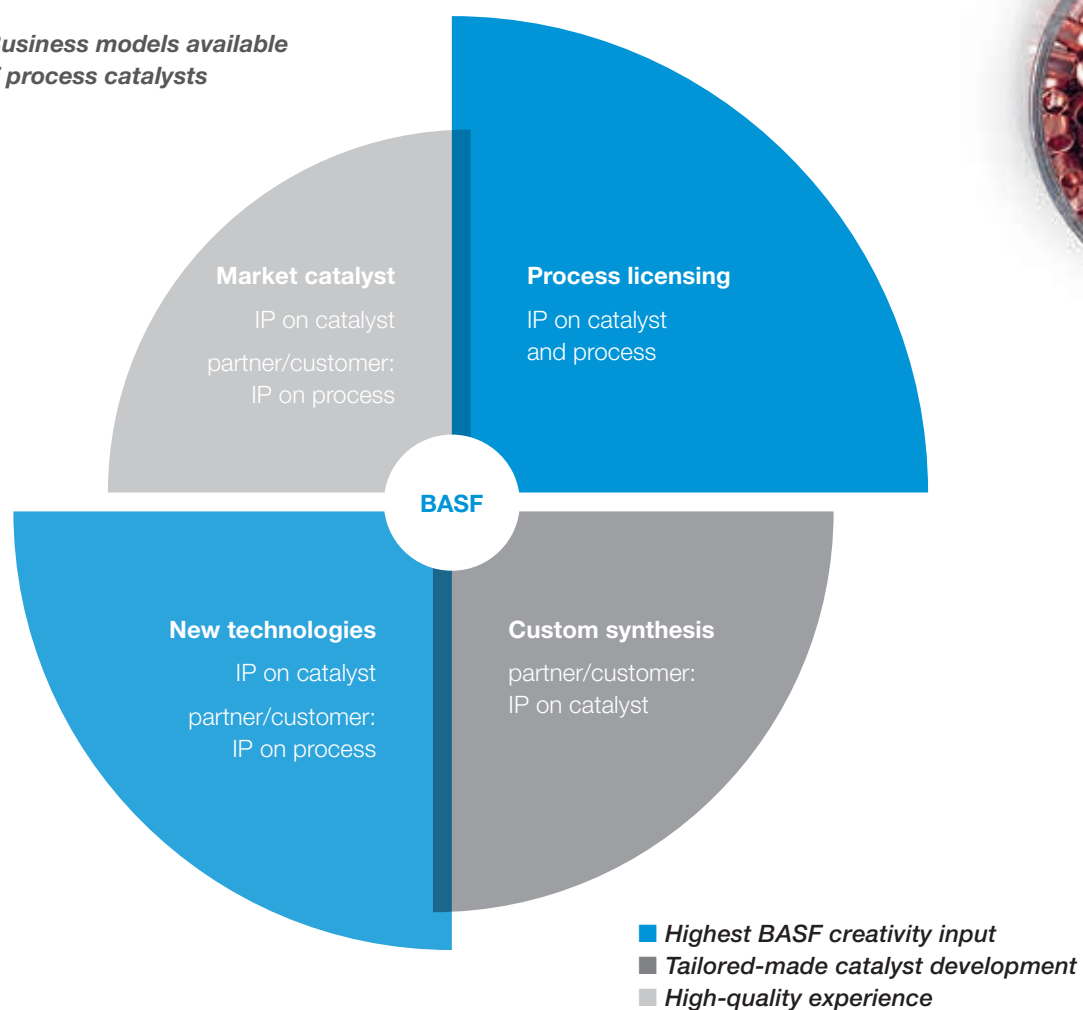
For customers seeking to enrich their investment projects with BASF expertise, we offer selected process technology licenses and a full-range of engineering and technical services.

New technologies

We are targeting a joint approach for the development and commercialization of new process and associated catalysts. Bringing our own ideas and creativity, we primarily focus on the development of the catalyst while our process engineering partner remains focused on the process aspects.

Going beyond mere catalyst supply

Scheme 1 Business models available within BASF process catalysts



New Technologies

Our creativity and expertise is the basis for **joint developments** of step-change innovations

Our Strategic Focus

Answering the need for new processes – BASF innovative approaches

In a moving world, BASF Catalysts division recognizes the growing need for process innovation answering modern industrial trends such as raw material change, growing environmental concerns and energy efficiency.

