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Advanced Technologies for Industry – Sectoral Watch

Technological trends in the chemical industry

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Introduction

This sectoral report has been prepared in the framework of the *'Advanced Technologies for Industry'* (ATI) project, initiated by the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the Executive Agency for Small and Medium-sized Enterprises.

It analyses trends in the generation and uptake of advanced technologies, related entrepreneurial activities and skills needs in the chemical sector, covering in particular industry domains, but also with emphasis on trends and challenges in the area of the most relevant technological trends, namely digitalisation and 'biologisation'. It interprets data from a list of data sources compiled to monitor advanced technologies and their applications in industry across Europe and key competitor economies.

The starting point of this analysis has been sixteen advanced technologies that are a priority for European industrial policy and that enable process, product and service innovation throughout the economy and hence foster industrial modernisation. Advanced technologies are defined as recent or future technologies that are expected to substantially alter the business and social environment and include advanced materials, advanced manufacturing, artificial intelligence, augmented and virtual reality, big data, blockchain, cloud technologies, connectivity, industrial biotechnology, Internet of Things, micro and nanoelectronics, mobility, nanotechnology, photonics, robotics, security.

The relevance of these specific technologies in the chemical industry has been explored through patent analysis and data on private equity investments, skills and technology uptake. The full methodology behind the data calculations is available here: https://ati.ec.europa.eu.

This report is structured as the following:

- The first section sets the industrial context.
- The second section analyses technological trends in advanced technologies applied in the chemical industry based on patents and text-mining of company websites.
- The third section presents findings about private equity investment and startup/spinoff activity.
- The fourth section explores the supply and demand of skills related to advanced technologies in the chemical industry.
- The fifth chapter concludes with a short future outlook.

Section 1

1. Setting the scene: industrial context

Key messages

While the European chemical industry plays a strategically important role for its economy providing materials and solutions to virtually all of its segments, its global market share has shrunk significantly since 1998.

In terms of value added (VA) at factor cost, the European (EU27) chemical enterprises contribute directly **€130 bn** to the European economy. The **indirect contribution of the European chemical industry is estimated to be three times higher** due to activities supported in the industry's broad supply chain. More than half of the EU chemicals (56%) are sold to downstream users in other industrial sectors. **Germany** is the largest chemicals producer in Europe generating 35% of the European VA, followed by **France** (15%), **Italy** (10%), **the Netherlands, Spain and Belgium** (7% each). The EU holds a strong position in **basic chemicals**.

As a consequence of a traditional **reliance on fossil resources** and **energy- and waste-intensive production**, the chemical industry has been one of the causes of the associated environmental problems. However, the modern chemical industry has been increasingly seen as **part of the solution to many environmental challenges**. Its contribution to sustainability is particularly evident through the **development and use of renewable bio-based materials as well as provision of technologies that help reduce waste, raise energy efficiency and improve production processes**. However, new bio-based materials still **play a minor role** in the European chemical industry **contributing only 1.5%** to its total turnover.

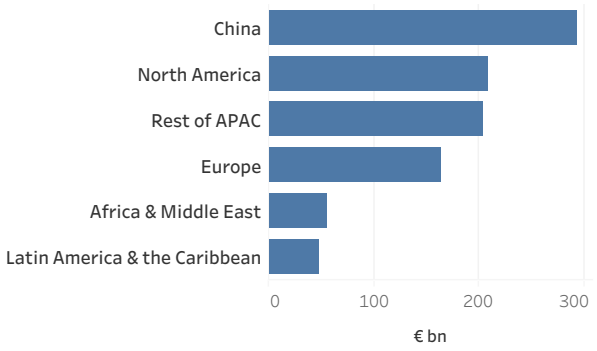
1.1 Chemicals value chain: market size and value evolution

The chemical industry[1] plays a particularly important strategical role for the economy, as it provides products and materials or solutions to virtually all of its segments. New materials supplied by the chemical industry often form the basis for product innovation in other industries. Innovations in chemistry may help to improve production processes of the end users and make them more cost-effective and environmentally friendly offering opportunities to engage in higher value and more sustainable production[2].

The global chemical industry has recently benefitted from relatively low oil prices, low interest rates and high demand in construction, automotive and electronics that are the most important chemical end-use markets. Raw material costs are an influential factor for the competitiveness of petrochemicals, polymers and basic chemicals.

In energy-intensive, fossil-based production, crude oil and gas prices therefore play a central role.[3]

Figure 1: Size of chemical industry (GVA) by region in 2017



Source: draws on Oxford Economics 2019. Estimations in US-$ were converted in € using the average US-$ exchange rate for 2017.

Between 1998 and 2018 the global chemicals market grew significantly, primarily due to a steep continuous increase of China's and other Asian countries' (excluding Japan) market shares.[4] As a consequence, China's chemical industry has expanded markedly during the last decades making it the world leading region in terms of the market share followed by North America and the

[1] In this report, the chemical industry is outlined according to the definition provided by the Division 20 of NACE Rev. 2 (Eurostat 2008): Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms; Manufacture of pesticides and other agrochemical products; Manufacture of paints, varnishes and similar coatings, printing ink and mastics; Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations; Manufacture of other chemical products; Manufacture of man-made fibres.

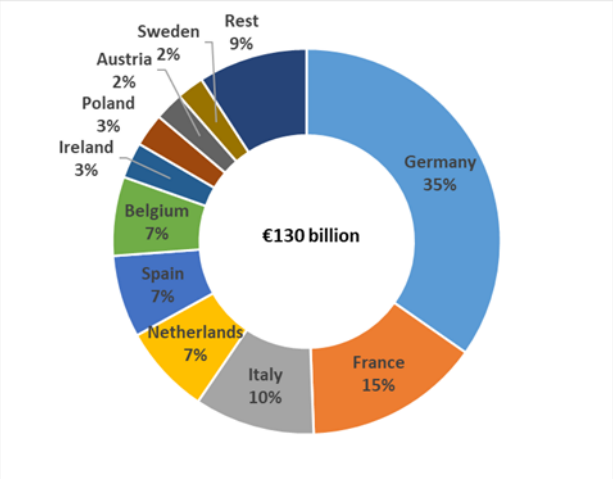
[2] Gehrke and Weilage 2018.

[3] Bioökonomierat 2015.

[4] Cefic 2020.

rest of APAC countries[5] (Figure 1), whereas the EU gradually lost its top position. After a steep decline in 2009, the GVA volumes at constant prices in the EU-28 grew at an average annual growth rate of 1% between 2010 and 2017[6]. China's and other APAC countries' growth trend is expected to continue in the future, although at a lower than recent rate, due to the anticipated strong chemical demand in these countries. If the current growth trend continues and disruptive market events do not occur, growth in Europe is prognosed to be moderate at just 1% during the next decade causing further losses of the European chemicals market share to China and other Asian countries.[7]

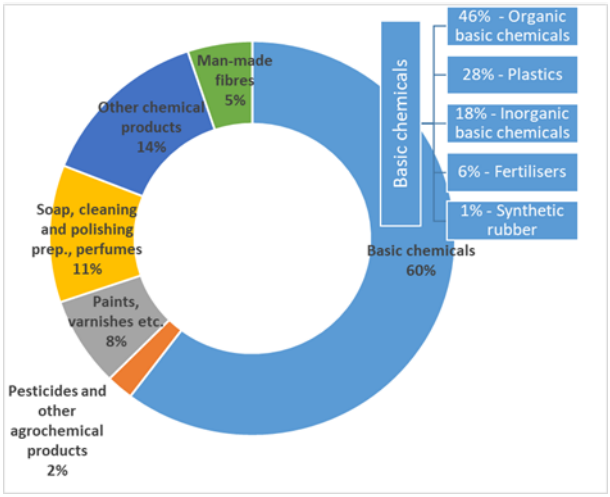
Figure 2: EU27 Chemicals Value Added at factor cost broken down by country in 2017



Source: Eurostat, Structural Business Statistics (SBS), own calculations

The European chemical enterprises contribute directly €130 bn to the European economy in terms of value added (VA) at factor cost. However its indirect contribution is estimated to be three times higher due to activities supported in the industry's broad supply chain.[8] Germany is by far the largest chemicals producer in Europe generating 35% of the European VA, followed by France (15%), Italy (10%), the Netherlands, Spain and Belgium (contributing 7% each) (Figure 2). On a sub-sector level, the European chemical industry[9] is characterised by a high market share of basic chemicals making up 60% of the total EU-28 chemical turnover in 2017 (Figure 3). Basic chemicals are largely dominated by organic basic chemicals (46%), plastics (28%) and inorganic basic chemicals (18%). 'Other chemical products' was the second largest sub-sector contributing 14% and soap and detergents, cleaning, perfumes and toilet preparations - the third largest sub-sector contributing 11% to the total European chemical industry turnover.

Figure 3: EU28 Turnover of chemical industry broken down by sub-sectors in 2017



Source: Eurostat, Structural Business Statistics (SBS)

1.2 Towards sustainable chemistry

The ecological footprint of the chemical industry has been substantial as a result of its reliance on fossil-based resources, high energy-intensity and the use of hazardous substances that have negative effects on the ecosystem. However, the chemical industry can also provide solutions to many environmental challenges. Its contribution to sustainability can be particularly realised through the development and use of sustainable bio-based materials in combination with more efficient production and logistics processes as well as the provision of technologies that help reduce waste, raise energy efficiency and enable circular economy in the downstream industries. A lot of R&D related to the chemical industry is inspired by the principles of Green Chemistry[10], which aim at reducing or eliminating environmental risks throughout the entire life cycle of a product or process.

In the course of national and European policy endeavours to reach circular economy targets and due to changing consumer preferences in favour of environmentally friendly products, efforts to integrate sustainable aspects into research and production processes of the chemical industry have intensified in recent years. Bio-based chemicals that are wholly or partly derived from materials of biological origin (for example biomasses, feedstock, but also plants, algae, crops, trees, marine organisms and biological

[5] "APAC" denotes Asia-Pacific countries. Asia-Pacific varies in area depending on context, but it generally includes East Asia (China, Japan, South Korea, Taiwan, Hong Kong) and South Asia (India, Nepal, Pakistan, Nepal, Bangladesh, Afghanistan, Bhutan, Sri Lanka).

[6] According to own calculations based on the EU KLEMS data: https://euklems.eu/download/

[7] https://www.de.kearney.com/chemicals/article?/a/chemical-industry-vision-2030-a-european-perspective

[8] Oxford Economics 2019.

[9] According to Eurostat SBS: Annual detailed enterprise statistics for C20 (NACE Rev. 2).

[10] https://en.wikipedia.org/wiki/Green_chemistry

waste) have already been used in bio-based and thermochemical processes.

