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Markets & Economy

World Competitiveness 2022, China's Quest for Self-sufficiency in Chemicals, Innovative Technology Can Help the Chemical Industry to Tackle Challenges

Process Technology

Microreaction Technology in Pharmaceutical Manufacturing, Energy Crisis: An Opportunity to Replace Fossil Fuels with Sustainable Alternatives

Innovation

Revolutionary Fractionation Technology for Biopolymers from Biomass, Forward-looking Data Analytics on Demand for Chemicals and Materials

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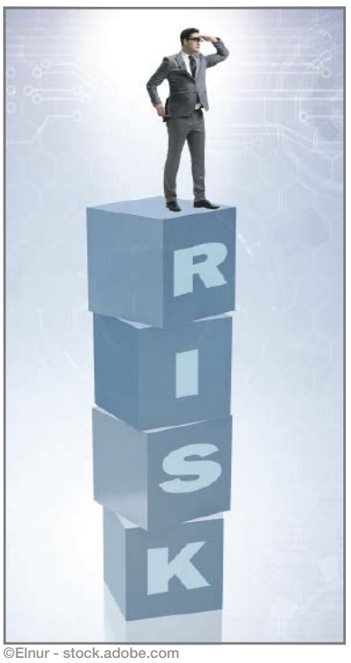

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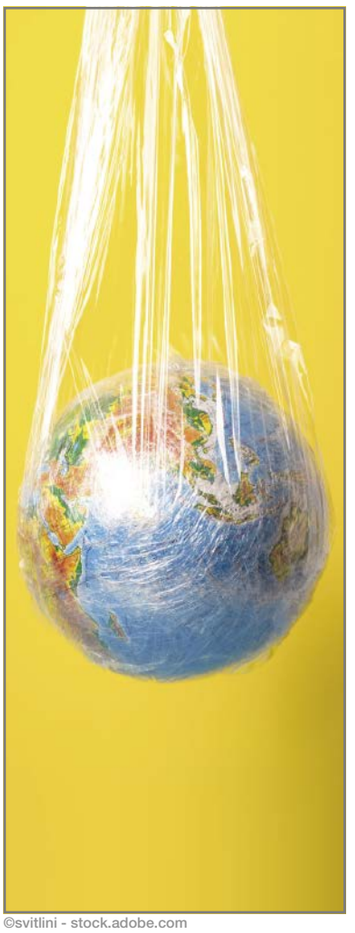
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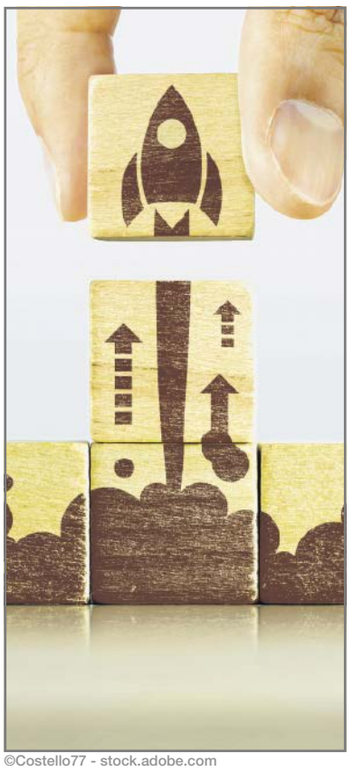
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Markets & Economy

Flow Chemistry

Sustainability

Innovation

The Re-Emergence of Global Geopolitical Risks

IMD World Competitiveness Yearbook 2022

The 2022 edition of the IMD World Competitiveness Yearbook, compiled by the International Institute for Management Development (IMD), is published at a moment of tremendous turmoil. The pandemic has affected all countries worldwide by giving rise to a health and economic crises. While Covid-19 is still affecting large parts of the world an additional perilous situation has emerged: the geopolitical risks re-introduced by the Russian invasion of Ukraine.

For this year's edition of the report, IMD has evaluated the competitiveness standings of 63 countries and how their economies developed since 2021. The results for the ten most successful countries are presented as follows.

Competitiveness of High-Ranking Economies

The variation in the overall competitiveness ranking among the ten highest ranking countries in IMD's report is presented in Fig. 1.

Denmark reaches the top spot (up from 3rd) for the first time in the history of the IMD World Competitiveness Ranking. Switzerland moves down to 2nd (from 1st), Singapore recovers to 3rd place (from 5th), Sweden declines to 4th (from 2nd) and Hong Kong improves to 5th (from 7th). While the Netherlands loses two places by dropping to 6th (from 4th), Taiwan gains one spot (up to 7th from 8th) and Finland joins the top 10 for the first time since 2009 reaching 8th position (from 11th). Norway declines from 6th to 9th and the USA once again rounds up the top 10.

Denmark

Denmark's achievement is mainly due to gains in the International Investment sub-factor, and a robust performance in the Government Efficiency (6th) factor, particularly in the Institutional Framework (2nd), Business Legislation (3rd) and Societal Framework (2nd) sub-factors. The country performs outstandingly in the Business Efficiency factor (1st) and sub-factors such as Productivity and Efficiency (1st) and Management Practices (1st); it also improves in Attitudes and Values (6th to 3rd). Denmark reaches 2nd place in the Infrastructure factor advancing in the Technological Infrastructure (6th to 3rd) and Scientific Infrastructure (11th to 10th) sub-factors but losing one place in Education (4th).

Switzerland

Switzerland's performance remains strong despite its slight drop in the overall ranking. It tops the Government Efficiency and Infrastructure factors and ranks 4th in Business Efficiency. The downturn in the overall ranking originates largely from a sharp decline in the International Investment sub-factor and, to a lesser extent, in the Employment sub-factor, which places the country in the 30th spot in the Economic Performance factor. However, it improves in International Trade (15th to 12th). In Government Efficiency, there are slight drops in Public Finance (1st to 3rd) and Societal Framework (5th to 6th), but Switzerland remains 1st in the Institutional Framework sub-factor. The improvement in the Business Efficiency factor (5th to 4th) is largely due to gains in Productivity and Efficiency (4th to 2nd) and Labor Market (6th to 5th). However, it is worth noting that the country's performance in the Attitudes and Values sub-factor remains moderately low at 14th.

Singapore

Singapore's recovery stems from strong improvements in Domestic Economy (1st from 15th), Employment (3rd from 18th), Public Finance (6th from 12th), and Productivity and Efficiency (9th from 14th). Slight gains in Business Legislation (2nd from 3rd) and Education (6th from 7th) also contribute to its recovery. In addition, Singapore's performance in the International Trade and Technological Infrastructure sub-factors remain robust; it ranks 1st in both. However, Singapore remains in relatively low positions in several sub-factors including Management Practices (14th) Scientific Infrastructure (16th) and Health and Environment (25th). In others, it experiences some declines: Societal Framework (17th to 22nd), Labor Market (4th to 12th) and Attitudes and Values (9th to 12th).

Sweden

Sweden's decline results from a slowdown in measures of Economic Performance such as the Domestic Economy, International Trade and Employment sub-factors. Trade and Employment, in particular, show a sharp decline. Sweden's performance in the Government and Business Efficiency factors remain stable placing 9th and 2nd, respectively. That said, when it comes to Government Efficiency, there are some declines; for example, in Public Finance (9th down from 7th) and Societal Framework (down to 5th from 4th). Similarly, in Business Efficiency the Productivity

Fig. 1: The IMD World Competitiveness Ranking presents the 2022 overall ranking for 63 economies, of which the top 10 are shown here. The economies are ranked from the most to the least competitive. The Scores shown to the right are actually indices (0 to 100) generated for the unique purpose of constructing charts and graphics. The final column shows the improvement or decline from the previous year.

and Efficiency sub-factor experiences a slight drop (to 4th from 3rd) but Finance (3rd) and Attitudes and Values (2nd) improve. Within the Infrastructure factor (3rd), Sweden experiences some slight declines; for example, in Technological Infrastructure (5th from 3rd), Health and Environment (2nd from 1st) and Education (5th from 4th).

Hong Kong

The recapturing of a top 5 spot by Hong Kong has its origins in Economic Performance (15th), particularly in the International Trade (4th) and International Investment (3rd) sub-factors. It experiences a slight decline in the Government Efficiency (2nd) factor despite improvements in the Public Finance sub-factor (up to 2nd from 9th). However, it remains relatively low in the Societal Framework sub-factor (33rd). In the Business Efficiency factor Hong Kong falls to 7th (from 3rd) mainly because of sharp declines in the Labor Market (20th from 8th) and Attitudes and Values (16th from 8th) sub-factors. Its performance in the Infrastructure factor (14th from 16th) remains relatively stable, showing some gains in Health and Environment (21st to 18th) but dropping from 8th to 13th in Education.

The Netherlands

The drop in the overall ranking experienced by the Netherlands is due to a significant downturn in the Economic Performance factor (19th). This decline results from slumps in Domestic Economy (25th), International Investment (46th), Prices (52nd) and—to a lesser extent—in the Employment sub-factor (7th). Elsewhere, the Netherlands continues to perform strongly, remaining in 12th place in Government Efficiency and slightly improving in both Business Efficiency (to 3rd from 4th) and Infrastructure (to 5th from 7th).