BASF New Technologies develops ideas and concepts answering these trends and proposes on-purpose design of catalysts in close cooperation with process engineering partners.

We are targeting a broad range of key chemicals, going beyond BASF's own chemical portfolio and looking constantly to bring a sustainable advantage to our customers and partners, through superior efficiency and/or mitigated environmental impact.

Our Approach

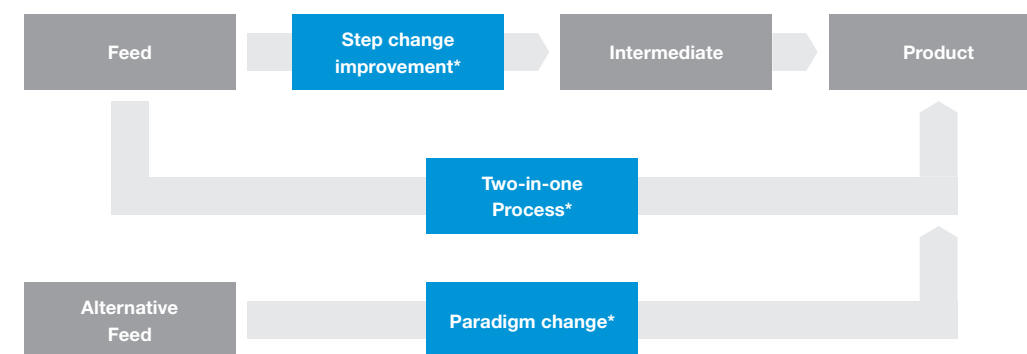
BASF New Technologies focuses on step-change innovations, i.e. innovations which make state-of-the-art technologies obsolete.

This may be either through revisiting existing processes and bringing a significant improvement through innovative catalyst development, or by establishing new paths to key industrial chemicals, such as a two-in-one type process, use of alternative feedstock or opportunity feedstock created by shale gas in North America or by coal-based syngas in Asia.

Scheme 2 Our strategic orientations



Scheme 3 Our approach – type of innovation



* Joint innovation

BASF New Technologies is focusing on step-change innovation going far beyond incremental improvement of existing systems



Reformer in Pullach

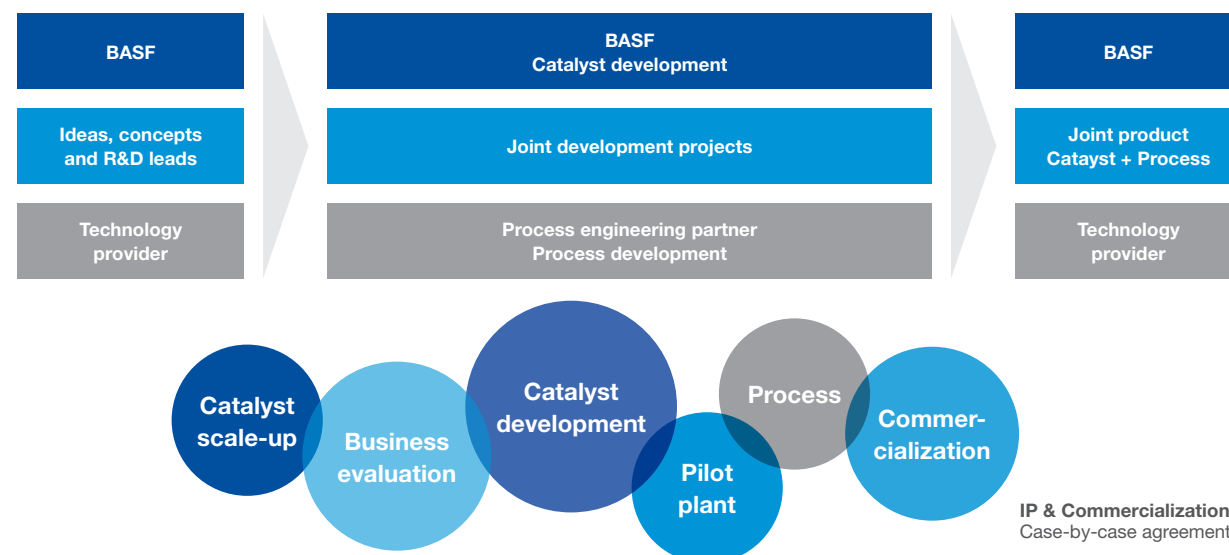
Our Partnering Model

BASF: your preferred partner for step-change innovation development

BASF can rely on its excellent own R&D network – 10,000 researchers, 1,100 of them in catalysis – and rich relationships with best-in-class academic research teams worldwide. With this outstanding basis, the new technologies team develops ideas, concepts and R&D leads for the most important processes to key industrial chemicals.

