Process catalysts –
Partnerships on new technologies and licensing that makes our partners love technology.
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 know-how 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.

htc Heidelberg
In short- and long-term R&D collaborations, htc – 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.

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**Scheme 1 Business models available within BASF process catalysts**

- **Market catalyst**
  - IP on catalyst
  - partner/customer: IP on process

- **Process licensing**
  - IP on catalyst and process

- **Custom synthesis**
  - partner/customer: IP on catalyst

- **New technologies**
  - IP on catalyst

- **BASF**
  - Highest BASF creativity input
  - Tailored-made catalyst development
  - High-quality experience
New Technologies

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.

Scheme 2 Our strategic orientations

Reduce our environmental impact
- Valorization of industrial offstream
- Supporting the development of renewable energy
- Alternative fuels
- Waste water treatment

Raw material changes: adapt to a new world
- Syngas-based economy
- Coal to chemicals

Sustainability

Efficiency leverage – make our partners more successful
- Energy efficiency in chemical processes
- Investment reduction
- Process selectivity
- Tailored solutions for niche applications

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 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
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

<table>
<thead>
<tr>
<th>BASF</th>
<th>Process engineering partner</th>
<th>Technology provider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideas, concepts and R&amp;D leads</td>
<td>Process development</td>
<td>Catalyst scale-up</td>
</tr>
<tr>
<td>Joint development projects</td>
<td></td>
<td>Catalyst development</td>
</tr>
<tr>
<td>Joint product</td>
<td></td>
<td>Process development</td>
</tr>
<tr>
<td>Catalyst + Process</td>
<td></td>
<td>Catalyst scale-up</td>
</tr>
</tbody>
</table>

**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.

### Scheme 5: Dry Reforming of Methane enables to use CO₂ as feed with reduced quantities of steam

* ATR: Autothermal Reforming
* ASU: Air Separation Unit

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

Our Scope – complete petrochemical value chain

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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.

Scheme 6 Scope of New Technologies

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

<table>
<thead>
<tr>
<th>Metal type</th>
<th>Typical application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base metals</td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>Steam reforming, Deasphaltation</td>
</tr>
<tr>
<td>Al</td>
<td>Alcohol dehydration</td>
</tr>
<tr>
<td>Cu</td>
<td>Oxo alcohols, Methanol, Water Gas Shift, desulfurization, aromatic amines</td>
</tr>
<tr>
<td>Precious metals</td>
<td></td>
</tr>
<tr>
<td>Pt</td>
<td>Hydrogenation, Isomerization, Fuel Cells</td>
</tr>
<tr>
<td>Pd</td>
<td>Hydrogenation, Aromatization</td>
</tr>
</tbody>
</table>
Process Licensing

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.

Process Licensing

Take advantage of BASF process Know-how

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Process Licensing

Table 2

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Task</th>
<th>BASF Technology</th>
<th>Industrial Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw C5 cuts</td>
<td>Selective hydrogenation of C5 olefins to C5 paraffins</td>
<td>SELOP® FC5</td>
<td>Ethylene Plant</td>
</tr>
<tr>
<td></td>
<td>Selective hydrogenation of C5 dienes and styrenics to C5 paraffins</td>
<td>SELOP® C5</td>
<td>Ethylene Plant</td>
</tr>
<tr>
<td></td>
<td>Hydrodesulfurization, hydrodenitrogenation, and hydrogenation of olefins and styrenics to paraffins with minimal aromatic losses</td>
<td>SELOP® HDS</td>
<td>Ethylene Plant</td>
</tr>
<tr>
<td>Pyrolysis Gasoline (PyGas)</td>
<td>Raw</td>
<td>Selective hydrogenation of C5+ olefins and styrenics without aromatic losses</td>
<td>SELOP® C5+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hydrodesulfurization, hydrogenotagensation, and hydrogenation of olefins and styrenics to paraffins with minimal aromatic losses</td>
<td>SELOP® HDS</td>
</tr>
<tr>
<td>Reformate</td>
<td>Selective hydrogenation of dienes and olefins with minimal aromatic losses</td>
<td>SELOP® C5</td>
<td>Ethylene Plant</td>
</tr>
<tr>
<td></td>
<td>Hydrogenation of aromatics</td>
<td>REDAR®</td>
<td>Ethylene Plant</td>
</tr>
<tr>
<td>Benzene</td>
<td>Production of high purity cyclohexane</td>
<td>BASF CX</td>
<td>Cyclohexane (cyclohexanol/cyclohexanone)</td>
</tr>
<tr>
<td>Coke Oven Light Oil (C/OLO)</td>
<td>Hydrodesulfurization, hydrogenotagensation, and hydrogenation of olefins and styrenics to paraffins with minimal aromatic losses</td>
<td>COLD HDS</td>
<td>Coke Oil manufacturing, Aromatics Plant</td>
</tr>
<tr>
<td>Bio-Glycerin</td>
<td>Production of high purity bio propylene glycol (1,2-propanediol)</td>
<td>BASF G2PG</td>
<td>Biodiesel Plant</td>
</tr>
</tbody>
</table>
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**

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

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
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.

BASF – We create chemistry

www.catalysts.basf.com/chemicals

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