Taiwan

Taiwan's improvement is due to a stable performance in the Government Efficiency factor which is the result of improvements in Tax Policy (6th from 11th), and one-rank gains in both Institutional Framework (8th) and Business Legislation (21st). There is, however, a noteworthy drop in the Public Finance sub-factor (4th to 10th). In the Business Efficiency factor, it improves one spot to 6th due to increases in Productivity and Efficiency (13th to 8) and Finance (11th to 8th). It remains 5th in Management Practices. Taiwan also advances in Infrastructure (14th to 13th) by improving in Technological Infrastructure (9th from 10th) and by steady performing steadily in Scientific Infrastructure (6th) and Education (16th). However, it experiences a drop in Health and Environment at 26th (from 24th).

Finland

Despite a downturn in the Economic Performance factor (44th) due to drops in the Domestic Economy (36th), Employment (40th) and Prices (40th) sub-factors, Finland joins the top 10 this year. The improvement comes on the back of advances in the Government Efficiency factor (14th to 10th) particularly in Tax Policy (52nd from 59th), Institutional Framework (3rd from 6th), Business Legislation (6th from 12th) and Societal Framework where it reaches 1st spot. Finland's performance in the Business Efficiency factor is similar rising to 5th (from 12th) due to advancements in all of its sub-factors, most notably in Labor Market (from 24th to 18th) and Attitudes and Values (from 14th to 5th). In the Infrastructure factor, Finland rises to 4th (from 5th) by improving in all of this factor's components with the largest increases in Basic Infrastructure (from 11th to 6th) and Scientific Infrastructure (from 15th to 12th). It ranks in the top 3 in the rest of the sub-factors.

Norway

Norway's decline in the overall ranking is the result of a downward trend in three of the four competitiveness factors. Although it remains in 25th place in the Economic Performance factor, its performance falls in the Domestic Economy sub-factor (28th), as well as in the International Investment (22nd), Employment (18th) and Prices (44th) sub-factors. Within the Government Efficiency factor, where Norway slightly declines to 5th (from 4th), it drops in Institutional Framework (5th), Business Legislation (10th) and Societal Framework (4th) but increases seven spots in Public Finance to reach 1st place. In Business Efficiency, Norway experiences a downturn from 6th to 10th as it drops in all sub-factors, the largest declines being in Management Practices (17th) and Attitudes and Values (18th). An exception is in the Labor Market sub-factor where it increases from 11th to 10th. In Infrastructure, it also falls from 4th to 6th because its performance declines in all of the factor's components with the largest drop being in Education (from 6th to 10th).

USA

In the overall ranking, the USA remains in 10th place, despite some notable declines at the sub-factor level. For example, its performance in International Trade (41st), Institutional Framework (23rd), Management Practices (15th) and Technological Infrastructure (11th) deteriorates. The country's rankings in other sub-factors remain low, such as in Public Finance (53rd), Societal Framework (40th) and Attitudes and Values (26th). Despite these trends, the USA reaches the top place in International Investment and remains 1st in Scientific Infrastructure. The country also advances in other areas, including the Employment (10th) and Labor Market (23rd) sub-factors.

What does the future hold?

For the last couple of years, IMD's analysis has focused on the health and economic crises that have been brought about by the pandemic. However, they have always claimed that that the fundamentals of competitiveness have remained the same, even under turbulent conditions. According to IMD, the institutional framework, the rule of law, infrastructure and education—the pillars of competitiveness—were relatively intact. The question is: Will this remain the case after the re-emergence of global geopolitical risks?

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This article presents some of the findings of the IMD World Competitiveness Yearbook 2022, issued by the International Institute for Management Development (IMD) via its IMD World Competitiveness Center in Switzerland. The complete report is available at www.imd.org/wcc.

China's Quest for Self-sufficiency in Chemicals

While China is a Net Exporter of Commodity Chemicals, it is a Substantial Importer of Specialty and Fine Chemicals

One of China's key objectives of the current 14th Five-Year Plan is to reduce the dependency on imports. At least partly, this is a reaction to rising political tensions with the USA. But is also well-aligned with several other longer-term goals of the country, particularly the shift to a more innovative economy that emerges as a global leader in selected new technologies. As we will see, many of the imports particularly in chemicals are of high-end materials that so far cannot be produced domestically.

It also fits in well with the "Dual circulation" policy propagated by Beijing. Domestic-international dual circulation (to give its full name) is a strategy to reorient China's economy by prioritizing domestic consumption („internal circulation") while remaining open to international trade and investment („external circulation"). Compared to the situation before the enactment of this policy, it means a stronger focus on the domestic market and less reliance on external trade (both exports and imports).

China's Trade Deficit in Chemicals

How self-sufficient is China with regard to chemicals? Recent trade data shows a substantial deficit. From January to August of 2021, the total import and export volume of the Chinese chemical industry was $544 billion, an increase of about 34% compared to the previous year. Of this total, the export amounted to $186 billion while the import was $358 billion, resulting in an overall trade deficit of $172 billion, an increase of 25%.

This may come as a surprise to those who followed US complaints about Chinese trade policies and trade imbalances. However, a slightly more differentiated view explains the situation. While China is indeed a net exporter of commodity chemicals (and even more so, of finished products requiring substantial input of such commodity chemicals), it is a substantial importer of specialty and fine chemicals. In the domestic discussion of the chemical industry, this is described as a „low-end surplus, high-end shortage", a surplus of basic chemicals and a shortage of functional chemicals.

Kai Pflug, Management Consulting — Chemicals

Indeed, in commodity chemicals, overcapacities are far more of an issue than shortages, and this issue is likely to get even more serious. While in 2019 about 60% of all petrochemical products in the Chinese market faced excess supply or severe excess supply, this share is expected to rise to 75% by 2025. For example, for ethylene oxide, China's capacity/demand ratio is 148% and the capacity utilization rate is 67%. For styrene, the predicted capacity/demand ratio for 2025 is 127% while for PTA, the current

production capacity of about 60 million t/a is estimated to increase by an additional 30 million t/a, which would also mean overcapacity. As a consequence, a government-issued list, the

"China has understood that innovation through specialty chemicals is possibly the most important competitive advantage."

„Market Access Negative List (2021 Edition)", puts restrictions on new chemical projects including those in the areas of ethylene, p-xylene, MDI as well as on coal-to-olefins and coal-to-para-xylene projects. If the "Dual circulation" policy is taken seriously, China cannot rely too much on utilizing these overcapacities for exports.

Thus, the self-sufficiency objective clearly focuses on higher-end materials. In a speech given to the National People's Congress in 2021, Yang Hua of Sinochem discussed „the structural contradiction between low-end overcapacity and insufficient high-end supply ... especially in the fields of high-end synthetic materials, functional materials, medical materials, and high-end electronic chemicals."

A few data points illustrate China's weakness in high-end chemical materials:

- The share of specialty chemicals as a percentage of the total industry value is only about 45% compared to 60-70% in the US and in many European countries, and 90% in Switzerland
- While there are about 100,000 different fine chemicals produced globally, in China the number reaches only 20,000, according to the Xingyuan Chemical Park Research Institute
- In many high-end segments, China has a low self-sufficiency rate (e.g., 65% for new chemical materials, below 50% in electronic chemicals)
- According to MIIT statistics in 2018, for 32% of the more than 130 key basic chemical materials, China has no substantial local production while for 52%, China still depends on imports
- All top 10 global specialty chemicals producers are foreign companies
- While China is the largest global consumer of specialty chemicals using about 26% of the global total, this is low compared to China's overall share of the global chemical market of about 44%, indicating underrepresentation of specialty chemicals
- China's share of various sub-segments of the global specialty chemical market ranges from 8–46%, again mostly substantially lower than the share in the overall global chemical market

This limited presence in high-end chemicals is a serious concern for China's government. Many high-level government objectives such as turning China into a global technology leader, decreasing the dependency on strategically important imports such as semiconductors, improving the environmental situation and moving from quantitative to qualitative economic growth strongly depend on high-end chemical materials. In addition, the higher value creation of these materials will also play a role in preventing China from getting stuck in the middle-income trap.

To support specialty and high-end chemicals in China, the government has therefore enacted a number of measures. Some of these take the shape of financial subsidies, e.g., tax incentives for R&D, land grants and preferred access to chemical parks. This includes the creation and upgrading of dedicated fine chemicals parks and the establishment of ten fine chemical technology centers in new fields to provide technical support.

High-end chemicals depend strongly on technological knowledge rather than on production assets. Consequently, China has in the past few years made progress with regard to IP protection, and there have been several court cases in which substantial damages were awarded to companies hurt by IP violations.

Multinational chemical companies are also encouraged to invest in higher-end chemical segments in China. In particular, the requirement for the formation of a joint venture with a domestic partner in petrochemicals has been lifted, thus reducing the concern of IP loss when setting up production in China.

