

SUSTAINABLE CHEMICAL INDUSTRY



TNO innovation
for life

CHEMICAL INDUSTRY: SPECIALISATION AND SUSTAINABILITY

TNO helps the chemical industry innovate by enabling companies to cut costs and put new products on the market more quickly. Businesses looking for new products or production processes call in TNO for advice, to design pilot installations, and to conduct research in our own or our partners' laboratories. In this way, TNO contributes continuously to successful innovation in the chemical industry.

Businesses in the chemical value chain often want to become less dependent on one type of raw material. The transition from fossil to renewable raw materials creates new opportunities and contributes to the sustainability of the chemical industry. Commodity chemistry in Europe has to contend with stiff competition from regions where the costs of energy and raw materials are low, such as the Middle East and the United States. In addition, emerging economies are the most important growth markets for the commodity industry's products. In response to these trends, the chemical industry in Europe is increasingly becoming a producer of specialist high value-added products for niche markets that can be produced locally in places where raw materials such as biomass and renewable energy sources are available.

DIVERSIFICATION AND SPECIALISATION

Given these developments, TNO has developed a vision that has been translated into three concrete proposals for the chemical industry to speed up innovation and thereby improve businesses' competitiveness. TNO employs these proposals to help the chemical industry employ alternative raw materials, produce more efficiently, and place new products on the market more quickly. In so doing, TNO focuses chiefly on suppliers of renewable raw materials, fine chemistry, specialty chemistry & polymers, and consumer chemicals. In this context, TNO supports industry not only with new technology but also with designing new value chains and business models.

TNO offers three propositions for the Chemical value chain: Feedstock Flexibility, Efficient Processing and Improved Product Functionality.



FEEDSTOCK FLEXIBILITY

TNO works for and with businesses on the flexibility in use of raw materials. This is necessary to produce more sustainably and be less dependent on resources such as fossil building blocks. A broader range of more locally available alternative raw materials and new processes for making these raw materials usable make businesses less vulnerable to fluctuations in demand and supply. This strengthens their position on the market and means greater security of supply. Sustainability, economic feasibility, safety, cost-effectiveness, and scalability are key concepts here.

TNO bridges sectors that are as yet not sufficiently familiar with one another but which may in the near future mean a lot for one another, and together for society: the chemical industry and suppliers of renewable raw materials, such as biomass. Biomass suppliers such as the agro-food sector are looking for ways of extracting value from residual waste. But the needs of the chemical industry are often insufficiently known, and conversely the chemical sector is not always aware of the value of such waste and the necessary procedures to make it suitable for their own processes. Because TNO knows both parties well, we can speed up chemical innovation together with them.



AROMATICS FROM BIOMASS

Within the Biorizon Open Innovation Programme at the Green Chemistry Campus in Bergen op Zoom, in collaboration with the Belgian organisation VITO and a growing number of companies, we are working on technologies to make aromatic building blocks from biomass. Aromatics are an important raw material for the chemical industry with in future most likely rising prices. We are, for example, engaged on a project to extract building blocks from household waste that can then be turned into aromatics. Together with waste businesses, a proof of concept has been developed that we are developing further. In another project, we have built a test set-up that produces furans from sugars. In ten years, this will enable our industrial partners to run a new, profitable continuous process.

We do all this as part of open innovation. Businesses and scientists pool their strengths and knowledge in joint facilities to develop new technologies more quickly in an efficient and cost-effective way. Biorizon will be a world leader in research on biobased aromatics. New partners are always welcome to collaborate on further scaling-up of technology.

VALUABLE INGREDIENTS FROM ALGAE

Another example is the VALORIE mobile pilot plant for algal biorefining that TNO has developed with a number of companies. TNO was the first in the world to manage to develop a modular technology enabling the cell wall of algae to be opened efficiently in order to extract valuable functional ingredients on a kilogram scale. Algae are the plant of the future because they can grow on infertile soil with the aid of CO₂ and sunlight. The ingredients extracted can be used in food, animal feed, and chemical and pharmaceutical products. The pilot plant is ultimately set to lead to commercial production. Here, too, new partners are welcome to take part in further increases in scale.



EFFICIENT PROCESSING

Other examples of projects are the use of superheated steam (SHS) technology developed by us as a way of opening up lignocellulose-containing biomass for further processing, such as waste from the agricultural sector and woody biomass. For the longer term the use of CO₂ as raw material for the chemical industry is an important factor in achieving sustainability and a circular economy. At a European level, we are involved in two large projects with researching long-term solutions for making sustainable raw materials from CO₂ for new applications in the chemical industry; as well as researching which products are relevant in the short term.