However, the market share of bio-based chemicals as well as investor interest still remain low. The main hindrance for a rapid expansion of bio-based chemicals is their high production cost as opposed to the low production costs of the fossil-based products, since they do not internalise the external costs of their environmental impact.[11] According to recent estimations, turnover of bio-based chemicals in Europe reached €9.2 bn[12] making up 1.5% of the total turnover in chemical products. Surfactants and paints, coatings, inks and dyes that are typically produced in large volumes dominate total EU production. They have a high bio-based share, whereas it is still very low for platform chemicals (0.3%) and polymers (0.4%). Compared to other regions, the EU has a high overall importance for the production of bio-based plastics, cosmetics and lubricants. Under a business-as-usual-scenario, the EU bio-based production is expected to grow at a compound annual growth rate (CAGR) of 3.6% by 2025.[13]

1.3 Growth trends in main application areas

Many industry sectors use a broad range of chemical products or rely on some form of inputs from the chemical industry. Therefore, the growth of the chemical industry depends to a large extent on the consumer spending and demand for goods involving the use of chemicals. More than half of the EU chemicals (56%) are sold to downstream users in other industrial sectors.[14] Beyond chemical manufacturers, the biggest industrial users of chemicals are the rubber & plastics (15.5%), construction (5.1%), pulp & paper producers (4.3%) and textiles (3.5%).[15] The remainder (44%) goes to other sectors, the largest of them are health and social work, agriculture and services.

All customers of the chemical industry are undergoing massive transformations that pose new requirements to the chemical industry. Automotive, construction, computer and electronics, and pulp production are the key end markets of the chemical industry.

In Europe, the demand from construction and automotive parts buyers has slowed down in last years. As the global automotive industry is facing major challenges (increasing e-mobility), sales are deteriorating in many key markets.[16] However, main technological shifts in the end markets, offer at the same time huge opportunities for the chemical industry. Lightweight materials are becoming increasingly important for many industries, particularly for the automotive. They are urgently needed to reduce the impact of additional system costs for electrification but also for CO2-optimised internal combustion engines.[17] As a consequence, the demand for the light materials has been growing during the last decade and is predicted to increase further in the future, suggesting that the lightweight share of the automotive industry may increase to 70% by 2030[18]. The global lightweight automotive market is expected to grow at a CAGR of over 4.5% during 2020 - 2025.[19] The chemical industry is one of the main suppliers of lightweight materials that benefit from the increasing demand providing special plastics, carbon fibres and polymer composites. Moreover, advances in chemical knowledge contribute to the improvement of the power and energy density of lithium-based batteries for the e-mobility[20] and help save greenhouse gas providing technology for the production of advanced biofuels.

Construction industry is the key market for chemicals and advanced materials. According to research reports, the global construction chemicals and advanced materials market is going to grow at a CAGR of more than 6% between 2016 and 2023.[21] The growth is particularly driven by the expansion of smart cities and green building construction enabled by the chemical industry innovations, such as photovoltaic paints and self-healing concrete, pollution-absorbing bricks, light-generating cement, high-reflectance coatings, high-performance insulation foams and phase change materials.[22]

The global electronic chemicals and materials market is expected to reach about €75 bn by 2024 by growing at a CAGR between 6 and 8 percent.[23] The growth is attributed to increasing technological advancements in manufacturing electronic products and the rise in demand for electronic high-tech goods.[24] Particularly in demand are advanced electronic materials which provide superior performance.[25] For instance, digital semiconductors, which are used in computers, servers, tablets, mobile phones and consumer electronics, require special electronic chemicals for high-end performance and

[11] Spekreijse et al. 2019.
[12] Spekreijse et al. 2019.
[13] Spekreijse et al. 2019.
[14] Cefic 2020.
[15] Cefic 2020, based on Oxford Economics 2019.
[16] Atradius 2019.
[17] McKinsey&Company 2012.
[18] McKinsey&Company 2012.
[19] https://www.mordorintelligence.com/industry-reports/global-market-for-lightweight-cars-industry
[20] https://www.de.kearney.com/chemicals/article?/a/chemical-industry-vision-2030-a-european-perspective
[21] https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Energy-and-Resources/gx-future-of-chemicals-brochure.pdf
[22] Deloitte 2019b.
[23] https://www.grandviewresearch.com/press-release/global-electronic-materials-chemicals-market
[24] https://www.marketsandmarkets.com/Market-Reports/electronic-chemicals-market-107930161.html
[25] https://www.marketsandmarkets.com/Market-Reports/electronic-chemicals-market-107930161.html

production.[26] Also bio-based and biodegradable materials and chemicals for electronics industry are expected to drive the market growth.[27]

Due to the growing environmental awareness and corresponding shifts in consumer preferences, the use of bioplastics becomes more widespread in an increasing number of markets, from packaging, catering products, consumer electronics, automotive, agriculture/horticulture and toys to textiles and other segments. Packaging is currently the largest field of application for bioplastics with more than 53 percent (1.14 million tonnes) of the total bioplastics market in 2019. Also, the automotive and transport industry as well as building and construction significantly increased their share in recent years.[28]

Key end markets of the chemical industry are all set to surge in Asia, driven by the growing local demand for chemicals.[29] However, the recent escalated tariff war between China and the US, has had a negative effect on the global chemicals prices and demand from key end markets.[30]

1.4 Employment effects

The European chemical industry provides employment to ca. 1.1 million people. Viewed over longer period of time, the employment development in the chemical industry within the EU shows an overall decreasing tendency since the beginning of 2000s: the number of people employed in the chemical industry in 2005 amounted to almost 1.3 million. However, this overall development conceals different trends at the level of individual EU countries: while some countries, such as France and Italy, have reduced employment, Germany has to a greater extent maintained its employee number. Other countries, such as Denmark and Poland, have recorded slight increases in employment since then.[31] Due to the large supply chains of the chemical industry, the sector induces significant amount of employment in other economic activities. According to the recent estimations of Oxford Economics 2019, each worker in the chemical sector supported another 11 jobs elsewhere in Europe in 2017. Such a high employment multiplier is mainly attributable to the large supply chain, many parts of which tend to be less productive than the industry itself.

The chemical sector belongs to the most productive industries: according to the Eurostat's Structural Business Statistics, its value added per employee is almost 80% over the level of the total manufacturing. As the industry itself has been increasingly R&D- and technology-intensive, it employs a relatively large share of high-skilled workers.

[26] https://www.prnewswire.com/news-releases/global-electronic-chemicals-market-stood-at-around--20-51-billion-in-2018-and-is-projected-to-reach-about--29-96-billion-by-2024--300835531.html
[27] https://www.grandviewresearch.com/press-release/global-electronic-materials-chemicals-market
[28] https://www.european-bioplastics.org/market/
[29] https://www.de.kearney.com/chemicals/article?/a/chemical-industry-vision-2030-a-european-perspective
[30] Atradius 2019.
[31] Gehrke and Weilage 2018.

Section 2

2. Technological trends

Key messages

The chemical industry currently undergoes a **fundamental technological transformation** throughout its whole value chain caused by new trends and adoption of disruptive technologies. Trends that have significant impact on the chemical industry at present and will have even more vigorously in the future are **sustainability** and the **circular economy, digitalisation and additive manufacturing**.

Advanced Materials is the most relevant advanced technology affecting the chemical industry in the EU27. The trends in Advanced Materials measured by patenting activities indicate a **top global position of the EU27**, however, its **relative share in global patents** had been **declining over 2010-2017**, while Japan and China are on the rise.

In the field of **Industrial Biotechnology**, the EU27 ranks third, although its contribution to the global patent applications in 2017 was somewhat lower than ten years ago. Within the EU27, especially **Germany, France, the Netherlands and Belgium** make considerable contributions to the EU27 patenting development in these technologies.

Advanced Materials are actively used by the chemical companies as the text-mining of company websites also confirms. Other technologies that appear in online content are related to Industrial Biotechnology, Nanotechnology, Big Data, Robotics and Artificial Intelligence.

Further relevant technology fields in which chemical companies in the EU27 are actively engaged are related to **Micro- and nanoelectronics** as well as **Advanced Manufacturing** technologies.

2.1 Technology shifts and advances – emergence and deployment of advanced technologies

Chemical companies are under growing pressure to adopt new technologies that can generate greater value and fuel new growth. The chemical industry undergoes a radical transformation throughout the whole value chain from raw materials supply, R&D via production to customers and end users presenting new challenges and opportunities to the chemical industry. It is increasingly exposed to disrupting trends such as sustainability and the circular economy, digitalisation and additive manufacturing.

Sustainability and the circular economy are becoming increasingly important in politics, industry and society. Circular economy represents a shift away from a linear "take-make-dispose" approach of resources towards a system of closed cycles, where materials are constantly cycled back through the entire value chain for re-use[32]. The chemical industry can contribute to the circular economy in manifold ways through: 1) creating materials that are more durable, sustainable and energy efficient, 2) using high shares of bio-based or renewable feedstock that meets sustainability criteria for the production of bio-based chemicals and 3) increasing the recyclability of end products.

The role of the chemical industry is particularly important as it acts as an enabler for the circular economy in downstream industries.

Figure 4: Overview of trends and related technologies

Trends	Technologies
Sustainability and Circular Economy	• Industrial biotechnology • Circulating molecules • Waste-to-Chemicals • Carbon Capture Utilisation • Bio-refineries
Digitalisation	• AI/Data Analytics • Internet of Things • Robotics • Blockchain
Additive/Adaptive manufacturing	• 3D printing • Advanced Materials

Source: Fraunhofer ISI

A number of chemical companies and R&D organisations in Europe are involved in innovation activities aimed at achieving higher efficiency in the (better) utilisation of waste materials and by-products and use of CO2 as raw materials (Waste-

[32] https://www.accenture.com/us-en/insight-circular-economy-european-chemical-industry

to-Chemicals and Carbon Capture Utilisation). Further important topics in the context of sustainability and circular economy are chemical recycling (also called feedstock recycling), biodegradability as CO2 cycle, and climate protection through 'biologisation of chemistry' (use of industrial biotechnology, genome editing for precision breeding, bio-refineries and the utilisation of renewables as raw materials).[33]

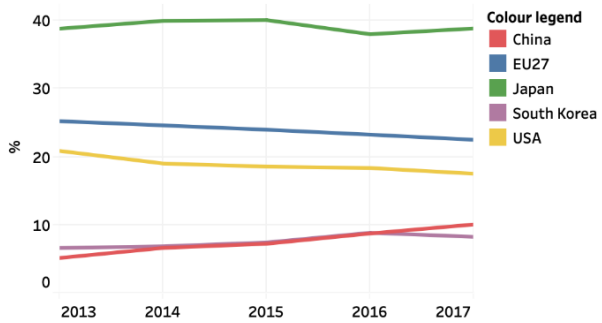
Digitalisation is another technological trend that has a significant impact on the chemical industry throughout its entire value chain. Advanced technologies, such as the Internet of Things (IoT), advanced data analytics, Artificial Intelligence (AI), Blockchain and Robotics already have a growing influence on the chemical industry and will play an even more crucial role in future. According to the research of Accenture, digitalisation could unlock up to €500 bn for the chemical industry over the next decade.[34]

Additive manufacturing enabled by 3D printing and novel materials is another area that opens up huge opportunities for chemical companies. As material developer and provider, the chemical industry has a crucial role in this value chain. Additive manufacturing offers a large growth potential driven by increasing demand for novel customised materials.[35] The market for polymers and chemicals used in additive manufacturing (AM) is currently growing at 30 percent a year.[36]

2.2 Trends in patenting of Advanced Materials and Industrial Biotechnology

The patent analysis presented in this sub-section sheds light on the technological trends and shifts affecting the chemical industry at the EU level and also in a global context. The chemical industry plays an important role in providing **Advanced Materials** that can be integrated into different technologies and systems enabling new products and improved performance - hence promoting technological advances in other areas. Data on transnational patent applications Figure 5) shows that inventive activities in technologies related to Advanced Materials are largely concentrated in few regions: Japan, the EU27, US, China and South Korea. Japan (39%) is currently leading in terms of the global patent application share followed by the EU27 (23%) and the US (18%). However, the trends in patent filings over time indicate a steady decline in the share of the EU27 since 2010. Similarly, the US is gradually losing their shares to competitors, whereas China is rapidly increasing its patent filings in Advanced Materials ranking fourth in 2017. By comparison, South Korea exhibits an increasing, albeit somewhat weaker growth trend reaching 8% of the global share in 2017. In terms of the percentage in total number of domestic patent applications, Japan shows the highest level (10%), followed by South Korea (6.5%), France (5.8%) and Germany (4.5%) (Figure 8).

