



PRODUCTS AND SERVICES

A subsidiary of
BASF – We create chemistry



hte – LEADING SOLUTION PROVIDER FOR A FAST AND COST-EFFECTIVE CATALYSIS R&D

hte – the high throughput experimentation company

At hte, we make R&D in the area of catalysis faster and more productive.

We enable cost-effective innovations and reduced time to market for new products, thereby allowing our customers in the energy & refining, chemical & petrochemical, and environmental industry to keep ahead of the competition. Our customers benefit from a broad technical and scientific expertise, an exceptional customer orientation, complete end-to-end solutions, and an outstanding data quality.

Our technology and services comprise

- R&D Solutions: contract research programs at hte's state-of-the-art laboratories in Heidelberg, and
- Technology Solutions: integrated hardware and software solutions, enabling our customers to establish high throughput workflows in their own laboratories.

We deliver

- Accelerated and cost-effective research
- High data quality and reproducibility
- An innovative approach with cutting-edge technology
- Fully integrated workflows and state-of-the-art data management
- R&D Solutions and Technology Solutions – two business fields with strong synergies under one roof

Whether customers decide to work with hte in a contract research program or opt to acquire hardware equipment and software solutions for establishing their own research projects, we offer solutions for various applications:



Environmental

- TWC
- DOC
- DeNOx/SCR
- Soot Combustion
- others



Renewables

Conversion of:

- Bio oil
- Carbohydrates
- CO₂
- Pyrolysis oil
- Lignin / Cellulose
- others



Energy & Refining

- Hydrotreating (ULSD)
- Residue Upgrading
- Hydrocracking
- Hydroisomerization
- Naphtha Reforming
- FCC
- others



Chemicals & Petrochemicals

- Oxidation
- Hydrogenation
- Dehydrogenation
- Oxidative Coupling
- Amination
- C-H Activation
- CO₂ Conversion
- others
- Gas-to-chemicals
- Reforming
- Syngas Conversion
- Gas-to-liquids
- Fischer-Tropsch
- Methanol Conversion
- Ethanol Conversion
- others

HIGH THROUGHPUT EXPERIMENTATION

High Throughput Experimentation (HTE) is a valuable solution for conducting faster, more cost-effective R&D.

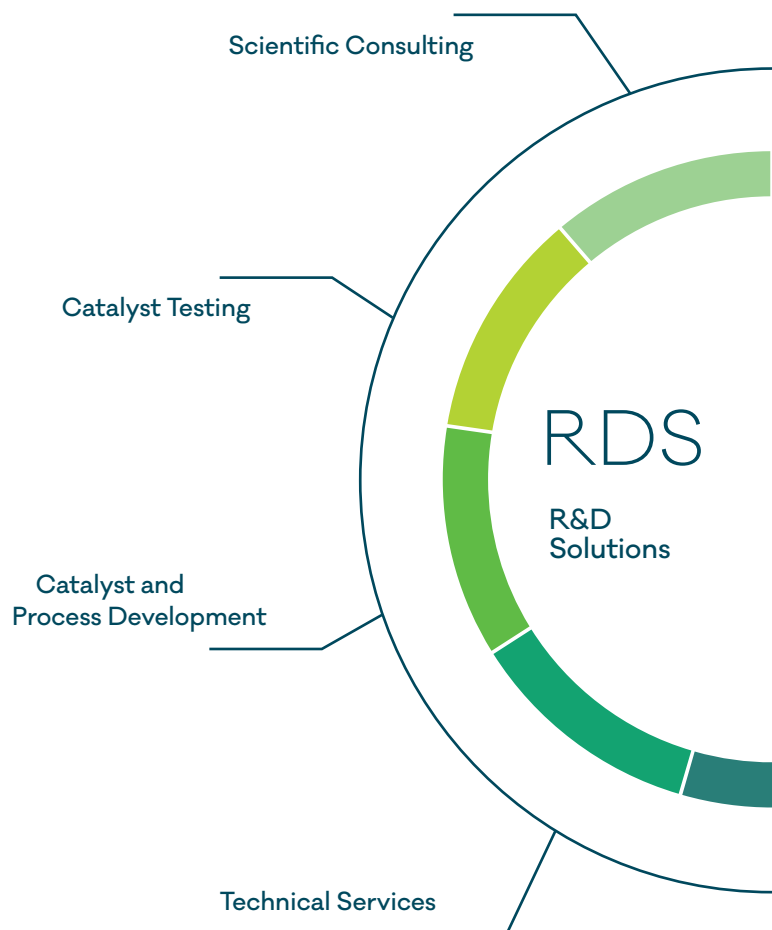
Parallelization of experiments allows for an increased experimental load without subsequently increasing personnel costs or development time; this shortens the time to market for new products. Furthermore, small-scale testing allows for a reduction in materials and feeds, ultimately reducing the total cost per experiment without compromising on data quality.

