Chemistry makes the World go Around!

A White Paper of the Diplomatic Council on the significance and change in the Chemical industry.

By Dr. Holger Bengs

Executive Summary

Chemistry creates prosperity. However, this is not always immediately appreciated - which is emotionally understandable when emergencies involving technical failures or misjudgments occur. But viewed rationally, many, many people already benefit greatly from Chemistry today. Chemistry is changing: with more sustainable processes, Green Chemistry and new market participants. This is where Start-ups play an increasingly important role. Chemistry is redefining itself: away from being just the inventors of new molecules and materials towards becoming a problem-solving industry with many players from other disciplines. It is about living together across borders, also in order to achieve the United Nations' Sustainable Development Goals together, such as zero hunger on earth, no poverty, sustainable economic growth. With this White Paper, the Diplomatic Council is becoming involved in Chemistry for the first time, and accompanies this change from the position of a strong, committed and international member community: from person to person and for us all as human beings.

Chemistry in Transition in the 21st Century

Chemistry is undergoing fundamental change at this, the beginning of the 21st century. The road leads to higher efficiency, increased sustainability and more environmentally friendly products with more efficient production methods. The associated goals can only be achieved in an interchange across regional, cultural, systemic and cross-disciplinary boundaries in shared cooperation; to master the challenges of food production, global health care, a continuous supply of energy and ever-increasing mobility, to name just a few examples.

These challenges are also the result of underlying developments and trends, such as the growing world population, booming megacities, the individualization of products and services and the Internet of Things, as well as the foreseeable symbiosis of humans and robots.

We all want our share of knowledge and prosperity; and mastering all of the issues related to these changes is also linked to the hope of a world in which we share knowledge, growth and prosperity together; based on a peaceful coexistence. The supply of clear water, the Blue Gold of the 21st century, may be the central symbol of this progress. Chemistry is at the core of many of these trends and the tasks and challenges associated with humanity as a very important source of solutions and progress.

Importance of Chemical products in everyday life

Chemistry as a science and industry occupies a very important position worldwide. This is where source

materials and substances required in many sectors of industry are invented, discovered, created and produced; just think about fast fiber-optic cables without which the Internet would not have achieved its present scope and importance in our professional and private lives.

Life is Chemistry, and life without the achievements made by Chemistry is unthinkable. Important user industries of chemical products and innovations are: the healthcare industry, the plastics industry, the agri-food industry, the consumer goods industry, the automotive and mechanical engineering industries, as well as the building materials, semiconductor and clothing industries, plus the communications, sports and industrial sectors and the leisure industry.

97 percent of all products derive from chemical production

Virtually all areas of our lives would be inconceivable without products that come directly or indirectly in contact with chemical production: It affects our working life and the modern office world as well as our private lives and thus our well-being and life fulfillment, health, leisure and personal protection. In a nutshell: around 97 percent of the products around us derive from chemical production or contain at least one chemical process step in their manufacture.(1) Worldwide production of chemicals in 2015 amounted to 3.53 trillion euros.(2)

It has been estimated that there are over 80,000 different Chemical production lines worldwide. Across all segments there are more than 1,000 large and large to medium-sized Chemical companies; the number of smaller and micro-enterprises is many times higher.(3)

More and more frequently, Start-ups - i.e. newly founded companies - can be found among the innovators in the broad field of Chemistry; Companies focused on a specific niche based on an invention or a new technology; these specialists often emerge from Universities, Colleges and Research Institutes; but there are also spin-offs from the big companies. Right from the beginning, Start-ups are guided by sustainability criteria in their businesses, well aware that consumers are constantly increasing their emphasis on environmentally friendly and sustainably produced goods.

Chemical industry in positive change

The Chemical industry first emerged around the year 1860. Over the past 150 years, much good been achieved: without the inventions of Chemists such as Justus von Liebig with his superphosphate fertilizer and the Haber-Bosch process for large-scale industrial production of ammonia from air, agricultural and food production would not have been able to keep up with a growing world population.