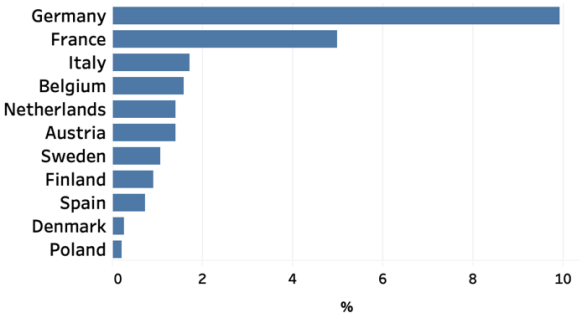
Figure 5: Share of global patent applications in Advanced Materials (2013-2017)



Source: ATI, 2019 Fraunhofer ISI calculations

Among the EU27 Member States, Germany performed the best in filing Advanced Materials related patent applications and accounted for almost 10% of all global patent filings in 2017 (Figure 6). Other European top performers are France (5%), Italy (1.7%), Belgium (1.6%), the Netherlands (1.4%), Austria (1.4%) and Sweden (1%). Both leading European patent contributors - Germany and France have a high relative share of Advanced Materials patent applications vis-à-vis total domestic patents (see Figure 8).

Figure 6: EU27 Member States' share in global patents in Advanced Materials (2017)



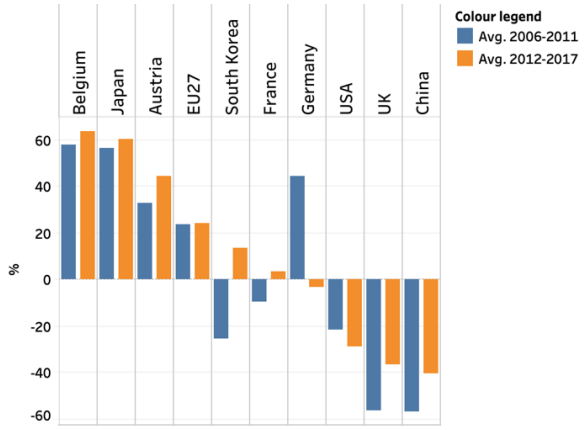
Source: ATI, 2019 Fraunhofer ISI calculations

The revealed patent advantage index[37] (RPA) – see Figure 7 – displays the extent to which countries have specialised in Advanced Materials.

[33] Deloitte 2017a.
[34] Accenture 2018.
[35] https://www.financierworldwide.com/impact-of-3d-printing-on-the-chemicals-industry
[36] https://www.mckinsey.com/industries/chemicals/our-insights/digital-in-chemicals-from-technology-to-impact

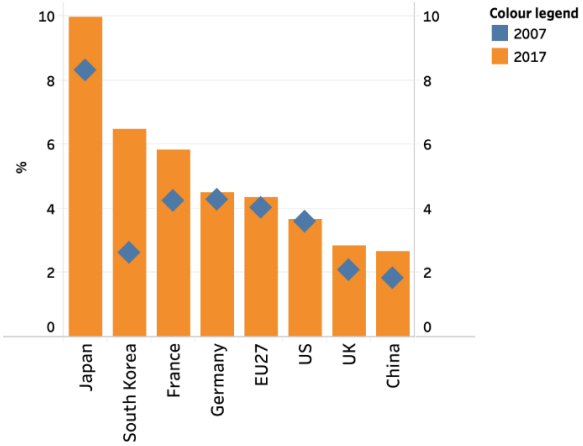
[37] The RPA index indices between -100 and -60 indicate an absence of specialization, whereas values between -60 and -20 points to a week specialisation, between -20 and +20 to an average specialization, between +20 and +60 to an above average specialisation and between +60 and +100 to a strong specialisation.

Figure 7: Change in Revealed Patent Advantage (RPA) Index in Advanced Materials (2006-2011; 2012-2017)



Source: ATI, 2019 Fraunhofer ISI calculations

Figure 8: Share of patent applications in Advanced Materials over total patent applications at country-level (2007 - 2017)



Source: ATI, 2019 Fraunhofer ISI calculations

Among the most specialised countries at the global level are Japan, the EU27 and South Korea. Belgium and Austria are the most specialised countries within the EU27. France stands out as a large EU country with increasing specialisation in Advanced Materials, whereas Germany has lost its strong specialisation during 2012-2017, compared to 2006-2011. A number of Central and Eastern European countries (CEEC), such as Latvia, Lithuania, Slovakia, Czechia and Poland display positive specialisation in Advanced Materials, although in absolute terms, their level of patenting activities remains low.

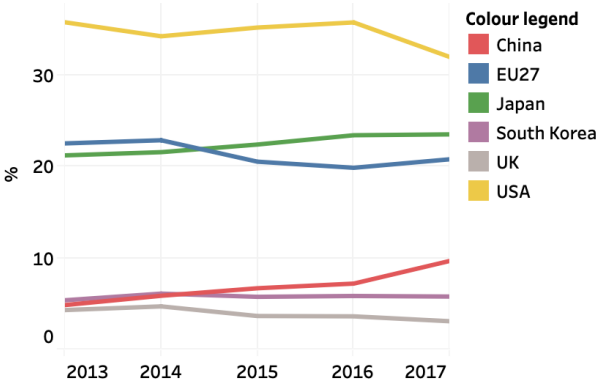
Based on the RPA analysis, the United States and China have a negative specialisation index, albeit China's specialisation index was improving during 2011-2017.

Industrial Biotechnology as a key enabling technology allows the use of biotechnological processes[38] in the industrial production and has a great potential in the transformation of the chemical industry towards "bio-based" chemistry,[39] but also in processing fossil-based feedstock, wastes and CO2. As the importance of the "bio-based" chemistry is constantly growing due to both sustainability and competitiveness considerations, continuing advancement in Industrial Biotechnology is significant for the chemical sector.

Figure 9 illustrates the recent development in global patent applications in Industrial Biotechnology for the EU27 relative to the major competitors. The leading country with the highest share of patent applications in Industrial Biotechnology is the US. The country accounted for 32% of total global patents in 2017, albeit its recent evolution is characterised by a somewhat declining trend.

Japan is another country that holds a considerable share of global patent applications in Industrial Biotechnology (23.6% in 2017) displaying a growing tendency since 2011. The EU27 ranks third, although its contribution to the global patent filings in 2017 (20.9%) was 15% lower than ten years ago (24.5%). Growing importance of Industrial Biotechnology in other countries, notably China and Japan, is the cause for the continuously decreasing shares of the US and EU27 in the global Industrial Biotechnology patent applications during the last decade.

Figure 9: Share of global patent applications in Industrial Biotechnology (2013-2017)



Source: ATI, 2019 Fraunhofer ISI calculations

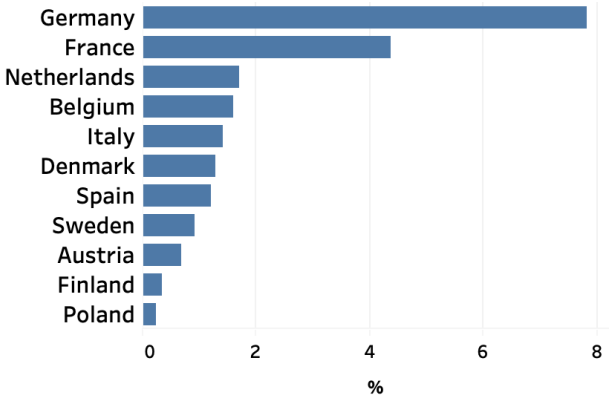
[38] Biotechnological processes use the metabolic or catalytic properties of microorganisms (bacteria, yeasts, fungi, microalgae) and subcellular components, mostly enzymes, for the production, conversion or degradation of substances. In most cases these are enzymatic processes or fermentations for the conversion of biomass for industrial material use (Aichinger et al. 2016).

[39] Aichinger et al. 2016.

Since 2007, China increased its contribution by more than 440%, however, starting from a low initial level. South Korea is another main patenting country in this technology field.

Within the EU27 (Figure 10), Germany is a key contributor with 7.8% of global patent applications in 2017. Further main patenting EU countries in Industrial Biotechnology are France (4.4%), the Netherlands (1.7%), Belgium (1.6%) and Italy (1.4%). Hence, the top 5 patenting countries for Industrial Biotechnology are identical to those for Advanced Materials.

Figure 10: EU Member States' share of global patents in Industrial Biotechnology (2017)



Source: ATI, 2019 Fraunhofer ISI calculations

At the level of individual countries, different development trends over time can be observed. For example, Germany showed a slightly lower share of patent applications in its total patent filings in 2017 (1.2%) (Figure 12) compared to 2007 (1.3%), similar to the Netherlands (1.3% in 2017 compared to 1.6% in 2007), whereas France's relative importance of Industrial Biotechnology patenting increased from 1.3% in 2007 to 1.8% in 2017 and Belgium's from 3% to 3.7%. Among all observed countries, Belgium records the highest relative share in the total domestic patents (see Figure 12 on the next page).

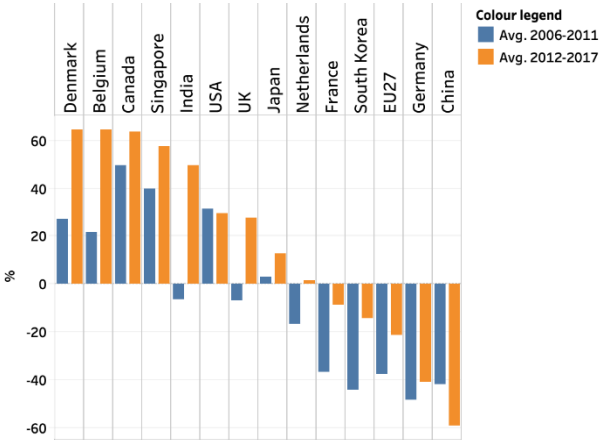
Canada, Denmark, Belgium and Singapore further specialised in Industrial Biotechnology during 2012-2017 as measured by RPA, remaining the most specialised economies worldwide in this technology (Figure 11).

India increased its share of patent applications in total domestic patent filings by almost twofold between 2007 and 2017 rising to the most specialised countries (Figure 12). India exhibits the highest growth in specialisation during 2011-2017 compared to 2006-2011, followed by Japan, Belgium and Denmark.

In the main patenting country - the US - the share of Industrial Biotechnology patents in total patents (Figure 12) decreased somewhat, similar to their specialisation index.

China's relative share in total patent applications in 2017 was 25% lower than in 2007. It exhibited further losses in its relative technological advantage during 2012-2017 (Figure 11).