The automation of high throughput workflows combines seamless operation with minimized intervention of lab technicians and increases reproducibility, while the High Throughput approach of experiments ensures that all catalysts experience the same process conditions, thus allowing a maximum of comparability and providing highly precise as well as accurate data.

RESEARCH & DEVELOPMENT SOLUTIONS

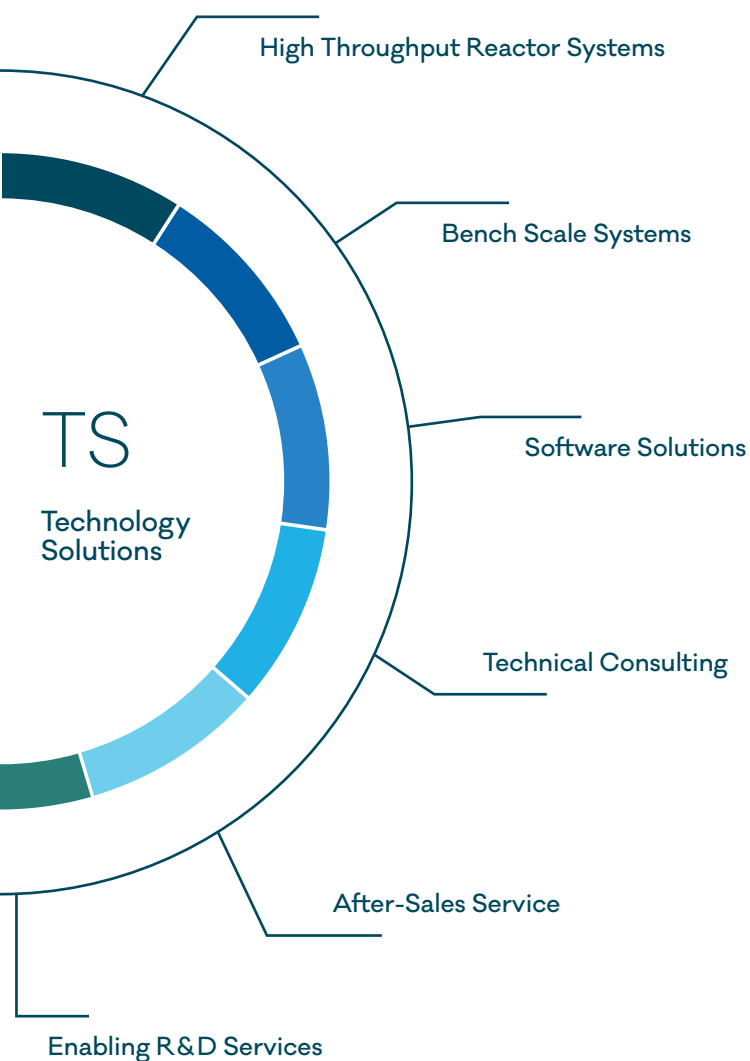
In R&D collaborations, we develop and optimize novel materials and processes on behalf of our customers in our facilities in Heidelberg. We offer access to our technology, know-how, and the necessary resources for the execution of short- and long-term research projects as and when needed.