Every truth also contains a counter-truth; and so it was with the Science of Chemistry and the burgeoning and growing Chemical industry, not everything followed a positive path: false, or sometimes not yet existing, knowledge, understanding or technology falling into the wrong hands or into abuse - could not be ruled out.

Today, however, we have standards in the world which are in the hands of many rational contemporaries and experts who want to use Chemistry for the benefit of the whole of mankind.

Principles of Green Chemistry

Twenty years ago, in 1998, the *Twelve Basic Principles of Green Chemistry* first saw the light of day.[4,5] The objectives: to avoid environmental pollution, to reduce and save energy consumption, and at the same time to minimize the potential for accidents in production. The canon of basic principles also includes the increased use of renewable raw materials, the requirement that it be possible to naturally degrade chemical substances after use and the avoidance of derivative materials during production; but for the increased use of catalysts in small amounts to carry out a single reaction many times, but do not result in large amounts of secondary waste substances; the avoidance of unnecessary intermediate steps in production is also part of the list of recommendations.

The 12 principles of Green Chemistry are:

1. Prevent Waste
2. Atom Economy
3. Less Hazardous Synthesis
4. Design Benign Chemicals
5. Benign Solvents & Auxiliaries
6. Design for Energy Efficiency
7. Use of Renewable Feedstocks
8. Reduce Derivatives
9. Catalysis (vs. Stoichiometry)
10. Design for degradation
11. Real-Time Analysis for Pollution Prevention
12. Inherently Benign Chemistry for Accident Prevention

From the disposable economy to the circular economy

An analysis of these twelve pioneering principles shows that they also significantly promote and drive the achievement of the UN's 17 *Sustainable Development Goals*[6] which include the fight against poverty and hunger, the development of sustainable cities in the face of predictions which suggest that 75% of the world's population will be living in urban areas in a matter of decades, and the generation of clean energy, turning to responsible consumption, and sustaining industry, innovation, and infrastructure.

The European Union Circular Economy Action Plan addresses this timely and much needed trend and assumes a fundamental supporting role:[7] The plan and its actions cover the entire product lifecycle, from design to material sourcing, manufacturing and use and consumption to disposal and on to the market for secondary raw materials from the recycling of used products.

It supports ways and projects that lead away from the linear disposable economy towards a circular economy. In it, the raw materials contained in products are reprocessed for use in the production process at the end of the product's life cycle. The Cradle-to-Cradle principle, describes - in addition to other concepts -

such an expression of change: in this case, raw materials recovered after the use of a product are recycled into the nutrient cycle or fed back into the technical cycle.[8]

End in sight: Rare Earth Elements and Phosphorus

According to calculations and estimates, we currently consume on average, resources equivalent to our entire planet earth one-point-six times every year worldwide. If we believe this plausibility check, we will need three point zero earths per year by 2050.[9] It is therefore good that in the light of finite resources a rethink is taking place.

The field of technology demonstrates the problem for us very quickly as soon as we think about the complex devices in our office and leisure communications: valuable metals such as Gold, Silver, Copper, Cobalt, Tin and Tungsten which are used in smartphones and tablet computers in various places and for various purposes and the so-called rare earth elements (earth metals), which are no less valuable, and come with such melodious names as Neodymium, Europium or Yttrium. And these will be irretrievably lost if we do not learn to reclaim them efficiently at the end of the useful life of an electronic device, or even better, to develop new technologies that do not require their use at all.