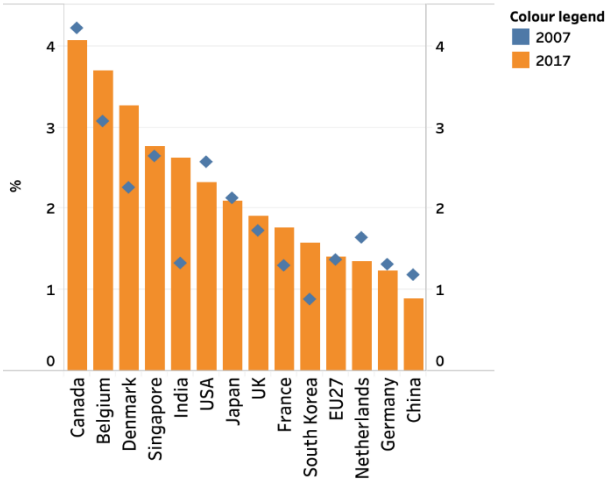
Figure 11: Change in Revealed Patent Advantage (RPA) Index in Industrial Biotechnology (2006-2011; 2012-2017)



Source: ATI, 2019 Fraunhofer ISI calculations

The EU27 as a whole has a negative specialisation in Industrial Biotechnology due to the negative or low average specialisation of its larger Member States, such as Germany, France, Italy and Poland along with a number of further countries (e.g. Sweden, Finland, Austria, Czechia, Ireland), although its relative performance was gradually improving during 2012-2017. Apart from the most specialised EU countries Belgium and Denmark, high specialisation values in Industrial Biotechnology were measured for Spain, Hungary, Latvia, Lithuania, Slovenia and Slovakia, although patenting activities in most Central and Eastern European countries remain low in absolute terms.

Figure 12: Share of patent applications in Industrial Biotechnology over total patent applications at country-level (2007 - 2017)

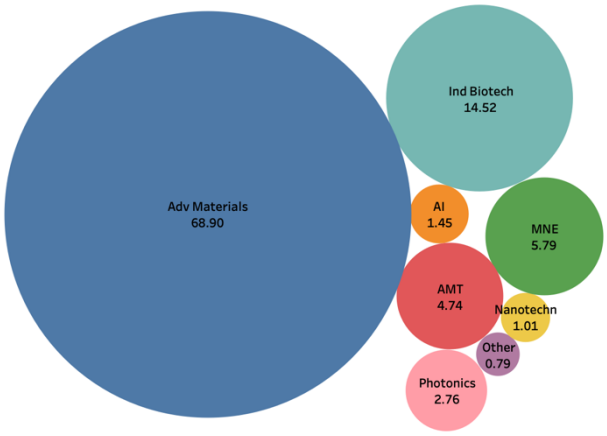


Source: ATI, 2019 Fraunhofer ISI calculations

2.3 Technological patenting of chemicals firms

With regard to new technology development, Advanced Materials represent the area where European chemical firms tend to patent most (Figure 13). Further relevant technology fields include **Industrial Biotechnology** and to a lesser extent **Micro- and nanoelectronics** as well as **Advanced Manufacturing** technology.

Figure 13: Share of technology patents by chemical firms in the EU27 (average over 2015 – 2017)

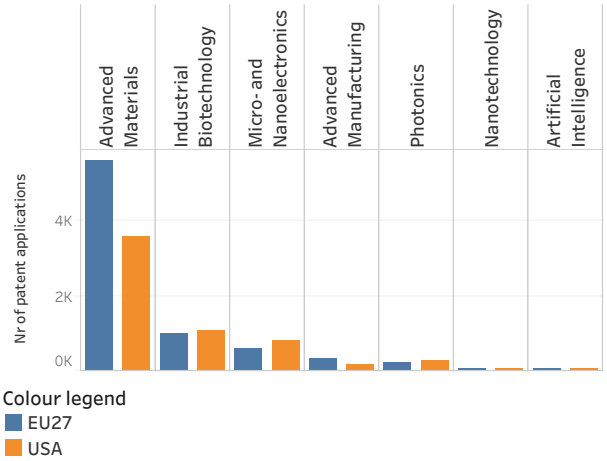


Source: ATI, 2019 Fraunhofer ISI calculations

Patent applications in Advanced Materials represent nearly 70% of all advanced technology patents filed by chemical companies in the EU27 (Figure 13). Overall, **the EU27 recorded a level of patenting activity in Advanced Materials** (performed by chemical companies) about **50% higher than that of the US** chemical companies (Figure 14).

European chemical companies also engage in Industrial Biotechnology innovations. Nearly 15% of all patents filed by European chemical companies are attributable to Industrial Biotechnology (Figure 13). The total amount of patents related to Industrial Biotechnology filed by US chemical companies during 2010-2017 was slightly higher (Figure 14).

Figure 14: Total patent applications of chemical firms in 2010-2017



Source: ATI, 2019 Fraunhofer ISI calculations

Developments in **Micro- and nanoelectronics and Photonics** increasingly require new and more efficient materials that are resistant and better adapted to higher frequency and thermal environment as well as novel materials with tailored optical properties. They are driven by the quest for ever faster and smaller devices for telecommunications, autonomous driving, AI applications, biomedical technologies, or by the need for more efficient and/or less expensive energy conversion. Accordingly, industrial interest in Micro- and nanoelectronics and Photonics materials is strong, as the field holds much potential for further advances in these technologies. Approx. 9% of all advanced technology patent applications filed by chemical companies in Europe are related to these two fields (Figure 13).

Advanced Manufacturing technologies are essential in order to allow the integration of novel materials into components and systems that enable new designs and improved performance in the chemicals industry. Therefore, material developments are closely linked to manufacturing innovation.[40] Currently, 5% of all advanced technology patents filed by the chemical companies in the EU27 can be attributed to the field of Advanced Manufacturing technologies (Figure 13).

[40] Grant and Mason 2013.

2.4 Technology adoption for enhanced products and services

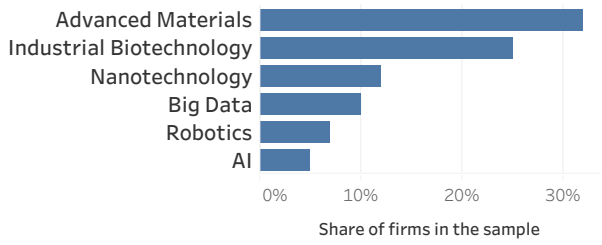
Advanced technologies create opportunities for innovation in the chemical industry that is not only a main developer of new materials, but also an increasingly important user especially of digital technologies. Chemical companies can take advantage of technological transformation to improve their production processes and productivity, but also to develop new products and services.

A large-scale text-mining[41] of company websites belonging to the chemicals industry shed lights on how advanced technologies are changing this sector and what type of new products are being enabled by novel technologies. The results of this analysis are in line also with the patent application trends and confirm that the most important advanced technologies that chemical companies have taken up are **Advanced Materials** and **Industrial Biotechnology**. New trends increase the need for novel materials and provides huge opportunities to innovate.

Other technologies that appear in online content are related to Nanotechnology, Big Data, Robotics and Artificial Intelligence (Figure 15).

Beyond advanced technologies, sustainability is a key topic and 67% of the chemical firms in our sample included information about sustainable development on their websites.

Figure 15: Share of chemical companies that have taken up advanced technologies, 2019



Source: Technopolis Group

Nanotechnology is closely related to the chemical industry as chemistry underlies many nanotechnology principles. The chemical industry is actually a producer of a wide range of nanoparticles that can be used by a lot of other industries. Nanotechnology provides an opportunity in particular to develop new materials that are lighter, stronger and more resistant.

Big Data and advanced analytics play an increasingly important role for the chemical industry. Companies generate a large amount of data and some have already realised the potential in exploiting this hidden asset. According to the analysis of chemical company websites, 10% of the firms references this technology field. Results from the Community Survey on ICT Usage shows somewhat higher values for the countries included in the sample[42]. Data is generated by chemical equipment and machinery that are equipped with sensors and wireless connections. These data can help chemical manufacturers reduce waste, raise energy efficiency and improve production processes that have an important implication for reaching circular economy targets.

AI technologies are likely to have far-reaching implications for the chemical industry, although the text-mining of company websites indicates that the use of AI by chemicals companies is still limited. AI has a potential to be applied within early product and process development stages to significantly speed up innovations allowing a more efficient time-to-market process.

AI can predict machinery failure and support more efficient chemical plant management. It can also enable the optimisation of chemicals development through the identification of trends and analysing customers' needs. Marketing and sales is an area where the most meaningful impact from digitalisation is anticipated, linked to the advantages from using AI and advanced data analytics to better understand and predict customers' demand[43] on the one hand and from enabling advanced customer services, such as inventory reminders, logistics tracking and product footprint tracking, on the other[44]. AI enables the management and integration of logistics and transport systems as well as customer platforms contributing to the optimisation of individual processes and including the end consumer in the decision-making process.[45] AI has been also successfully used for the development of materials such as advanced polymers[46].

[41] Based on a search algorithm, company websites were analysed for links to each specific technology. The analysis consists of 5,503 websites of chemicals firms across seven European countries, including Denmark, France, Germany, Italy, Netherlands, Poland and Spain. This analysis can reflect about the use of technologies embedded in new products and services and about technological advantages that companies communicate about. It cannot be used however to conclude about the adoption of advanced technologies in terms of the more hidden production processes that are being less revealed in these types of online content.

[42] Eurostat. Data relates to the sectors C19-C23 (NACE Rev. 2): manufacture of coke, refined petroleum, chemical & basic pharmaceutical products, rubber & plastics, other non-metallic mineral products (10 persons employed or more).

[43] Cefic 2019.

[44] Deloitte 2019a.

[45] Kramer et al. 2019.

[46] https://www.designnews.com/materials-assembly/researchers-use-ai-discover-new-polymers/67744341261255

The highest potential for the chemical sector from the digitalisation is expected in manufacturing[47] by using digital technologies to optimise plant performance. This includes the automation of engineering of key chemical processes and manufacturing by means of **Robotics** and **Internet of Things** infrastructure, leveraging of AI and advanced data analytics for intelligent management of energy, yield and throughput as well as performance monitoring and predictive maintenance.

Blockchain has the potential to make a considerable positive impact on the chemical sector[48]. Blockchain can increase traceability of chemicals throughout the value chain, safety and security of chemical plants and improve compliance while lowering transaction costs. By integrating Blockchain technologies, chemical companies can securely automate business transactions with their suppliers throughout the value chain and customers by establishing transactional relationships with smart contracts, certifications and digital compliance.[49] Blockchain technology can enable real-time visibility into shipment logistics and thereby lessen the reaction time. Furthermore, blockchain technology and predictive analytics can be integrated with existing Internet of Things infrastructure to allow for track-and-trace capabilities to undertake fine-tuning of production yields in response to fluctuating demand of end-products and prices of feedstock. In the future, blockchain technology and machine learning algorithms can be used to track, trace and predict the actual environmental footprint of the new product or solution.[50]

A number of chemicals companies, including producers of chemical raw materials and of semi-finished or finished goods such as plastics, have taken advantage of **additive manufacturing** (AM) technology both to produce parts for themselves and to become vendors of AM materials to other companies.[51] It is expected that tailored polymers and chemicals for different additive manufacturing systems will become increasingly more important in the future, which brings enormous growth opportunities for chemical companies making photopolymers, high-performance thermoplastics, and other advanced materials that can be used in these applications.[52] 3D printing provides new options in terms of design and maintenance processes, and contributes to cost savings and resource efficiency in R&D processes.[53]

Apart from the customisation and personalisation of products, additive manufacturing offers a large potential for localisation and deglobalisation, i.e. bringing production closer to consumers, at their point of need. This can help shift production back to Europe and North America, hence paving the way for new supply chains, smaller production units, better scalability, faster time to market, reduced waste and new efficiencies.[54]

[47] Cefic 2019.
[48] http://www.suschem.org/
[49] IBM Chemicals & Petroleum 2017.
[50] Deloitte 2019a.
[51] https://www.ey.com/en_us/advisory/how-additive-manufacturing-is-becoming-a-core-process-and-value-driver
[52] https://www.mckinsey.com/industries/chemicals/our-insights/digital-in-chemicals-from-technology-to-impact
[53] Kramer et al. 2019.
[54] Accenture 2018.