- Scientific Consulting
- Catalyst Testing
- Catalyst and Process Development
- Technical Services
 - Independent Catalyst Testing
 - Quality Control
 - Production Support
 - Feed Studies
- Enabling R&D Services consisting of e.g.
 - Catalyst Synthesis Services
 - Reactor Loading
 - Analytical Services



Business Offering hte





TECHNOLOGY SOLUTIONS

We design, construct, and implement tailor-made catalyst test technology. Moreover, our reactor systems come with software solutions, enabling our customers to establish high throughput workflows in their own laboratories. We offer:

- High Throughput Reactor Systems
- Bench Scale Systems
- Software Solutions
- Technical Consulting
 - Workflow Analyses
 - Design and Feasibility Studies
- After-Sales Service

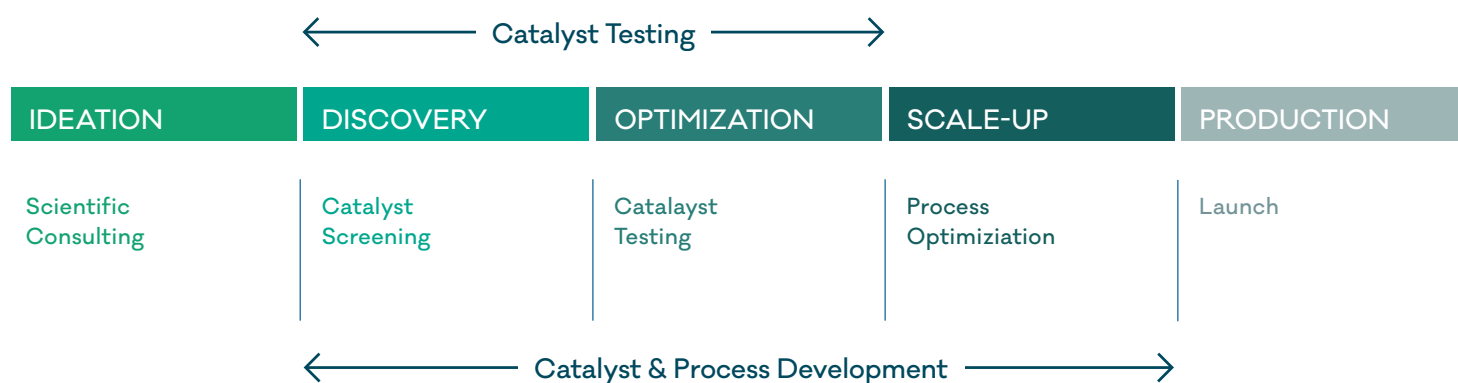
YOUR BENEFITS WITH HTE

- Shorter time to market for new products
- Testing of a broader parameter space in a shorter time
- Reduced cost per experiment
- Increased experimental load without increasing personnel costs or development time
- Reduction in materials and feeds
- Increased reproducibility and statistical significance
- Highly precise and accurate data
- Freedom and flexibility in catalyst research programs
- Access to trained personnel and state-of-the-art technology



R&D SOLUTIONS FOR MORE EFFICIENT CATALYSIS R&D

We help our customers to bring their innovation faster to the market, providing R&D services for all phases of the catalyst development process, including catalyst production support:



Scientific Consulting

We offer scientific consulting from problem definition, through DoE and reactor design, right up to patent research.

Catalyst Testing

For the discovery and optimization of catalysts, we carry out independent “black box”^{*} catalyst testing projects, for example by screening the activity, selectivity, and aging of catalysts. The catalytic materials are provided either by our customers or synthesized in our own state-of-the-art synthesis laboratories. We deliver testing data and their evaluation, the catalyst and process IP stays with our customers.