Safeguarding world food

An even greater and more urgent problem is the shortage of the vital element Phosphorus, a central building block of life; our genetic material contains Phosphorus, it is also contained in our bones and in every plant, and it is Phosphorus-bearing fertilizer that promotes their growth[10]. It is uncertain how long remaining deposits can keep the phosphorus resource at our disposal: some sources are already saying that the Peak Phosphorus, i.e. the maximum annual amount of decomposition, will be reached in a few years.[11]

A change of mindset is also taking place with regard to coming generations: Chemistry, together with other disciplines, is not only required but is also able to provide solutions to this massive problem. Projects are already under way which are dedicated to the recovery of Phosphorus from, for example, waste. One participant in this initiative is the Start-up Parforce, that aims to extract Phosphorus from sewage sludge in a technically efficient manner.[12]

Chemistry reinvents itself

The Chemical industry is progressing well towards its goal of Green and Sustainable Chemistry. Noteworthy here in the first instance is the European Technology Platform for Sustainable Chemistry, SUSCHEM.[13] Rethinking is taking place not only in science and education, but also in the Chemical industry; and here not just in terms of content, but also with regard to structures and the nature of cooperation. Whereas in the early days of the industry, new molecules and materials had to be designed to enable progress, today systems and solutions are in the spotlight: "From Materials and Molecules to Systems and Solutions" is the double alliteration from innovation researcher Professor Klaus Griesar from the oldest Pharmaceutical company in the world - Merck from Darmstadt. His article is commented on by the well-known US researcher, Georges M. Whitesides, who adds: "*Chemistry reinvents itself*."[3,14]

It is therefore very fitting that traditional industry is becoming more and more open to new ideas. This is true for both the way we collaborate as well as the way we innovate: ***Chemistry makes the World go Around!***

Chemical production and the resulting products that surround us are today being influenced and changed in many ways: Chemical production and chemistry-based products are also influenced and shaped by other disciplines: The Industrial Biotechnology sector is one of them.

Industrial Biotechnology enriches Chemistry production

Enzymes, well known to us all from modern laundry detergents, not only reduce energy requirements during the washing process, but can also mean that the machine can run at much lower temperatures: Moreover, they can also shorten and improve chemical production times: for example - a chemical process step can, in certain cases, be performed with an enzyme more cost-effectively and with less resulting waste.

Further examples of rapidly growing interdisciplinarity follow:

With the help of big data and digitization, more efficient process paths can be established and followed. Renewable raw materials offer alternatives to traditional resources such as petroleum and petrochemicals. And the examples continue to multiply: biotechnological developments are creating new chemical molecules and biomolecules that make cosmetics, food or plastics more natural and sustainable, or even equip them with new properties. Some molecules and chemical substances can only be synthesized using methods way outside of classical synthetic laboratory synthesis; Biotechnological production via microorganisms can often help to produce complex molecules faster. The possibilities are growing.

Chemical production with new facets

Classic chemistry, based on the Periodic Table of the Elements which we all remember from our school days, is today being enriched by insights and achievements out of industrial biotechnology, bionics, nanotechnology, digitization, and by computational methods and algorithms which all have their positive influence on processes, structures, and products.

The subject matter, views and insights of different disciplines complement each other, sometimes they can even replace each other, but in any case, in the totality of action and omission, they lead to a better outcome for us all. The one is not always good, the other is not always bad: organic products will not always be able to replace chemical products; but bioactive natural products, nature-based enzymes and tailor-made microorganisms greatly enrich the spectrum of our production possibilities and with that the facets of chemistry.

Start-ups as a pool of sustainable Chemistry

Even the not-invented-here - or 'we can do it much better on our own' syndromes - have been overcome in many areas in the Chemical industry. In the face of the pure numerical diversity of scientists and information gain, experts, mainly from the big companies, are looking again at cooperation.[15] The industry is also re-positioning itself in terms of international competitive structures. The focus is on cooperation with other industries and with customers in order to maintain the innovation lead. There are more and more Start-ups among the partners.