Section 3

3. Venture capital investment and startup creation

Key messages

The chemical industry greatly benefitted from the low-interest-rate policies and the resulting **low cost of equity and borrowing cost**, which led in **increasing investments in equity and mergers and acquisitions (M&A)** in Europe, US and China.

Average private equity and venture capital investment in chemicals was highest in **Germany**, followed by **Belgium, the Netherlands, France and Italy** during the timeframe of 2010-2019. Equity funding in the European chemical sector included various types and series and indicates a **particular relevance of early funding**. The development of Advanced Materials has concentrated in Germany, Netherlands and France.

The chemical sector of European countries is one of the main destinations for investments by foreign companies. Investments by foreign companies located outside the EU27 grew significantly since 2013.

Startups in chemicals have been the most active in the field of **Life sciences and Industrial Biotechnology**, followed up by environment and sustainability-oriented startups. Analytics and digital solutions have been a third important topic, however, links to more specific digital technologies are weak.

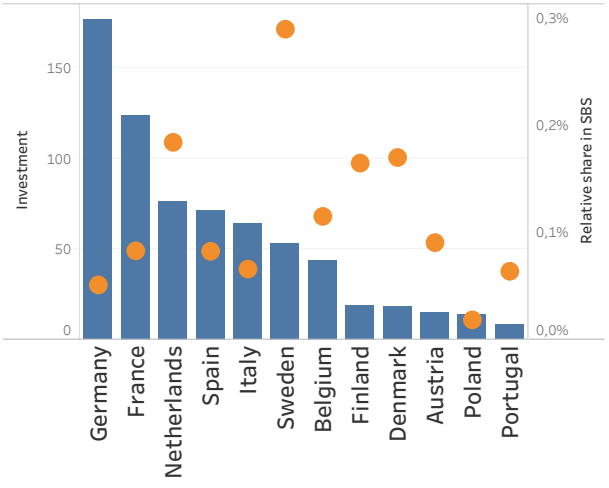
Private equity, venture capital investment and related innovative startup creation have been explored based on a merged dataset available in Crunchbase and Dealroom. Crunchbase provides information on venture capital backed innovative companies. Dealroom contains the same type of information but with a better coverage for Europe. The investment figures presented in this section refer only to the funding rounds where a value has been disclosed.

3.1 Private equity investment in the chemical industry

The low-interest-rate policies and the resulting low cost of equity and borrowing cost were used by many chemical industry businesses for investments in equity and mergers and acquisitions (M&A). While most of M&A have taken place in the US, investors from Europe and China were predominantly involved in large, multi-billion-dollar deals looking to consolidate their current key positions, as well as diversify their product portfolios. Buying assets and companies in other countries is one important growth strategy of the Chinese chemical companies.[55]

Private equity and venture capital investment in the EU27 has been the highest in Germany, France and Netherlands, followed by Spain and Italy. Companies that received investments in France, for example, largely specialise in biotechnology, chemical engineering and sustainable chemicals. The relative strengths (venture capital investment compared to the number of enterprises in the industry) have been, however, the highest in Sweden, Netherlands and Denmark (Figure 16).

Figure 16: Number of VC investment-backed firms in the field of chemicals and share relative to the number of chemical companies in Structural Business Statistics (SBS), 2010-2019



Source: Technopolis Group based on Crunchbase and Dealroom data

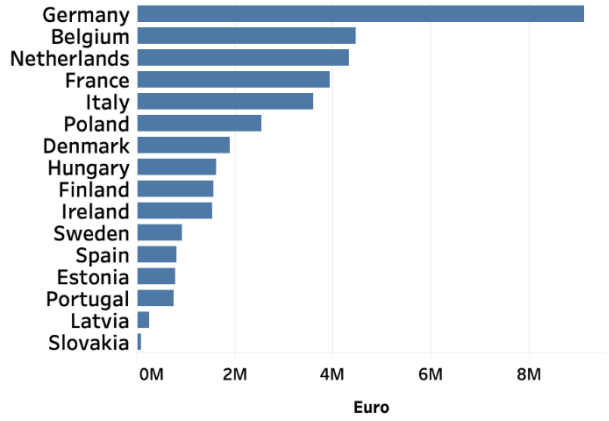
Note: Share is calculated to the total firms in C20 in Structural Business Statistics (SBS)

To provide further insights, the average private equity investment – as outlined in Figure 17 - was

[55] Deloitte 2017b.

highest in Germany, followed by Belgium, the Netherlands, France and Italy during the timeframe of 2010-2019.

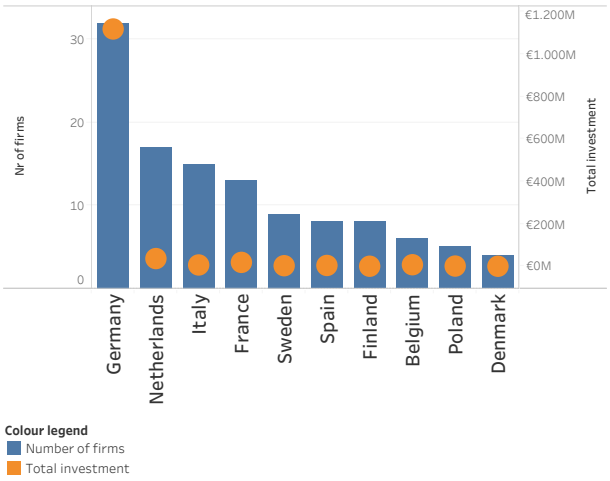
Figure 17: Average private equity investment in chemicals (€)



Source: Technopolis Group based on Crunchbase and Dealroom data

VC investment in Advanced Materials soared in the last decade which is a field that is the most closely linked to the chemical industry. Figure 18 shows the number of active investment-backed firms in 2019 and the level of private equity and venture capital investment in Advanced Materials.

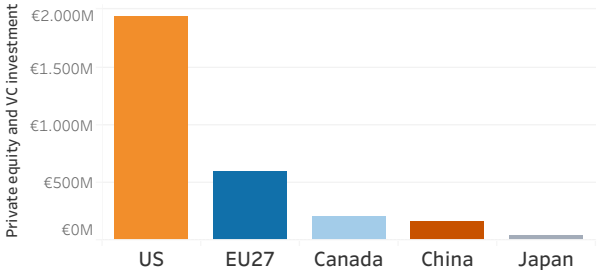
Figure 18: VC investment in the field of Advanced Materials, 2010-2019



Source: Technopolis Group based on Crunchbase and Dealroom data

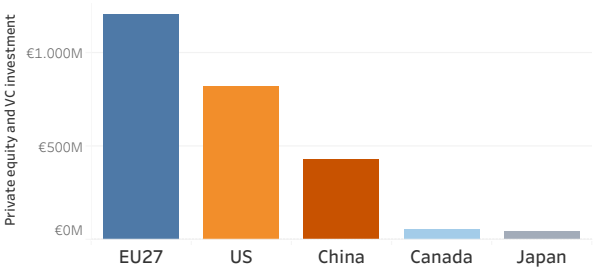
When analysing the global investment landscape, the **EU27 leads in terms of investment in Advanced Materials**, however, VC funds invested more in US chemical ventures, as shown in Figure 19 and 20. Private equity and venture capital investment in the chemical industry have been increasing since 2010 in the EU27.

Figure 19: Private equity and venture capital investment in chemicals (2010-2019) in international comparison



Source: Technopolis Group based on Crunchbase and Dealroom data

Figure 20: Private equity and venture capital investment in Advanced Materials (2010-2019) in international comparison



Source: Technopolis Group based on Crunchbase and Dealroom data

The chemical sector of European countries is one of the main destinations for investments by foreign companies. Investments by foreign companies[56] located outside the EU28 grew significantly since 2013 - first period, for which statistical data is provided - in the majority of European countries (Figure 21 next page).

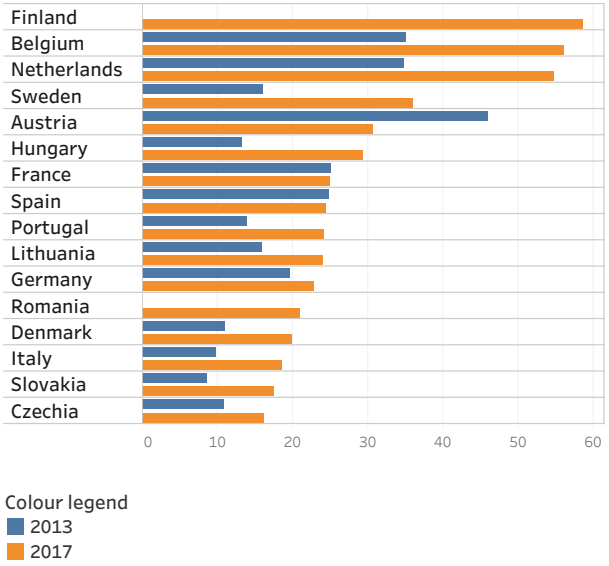
The largest increases occurred in Sweden (+126%), Hungary (+124%), Slovakia (103%), Italy (88%) and Denmark (82%). The highest extra-EU investments per person employed were recorded in Finland, Belgium, Netherlands and Sweden. The main investor countries are the US, Japan and China.

In some instances, the investment of EU28 companies in the neighbouring European countries is even higher or comparably high, which means that companies actively invest in chemical industry in other countries within the EU (Figure 22). Finland attracts the highest investments in chemical companies from their parent companies located in other European countries. Further

[56] Investment of foreign companies in affiliates located in European countries over which foreign companies have control.

countries displaying high investments from other European countries are Belgium and Portugal. The largest intra-EU investment rise between 2013 and 2017 materialised in Czechia (+165%), Austria (+84%), Hungary (+69%) and Slovakia (+68%).