Benefits for the High-end Chemical Sector

Perhaps counterintuitively, some of the measures which at first glance seem to burden the chemical industry in China—such as tightened environmental regulation and the forced shift to chemical parks—may also in the longer run be beneficial for the high-end chemical sector. For one thing, the burden of these measures falls more heavily on small companies with low technology and low-end products. It also gradually leads to the closing down of the weakest, smallest players, to industry consolidation, and to higher prices and margins, which in turn should allow more investment in R&D.

"While China is a net exporter of commodity chemicals, it is a substantial importer of specialty and fine chemicals."

A first consequence of this shifted emphasis is that in the most recent list of top 500 Chinese chemical companies, there are about 100 new entrants, most of which focus on high-end specialties and replacing basic chemical producers. So, the overall industry structure is already moving towards specialties.

The change can also be seen in the recent activities of some leading Chinese chemical companies. Wanhua is a good example. While a few years ago the company focus was primarily on upstream integration into petrochemicals, the most recent projects clearly focus on specialties in areas such as battery materials, engineering plastics and nutrition.

Overall, China seems to have understood that innovation through specialty chemicals may be its most important competitive advantage as more and more areas of the chemical industry become commoditized. As a consequence of the resulting support, China is expected to have strong growth in areas such as electronic chemicals, engineering plastics, bio-based materials, metal catalysts, cosmetic chemicals, flavors and others.

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Chemistry and the „Next Normal"

Sustainability and Resilience as Ways out of the Crisis

Numerous crises such as climate change, energy shortages, raw material shortages, war in Ukraine and the consequences of the pandemic are putting value chains worldwide to the test. The chemical industry, as a key supplier of raw materials and intermediates to almost all areas of daily life, is particularly affected by this. The International SAP Conference for Chemicals, held in Madrid on Sept. 28 – 29, was designed to show the extent to which digitization and innovative technology can help meet these challenges and open up ways out of the crisis. The focus was on topics such as digitalization, sustainable business models, and transparent and resilient value chains.

Sustainability as a Corporate Goal

Keynotes and numerous case studies from SAP customers and partners provided insight into SAP's future strategic direction and the extent to which customers are already using SAP's platform and cloud solutions to develop innovative business models, sustainable processes and cross-industry networks towards to ensure future competitiveness. For example, in his keynote, SAP's Joao Paulo da Silva highlighted the need to move away from linear value chains towards a circular economy.

The path to holistic sustainable value creation with products, services and business models geared to this can essentially be described in three transformative steps. The decisive factor in this transformation is that the sustainability goals are measured on the basis of economic performance indicators and go hand in hand with the profitability goals of the company.

SAP's Business Technology Platform as an Innovation Driver

In another keynote, SAP's Frank Ruland explained the importance of SAP's Business Technology Platform (BTP) and SAP Cloud solutions as the basis for innovations at the industry and process level, the so-called „next practices." Here, cross-industry consortia are increasingly coming to the fore. „Catena-X", for example, is the first collaborative, open data ecosystem that links global players from the automotive and chemical industries, among others, to form end-to-end value chains, with the aim of enabling standardized, global data exchange based on European values. An additional example is the „Global Battery Alliance", in which SAP and numerous partners have set themselves the goal of recycling batteries in the sense of a circular economy.

Blockchain-based processes can also be implemented with the help of the SAP Business Technology Platform and are increasingly finding their way into the world of innovative business models. David Pereira from Eastman Chemical showed how circular economy for polymers can be realized using the example of an end-to-end transparent blockchain-based

control chain with the help of SAP's Green Token solution. Here, mass balances can be used to trace the proportion of recycled material for each step of the chain in a tamper-proof manner. The decisive factor here is that all business partners agree on mass balance standards and a basic certification framework. QR codes in particular should serve as proof of origin.

As Claude Philippe Medard from SAP showed, even processes such as the output of a steam cracker can now be simulated or optimized with the help of complex mathematical models and the SAP HANA database. For example, the yield and distribution of the end products (C2, C3, C4 fraction as well as aromatics) can be represented as a function of the raw materials (e.g., naphtha, LPG or recycled ethane) and the operational parameters of the cracker using polynomial systems of equations or matrices, and optimized with the help of linear or nonlinear programming. On this basis, a digital twin of a steam cracker can be created and dynamically adapted as the system's boundary conditions change, thus creating the basis of a „closed-loop" system.

Another interesting application of SAP HANA, especially against the background of considering the difficulty to predict commodity prices and margins, was presented by Robert Vultier and Karel Jirik (Mibcon NDC). The current situation on the market not only leads to strong fluctuations in raw material prices, but in addition, changes in raw material prices are traditionally communicated towards sales with a delay, so that a timely adjustment of prices taking into accountwith the goal to achieve target margins is often delayed. The SAP HANA-based application developed by Mibcon NDC for Clariant allows cost, price and margin simulations in real time across multiple process stages and based on a variety of different scenarios. With the help of the SAP Data Warehouse Cloud, raw material forecasts and simulations can be directly linked to Cost of Goods Sold (COGS) and Net Income data. This gives sales the transparency they need at all times to adjust prices and target margins based on current raw material price fluctuations in real time.

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Strategic Priorities for the Chemical Industry

The current global environment not only presents major challenges for chemical companies, but also offers opportunities to emerge stronger from the current crisis. In his keynote, Matt Reyman of SAP outlined four strategic priorities for greater differentiation and realignment for the future. First, operational efficiency must be increased. To do this, all processes along the value chain must be fully integrated and automated. New technologies such as blockchain, artificial intelligence, digital twins, etc. play a crucial role in this. The end result is the vision of the self-controlling, autonomous company. Second, collaboration must be strengthened across industries with the aim of opening up new value-creating platforms and networks based on „shared risk and reward" models. Third, companies need to become strategically agile, which means enabling themselves to dynamically adapt their own product and solution portfolio based on market requirements and to seize new growth opportunities through differentiation and diversification. Fourth, there should be a stronger orientation away from purely product-centric sales toward more customer-centric business models. This means looking at customer relationships more from the customer's perspective, better understanding the value of one's own products and services for the customer and, if necessary, taking over parts of the value chain from the customer in the sense of a „win-win" partnership. The end result is not only higher margins, but also greater customer loyalty.

Conclusion

The „International SAP Conference for Chemicals" showed ways in which companies in the chemical industry can not only master current challenges with the help of digital transformation and innovative technologies, but also gain a long-term competitive advantage. Resilient and sustainability-oriented processes and value chains play a key role here. SAP, with its business technology platform, cloud solutions, and industry-specific applications, has proven to be a strategic partner for this transformation process for many customers.

Stefan Guertzgen, CHEManager

Curiosity, Disillusionment, Persistence, Success

Finally, Flow Chemistry is Establishing as Green, Sustainable and Profitable Process Technology

Around 1995, the path of the microreaction technology platform began when Wolfgang Ehrfeld, then professor and head of the Institute of Microtechnology in Mainz, Germany, was driven by the question: If the topic of „micro" has led to enormous performance increases and innovations in electronics, why should this not be possible in the field of process technologies?

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Segments like pharmaceuticals, fine and specialty chemicals, agrochemicals, and chemical ingredients for consumer care products and food and beverages have emerged as particularly attractive for the application of microreaction technology.

Microreaction technology means channel dimensions in the micro and millimeter range with significantly improved surface-to-volume ratios compared to established process technologies and shorter mixing times. For fast, highly exothermic reactions, there is considerable potential for improving product quality, product yield, raw material and energy requirements, process safety and manufacturing costs and EBIT, with attractive capital payback times.

Advantages of microreaction technology are fast and good mixing and excellent heat transfer performances, enabling higher selectivities and yields while lowering raw material requirements. Besides, the number of by-products and the energy demand for their separation (downstream processing) is reduced. About 70% of energy costs correspond to the separation of by-products. In terms of safety, fast, explosive, and highly exothermic reactions involving toxic substances can be run in much smaller reactor volumes compared to batch reactors.

Developing New Synthesis Pathways

However, micrometer-scale channel dimensions are not suitable for use in production because they are too prone to clogging, do not meet the robustness requirements of a production operation and allow only relatively small throughputs. For production, therefore, a scale-up to the millimeter scale is necessary, which retains the advantages of microtechnology in terms of heat transfer performance and mixing speed. In the scale-up process, the transition of channel geometries from the micrometer to the millimeter scale already takes place in the laboratory. Conversions, yields, process parameters and product qualities determined in this way in laboratory can be transferred directly to conditions in production reactors with same channel geometries. A scale-up step on a pilot scale is no longer necessary, although of course pilot tests with real raw material qualities from production to investigate fouling, cleaning procedures and longtime stability of the process cannot be dispensed with. The integrated scale-up concept leads to a quick scale-up to production.

From our point of view, a few segments have emerged as particularly attractive for the application of microreaction technology: pharmaceuticals, fine and specialty chemicals, agrochemicals, and chemical ingredients for consumer care products and food and beverages.

In many industries in Europe and the US, postponing of innovation is quite common, the pharmaceutical and fine chemicals industries included. However, continuous optimization is and will remain an increasingly important issue for companies in order to keep up with the current pace of technological evolution and to be innovative. Redesign of a chemical process is mandatory for a transfer from a batch to a continuous process. It is probably due to this time effort that people fall back on the original manufacturing method instead of running processes continuously and thus more efficiently, sustainably and safely. Continuous approaches can contribute to developing new optimized synthesis pathways. However, the priority of the pharmaceutical industry is the on-time delivery of life-saving drugs.