We aim at leveraging these capabilities by establishing strong cooperation with selected process engineering partners, resulting in joint development projects where catalyst and process are commonly developed and commercialized as a holistic [process + catalyst] product. This kind of long-term partnership from both sides produces optimal path to bring real, step-change innovations to market.

Scheme 4 Our joint development model



Gathering best-in-class skills in catalyst design and process engineering in joint development projects to generate step-change innovations

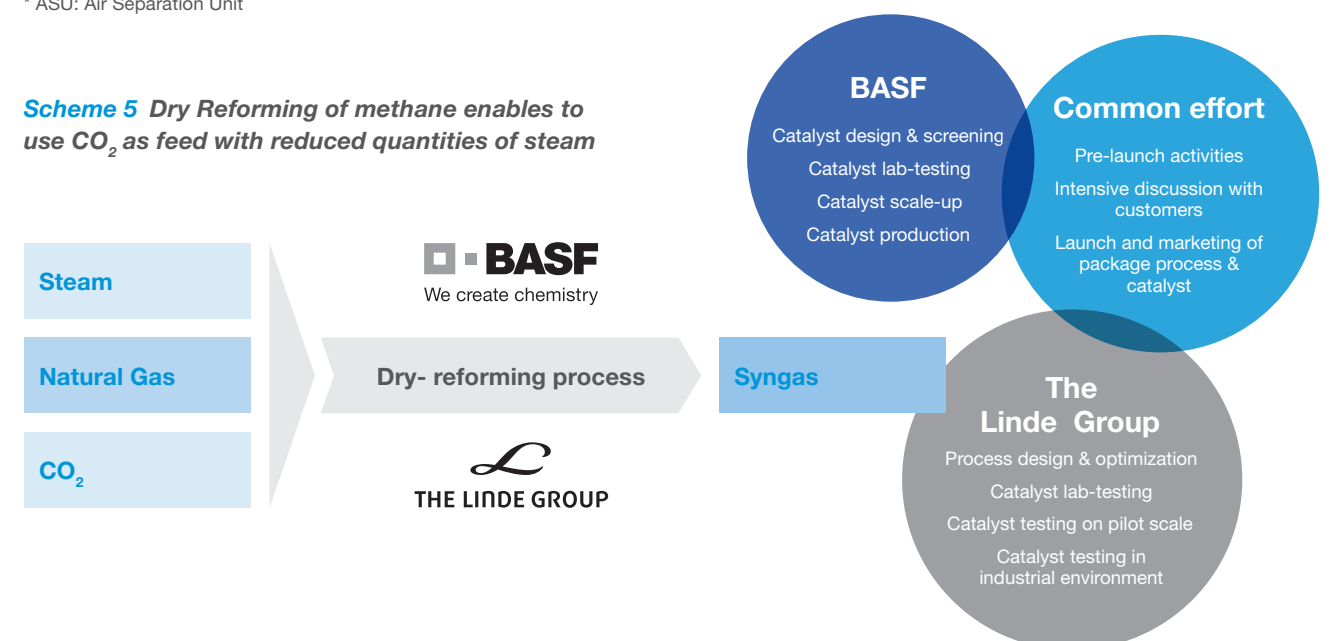
Case Study: Dry Reforming of Methane

The CO₂ reforming of methane, also known as dry reforming (DRM), is an attractive alternative technology to ATR* and POx technologies for the production of syngas with low H₂/CO ratio without ASU* need. Basic research was done by BASF/hte and Linde Engineering in partnership with the Karlsruhe Institute of Technology, the Technical University of Munich, the University of Leipzig and the DECHEMA Gesellschaft für Chemische Technik and Biotechnologie e.V. Based on these first results, BASF and Linde Engineering developed jointly a catalyst and process package allowing for the production of CO₂-rich synthesis gas at industrially relevant pressures,

with a decreased energy consumption and lower CO₂ footprint, providing in addition an elegant usage of CO₂ offgas streams. Development efforts are supported jointly by both companies, BASF focusing on the design, development and scale-up of a step-change catalyst and lab-scale catalyst testing, Linde focusing on the process design and piloting of the catalyst and process. Marketing activities are carried out on a common basis, leveraging the global reach of the two partners and demonstrating the synergies resulting from such a partnership approach not only on the technical but also on the business side.