Many large Chemical companies also run so-called Corporate Venture Units to finance Start-ups. Nevertheless, and despite all the efforts currently being made, such as seed financing through the "*High-Tech Gründerfonds*" in Germany, a vibrant and broad venture capital scene is yet to develop.[16] The business models of Chemical Start-ups do not always fit into the portfolio thinking of investors. Although a growing number of Chemical Start-ups and those that have already outgrown the founding years are out there to be found.[17,18]

Leaving the comfort zone: finding solutions

The central challenge is to take this new awareness and information flow and convert them into knowledge and, above all, innovative products that can satisfy the needs of a sustainable economy.
To do this, the protagonists also have to get to know each other, abandon established patterns of behavior, leave comfort zones and approach each other. For example, the European Chemistry Partnering® meeting in Frankfurt is an annual gathering that promotes contact between creative people, innovators, investors, and industry decision makers of all kinds.[19]

While considering disruptive innovation and interdisciplinary cooperation, the United Nations Millennium Development Goals also remain in focus: these goals include - eliminating extreme poverty and hunger, reducing birth mortality and combating HIV/AIDS and Malaria.[20] One of the Millennium Goals is the question of ecological sustainability. The very important issue of sustainability also finds its echo in the 17 Sustainable Development Goals.[21] Chemistry, in particular, contributes directly to the following goals:

- No. 1: No Poverty
- No. 2: Zero Hunger
- No. 3: Good Health and Well-being
- No. 6: Clean Water and Sanitation
- No. 7: Affordable and Clean Energy
- No. 9: Industry, Innovation and Infrastructure
- No. 11: Sustainable Cities
- No. 12: Responsible Consumption and Production
- No. 13: Climate Action
- No. 14: Life Below Water
- No. 15: Life on Land
- No. 17: Partnerships for the Goals

Two aspects here are significant: On the one hand, the topic of environmental protection and ecology is very important. But sustainability also includes social aspects and issues relating to a caring society as well as

economic efficiency and economy. All three aspects - environment, society and the economy must be consistent, such as in the fight against poverty, the improvement of health, the supply of good quality food and water, the development of sustainable cities and industry, innovation and infrastructure. *Chemie hoch drei* (Chemie^3) is a very good example: it is the sustainability initiative of the German Chemical industry - with the support of three strong organizations: the German Chemical Industry Association (VCI), the Mining, Chemical and Energy Trade Union (IG BCE) and the Federal Employers' Association for Chemistry (BAVC). (22)

Crossing borders in common togetherness

This is where Chemistry assumes a responsible role. Its position is important, but without interdisciplinary cooperation, the big tasks will not get solved. That's how things have changed over time.

To the problems in many of the above sectors, Chemical innovation can offer a solution; as was the case in past centuries. But today what has changed is that completely different players are sitting at the table. And maybe we should not call them players, because our future is not a game: They are the shakers and movers, creative minds, entrepreneurs, scientists, experts from every conceivable discipline and social group: experts and members of the public – all are sitting around the table.

We are not just talking of natural scientists and traditional industrialists; but also creative business people and those who grew up in the digital world. In order to achieve added value in the world of Chemistry, Chemical knowledge is required, but that alone is not enough, many other aspects are also needed; In this way, logistics and shopping chains can function on the Internet thanks to the massive digitalization made possible by creative people in the Internet industry, without having to be Chemistry experts. This kind of task is solved by team-work.

Internationality and Interdisiplinarity

Disruption, or the creative destruction of the existing order through innovation is, according to the Austrian national economist Josef Schumpeter, the decisive process in the progression of an economy.(23) Today we know that great changes often take place at borders when opposites meet, for example: when an Asian meets a European to discuss market specialties. Then, there is the case of the skilled industrial mechanic and the PhD in Physics, or when a Chemist talks shop with a Biologist, and when an agile Start-up entrepreneur meets an experienced industry decision maker.

Computerization, digitization, robotics - in many places our traditional professions and activities are being changed. The curiosity of the human mind in itself does not allow for a stop: That which can sensibly be discovered, invented and implemented, is discovered, invented and implemented. That is the consequence of the urge to action that lies within us humans.