Catalyst & Process Development

In order to commercialize a promising catalyst material, the process conditions for its application need to be optimized. We examine a wide range of parameters such as temperature and pressure and evaluate them in

comprehensive kinetic studies and modelling. Taking knowledge obtained in the lab and scaling up allows our customers to effectively bridge the gap between high throughput catalyst screening and production plant scale. We formulate the experimental strategy, the catalytic materials are provided either by our customers or synthesized in our own synthesis laboratories. We deliver testing data and their evaluation, the catalyst and process IP stays with our customers.

Service for catalyst suppliers and users

hte's technical service for catalyst suppliers comprise performance testing of the catalyst batch quality and independent catalyst testing for catalyst users, e.g. refineries for benchmarking. Moreover, catalyst samples can be tested under various process conditions in order to determine activity and selectivity under different reaction conditions. Further production support, as e.g. drop-in solutions, and feed studies complete hte's technical services for catalyst users and suppliers.

^{*}The customer sends us a proprietary or commercial catalyst without the need to provide any information on the catalyst.



SERVICE

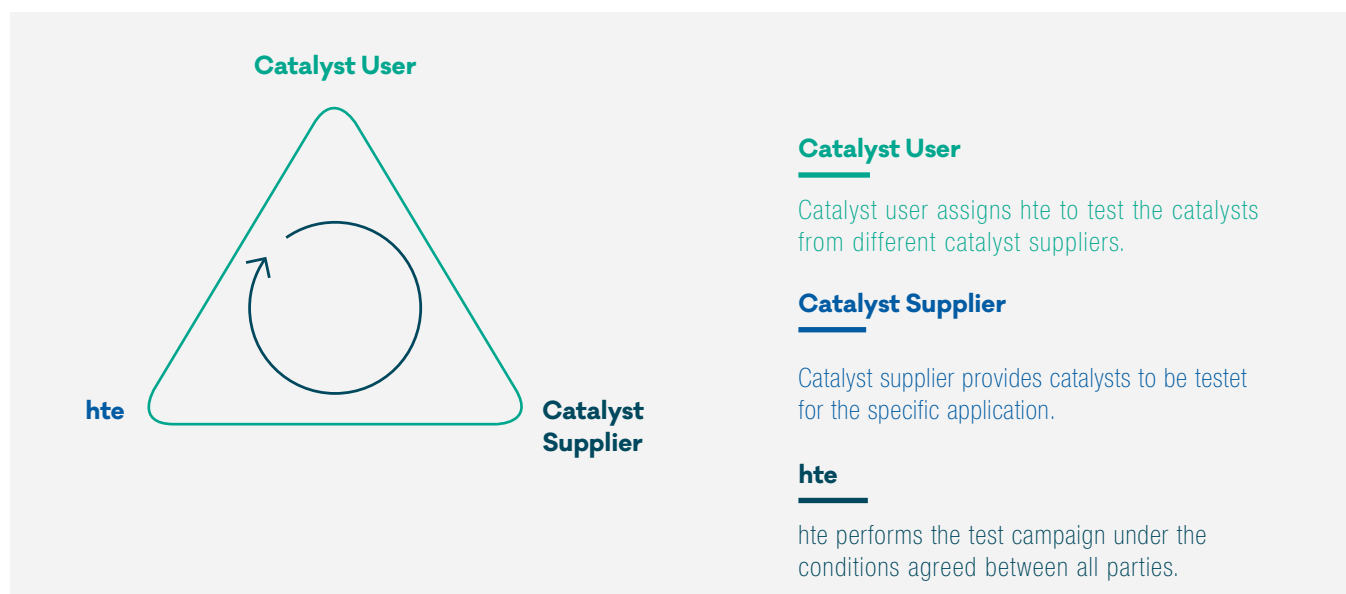
Services for catalyst suppliers and users

YOUR BENEFITS

- Access to the latest high throughput technology, methodology, and knowledge
- Highly qualified and experienced experts in chemistry, engineering, and software
- Purpose-built laboratory environment and infrastructure with auxiliary technology and services (catalyst synthesis, reactor loading, analytics, software)
- On-site support around the clock
- All process and material intellectual proprietary rights remain with the customer.