Increasing Flexibility and Sustainability

Active pharmaceutical ingredients (APIs) are usually produced in multi-step synthesis processes due to the very often complex structure of the molecules. Take lithiation as a simple two-step example: In a batch process, the addition reaction step proceeds very slowly because the unstable and highly reactive intermediates decompose rapidly. The reaction must be run at extremely low

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Anne Kaaden, Ehrfeld Mikrotechnik

temperatures (-48°C) while the continuous process can be run at room temperature because of the excellent heat exchange, effective mixing and precise control of process. This results in less by-product formation and therefore higher yields, making the process safer and „greener". Besides, energy savings due to avoiding cryogenic conditions make the continuous process highly cost effective.

Additionally, manufacturers are dependent on effective supply chain processes. This has become much more apparent after the outbreak of the Covid pandemic. Critical delays in the supply of raw materials can have a significant impact on projects. Pandemic-related disruptions of transportation links have been a major challenge for many chemical companies. Producing key raw materials instead of sourcing them is becoming more essential for companies and definitely more profitable under companies' perspectives. Microreaction technology can be the key to success right here, as required quantities can be produced selectively and sustainably in a short time with low hold-up and space requirements.

"Continuous approaches can contribute to developing new optimized synthesis pathways."

Sustainability can be viewed from two sides here, from an environmental perspective and from an economic perspective. The environmental aspect of flow chemistry/microreaction technology combines two factors:

the lower formation of by-products—which leads to higher yields and smaller amounts of raw materials—and the abdication of additional solvents—which do not have to be separated later in cost-intensive steps. Process reliability also plays a major role. The much smaller internal volumes of the micro and millireactors, do not have to be filled or emptied like batch reactors, what prevents the risk of explosions and fires. From an economic point of view, cost savings can be established through improved product quality, raw material savings, reduced space requirements, sustainable plant safety, lower energy consumption, and, in consequence, more favorable CO_2 balances.

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Miprowa production reactor with 154 reaction channels and static mixing inserts.

Making the Transition

Thus, the principles of Green Chemistry can be perfectly met by the application of flow chemistry/microreaction technology. Flow chemistry applications are inherently safer because they require comparably smaller reaction volumes and lower amounts of solvents and chemical substances. The risk of environmental exposure from chemical substances is almost non-existent, and processes can be scaled up easily and quickly without the need for the optimization of reaction conditions.

Considering these advantages suggests the question: why is flow chemistry, and in particular microreaction technology, not already established process technology? The answer is multilayered.

Developing continuous processes requires significant financial investment for most companies. Therefore, direct evidence of the return on investment (ROI) is critical for a company to make the transition. Drivers for moving from batch to flow processes include reducing capital expenditures (CAPEX) and operating expenses (OPEX), as well as significantly increasing process safety and product quality.

Any development cycle consists of the following phases: curiosity, disillusionment, persistence and success. At the very beginning, microreaction technology was known as a „panacea" for all process engineering problems, whereupon curiosity led to the integration of the technology, which quickly turned into the disillusionment phase. At that time, the technology was still far from being ready to survive, especially in production. New developments take an average of about 30 years to be established in the market. Now, we are in the persistence phase, whereby transition to the success phase has already started in some cases. Given the challenges the pharmaceutical industry is facing—secure material supply, reduce operation cost and increase flexibility, enhance sustainability and safety, innovate and reduce time-to-market—the question regarding the breakthrough of flow chemistry is: if not now, when?

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Flow Chemistry

Key Technology for Sustainable Processes

Continuous Manufacturing (CM)—also called Flow Chemistry or Micro Reaction Technology (MRT)—is a technique that has been gaining global importance over the past decade as a result of improved process control and reduced operating costs, leading to increased manufacturing profits and a competitive edge. Recent years have shown that the reason for a company to change from "batch" to "flow" have been varied, often depending on the sector, process type of interest and scale of operation. Supply chain security and improvements in process sustainability are strong emerging drivers for the adoption of CM.

With the product key, the infrastructure needed varies greatly and depends on the available chemistry, cost of goods, volumes required and the hazard profile of a transformation. The modularity and flexibility of continuous flow set-ups enables the development of small, agile production plants that can be used for the manufacture of multiple products—with easy re-configuration allowing for rapid product changeover.

Following on from this, the ease of replicating these small footprint systems represents an opportunity for manufacturers to develop a process and subsequently deliver production units across multiple countries to serve the local product demands. This is in stark contrast to the current approach of a single large-scale plant, with warehousing used to manage supply chain disruptions.

With all of these benefits, a logical question follows: Why the slow adoption of MRT?

CHEManager asked executives and industry experts to share their views on drivers as well as barriers for the use of flow chemistry and the prospect for this technology in their industry sector. We proposed to discuss the following aspects:

- In your opinion, what are the strongest drivers (success factors) of the implementation of flow chemistry processes?
- Which barriers are slowing down or impede the implementation of flow chemistry processes?
- What does it need for flow chemistry to be implemented more widely?

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Read the insightful answers of the experts on pages 12/13.

Flow Chemistry: Some Precautions to Take but also Many Advantages

Kai Rossen, Chief Scientific Officer, Euroapi

"There are many types of reactions and reaction conditions that simply cannot be performed in batch."

The synthesis of organic compounds is a science that is practiced for the last good 150 years, but the last 20 years have seen a re-discovery of flow chemistry, which is a deviation from the classical batch process. The classical batch process works well, but there are many types of reactions and reaction conditions that simply cannot be performed in batch. These would be ignored in an optimization and are thus highly limiting. The application of flow chemistry is thus a critical tool in finding the optimum for the synthesis of a compound, such as an API. Continuous reactions can give access to higher temperatures and pressure, enabling more efficient synthesis routes and the process can generate less hazardous substances and toxic releases. Regarding highly potent active pharmaceutical ingredients, it can also reduce cross-contamination and cleaning needs.

It is nevertheless mandatory to be objective — simply putting a poorly designed reaction into a flow reactor is simply false advertisement. There is no doubt that processes that cleverly combine the potential of continuous processes into the design are extremely powerful and enabling. An example from Euroapi is our continuous production of Sevelamer, where the holistic design of a process is now enabling the continuous production without the use of a solvent. This is a very good example that highlights the powerful potential of a flow reaction when excellent understanding of the underlying chemistry is combined with creative engineering.

This development is enabled by open communication between the different disciplines of science, something that is helped when organic chemists have at least a basic knowledge of chemical engineering, just as chemical engineers are trained in organic chemistry. It is very good to see that the coming generation of scientists have this training and one can expect that the new generation will discover even more opportunities leading to better processes to produce APIs.

Using Flow Chemistry to Explore the Potential of API Manufacturing

Jean-Baptiste Guillermin, Technical Sales Manager, Axplora

"Flow chemistry has become increasingly important in API manufacturing over the last two decades."

Flow chemistry has become increasingly important in API manufacturing over the last two decades, and even more recently, with the difficulties encountered in the supply chain during the Covid-19 crisis, and the necessity to accelerate time to market to answer patients' needs.

Flow chemistry is particularly suitable for reactions with fast kinetics due to the increased heat and mass transfer characteristics of flow reactors. It is a very powerful technology for reactions requiring conditions difficult to meet with traditional batch reactors (e.g.: high temperature, high pressure) and opens the way to new chemical transformations with technologies that were previously complicated to scale-up (photochemistry or electrochemistry). It is also a great tool to better control the formation of unstable intermediates, increase selectivities, or produce highly energetic intermediates under safer conditions.

Thanks to increased performance of these reactors, continuous processing is often performed under higher concentration and milder temperature conditions, allowing a decreased energy consumption and decreased process mass intensity (PMI). Sustainability is a key metric to be taken into consideration from early development up to commercial manufacturing, therefore technologies allowing us to reduce the carbon footprint of chemical processes are extremely attractive.

Even if the pharmaceutical industry has been slow in implementing this technology, compared with other industries, continuous processing has been used for many years in this sector (e.g.: continuous chromatography — SMB), demonstrating its robustness at manufacturing scale. Given the widespread use of batch reactors, barriers for a wider adoption of this technology remain, but recent investments in this field will result in growing applications.

Axplora, created from the merger of Farmabios, Novasep and PharmaZell, is a reliable and agile partner, with 30 years of experience in continuous processing, able to evaluate and propose the most efficient solutions for the manufacturing of APIs.

Efficient Preparation of High-quality Pharmaceutical Ingredients

Shawn Walker, SVP Development of Operations & CTO, Veranova

"In the pharmaceutical industry, there is growing awareness of the benefits of continuous manufacturing using flow chemistry."

Although the pharmaceutical industry has historically relied on batch or semi-batch manufacturing processes for pharmaceutical ingredients, there is growing awareness of the benefits of continuous manufacturing using flow chemistry. These benefits include enhanced process safety through the more efficient removal of heat in flow processes compared to batch manufacturing, the ability to produce and rapidly react unstable or short half-life intermediates, as well as improving access to chemistry that has been historically challenging to scale-up in batch, such as photochemistry, electrochemistry, and high temperature/pressure processes.