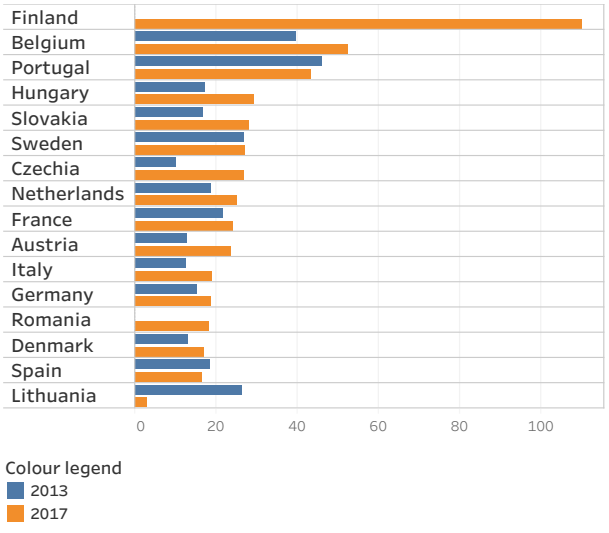
Figure 21: Investments per person employed in the chemical industry by foreign (extra EU28) companies in thousand € per person employed



Source: Eurostat, SBS

Note: Data refers to investments made by parent companies resident outside the EU

Figure 22: Investments per person employed in chemical industry by foreign (intra EU28) companies, in thousand € per person employed



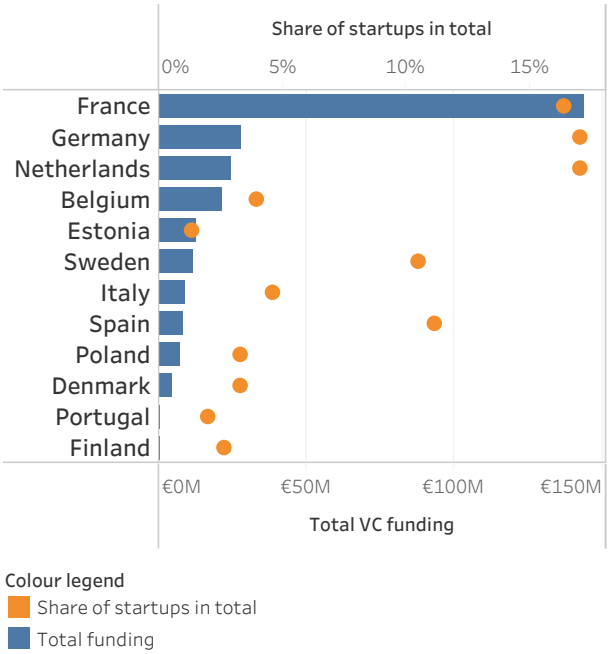
Source: Eurostat, SBS

Note: Data refers to investments made by parent companies resident inside the EU

3.2 Chemical industry and Advanced Materials startups

With the aim of exploring entrepreneurship trends in the European chemical industry, the number of startups from 2009 until 2019 was analysed based on Crunchbase and Dealroom data. The country distribution of startups is visualised in Figure 23. According to this analysis, the largest VC-backed startup hubs for the chemicals industry are located in France, Germany and the Netherlands.

Figure 23: Startup creation and VC investment in startups in the chemical industry in the EU27 (2009-2019)

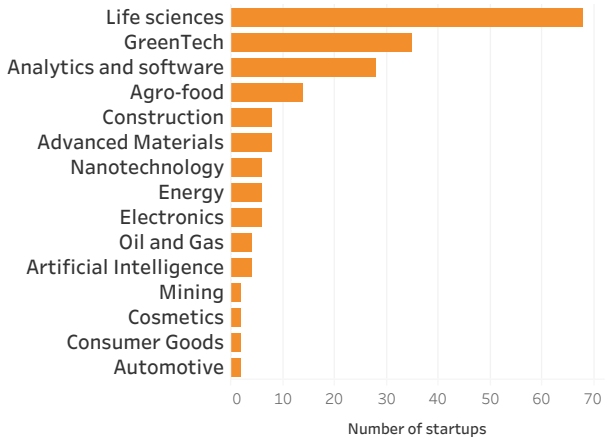


Source: Technopolis analysis based on Crunchbase and Dealroom data

Startups in chemicals have been the most active in the field of Life sciences and Industrial Biotechnology, followed up by environment and sustainability-oriented startups. For instance, the development of biodegradable sealants and adhesives has been a common topic for startups.

Analytics and digital solutions have been a third important area, however links to more specific digital technologies, such as AI or the Internet of Things, are still weak.

Figure 24: Type of related fields of chemical industry startups (2009-2019)



Source: Technopolis analysis based on Crunchbase

Section 4

4. Skills supply and demand

Key messages

Transformations and fundamental shifts in the chemical industry require **diverse advanced skills**, which are one of the key factors determining the future success of the European chemical industry. According to the analysis of LinkedIn data, professionals employed in the chemical industry with technological skills in the area of **Advanced Materials** represent the highest share among all advanced technology professionals in the EU27. Further prominent categories include **Advanced Manufacturing and Nanotechnology**.

In terms of **growth** in the number of professionals hired in the chemicals industry from 2018-2019, the technological skills that showed the highest increase are **AI and Big Data** followed up by Connectivity, Security and the Internet of Things. The fastest growing skills demanded by chemical industry companies have been **Java, SQL, MATLAB** that indicates the growing importance of advanced analytics as well**.**

While **Germany, France and the Netherlands** are leading in terms of absolute number of professionals employed in the chemical industry with advanced technology skills, the relative share of professionals is actually highest in **Finland, Denmark and Sweden**. The German chemical industry is leading in the share of professionals with digital skills and in particular in AI and Big Data. Finland is on the top of the list in Advanced Materials and Denmark in Industrial Biotechnology.

The **European chemicals industry**, however, **shows less dynamics in exploiting the opportunities of digital transformation** when compared to the US.

4.1 Availability of new technological skills - prominence of advanced manufacturing

The fundamental transformation of the chemical industry as presented in the previous Sections requires diverse technological skills, talent capabilities and fast adaptation in the job profiles of chemical companies. Matching the continuous rise in the demand for these highly specialised technological skills is one of the most important challenges in the chemical industry today.[57]

Figure 25 visualises the currently available supply of professionals with advanced technological skills relevant in the chemical industry in 2019 based on the analysis of LinkedIn[58] data. Within the registered professionals on LinkedIn employed in the chemical industry, **Advanced Materials** represents the highest share in the EU27, reflecting a particular important role of this field of technology for the European chemical industry and a high demand for specialists with core skills. Innovation in chemical components such as the development of lightweight materials, bioplastic, nanomaterials needs talented professionals, who can drive the European chemical industry towards a **solution provider for a low carbon and circular economy**.

The second largest professional group is linked to relevant skills in the area of **Advanced Manufacturing** technologies. Further prominent categories with high relevance for the European chemical industry include technological skills related to **Nanotechnology, Cloud, Industrial Biotechnology, Artificial Intelligence & Big Data and Robotics**. Skilled professionals in the Internet of Things and Security are at the bottom of the list.

Skills in AI and Big Data are relevant for the industry where the combination of chemical engineers, electrical engineers and computer scientists can bring a new competitive advantage through more automated production processes, robotics and analytics.

While Figure 25 illustrates the general distribution of technological skills in the chemical industry across all EU27 countries, It can be observed that while **Germany, France and the Netherlands** are leading the list in terms of absolute number of professionals with advanced technology skills employed in the chemical industry. When we look at the share of these professionals in the total industry professionals (as captured by LinkedIn), we find that **Finland, Denmark and Sweden** have the highest share, although Germany and the

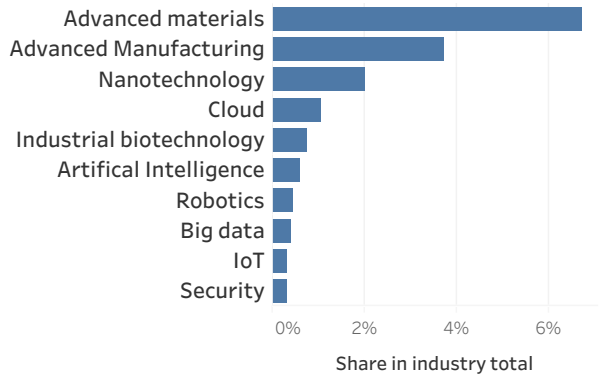
[57] Kramer et al. 2019.

[58] To harvest the data from LinkedIn, keywords capturing skills by advanced technology have been defined and reviewed by technology experts. Queries have subsequently been constructed to filter the database by location and industry.

Netherlands are again among the top countries. The high relative share of advanced technology professionals in the Nordic chemical industry might reflect also the strengths of these countries in digital technologies and hence having a pool of skilled talent available close by.

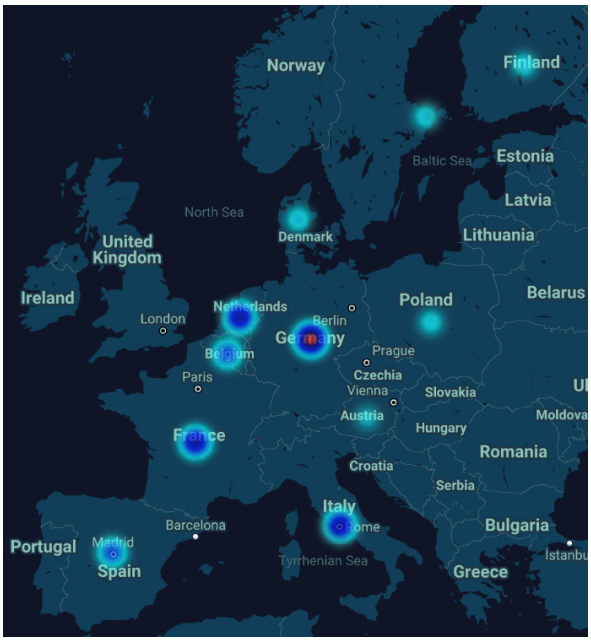
Figure 27 displays the geographical distribution of technological skills applied in the EU27 countries with above median total professionals.

Figure 25: Share of professionals with advanced technological skills in the chemical industry, EU27, 2019



Source: Technopolis Group based on LinkedIn analysis

Figure 26: Concentration of professionals with AT skills in the chemical industry in the EU27

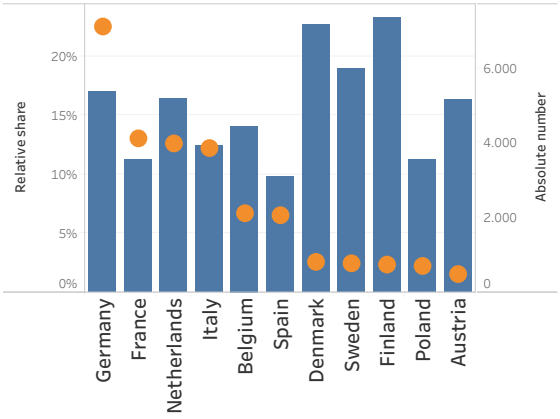


low high

Source: Technopolis Group based on LinkedIn analysis, using geolytics map

It can be observed that while **Germany, France and the Netherlands** are leading the list in terms of absolute number of professionals with advanced technology skills employed in the chemical industry. When we look at the share of these professionals in the total industry professionals (as captured by LinkedIn), we find that **Finland, Denmark and Sweden** have the highest share, although Germany and the Netherlands are again among the top countries. The high relative share of advanced technology professionals in the Nordic chemical industry might reflect also the strengths of these countries in digital technologies and hence having a pool of skilled talent available close by.