This thirst for action is needed while chemical knowledge is essential in order to meet many challenges: Examples of current tasks for which chemistry is required in an interdisciplinary way: electrification of transportation and the development of new fuels, the use of renewable resources, the implementation of

energy efficiency in households and in manufacturing, the permanent availability of clean water and healthy food, in polymer recycling and polymer composting and in the continued rise of solar and wind power as well as in mastering the challenge of achieving a zero carbon footprint; these are just a few areas involving responsible research and development that require a lot of innovation.

From human to human

Man himself is a trigger. He is also a partner and co-designer. That's good, that's right. Innovations must be applied where they can help us humans in the process of making progress and in the development of our prosperity.

Man is, and will remain, in demand where new things and innovations are concerned. And there he is – at the center of the action - no database, no computer and no robot. In order to lift the treasures of knowledge and innovation, there is a need for an exchange between real people. This is the only way to solve the challenges associated with the megatrends of our time: global population growth and the related demand for everyday necessities, such as healthy food, clean water, clothing and habitation for protection; but also beyond that for a fulfilled life - for the many, for very many, for all people.

Diplomatic Council and Chemistry

The Diplomatic Council (DC) draws its strength from common togetherness. The DC is an international network, an intercultural melting pot and a cross-system catalyst. Human coexistence and the well-being of all of us is the focus of our joint activities and efforts within the Diplomatic Council.

As international and significant as the Diplomatic Council is, so equally international and significant is Chemistry.

Two players, a *community of values* and above all - a *global community*:

Let us discuss together in search of innovation - for ourselves, for many, for everyone, for a better tomorrow.

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- Diplomatic Council Member since 2014

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(15) Jürgen Rütgers, 1998 im Bundeswahlkampf als designierter Bundesbildungsminister: „Im Jahr 2000 werden genauso viele Wissenschaftler leben, wie insgesamt in den 2000 Jahren zuvor.“ (*In 1998 in the German Federal election campaign as designated Federal Minister of Education: "In the year 2000, the same number of scientists will be living as in all the 2000 years before.")*
(16) www.htgf.de
(17) www.chemistry-compass.eu
(18) 1st, 2nd und 3rd Compass to Europe´s Innovative Chemical Companies, Hrsg. BCNP Consultants GmbH, in Form des E-Books als Gratis-Download in vielen Online-Bookshops verfügbar (*as a free download E-Book available in many Online-Bookshops)*
(19) Das European Chemistry Partnering® (ECP) ist ein jährliches Partnering-Event mit dem Ziel des grenzüberschreitenden Austausches, über nationale, systemische, kulturelle und Disziplinen-Grenzen hinweg. Ein inhaltliches Aufeinandertreffen, dass es darüber hinaus ermöglicht neue Geschäftsmodelle und neue Formen der Zusammenarbeit zu finden und zu kreieren, weg von einer rein linearen Geschäftsausrichtung hin zu multilateralen Kooperationen in hierarchiefreien Strukturen in denen die gemeinsame Zielerreichung und neue Innovationen im Mittelpunkt stehen. Das European Chemistry Partnering® fand erstmals am 16. Februar 2017 statt. Das 2nd European Chemistry Partnering ist am 23. Februar 2018. Veranstaltungsort ist Frankfurt am Main, Deutschland.
((ECP) is an annual Partnering event with the goal of cross-border exchange across national, systemic, cultural and disciplinary boundaries. A substantive meeting that also allows participants to find and create new business models and new forms of cooperation, away from a purely linear business orientation to multilateral cooperation in non-hierarchical structures in which the common goal achievement and innovation are at the center. The European Chemistry Partnering® first took place on 16 February 2017. The 2nd European Chemistry Partnering is on February 23, 2018. The venue is Frankfurt am Main, Germany.)
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Author's note: The content of this Paper was written in such a way that it could be accessible to a wide audience. Simplifications have therefore been made in some places with the aim of improving understanding and increasing its readability for all interested parties.