← Support →

How we work in independent catalyst testing



Fully confidentiality and IP protection by patent owner.

TECHNOLOGY SOLUTIONS ESTABLISH YOUR OWN HIGH THROUGHPUT WORKFLOW

As a technology provider we design, construct, and implement high throughput and bench scale systems in research laboratories worldwide. Our reactor systems include auxiliary laboratory equipment which help our customers to build up inhouse high throughput workflows.



IDEATION

Workflow Analyses
Design and Feasibility
Studies

DISCOVERY

High Throughput Reactor Systems



From 16- to 48-fold
Up to 10 ml
Powders/
Shaped Materials

OPTIMIZATION

Bench Scale Systems



From 4- to 16-fold
Up to 50 ml
Powders/Shaped Materials



From 1- to 8-fold
Up to 300 ml
Shaped Materials

SCALE-UP

PRODUCTION

ORDER	DESIGN	MANUFACTURING	START-UP	COMMISSIONING
Customer provides specifications and commissions hte	Inhouse Design & Engineering <ul style="list-style-type: none"> Basic and detailed design • Process engineering • Mechanical engineering • Electrical engineering 	Inhouse Construction <ul style="list-style-type: none"> • Purchasing & procurement • Manufacturing • Assembly 	In our laboratories <ul style="list-style-type: none"> • Set-up and validation (physical and chemical) • Dispatch preparation • Training 	At customer's site <ul style="list-style-type: none"> • Acceptance test • Training • After-Sales services

From Purchase Order to Operation

Technology Solutions

Our reliable, turnkey ready systems follow international engineering standards and are developed and used over several years in hte's contract research programs. Customers gain a complete lab-in-lab solution validated with their chemistry and immediately operational at their site. From purchase order to commissioning the system, all process steps at hte are carried out inhouse with the utmost professionalism.

SERVICE

Bench Scale Systems



From 1- to 8-fold
Up to 300 ml
Shaped Materials

The systems cover

- Reaction types from gas-phase reactions, through gas-to-liquid, right up to trickle-bed applications
- Temperatures ranging from 0 – 1,100 °C
- Pressures ranging from 0.3 – 300 barg
- Catalyst volumes from 0.1 ml up to 300 ml
- Degrees of parallelization from 1 to 48
- Form ranging from explorative powders up to shaped materials
- Demanding feeds: liquefied gases (e.g. LPG), vacuum or atmospheric residue, and many others

YOUR BENEFITS

- Robust and reliable reactor systems with outstanding performance at speed and efficiency
- The latest technology with integrated analytics delivering high data quality and accuracy
- Modularized technology offering flexible design and easy maintenance
- Integrated software solutions for running experiments, evaluating, and managing data
- The highest quality standards, thereby guaranteeing user safety and system integrity
- Full and extensive training for independent operation, which can be provided both in our state-of-the-art laboratories in Heidelberg and at the customer's site
- Worldwide, fast, and personal customer service with 24-hours availability

CATALYST TESTING WORKFLOW FOR R&D SOLUTIONS & TECHNOLOGY SOLUTIONS

With our experts, technology, and our unique software solution myhte™ we support our customers in each step of the catalyst testing workflow. In R&D Solutions we offer services from scientific consulting up to customized reporting. Within Technology Solutions we deliver all necessary hardware and software equipment for an end-to-end Lab 4.0 solution. In this way, customers benefit from speeding-up their catalysis R&D.

8. / 9.



Automated Evaluation & Management of High-Quality Data and Customized Reporting

All steps of the high throughput workflow are supported and enabled by hte's software solution myhte™. The powerful data management software retrieves, integrates, stores, and enables the user to analyze and visualize the data generated within the workflow. It connects huge amounts of online and offline analytical data with experimental context and synthesis parameters in one database, allowing the researcher to optimize the design of the experiment in the next workflow step.