In addition, small volume continuous manufacturing provides the flexibility of using a modular equipment footprint, where individual unit operations (including reaction, work-up extraction/distillation, and product crystallization) can be conducted on portable skids. This cost-efficient approach requires less manufacturing space, minimizes downtime due to equipment turnover, and supports like-for-like tech transfer, as the same equipment used for process development can be assembled or shipped for manufacturing.

Manufacturing with flow chemistry is also more amenable to the use of process analytical technology (PAT) tools to increase process control, reduce variability, and assure product quality. Looking to the future, the application of machine learning tools and artificial intelligence should also aid the development of self-optimizing reaction systems and automated process characterization based on modulating flow chemistry parameters such as temperature, feed rate, residence time etc.

In summary, due to the advantages highlighted above, global health authorities as well as the pharmaceutical industry and their partner (CDMO) organizations are increasingly looking to implement flow chemistry processes for the efficient preparation of high-quality pharmaceutical ingredients.

Providing an Opportunity to Explore Novel Process Windows

Srividya Ramakrishnan, Head, API Process Engineering, Dr. Reddy's Laboratories

"The ability to handle hazardous reactions in flow significantly improves green chemistry metrics."

The strongest drivers are process safety, speed, cost, quality, and sustainability.

The enhanced mixing, mass and heat transfer in flow reactors, and the ability to precisely control the residence time and operate at extreme conditions provide an opportunity to explore novel process windows. Flow can boost reactions by running at temperatures and pressures considered unsafe in batch while significantly minimizing solvent usage. By controlling the residence time, the kinetics can be precisely optimized to increase the purity and decrease impurities.

The ability to intensify and handle hazardous reactions in flow significantly improves green chemistry metrics and reduces raw material costs, resulting in sustainable manufacturing at a lower price. With an effective control strategy, continuous manufacturing provides greater assurance on quality.

The biggest barriers are sunken capital and scarcity of talent. Considering the sunken capital into batch plants, any further investment into continuous may be difficult to rationalize based on return-on-investment alone. Hence, the benefits should be evaluated holistically to encourage adoption.

As this is an evolving technology, experienced talent is scarce and few undergraduate chemistry curriculums include flow chemistry. At Dr. Reddy's, we utilize flow chemistry for hazardous and cryogenic reactions, which are safer in flow and with lower operating expenses. We are also in the process of commissioning a modular plant for an intermediate to API process encompassing multiple reactions and unit operations. The driver to adopt this is a move towards sustainable manufacturing with improved green metrics, lower operating costs, and minimal manual operations. All this helps us in our mission to accelerate access to high quality and affordable medicines.

Integral Part of CDMO Service Offerings

Ulrich Mayerhoeffer, Head Technical Evaluation and Development, Arxada

"We are strong believers in the benefits of flow chemistry."

When discussing flow chemistry, we often hear buzzwords or phrases such as 'faster and safer processes', 'ease of scalability', and 'improved quality'. Nevertheless, the CDMO space in pharmaceuticals and fine chemicals is still widely dominated by batch and semi-batch processes. At Arxada, we operate a variety of both semi-batch and flow processes within our multipurpose plants at our site in Visp.

Our technology selection is mainly driven by process safety, quality, sustainability, and overall economic considerations, with safety as the strongest driver towards a flow process. For us, flow chemistry facilitates the safe handling of thermally labile compounds, such as azides and nitro compounds. By minimizing the reaction volume, flow processes offer excellent heat exchange performance to control highly exothermic reactions. Within a cascading reaction set-up, the accumulation of explosive or hazardous intermediates can be minimized as they are directly telescoped and converted in the next stage of the process.

These advantages in terms of process parameter control are often also beneficial quality-wise. The strengths of flow chemistry are clearly demonstrated in reactions where the control of side product formation or the control and preservation of stereo-information are vital. Other than in semi-batch mode, flow technologies allow processes to run in steady states at the ideal reaction conditions.

At Arxada, we are strong believers in the benefits of flow chemistry. That's why we are constantly investing in our technological development capabilities to facilitate the use of flow processing as an integral part of our CDMO service offerings.

Complementary Technology to Batch Manufacturing

Mark Muldowney, Head of Technology & Innovation, Sterling Pharma Solutions

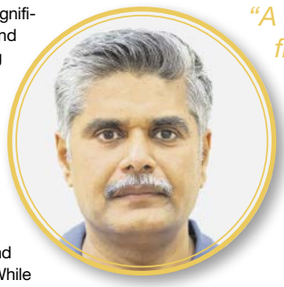
"Flow chemistry is not a 'one size fits all' technology for chemical manufacturing."

It is important to remember that flow chemistry is not a 'one size fits all' technology for chemical manufacturing, and not every process will be relevant for flow chemistry at commercial scale. However, one of the greatest benefits it offers is through safety when handling highly potent and hazardous or highly reactive species, as it reduces the risk of exposure to operators and scientists by having smaller quantities of materials within the reaction vessel at any one time.

The technology broadens the toolkit for development chemists and should be seen very much as complementary to batch manufacturing, rather than a replacement. Its use allows the variation and control of scale-up conditions for manufacturing and provides access to new chemical reaction space through higher temperatures, pressures, concentration, and kinetics. From a process control and material quality standpoint, developing a flow reactor and specific reaction parameters that can be constantly monitored and adjusted within a defined range can ensure a more consistent product specification. Flow synthesis also generates new development opportunities based upon utilizing biocatalysis and heterogenous catalysts, as well as electrochemical oxidation and reduction, where the technology could be advantageous to improve not only chemical selectivity and quality, but also to avoid exposure to toxic intermediates. Additionally, photochemistry lends itself perfectly to flow chemistry, where there is a move away from traditional routes that use metal catalysts, and opens up new methodologies that are cleaner, more energy efficient and cheaper to run at scale. Using flow chemistry also allows the design of potentially integrated multi-step chemical synthesis.

Sustainability Is a Key Focus

Baburaj Krishnan, Head-CDMO, Drug Substance Development, Aurigene Pharmaceutical Services



"A strong driver of flow chemistry is the aim to design more sustainable processes."

Flow chemistry processes significantly increase productivity and process safety, but a strong driver is the aim to design more sustainable processes, which goes hand in hand with these aspects. Sustainability is also the key focus for large-scale API manufacturing. It can be achieved by combining the green chemistry principle and continuous processes. While green chemistry brings a better atom economy, continuous processes improve reaction selectivity and yield. Flow chemistry can significantly minimize the use of solvents, which usually contribute 50% of the input mass in any batch manufacturing process. Integrating unit reactions and operations reduces the overall processing time and results in energy saving and high-throughput efficiency.

The technical capabilities in performing heterogeneous reactions and continuous crystallizations are an area to evolve. Batch processes provide flexibility for a wide range of reactions. Many homogenous and heterogeneous reactions can be performed in a single batch reactor without altering the equipment configuration. However, the flow process has particular limitations in accommodating different reactions in a single reactor.

Aurigene Pharmaceutical Services has a well-evolved methodology for establishing continuous processes. A recent example is a process that has been successfully developed and performed with continuous flow, which, otherwise, cannot be linearly scaled due to stability issues, its hazardous nature, and by-product formation.

Flow Chemistry has No Real Showstoppers

Christophe Girard, Process Engineer, Siegfried

"Implementing flow chemistry has several advantages compared with batch chemistry"

Implementing flow chemistry has many advantages compared with batch chemistry. Firstly, safety is improved because there is less danger from exothermic reactions or toxic substances. The yield and purity can be increased because of more precise control over reaction variables such mass and heat transfer.

Additionally, sustainability is improved, attributable to lower solvent consumption and energy use. Capital expenditures are also reduced because compact modular process skids enable one to perform a large number of flow processes within a small area.

The main challenge of flow chemistry is [performing] highly heterogeneous reactions that can clog the reaction system. Furthermore, the relatively small number of batches and the challenges of batch traceability have hindered acceptance in pharma manufacturing - yet these regulatory issues are being resolved.

Although it is often easier to produce the first kilograms in batch mode, multidisciplinary teams can readily take advantage of the benefits of flow chemistry. Therefore, flow chemistry has no real showstoppers.

At Siegfried, we will use flow chemistry for reactions that are difficult to control or too hazardous to perform with standard batch equipment. We will combine flow chemistry with continuous downstream processing such as extraction and distillation to drive maximum process stability, product quality, and yield.

Providing the Value of Flow Chemistry wherever Possible

Stephen D Drake, Director of Marketing and Development, Kaneka Americas Holdings

"The biggest barrier we see to using this technology is the customer buy-in, unfortunately."

Since 2017 Kaneka has been invested in developing commercial manufacturing approaches using flow chemistry and we currently have an FDA inspected GMP intermediate process using flow to produce ~3 Mt/year of an intermediate through phosgenation. Our reactors are designed in house and customizable to many types of chemistry to produce RSMs, intermediates, and APIs at the pilot and commercial scale with a relatively seamless scale-up from the lab. This is an area we continuously invest in with our customers to provide the value of flow chemistry wherever possible.