* ATR: Autothermal Reforming
* ASU: Air Separation Unit

Scheme 5 Dry Reforming of methane enables to use CO₂ as feed with reduced quantities of steam

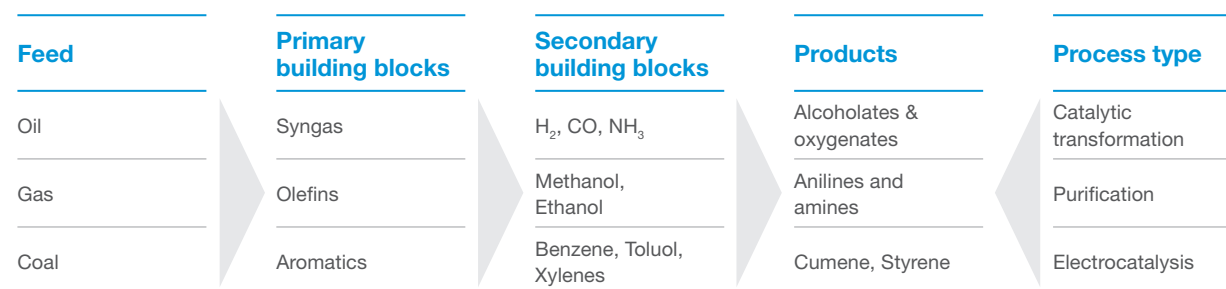




Our Scope – complete petrochemical value chain

We are actively scouting for innovation opportunities in the field of process **catalysis** and **purification** along the complete petrochemical value chain. We are also actively seeking opportunities in other fields where catalyst play a key role and BASF’s capabilities can be leveraged optimally, such as in **electrocatalysis**.

Scheme 6 Scope of New Technologies



Our Scope – broad metal basis

Our portfolio of concepts and R&D projects covers a large family of chemical transformation, involving the development of step-change catalysts based on a broad range of metals including EHS sensitive Nickel and Cobalt as well as precious metals such as Platinum and Rhodium.

BASF’s expertise includes extensive testing facilities, scale-up and production capabilities. We are proud to say that we are able to process all kind of metals and carriers, wether extrudates or full tablets with the highest EHS standards, performance and reliability.

Table 1 Some of typical catalytic applications for base and precious metals

Metal type	Typical application
Base metals	
Ni	Steam reforming, Dearomatization
Al	Alcohol dehydration
Cu	Oxo alcohols, Methanol, Water Gas Shift, desulfurization, aromatic amines
Precious metals	
Pt	Hydrogenation, Isomerization, Fuel Cells
Pd	Hydrogenation, Aromatization