Please see for more information [TNO.NL/CHEMICALS](https://www.tno.nl/chemicals).

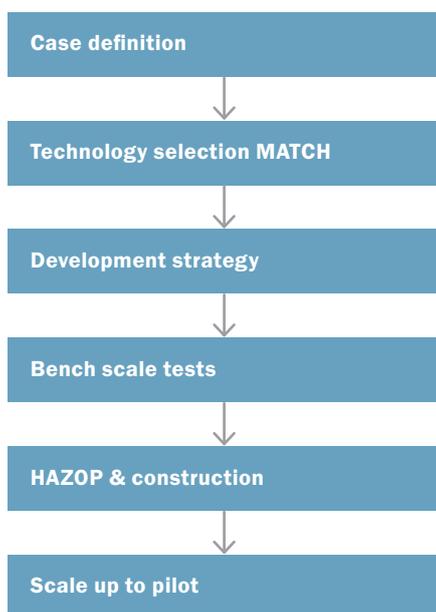
One of the great challenges facing the chemical industry is to become more competitive by specialising and serving niche markets. Businesses want to place high-grade products on the market in a better and quicker way than their competitors. TNO develops technologies, methods and business models for the chemical industry to be able to manufacture smaller quantities of various products continuously in a flexible and scalable manner.

A higher yield and selectivity are the aim, with sustainability and safety being of prime importance. More efficient production can be achieved by, among other things, continuous flow chemistry and electrochemistry. These are chemical production processes in which TNO is highly specialised. For example, we help industry in the transformation from an efficient production system to a system for product development that is as efficient as possible. Smart, flexible production methods also enable businesses to launch new products more quickly and cheaply.

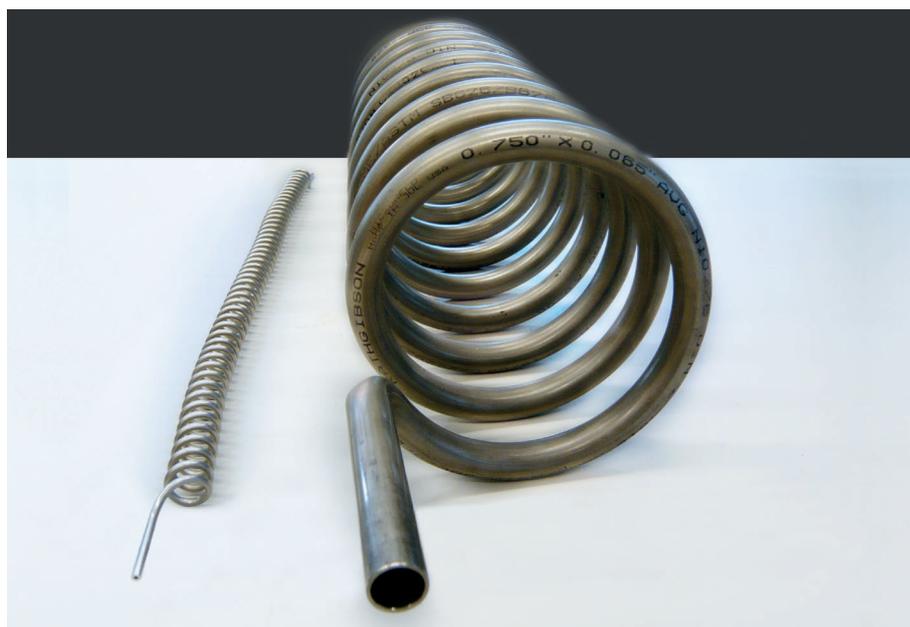


PROCESS SYSTEM ENGINEERING

In designing new processes and production systems, TNO adopts a top-down process system engineering approach. The client informs us of the required functionality, and combined with the key performance indicators and technology readiness level (TRL) TNO independently makes a choice between various technical components needed to go through the desired process steps. Examples include reactor technology, separation technology, and process analysis and control. Using this MATCH method, we take essential decisions in close collaboration with the client and facilitate the transfer of knowledge. We then acquire the missing information by experiments on laboratory, bench, and pilot scales. This approach helps the client take the right technological and business decisions for investment in a new process installation and thus cuts the risks considerably.