The biggest barrier we see to using this technology is the customer buy-in, unfortunately. There is a large interest in discovery to evaluate this technology, but it often is decided by our customers to not be implemented at production scale, for various reasons unrelated to our capability.

The Energy Crisis as Opportunity

Harnessing Public Awareness to Replace Fossil Fuels with Sustainable Alternatives

We are all aware now of the impact of limited gas and oil resources. The energy crisis is top of mind, dominating media, political and even personal agendas. We are facing higher bills, possible blackouts and a major impact on the cost and quality of life.

These are difficult times, but they may serve a higher purpose. It is clear that we need to reduce our reliance on fossil feedstock and look to sustainable alternatives. While the current situation is more about geopolitics than environmental factors, we must never forget the damage that fossil feedstock industries have done to our ecosystem. This period of heightened public awareness is a major opportunity to start thinking holistically—not only about energy needs now, but around long-term sustainability and independence from fossil-based fuels and materials, forever.

We need to move to renewable feedstock and circular materials. Both are needed. Both are possible. The end result of this is a renewable and circular industry: this is the true sustainability that people are looking for.

Our reliance on fossil carbon causes huge environmental damage, and our dependence on oil allows regimes to exploit power imbalances and push people into poverty. While vocal commitments and short-term measures from politicians may generate immediate headlines, they won't drive meaningful change. We need more than just targets and strong words. We need action that can facilitate the sharing of ideas and information, incentivize open and transparent collaboration, and reward long-term thinking.

Inspiring Action across the Board

Energy shortages and price rises are brutal, but they are merely extreme symptoms of the bigger issue. The UK Government's plan to re-introduce fracking in the UK is a clear example of a 'quick fix', but gas is a finite source, so this is far from long-term and simply a stopgap solution.

A sole focus on recycling of fossil plastics is also the type of fix that will postpone the implementation of real sustainable solutions. The system will always require significant volumes of virgin feedstock. Let's make sure we use renewable carbon sources, such as plants and CO_2, to provide carbon that will keep the cycle going.

There has been a historic lack of commitment to sustainable and renewable resources in energy but also in the production of chemicals and materials such as plastics. It is necessary that the chemical and plastics industry, accounting for around 4% of global greenhouse gas emissions, moves away from its dependence on fossil-based resources.

Now we need to create a real tide shift in meaningful action and long-term solutions that see us reducing our reliance on materials like plastics with sustainable alternatives.

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Tom van Aken, Avantium

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Alternative Solutions

The key to finding alternatives lies in partnership. Our vision of a greener world cannot be achieved alone and collaboration between businesses, scientists, and policymakers can help incite greater change. There is tremendous potential to build new circular supply chains and practices that are not harmful to the environment, with stakeholders across industries using all parts of a plant to make chemicals and materials.

It would be naive to think that the scientific and commercial worlds are independent of each other. Any solution must work for the environment and the global economy. That's why collaboration is so important and will help us to reach success faster. We need to focus on solutions rooted in scientific research, but without the support of commercially facing companies from the offset, we don't have the facilities to make it market ready.

This year, Avantium began construction of the world's first furandicarboxylic acid (FDCA) plant to enable the production of polyethylene furanoate (PEF)—our unique plant sugar-based, recyclable, degradable, super-strong yet lightweight plastic material. As a result, this year we have signed offtake agreements with Carlsberg, ABInBev and Moet Hennessy/Louis Vuitton (LVMH) to provide them with PEF to create sustainable packaging for their products, which will soon be on the shelves. We are always looking for more partners so that we can continue to create new solutions for consumers.

This type of application—fusing sustainable chemistry with the power of big brands—can bring about sustainable change and deliver products that consumers can use and purchase right away.

A United Front

This crisis, compounded by economic downturn and the war in Ukraine, has led to an incredibly difficult moment globally, but it can be a turning point.

Globally, governments and other world leaders seem to be waking up to the devastation that our reliance on fossil feedstock has caused to our planet. However, they are still held back by the stranglehold that oil producers have on our economy.

That means that we, the innovators, need to step in to fill the gaps and prove that there are commercially viable alternatives. Industries need to lead by example and commit to and invest in the green economy. By cutting off funding to climate destroyers they send a strong message. It's time that the rest of the chemical industry also stand up, take notice and join the mission for a fossil free economy.

What we have now is an opportunity to harness our collective concern, anger and frustration to deliver meaningful, lasting change that is good for people, economies, and the planet and break free from oil for good. It's up to us take it.

Tom van Aken, CEO, Avantium, Amsterdam, The Netherlands

■ www.avantium.com

Tackling Scope 3 Emissions

TFS Launches Guidance for Calculating Product Carbon Footprints

Scope 3 emissions of purchased goods have historically been challenging to measure for chemical companies due to the complexity of chemical production. The global chemical sector initiative Together for Sustainability (TFS) has recently launched a guidance for calculating product carbon footprints (PCFs) in the chemical industry and beyond.

The PCF Guideline is the first-of-its-kind guideline to transform the way chemical companies calculate and track upstream supply chain emissions. The open-source PCF Guideline can be used by both corporations and suppliers to identify, track and reduce Scope 3 upstream emissions and will be applicable across industries, thus being useful for other industries using chemical materials.

The new TFS PCF Guideline for Product Carbon Footprint and corporate Scope 3 emission reporting provides specific calculation instructions for emissions from "cradle-to-gate" for chemical materials. It harmonizes PCF calculation approaches across the industry and is applicable to the vast majority of chemical products. In the future, this will allow consumers and the wider market to directly compare and assess the climate impact of products.

For example, citric acid is one of many components found in household cleaners. However, estimating the PCF for citric acid has many challenges, from comparing biobased materials to calculating allocation schemes and varying uses of electricity. The PCF Guideline offers clear instructions on calculating greenhouse gas (GHG) emissions for specific chemicals production, e.g., citric acid production. It specifies, for example, how to assess the use of grid electricity or renewable energy. The detailed new guideline provides producers of chemical materials (in this case citric acid) and their suppliers with a step-by-step assessment approach addressing important aspects of the chemicals industry.

PCF calculations provide the best product-level emissions transparency for the identification, tracking and reduction of Scope 3 GHG emissions. Furthermore, they enable companies and suppliers to work on the reduction of their emissions, which ultimately will improve the industry's carbon footprint.

While created initially to meet the needs of chemical corporations and their suppliers, the TFS Guideline can be used as a calculation guideline and drop-in solution in any other global industry using chemical products. To ensure a harmonized, standardized, and widespread use, TFS has therefore decided to publish the Guideline as open source.

Bertrand Conquéret, TFS president, president of Global Supply Chain & Chief Procurement Officer at Henkel, said: "The new PCF Guideline is part of TFS' mission and our speedboat to foster sustainability and have impact in global chemical supply chains. The early involvement of key NGOs, climate experts and other major stakeholders allowed us to create a harmonized and aligned guideline that creates a PCF calculation standard for the chemical industry.

"As the TFS Guideline is available as open-source data, TFS aims to drive change beyond the chemical industry, providing the foundation for other industries to work on carbon reductions. By working collaboratively with cross-industry initiatives, we hope to build a more sustainable future."

TFS members (40 companies as of press date) drew upon expertise in GHG accounting, as well as the chemical supply chain, and the new guideline is the culmination of a workstream dedicated to finding a solution to the Scope 3 problem, implementing meaningful PCF information. The Guideline has been published as open source with the ambition that it may be used in other industries too.

TFS worked alongside global NGOs, corporate sustainability experts, chemical industry experts and organizations such as the World Economic Forum (WEF), and the World Business Council for Sustainable Development (WBCSD) to ensure global best practices for emissions accounting.

Given the urgent need for a harmonized PCF calculation approach within the chemical industry, the first edition of the PCF Guideline focuses exclusively on prescribing the specifications for supplier PCF calculations. Four additional chapters including reporting principles and guidance on Scope 3.1 calculation on corporate level will be published in November 2022.

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INNOVATION PITCH

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From Waste to Value
New Fractionation Technology to Extract Biopolymers from Biomass

Forward-Looking Data Analytics
ML Decision Support on Chemicals and Materials Trends

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Bioforsense – From Waste to Value

Utilizing Bio-based Side Streams to End the Increase of Industrial Waste

CH-Bioforce, based in Raisio, Finland, strives for a cleaner world. With their revolutionary technology, side streams from the manufacturing industry can be converted into high-value consumer products in an economically profitable way. These biomasses are fractionated into their main components: hemicellulose, lignin, and cellulose, with high purity and yield. These biopolymers can replace oil-based raw materials and cotton as binders, fillers, emulsifiers, textile fibers, and even as components in medical applications. CHEManager talked to Petri Tolonen, CEO of CH-Bioforce, about the company's innovative technology and how the team wants to continue its success story.

CHEManager: Mr. Tolonen, how did the idea for CH-Bioforce come about?

Petri Tolonen: Back in 2011, wood chemistry specialists Sebastian von Schoultz, Lari Vähäsalo and Nicholas Lax discovered that by using vacuum and ensuring precise chemical control, it was possible to extract hemicelluloses in high yield and purity in their native polymeric form. They started to develop their findings further and, after a few years of experiments, established CH-Bioforce in 2016.