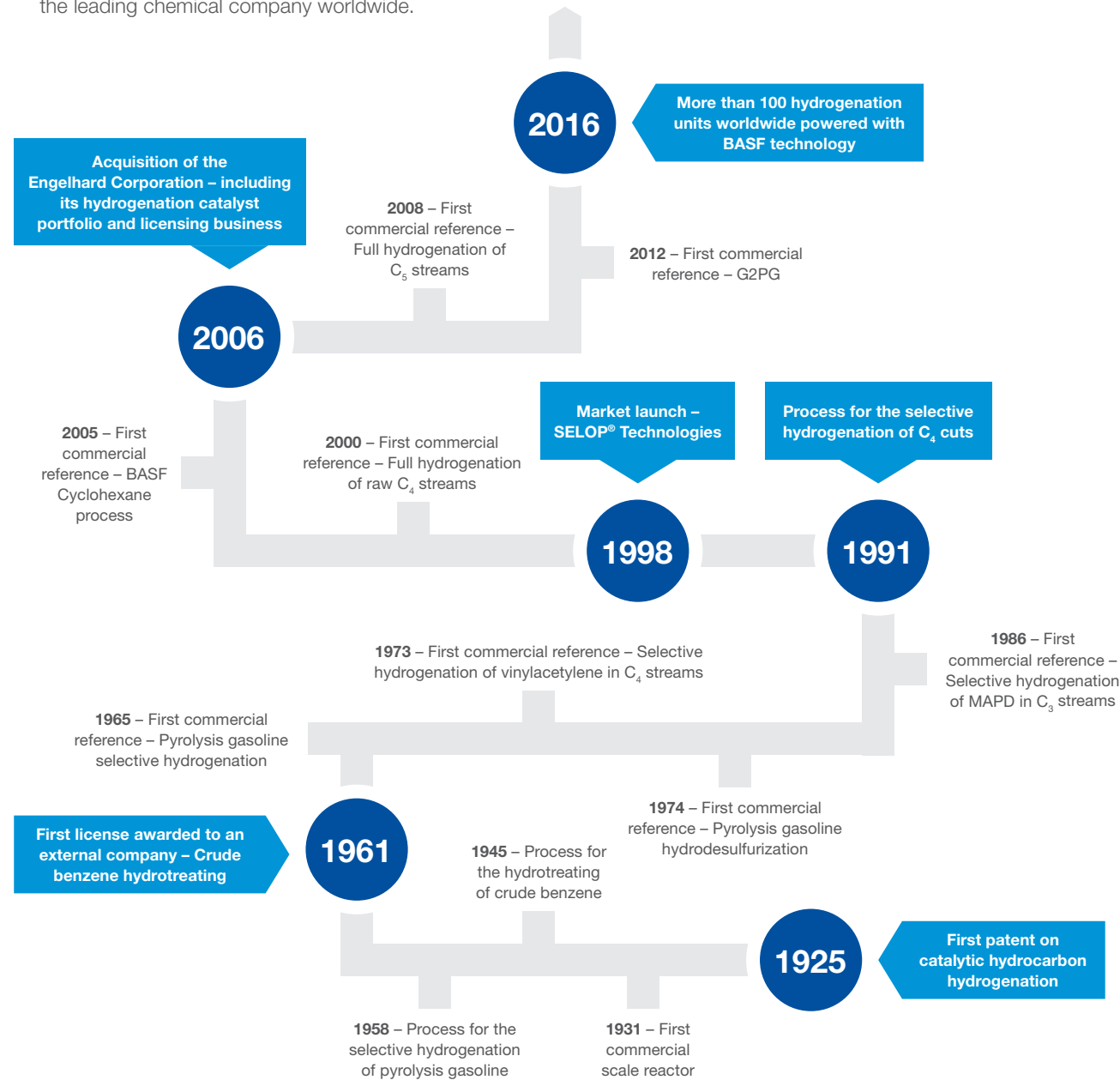
Process Licensing

Take advantage of **BASF**
process **Know-how**

Innovation Loves Tradition

Process innovation has driven the success of BASF since its inception. BASF researchers have achieved some of the major technology breakthroughs in chemical engineering, including the Haber-Bosch process for ammonia synthesis or the catalytic process for the production of sulfuric acid. Due to this tradition of innovation, BASF owns a broad portfolio of self-developed technologies which allows us to perform as the leading chemical company worldwide.

BASF also licenses some of these proprietary processes and exclusive technologies knowhow accessible to our customers via a process licensing business. The licensing portfolio of BASF's process catalyst department currently includes several processes, which profit from our expertise in heterogeneous catalysis.



Portfolio Overview

Table 2

Feedstock	Task	BASF Technology	Industrial Applications
Raw C ₃ cuts	Selective hydrogenation of methylacetylene and propadiene to propylene	SELOP® C ₃	Refinery Ethylene Plant Propane Dehydrogenation Plant
C ₄ streams	Acetylene rich	SELOP® VA	Butadiene Plant
		SELOP® VABD	Butadiene Plant
	Butadiene containing	SELOP® C ₄	Ethylene Plant Olefin Metathesis Plant, Butadiene Plant Methanol-to-Olefins Plant, Butane Dehydrogenation Plant
		SELOP® FC ₄	Ethylene Plant
	Butadiene free	SELOP® FC ₄	Ethylene Plant
Mixed C ₄ /C ₅ streams	Hydrogenation of C ₄ and C ₅ olefins to C ₄ and C ₅ paraffines	SELOP® FC ₄ -C ₅	Ethylene Plant
Raw C ₅ cut	Selective hydrogenation of C ₅ dienes to C ₅ olefins	SELOP® C ₅	Olefin Metathesis Plant
	Hydrogenation of C ₅ olefins to C ₅ paraffines	SELOP® FC ₅	Ethylene Plant
Pyrolysis Gasoline (PyGas)	Raw	SELOP® C ₅₊	Ethylene Plant Aromatics Plant
	Stabilized	SELOP® HDS	Ethylene Plant Aromatics Plant
Reformate	Selective hydrogenation of dienes and olefins with minimal aromatic losses	SELOP® C ₆	Refinery
	Hydrogenation of aromatics	REDAR®	Refinery
Benzene	Production of high purity cyclohexane	BASF CX	Cyclohexane Plant (cyclohexanol/cyclohexanone)
Coke Oven Light Oil (COLO)	Hydrodesulphurization, hydrodenitrogenation, and hydrogenation of olefins and styrenics to paraffines with minimal aromatic losses	COLO HDS	Coke/steel manufacturing, Aromatics Plant
Bio-Glycerin	Production of high purity bio propylene glycol (1,2-propanediol)	BASF G2PG	Biodiesel Plant Fatty Acid Plant