Figure 27: Professionals on LinkedIn employed in the chemical industry and with skills in advanced technologies, top EU27 countries



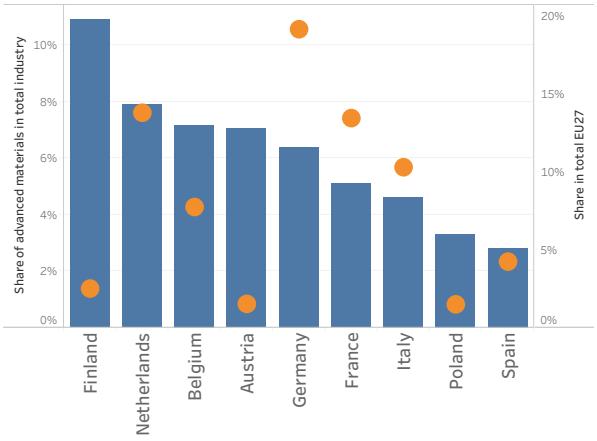
Source: Technopolis Group analysis based on LinkedIn

Note: Only countries with above median total industry professionals are displayed

Figure 28 on the next page demonstrates the allocation of the most represented technological skills' supply related to **Advanced Materials** across top performing EU countries.

In terms of the relative shares within the total chemical industry professionals, Finland is leading the country list, followed by the Netherlands, Belgium, Austria and Germany. Some of these countries are also those with the highest patent share in Advanced Materials (Figure 6) and these countries of course rely on a high number of specialised skilled workforce.

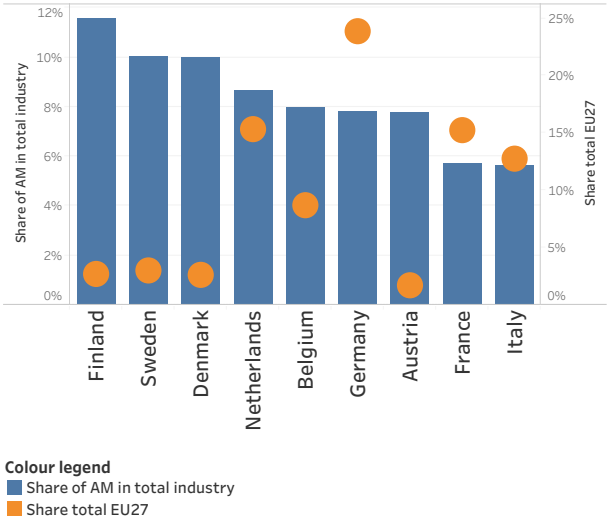
Figure 28: Chemical industry professionals with skills in advanced materials among selected EU countries



Source: Technopolis Group based on LinkedIn analysis

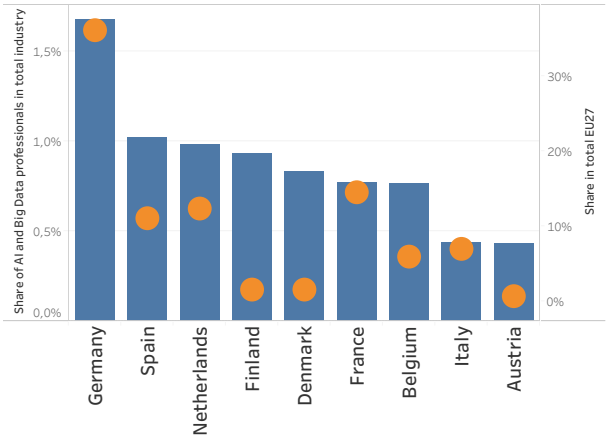
The increasingly automated production processes and robots used on chemical plants require professionals with Robotics and Advanced Manufacturing skills. In terms of skills in **Advanced Manufacturing and Robotics**, the list is led by the Nordic countries notably: Finland, Sweden and Denmark, followed by the Netherlands, Belgium and Germany.

Figure 29: Chemical industry professionals with skills in Advanced Manufacturing and Robotics in top EU27 countries



Source: Technopolis Group based on LinkedIn analysis

Figure 30: Chemical industry professionals with skills in AI & Big Data in top EU27 countries, 2019

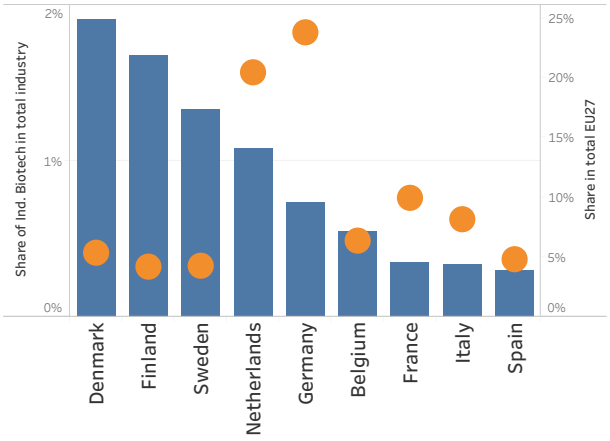


Source: Technopolis Group based on LinkedIn analysis

The chemical industry is highly impacted by the opportunities that the vastly available data through chemicals plants would make possible as highlighted also in the previous sections. The share of professionals with **AI and Big Data** skills within the total number of professionals in the chemical industry is highest in Germany, followed by Spain and the Netherlands as the analysis of LinkedIn data demonstrates (see Figure 30).

Industrial Biotechnology skilled professionals are relatively the most available in Denmark, Finland and Sweden. Interestingly, the number of professionals is much lower than in the case of other technologies (for instance compared with Advanced Materials), which reflects that actually a much smaller number of employees are driving the very important innovations in this area.

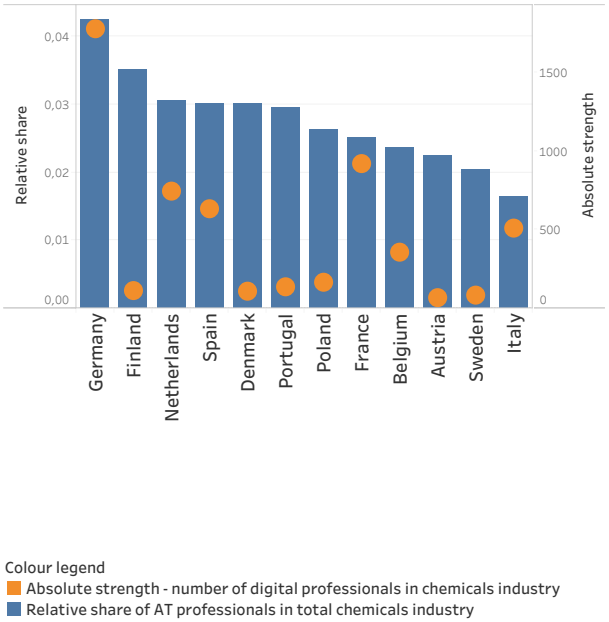
Figure 31: Chemical industry professionals with skills in Industrial Biotechnology in top EU27 countries



Source: Technopolis Group based on LinkedIn analysis

When analysing the supply of professionals with digital skills employed in the chemicals industry (including AI, Big Data, Cloud, Connectivity, IoT, Security), the analysis shows that Germany, Finland and the Netherlands are the countries with the highest shares (see Figure 32).

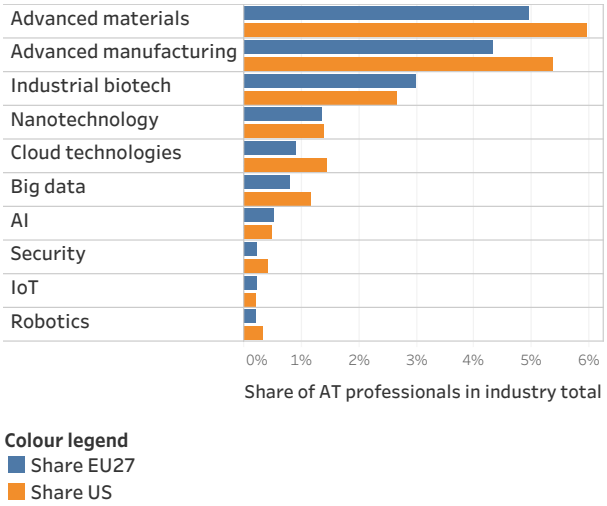
Figure 32: Chemical industry professionals with digital skills in top EU27 countries, 2019



Source: Technopolis Group based on LinkedIn analysis

LinkedIn data also allows the comparison of the chemicals industry in terms of skilled professionals in the EU27 and the US. After taking the share of professionals with advanced technology skills employed in the chemicals industry within the total number of chemical professionals, it can be observed that the EU27 is leading in Industrial Biotechnology. Nevertheless, the US has a higher share of professionals with Advanced Materials and Advanced Manufacturing skills (which somewhat contradicts the EU27 strengths in these fields as demonstrated earlier). Overall, the US has an advantage in employing digitally skilled professionals in the chemicals industry. Interestingly, the shares of employed AI professionals are very close. These results might indicate that the **European chemicals industry is currently less dynamic in exploiting the opportunities of digital transformation** at least as reflected by the share of employed professionals and in the six selected digital technologies. This finding needs to be interpreted with caution given the use of LinkedIn data (the caveats are explained in the ATI methodological report).

Figure 33: Chemical industry professionals with skills in advanced technologies in the EU27 and US



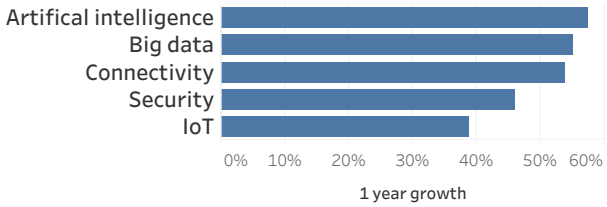
Source: Technopolis Group based on LinkedIn analysis

4.2 Demand for new skills and especially big data and AI

After analysing the availability of technological skills in the chemical industry it is also important to look at which skills have been the most common in the recent hires. In order to measure this demand, the 1-year growth rate of technological skills has been analysed by comparing the skills indicated in 2018 and its change to 2019.

Figure 34 visualises the five technological skills that showed the highest growth within the last year (from 2018 to 2019). We see AI and Big Data on the top followed up by Connectivity, Security and the Internet of Things.

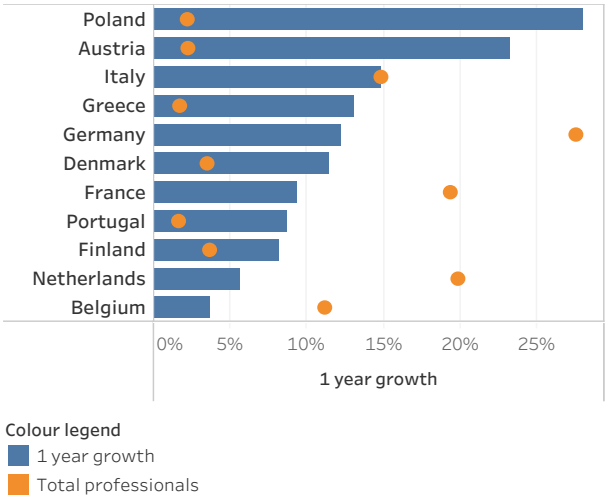
Figure 34: 1-year growth of top 5 skills



Source: Technopolis Group based on LinkedIn analysis

Emerging technological skills linked to Artificial Intelligence are rapidly gaining in importance for the chemical industry. The LinkedIn data provides evidence for particularly high recent growth rates in these areas. According to the available data, the rise in AI professionals was remarkable especially in Finland, Italy, Poland and the Netherlands. Big Data attributable skills increased the most in Italy, Finland, Poland, Spain and Germany.