Process development framework



SMALL-SCALE AND MODULAR

TNO focuses here in particular on fine chemistry, specialities, and the pharmaceutical industry. These industries can renew their production processes by switching to or beginning small-scale, modular production of smaller quantities of products with high added value. Many businesses are therefore looking for methods and technologies that are easily scalable. Flow chemistry offers a good many benefits that meet these needs. TNO has extensive experience with tubular reactors, such as the Oscillating Baffled Reactor (OBR) and the Static Mixer Reactor

(SMR) and our own Helix® reactor. In fine chemistry and pharmaceuticals, tubular reactors are principally suitable for highly toxic processes, or those entailing safety issues such as explosiveness or flammability. The smaller volumes limit the quantity of hazardous substances in the reactor. In addition, much higher product quality can be achieved in these sectors.

IMPROVED PRODUCT FUNCTIONALITY

ELECTROCHEMISTRY

With knowledge partners and businesses, we develop new technologies for the electrification of the chemical industry. Electrochemistry offers the sector great opportunities. This technology enables chemical transformations to be achieved much more selectively under lower pressure and temperature. In addition, this means much less waste production and raw material consumption. Increasingly sustainable electricity is becoming available from the sun and wind. However, the supply from these sources is by definition highly variable. By building small-scale chemical installations at windmills or solar panels, in future the industry will be able to directly harness this sustainable electricity. But there are also opportunities in the short term. We are investigating how, via electrolysis and electrosynthesis, we can find methods of enabling the chemical industry to better profit from higher selectivity in combination with sustainable energy from electricity. This means a gain on three fronts: lower energy costs, sustainability, and new high-grade products.

Please see for other examples of projects and technologies [TNO.NL/CHEMICALS](https://www.tno.nl/chemicals).

In all kinds of areas, the consumer is accustomed to high-grade products coming onto the market in improved versions at an ever faster rate. This forces the chemical industry in particular, as well as pharmaceutical and personal and home care companies, to work continuously on improving product functionality. TNO develops technologies enabling the properties of substances and materials to be predicted and modified.

SAFE DESIGN

Sustainability and safety are of key importance in this regard. For example, we have developed the DIAMONDS method to be able to predict the complex toxicology of new and existing substances. This means that businesses wanting to develop new chemicals can establish at an early stage whether the chosen route to the product is the right one. The TNO model combines data from a large number of publically available databases. These include studies, scientific articles, and

other sources covering many thousands of substances. The DIAMONDS method maps the relationships between chemical structure and toxicity. The predictions mean that businesses can make the right choices for a safe design at the beginning of the process and thereby cut their development costs and shorten their time to market.

NEW FUNCTIONALITIES

Our knowledge of formulation, particle engineering and encapsulation ends up chiefly in speciality chemistry, the pharmaceutical industry, and consumer chemicals. Companies in these fields are constantly looking for new functionalities. These may entail products for personal care, cosmetics, cleaning products, paint, or medicines. TNO advises on matters such as the most practicable method for encapsulating products, looking both at the formulation of the active ingredients and at the production process.



OUR PRODUCTS AND SERVICES



ANALYSING SUSTAINABILITY

For TNO, innovation with which to strengthen the chemical industry goes hand in hand with the search for sustainability. This means that we not only look at the sustainability of products and production processes but also analyse all the factors involved in a product's entire life cycle: use of land and water, alternative raw materials, energy consumption, and potential for recycling. We team up with businesses to work on new methods for fully and measurably describing the sustainability performance of products. This enables companies to manage sustainable innovations in the value chain. New developments in biomass and nanotechnology particularly attract our attention in this regard.

Please see for other examples of projects and technologies TNO.NL/CHEMICALS.



Consultancy and offering options to our clients on choices to be made, in which we examine technology, sustainability, safety, and economic feasibility in a coherent way.

Our **Engineering** services are intended for businesses needing new concepts for products or processes. We design and build with our partners test set-ups on a bench or pilot scale.

We transfer **Technology supply** developed by TNO or third parties to clients via contract research or licences. The intellectual property of the technology may in this context remain both with TNO and the client.

Via **Open innovation** programmes, our clients benefit from cooperation between knowledge institutes, business institutes, and government bodies, which means that the development costs and risks are shared.



CONTACT

We cordially invite you to consult us to see how TNO, an independent R&D organisation with 3000 experts working daily to support thousands of customers worldwide, can apply its solutions in terms of raw materials, processing, and products to help improve your competitiveness.

Arij van Berkel
T +31 88 866 21 57
E arij.vanberkel@tno.nl

Peter Wolfs
T +31 88 866 56 45
E peter.wolfs@tno.nl

TNO
Leeghwaterstraat 44
2628 CA Delft
The Netherlands

[TNO.NL/CHEMICALS](https://www.tno.nl/chemicals)

TNO.NL