What makes your Bioforsense technology unique?

P. Tolonen: This Bioforsense technology is the only solution available that gently extracts all the main components of biomass in one process. The resulting biopolymers—dissolving cellulose, polymeric hemicellulose, and sulfur-free lignin—are extremely pure and close to their natural form. It is possible to replace oil- and cotton-based materials in the manufacturing of consumer goods completely with these biopolymers.

What problem do you solve?

P. Tolonen: The world is drowning in non-renewable waste. Our seas, rivers, and lakes are full of microplastics, greenhouse gases are changing the climate, and our fragile nature is being overexploited. We dream of a world without plastic waste and oil-based consumer goods that end up destroying the planet.

In our vision, a circular bioeconomy ensures the utilization of industrial side streams, and natural renewable biopolymers are a sustainable alternative to non-renewable raw materials.

Modern consumer industries use tons of fossil-based raw materials in their production. At the same time, many agricultural side streams, like straw, end up being burned.

Burning valuable biomaterial side streams causes billions of tons of greenhouse emissions globally, whereas they could be used to replace various harmful or fossil-based components in the manufacturing process.

This doesn't have to be the status quo. We want to change that. We want to turn waste into high-value raw materials for our and the globe's sake. This is what our technology solves, and it is already in use.

Our technology produces more environmentally friendly raw materials for consumer goods, and industrial side streams will be used as efficiently as possible.

Can you give us an example?

P. Tolonen: Together with one of the world's largest brewing companies, we investigated how the side stream from the brewing process that currently ends up as waste can be utilized. We collect the brewer's spent grain and the straw waste from farms, and by using our Bioforsense technology we turn the waste material into high-value biopolymers—lignin, hemicellulose, and cellulose.

Cellulose, for example, can be used as a sustainable alternative for textile fiber production, replacing cotton-based textiles. We have been partnering up with Spinnova, for example, which makes sustainable materials for clothing brands like Adidas, The North Face, and Marimekko.

What's more, farmers that grow the initial cereal—wheat, oat, rye, rice, you name it—earn income by selling the "waste" to a producer that utilizes Bioforsense technology as I described.

How strong do you anticipate the demand for your technology to be?

P. Tolonen: Consumers demand more sustainable goods and apparel. At the same time regulations and legislation, such as the single-use plastics directive, drive manufacturers to find renewable, bio-based raw materials for their products.

Bioforsense technology is not limited to any specific raw material—quite the opposite. Our technology can extract biopolymers from wood, and also from other lignocellulosic feedstock, such as agricultural and industrial side streams. By 2025, it's estimated that the market size of industrial biomass waste will be tens of billions of US dollars annually, and this estimate is increasing rapidly.

At the same time, consumers want to use even more sustainable and environmentally friendly products in their everyday lives, whether we are talking about clothing, cosmetics, or food packaging. The problem is any oil-based raw material in the manufacturing process of these consumer goods, and the solution to make them more sustainable, and better, is CH-Bioforce and Mother Nature.

How do you see the future development?

P. Tolonen: The demand for sustainability from consumers is rising exponentially and multinational brands need to take action to respond to this. They want solutions that maintain their products, and one no-brainer solution is to make the products and processes more natural and environmentally friendly without decreasing product useability or durability.

Our technology's products maintain the features of face lotions, shirts and jeans, and food packaging. At the same time, the brands—if nothing else changes—produce way less CO_2 emissions in the production, emit fewer microplastics into the world, decrease the demand for oil-based raw materials, and use much less water—especially in the clothing business.

Petri Tolonen, CH-Bioforce

Personal Profile

Petri Tolonen, CEO of CH-Bioforce since 2021, has more than 30 years of international business experience at UPM, Valmet, and Wärtsilä, in sales, marketing, business development, and leadership. Tolonen holds an M.Sc. (Eng.) in Paper Technology and Production Economics. He stated when joining the firm that "We are on the crest of the wave when it comes to green technology. To slow down climate change and conserve natural resources, the necessary direction is to process all possible industrial and agricultural by-products into useful end products instead of being incinerated or landfilled – globally."

Business Idea

Biomass Fractionation Technology

Finland-based CH-Bioforce provides the world's only technology which extracts all of the main components of biomass in one process. The resulting biopolymers—dissolving cellulose, polymeric hemicellulose, and sulfur-free lignin—are extremely pure and close to their natural form.

The proprietary Bioforsense technology can utilize almost any kind of biomass as feedstock: wood species and non-wood, such as straw, which has become one of the most important raw materials. We provide a new feedstock option to multiple industries.

Renewable raw materials for sustainable living

With our technology, multiple oil-based products can be replaced in consumer goods with natural biopolymers while still maintaining the products' quality, durability, and useability.

At the same time, more environmentally friendly goods will be produced, and the industrial side streams will be used efficiently rather than ending up as waste or being burned. Using natural raw materials is an action for nature's well-being. Fewer harmful emissions will be produced, and fewer oil-based raw materials will be needed in the future.

Anticipating the future carbon-neutrally

We will build a next-generation biorefinery, which fractionates over 90% of biomass to produce biopolymers. Thanks to our revolutionary technology, a multitude of biomasses can be valorized on an industrial scale. Our process is carbon-neutral or even carbon-binding when renewable energy sources are being used.

The combination of technologies we use preserves the natural properties of all the main fractions better than any other technology. The unique quality of these biopolymers opens up a plethora of possible valorization routes.

Our competitors in the biorefinery industry mainly use wood-based raw materials, and in the bio-based chemical industry food-based feedstock. We strongly believe that nutritional resources shouldn't be wasted like this. Fortunately, there is already a solution—CH-Bioforce and Bioforsense technology.

- CH-Bioforce Oy, Raisio, Finland
- www.ch-bioforce.com

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Elevator Pitch

A World Without Waste

The world is drowning in non-renewable waste. Our seas, rivers, and lakes are full of microplastics. Oil-based raw materials are commonly used to make consumer goods. That is a huge problem, and the situation can't continue like this.

Luckily there's a solution: CH-Bioforce's unique Bioforsense technology extracts all of the main components of almost any biomass in one process. The resulting biopolymers—dissolving cellulose, polymeric hemicellulose, and sulfur-free lignin—are extremely pure and close to their natural form, and can be used to replace non-renewable raw materials in the production of consumer goods—oil in cosmetics and plastics in clothing, for example.

The company's technology is founded on a deep understanding of fundamental biomass chemistry. Broad academic and industrial collaboration and networking enable us to create state-of-the-art technologies where ingenious chemistry is combined with innovative reactor design and processing.

The idea behind our innovation is to find sustainable raw materials which can replace non-renewable, oil-based raw materials by using industrial and agricultural side streams as feedstock—converting waste into value.

Milestones

2011
- Discovery of fractionation technology

2016
- CH-Bioforce established

2017
- Small-scale plant in Finland with a capacity of 1 ton per batch

2019
- Construction of automated plant in Finland begins
- EU Horizon SME funding

2020
- Technology develops and CH-Bioforce enters global rankings

2021
- Several partnerships and new collaborations locally and globally

2022
- Bioforsense technology used in real applications

Roadmap

2025
- First plant to be commissioned with a capacity of 20,000 t/y

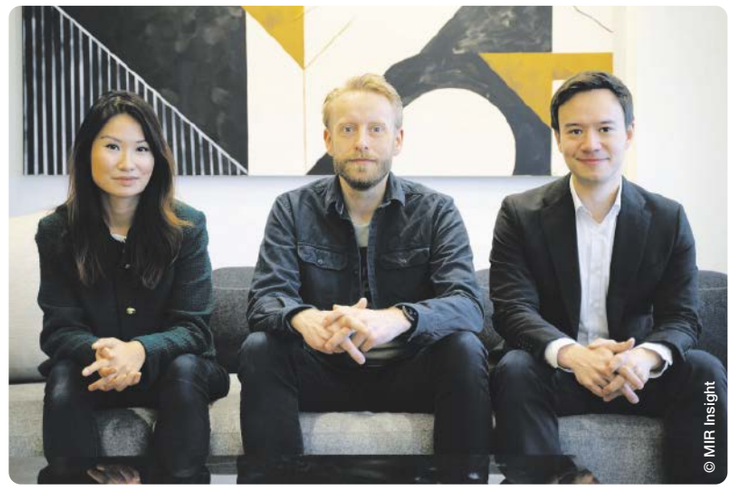
Fig. 1: Wood chemistry specialists Nicholas Lax, Sebastian von Schoultz and Lari Vähäsalo are the founders of CH-Bioforce.

Fig. 2: CH-Bioforce has developed Bioforsense, an innovative biomass fractionation technology.

Unlocking Forward-looking Data Analytics Synergies

Advanced Machine-learning Decision Support on Chemicals and Materials Trends

Mir Insight provides advanced machine-learning (ML) decision support and forecasting on chemicals and materials trends by offering an enriched and forward-looking data analytics software for the materials sector. The company's vision is to empower companies in the value chain by enabling them to collaborate with better data while keeping company secrets safe. The Oslo, Norway-based company was established in late 2021 with the aim to empower domain experts with explainable forecasts of future product trends based on global market activity. CHEManager asked co-founders Bjol R. Frenkenberger and Lisa Z. Mobech about their path so far and future plans and goals.