Figure 35: EU-countries with highest 1-year growth of Advanced Materials professionals of chemical industry



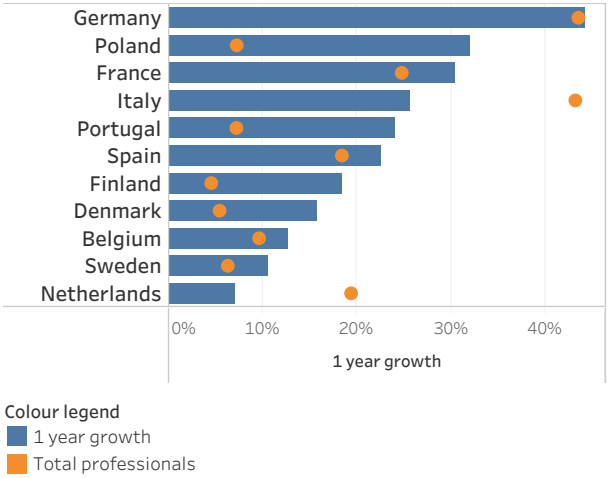
Source: Technopolis Group based on LinkedIn analysis

The countries that have witnessed the highest growth in terms of new hired professionals in Advanced Materials are Poland, Austria and Italy (Figure 35).

The second wide spread technological skill with high relevance for the chemical industry - Advanced Manufacturing - shows even more significant 1-year growth rates for individual EU countries (Figure 36). Germany (+44%), Poland (+32%) and France (+30%) experienced the highest rise in demand for professionals in this field of technology.

Based on the skills requirements of the online job advertisements posted on LinkedIn by European chemical industry firms, we observe that the fields with 'very high hiring demand' as captured in LinkedIn include the following: Big Data, Connectivity and Security. Hiring demand is also high for skilled professionals in AI, Cloud, IoT and Robotics (see Figure 37). Hiring demand is defined as the share of job ads published on LinkedIn and requiring the specific skill.

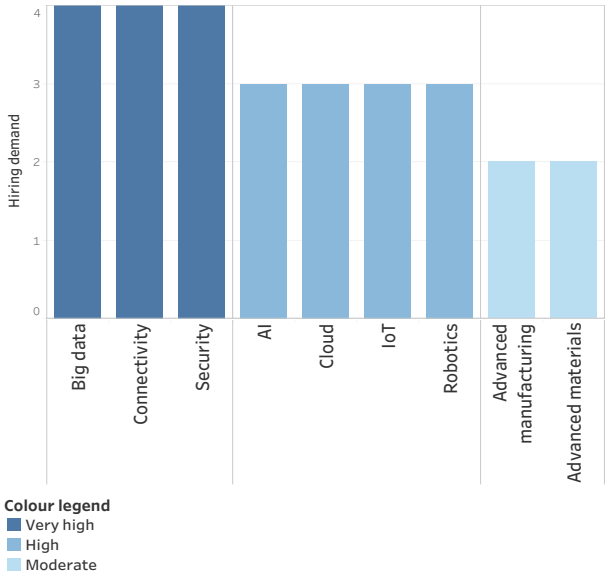
Figure 36: EU countries with the largest 1-year growth of chemical industry in Advanced Manufacturing



Source: Technopolis Group based on LinkedIn analysis

In the most recent hires of the EU27 chemical companies, the fastest growing skills demanded have been Java, SQL, MATLAB (that indicates the growing importance of advanced analytics) and Life Sciences.

Figure 37: Hiring demand in the chemical industry, Dec 2019 – March 2020



Source: Technopolis Group based on LinkedIn analysis

Section 5

5. Future outlook: challenges and opportunities

5.1 Insecure environment in the global economy

The chemical industry is a cyclical, trade intensive industry with highly globalised supply chains. The global trade in chemicals is characterised by a large share of trade in intermediary inputs. As such, the chemical industry is highly dependent on the economic performance in other regions and sectors and susceptible to economic crises. The ongoing trade issue tensions have left their mark on the European chemical industry resulting in higher costs of raw materials and delivery problems of some chemical components and creating uncertain demand environments. The trade tensions are giving rise to some relocations of production facilities and the development of domestic supply chain with vertically integrated industries, which in turn will sustainably change the directions and scope of future trade flows. Currently, the COVID-19 crisis and its aftermath threaten to impose further strain on many sectors of the economy, including the chemical industry, the implications of which are difficult to assess for the time being[59]. These recent developments coupled with the overall continuing decline in growth, both in the industrialised and emerging countries, along with stagnating chemical turnover in the last years pose additional challenges to the European chemical industry.

5.2 Increasing competitive pressure

The chemical industry operates in a highly competitive environment. The competition has intensified in recent decades due to accelerated innovation cycles and the emergence of new competitors. The international competition is continuously increasing for the European chemical businesses, particularly from Asian countries that are constantly climbing up the value chain.[60] For instance, the "Made in India" strategy or China's "13th Five Year Plan" foresees substantial investments in chemical R&D to move up the value chain from bulk chemicals towards more research-intensive products. But also the current "America First" industrial policy gives a significant boost to the US chemical industry.

China is catching up strongly in chemical R&D: it increased its share in worldwide chemical R&D expenditures from 9.7% in 2008 to 27.4% in 2018[61] and is expected to reach even higher shares by 2030[62], whereas the EU's share of global R&D expenditure is declining despite increased R&D budgets (from 31% in 2008 to 23.3% in 2018). In absolute terms, with its total chemical R&D spending of €11.8 bn in 2018, China already outperforms the world leaders, such as the US (€8.5 bn) and Japan (€7 bn).[63] There are some segments in which the Chinese chemical industry is starting to get a technology edge over multinational companies (MNCs), continually establishing itself as a global leading producer and achieving process and quality improvements. This has been the case in a number of industrial biotech-based products and development of new advanced materials.[64] This increases the competitive pressure on the European chemical industry emphasising the need of focusing more on R&D and innovations in order to maintain and improve its competitive advantage. Therefore, the preservation and further nurturing of the competitive edge in key areas is essential and a key challenge for Europe. This cannot be achieved without developing advanced and environmentally friendly chemicals and new materials.

5.3 Significant growth opportunities through innovations

There are significant opportunities in research and development to create higher value-added, higher margin products at a faster pace that would help European chemical businesses to enhance their strong position in the global value chain. Inventions aligned with global technological, environmental, demographic and societal mega trends offer the most promising growth potential. These include alternative feedstock and energy sources, improved energy storage, environmentally friendly technologies, intelligent

[59] There is a clear evidence that the COVID-19 crisis, during which this report was produced, has an adverse impact on the chemical industry. This especially concerns problems caused by demand shocks across end markets and disruption of global supply chains. As a consequence, the demand for chemicals is falling by up to 30% during the corona crisis: https://www.consultancy.eu/news/4078/how-covid-19-is-impacting-the-global-chemicals-industry

[60] Atradius 2019.
[61] Based on estimations provided by Celfic 2020.
[62] Kramer et al. 2019.
[63] Calculations are based on estimations provided by Celfic 2020.
[64] https://www.mckinsey.com/industries/chemicals/our-insights/chinas-chemical-industry-new-strategies-for-a-new-era

materials and nutrition.[65] For example, the chemical industry can largely contribute to clean tech innovations, providing new chemical solutions and sustainable products to further improve the weight reduction, energy efficiency, durability and recyclability of materials driven by the global trend towards the CO2 reduction and resource efficiency. The clean tech platform offers a significant growth potential because of anticipated innovations in chemicals. Besides, the demand of clean technologies is expected to grow in future along with the pressure on the companies to make sizable investments in technologies that contribute to the reduction of environmental and carbon footprints. Advances in chemicals are critical to improving the safety, power and energy density of automotive batteries as well as their recycling capacities as the transportation moves towards e-mobility. Chemistry also plays a crucial role in the development of disruptive process technologies leading to an increased and more efficient application of biological raw materials in production processes ('biologisation' of chemistry) as well as improved utilisation of renewable sources of energy. In the medium term, the production of chemicals from electricity, hydrogen and CO2 will gain in importance.[66]

Advances in chemical science may bring about the most needed solutions for energy storage (e.g. chemical energy storage). These are just a few examples for great needs of action and opportunities for European chemical companies where they can leverage their existing strengths and further develop their innovation capacities to secure the competitive edge in the future. However, besides being important driver, these huge opportunities pose at the same time significant challenges for chemical companies, as they have a massive impact on existing technologies, product portfolios, structures of value creation and business models in both the chemical industry and its customers and suppliers[67] that need to be addressed to be able to leverage these opportunities. This will require considerable joint efforts by the industry and policy makers to make the necessary R&D, infrastructure and other business investments, promote demonstration projects and further remove innovation barriers.

5.4 Taking advantage of digital technologies

Digitalisation presents huge opportunities for the European chemical industry and is predicted to become an integral part of the business and success model of the chemical industry.[68] China is among the top regions in the world for investments in key digital technologies for the chemicals sector, including virtual reality, robotics, drones and Artificial Intelligence. Likewise, the US chemicals sector is transforming itself through major investments that were made or are planned in digital technologies.[69] In comparison, European chemical companies invest less in digital technologies. As also concluded by the analysis of LinkedIn data European chemical companies lag behind the US in terms of digitalisation.

On the one hand, the potential of digitalisation for the chemical industry lies in the adoption of digital business models and platforms. They open up new business opportunities through digital augmenting of existing products and services and increase customer utility through offering new products and customised services. The emergence of digital platforms is another fundamental innovation resulting from digitalisation. These are digital marketplaces, communication forums and data pools that link producers, wholesalers and consumers. This requires investment in the necessary IT infrastructure, combined with efforts in training and education. At the same time, divisional boundaries must be overcome, new, overarching structures and competences created and new forms of internal cooperation found for their implementation.[70]

On the other hand, digitalisation offers several opportunities to improve chemicals technology and optimise different processes linked to the production. It also provides new opportunities for chemical research and innovation.[71] Moreover, increasing digitalisation can accelerate the transition to bio-based chemistry as demonstrated also in recent studies.[72] There is a large potential for mutually reinforcing effects and enhancement of digital technologies and the circular economy. Hence, digitalisation is essential for the European chemical industry to secure its business success and to retain its competitive edge.

[65] https://www.de.kearney.com/chemicals/article?/a/chemical-industry-vision-2030-a-european-perspective
[66] Deloitte 2017a.
[67] Deloitte 2017a.
[68] Deloitte 2017a.
[69] Kramer et al. 2019.
[70] Gehrke and Rammer 2018.
[71] Gehrke and Rammer 2018.
[72] Deloitte 2017a.

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About the 'Advanced Technologies for Industry' project

The EU's industrial policy strategy promotes the creation of a competitive European industry. In order to properly support the implementation of policies and initiatives, a systematic monitoring of technological trends and reliable, up-to-date data on advanced technologies is needed. To this end, the Advanced Technologies for Industry (ATI) project has been set up. It provides policymakers, industry representatives and academia with:

- Statistical data on the production and use of advanced technologies including enabling conditions such as skills, investment or entrepreneurship;
- Analytical reports such as on technological trends, sectoral insights and products;
- Analyses of policy measures and policy tools related to the uptake of advanced technologies;
- Analysis of technological trends in competing economies such as in the US, China or Japan;
- Access to technology centres and innovation hubs across EU countries.

You may find more information about the 16 technologies here: https://ati.ec.europa.eu.

The project is undertaken on behalf of the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the Executive Agency for Small and Medium-sized Enterprises (EASME) by IDC, Technopolis Group, Capgemini, Fraunhofer, IDEA Consult and NESTA.

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