SELOP® – BASF Olefins Hydrogenation Technology

In 1998, BASF introduced the trademark SELOP® for the commercialization of a broad spectrum of hydrogenation process technologies. As of today, our customers have selected BASF superior performing SELOP® technology for more than 70 hydrogenation units worldwide. This achievement is a consequence of our firm commitment to focus on our customers' needs and contribute to their success with innovative and sustainable solutions.

The SELOP® process technologies are applied for the selective hydrogenation, full hydrogenation and/or hydrodesulfurization of many different hydrocarbon streams with applications in the refinery and petrochemical fields. BASF delivers tailored made designs that minimize the CAPEX and OPEX and maximize the return of investment.

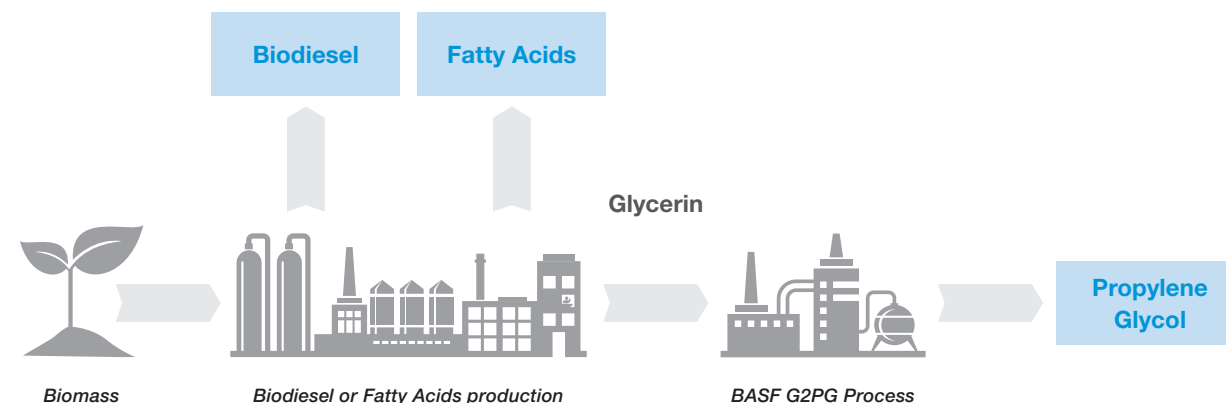
Scheme 7 SELOP® – BASF olefins hydrogenation technology



Upgrading Bio-Glycerin with the BASF G2PG Process

In the manufacturing of bio-diesel and fatty acids from bio-renewable materials significant amounts of low value glycerin (a.k.a. glycerol) are co-produced. BASF G2PG process technology allows our customers to upgrade the glycerin to propylene glycol (1,2-propanediol), a valuable chemical used for the production of polyester resins, functional fluids, detergents and in the food, cosmetic and pharmaceutical industries.

Scheme 8 Green chemistry route to propylene glycol



Due to the outstanding product quality and the superior yields obtained, the BASF G2PG process is recognized as the leading commercially proven technology for the production of propylene glycol from glycerin.



High Purity Cyclohexane with the BASF CX Process

High purity cyclohexane is mainly used to produce cyclohexanol and cyclohexanone, which are precursors of adipic acid and caprolactam. Hence, cyclohexane derivatives find applications on the automotive, construction and textile industries.

BASF CX process combines a special noble metal catalyst with reliable and easy-to-operate fixed bed reactor technology to produce highest purity cyclohexane from benzene resulting in reduced capital (CAPEX) and operational expenses (OPEX).