Co-founders of Mir Insight (from left to right): Lisa Z. Mobech (COO), Fredrik Larsen (CTO), Bjol R. Frenkenberger (CEO)

How did it all start, when did the founding team first meet?

Lisa Z. Mobech: The team met during a venture program and decided to start the company as we combine diverse perspectives to tackle this complex issue of trend forecasting from multiple angles. In November 2021, Mir Insight was incorporated.

What did motivate you to address the topic of forecasting?

Bjol R. Frenkenberger: When faced with uncertainty we always rely on our experience and feelings and combine them with rational facts. The better our facts, the better we can evaluate the 'reality' of our feelings, the better our decisions will be. Solely relying on information from customers, suppliers and historical activities is not enough in today's increasingly complex world, especially in terms of accuracy.

L. Mobech: Especially when we know how complex our world is becoming and how unique each supply chain is and how differently affected they are by external influence, we still tend to use the same traditional approach when forecasting, by going after the already known—there should be a smarter and better ways to solve this.

How did you develop your data analytics software?

B. Frenkenberger: The team has continuously iterated and tested the method and model with feedback from SMEs and multinationals in Europe and uses 500 million data series covering 40+ countries. Our methodology and ML-model has proven to generate a 50% better forecasting output than traditional forecasting techniques.

Did you get feedback from users already, how was the response so far?

L. Mobech: We have just started out, but the results we have achieved are promising. According to some users we managed to provide them with the additional information they needed to minimize risk and save time on planning, so they can evaluate new trends related to more sustainable materials and their replacement potential. They also say that they gain better visibility when making purchasing decisions, obtain a more holistic understanding of upcoming demand trends beyond what they would get from their customers and partners alone. So, with our help the users can be more specific and explain to their customers why and when they should act, ahead of time. This creates a positive domino effect down the value chain and reduces the information lag, one step at the time.

This sounds promising, but what about the good old-fashioned consideration of experiences and assumptions and the reliance on instinct and intuition?

L. Mobech: Our forecasting and decision support software does not intent to eliminate human Instinct and intuition. Gut feelings from past experiences will always be important but we aim to reduce guesswork and assumptions with explainability. That is why we provide a decision support tool to ensure that companies get more depth and visibility into actual activities, with more speed and precision. So, they can stay more ahead and eliminate guesswork.

B. Frenkenberger: The world is heading towards large-scale change, which most people have never been exposed to in their professional lives. This will lead to even greater explanation difficulties. That's why we think it's necessary to move towards informed, data-driven decision making by keeping up with your partners and market trends in real-time. This is what Mir Insight strives to enable.

So, what is on your agenda right now to develop the company?

L. Mobech: We are currently fundraising and always interested in talking to industry experts, who could give feedback regarding what we do. The only way forward for an early-stage business like ours is active engagement with all of you, so we can arrive at a solution that works for the industry as a whole. So please get in touch, we would be more than happy to hear your thoughts.

Personal Profile

Lisa Z. Mobech, CCO of Mir Insight, worked several years with multiple supply chains and industries—from insurance and risk management to raw materials and chemical distribution—and gained experience as an intermediary between suppliers' and customers' needs in B2B sales and product development roles. She studied International Marketing at BI Norwegian Business School, International Marketing and Business at Nanyang Technological University, Singapore, and received her MSc degree from Universitat Pompeu Fabra, Barcelona. She also took graduate courses at Harvard Extension School and is a specialist in business, operations and marketing management.

Bjol R. Frenkenberger, CEO of Mir Insight, received his PhD in Entrepreneurship Studies/Anthropology from the University of Oxford. During his thesis he gained deep understanding on how uncertainty affects decision making in organizations. He combines this knowledge with his experience of more than six years in AI and data analytics start-ups. Bjol advanced the international expansion of start-up businesses as Global Business Manager and Business Development Lead at Fuller and at FiNC Technologies. Before co-founding Mir Insight, Bjol performed as a prize-winning concert pianist across Europe.

Business Idea

Smart, Dynamic and Customized

Today, it seems that companies want to keep up with fast-moving and ever-changing events and, therefore, the time of static forecasting approaches its end.

We are living in the information era. There are great amounts of information available but underutilized because companies lack the right methods, know-how and applications to collaborate, draw the right conclusions, and produce the necessary results and use cases.

However, too much information is not necessarily beneficial for precise decision making, it is about understanding and acquiring the right information relevant for a company's needs on a continuously updated basis. It is essentially about acknowledging the fact that every product has a unique supply chain with their unique sets of drivers. This is what Mir Insight delivers.

The Oslo-based start-up offers enriched and forward-looking data analytics software for the materials sector to facilitate data collaboration within the supply chain. The team has continuously revised its product, adjusted its offering based on customer needs and tested with different companies to create a methodology and predictive model fitting the chemical supply chain using advanced machine-learning (ML) techniques.

Unlike traditional black box ML algorithms, which are hard to explain and difficult to understand even by the best domain experts, Mir Insight develops transparent ML models that produce understandable results, discover overlooked information on a continuous basis and breaks down global market activity to a product level. Their service dynamically analyses 500 million data series regarding economic, financial, or industry activity and brings them in connection with your own product trends. Going forward the service will also enable data synergies between supply chain partners in an anonymous and confidential manner. Customers can then easily understand how and why their product trends have been affected by market developments throughout time and draw their own conclusions.

- Mir Insight AS, Oslo, Norway
- www.mirinsight.com

Elevator Pitch

Business Planning and Forecasting

A diverse and passionate team on a mission to enrich and empower domain knowledge with cutting-edge technology, Oslo-based start-up Mir Insight combines more than 30 years of experience from the chemical industry, software development, research, data science, sustainability, materials, risk management, renewables, and finance.

The growing team of domain experts from multiple industries strives to provide the best practices from a large variety of sectors — towards a world where companies can easily make informed decisions to accelerate sustainable innovation with significant societal impact.

The name Mir stems from multiple languages such as Japanese, Russian or Spanish, meaning: to look into the future, peace, and mirror. As a small but multidisciplinary and multicultural team with the relevant industry experience as well as scientific and technological expertise, the founders of Mir Insight see and understand the world differently, which enables them to push the boundaries of innovation in a useful and creative way.

Milestones

2021
- Mir Insight incorporated (November)

2022
- Granted Commercialization funding from Innovation Norway (Norwegian Government)
- Granted Skattefunn from Norwegian research council
- Joined FECC (Association of European Chemical Distributors) as a member
- Participated in the FECC Annual Congress in Sitges, Spain
- Forecasted 36 unique chemicals and materials for pilot customers across Europe
- SMBs and multinationals
- Reached on average 50% higher accuracy on forecasts than traditional methods covering 40+ countries, and markets from petrochemicals to renewable materials and minerals

Roadmap

2023
- Further development on explainability and simulation
- First projects with customers to figure as independent data link between them and their partners
- Research project on the modelling of supply chains with leading European research institution

Mir Insight facilitates networking possibilities with industry experts across supply chain verticals from the Nordics, Benelux, UK, DACH region or Asia.

Mir Insight offers enriched and forward-looking data analytics software for the materials sector to facilitate data collaboration within the supply chain.

European Coatings Show 2023

The European Coatings Show (ECS) covers all aspects of the production of paints, coatings, sealants, construction chemicals and adhesives on March 28 – 30, 2023, in Nuremberg, Germany. The demands placed on paint and coatings are constantly growing. Therefore, the coatings industry faces great challenges. ECS gives them the opportunity to meet innovation leaders and discuss the latest developments in materials as well as technologies and equipment.

■ www.european-coatings-show.com

Interphex 2023

The International Pharmaceutical Expo (Interphex), dedicated to pharma and biotech innovation from development to marketing, is scheduled to take place on April 25 – 27, 2023, in New York, NY, USA. The annual trade show and technical conference brings over 10,000 global industry professionals and 625+ leading suppliers together. The event provides a combination of no cost technical conference, exhibits, demonstrations, and networking events.

■ www.interphex.com

Chemspec Europe 2023

Chemspec Europe is to take place on May 24 – 25, 2023, in Basel, Switzerland. The event is the key platform for manufacturers, suppliers and distributors of fine and specialty chemicals to showcase their products and services to a dedicated audience of professionals in the industry sector. The product portfolio of this event covers fine and specialty chemicals for various industries. Conferences presenting the latest results of ongoing R&D projects round-off the show.

■ www.chemspeceurope.com

CESIO World Surfactant Congress 2023

The 12th CESIO World Surfactant Congress, to be held in Rome, Italy, on June 5 – 7, 2023, provides an opportunity for experts across the surfactants value chain to meet. The theme for this edition will be: "Surfactants — High Performance Solutions for a Better World". This event represents the perfect opportunity to learn about the latest developments in key areas such as business & market trends, safety & regulatory affairs and technical & applications.

■ https://cesio-congress.eu

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