9. Customized Reporting

8. Automated Evaluation & Management of High-Quality Data

7. Sophisticated On- and Offline Analytics

6. Reliable Sample Logistics

myhte
Scientific Data Warehouse

7.

Sophisticated On- and Offline Analytics

Using high throughput methodologies generates large numbers of samples which need to be analyzed fast. hte's analytic team develops and provides robust and reliable analytical methods for online and offline analytical instruments which are fully integrated into myhte™.



6.

Reliable Sample Logistics

In the course of an experiment thousands of online gas-phase samples and hundreds of liquid samples are produced. All samples have a time stamp with respect to the experimental time on stream. Liquid samples and their derivatives are tracked by bar codes within myhte™ and sent to different offline analyses instruments.



1.



Consulting

Consulting comprises hte's capability to apply high throughput experimentation to the most challenging projects in industrial catalysis. hte's experts are combining an outstanding expertise in many scientific and technical fields around catalysis, as e.g. materials sciences, industrial process know-how, engineering & construction, analytics, and data evaluation.

2.



Design of Experiments

High Throughput Experimentation in many cases is the door opener to apply a rational design of experiments as well as statistical methods, e.g. full factorial designs or others, of planning and evaluating large sets of experiments. It is suitable for catalyst synthesis and performance testing. With e.g. 16- or 48-fold reactors 16 or 48 catalytic materials can be explored with smart statistical designs in one single experiment.

3. / 4.



Industrial Relevant Catalyst Synthesis and Reproducible Reactor Loading

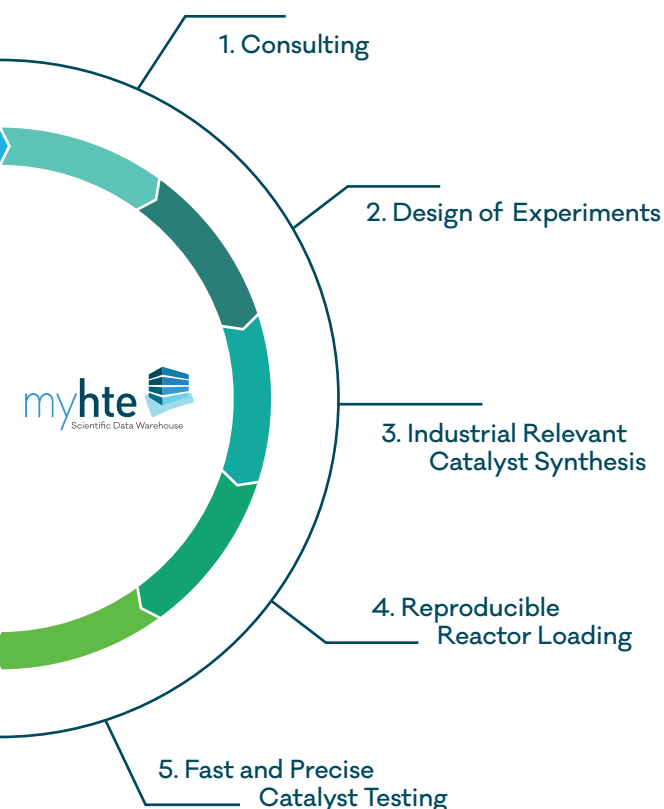
Handling large numbers of catalyst materials is a challenging task. Their composition, preparation, shaping, and reactor loading method strongly influence the performance of catalysts. At hte, we offer unique synthesis services for materials formulation, catalyst shaping, characterization, and reactor loading.

5.



Fast and Precise Catalyst Testing

For the discovery and optimization of catalysts, we carry out catalyst testing projects on our reliable reactor systems. The systems are fully supported by hte's software solutions, enabling our customers to realize the productivity benefits of high throughput technology. A dedicated process control suite, hteControl™, provides the flexibility to execute complex experimental protocols, including demanding activation procedures, and allows unattended 24/7 operation of the unit over multiple months.



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