After benchmarking the BASF CX process against state-of-the-art technologies, BASF selected the BASF CX process to construct a world-scale production plant, which is successfully in operation since 2005 and is able to process simultaneously benzene separated from aromatics or produced by hydrodealkylation of toluene.

Now, BASF is making this exclusive technology available to our customers.



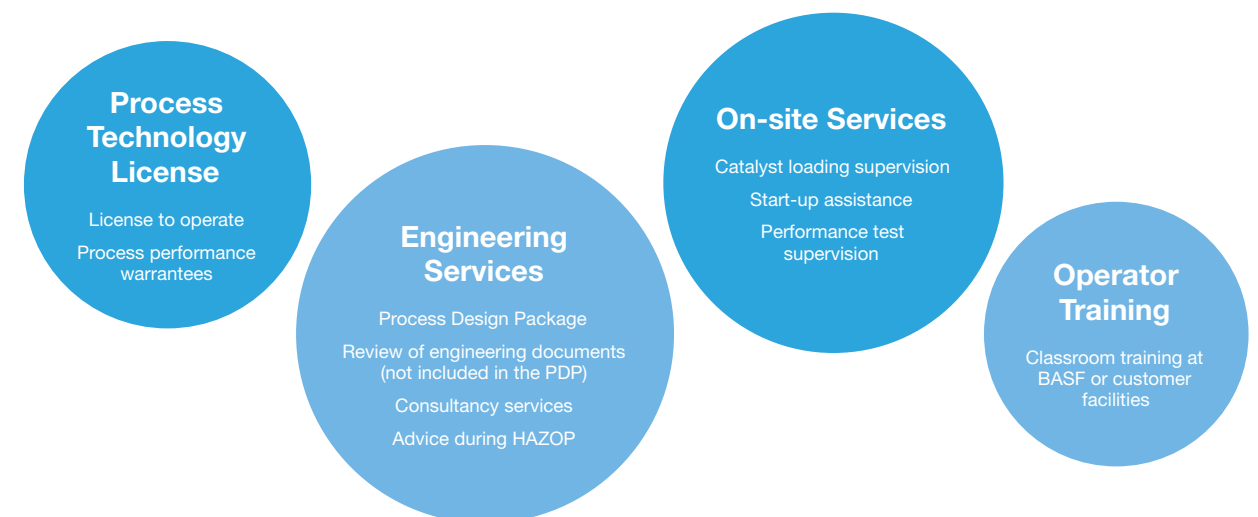
Features of the BASF CX process:

- Excellent product quality
- Outstanding cyclohexane yield
- Superior operation flexibility
- Highest reliability and longest on-stream time
- Advanced heat integration concept

BASF aromatics complex in Ludwigshafen am Rhein benefits since 2005 from its BASF CX world-scale plant

Services for Our Licensees

As part of our commitment to the success of our customers, BASF offers the entire spectrum of services associated with the licensing of process technology.



Our Business Partners

We possess extensive experience collaborating with leading engineering companies or in-house engineering departments to bring BASF process technology to your site. Some of the companies belonging to our engineering network are:

- Air Liquide Global E&C Solutions
- CB&I / Lummus
- Linde Engineering
- Saipem
- TechnipFMC Process Technology
- ThyssenKrupp Industrial Solutions
- Toyo Korea



Americas

BASF Corporation
25 Middlesex/Essex Turnpike
Iselin, New Jersey, 08830, USA
Tel: +1-732-205-5000
Fax: +1-732-205-7725
Email: catalysts-americas@basf.com

Asia Pacific

BASF (China) Company Limited
300 Jiang Xin Sha Road
Pudong, Shanghai 200137
P.R. China
Tel: +86-21-2039 2549
Fax: +86-21-2039 4800-2549
Email: catalysts-asia@basf.com

Europe, Middle East, Africa

BASF De Meern BV Catalysts
The Netherlands
Tel: +31-30-666 9437
Fax: +31-30-666 1531
Email: catalysts-europe@basf.com

About Us

BASF's Catalysts division is the world's leading supplier of environmental and process catalysts. The group offers exceptional expertise in the development of technologies that protect the air we breathe, produce the fuels that power our world and ensure efficient production of a wide variety of chemicals, plastics and other products, including advanced battery materials. By leveraging our industry-leading R&D platforms, passion for innovation and deep knowledge of precious and base metals, BASF's Catalysts division develops unique, proprietary solutions that drive customer success.

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www.catalysts.basf.com/chemicals



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