

M O L E C U L E M A N A G E R S

A journey into the **Future of Europe**
with the **European Chemical Industry**



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WELCOME TO 2050!

Cefic's 8-Point Vision of the Future of Europe and its Successful, Competitive Chemical Industry in 2050

1 Geopolitics



THE WORLD HAS BECOME MORE PROSPEROUS AND MORE COMPLEX, WITH A FRAGMENTED AND VOLATILE GEOPOLITICAL ENVIRONMENT.

Global trade flows have shifted considerably as the result of both technological developments and increasingly insular, regional politics that hamper multilateralism and disrupt value chains. There is more economic and political integration within most regions, but more fragmentation between regions. China and India have developed into leading global economies and Africa has evolved into an important market.

2 Economics



EUROPE HAS DEVELOPED ITS OWN DIFFERENT BUT COMPETITIVE PLACE IN THE GLOBAL ECONOMY.

European chemical industry revenues growth has outpaced European gross domestic product (GDP) each year. The value of European chemicals production has increased through specialisation and a focus on digitalisation even as growth in chemical production volumes has stabilised. A supportive regulatory environment and a competitive base of commodity chemicals production favour efficient, well-maintained, state-of-the-art and clustered assets in Europe.

3 Circularity



THE EUROPEAN ECONOMY HAS GONE CIRCULAR, RECYCLING ALL SORTS OF MOLECULES INTO NEW RAW MATERIALS.

Europe's chemical industry is at the centre of this evolution, acting both as producer of products valued by society and a leader in recycling. The industry performs a role as the recycler of the circular society, transforming waste into valuable new raw materials. The issue of plastic waste in the environment has been tackled.

4 Climate



CLIMATE CHANGE CONTINUES TO TRANSFORM OUR PLANET.

European society is close to achieving net-zero greenhouse gas emissions, while keeping all European citizens and regions on board. Virgin fossil carbon is used selectively and productively. The European chemical industry has achieved a significant reduction of its own greenhouse gas (GHG) emissions and adapted to a changing climate. It plays a pivotal role in providing technologically and economically feasible pathways toward achieving Europe's ambitious GHG emissions reduction goals.

5 Environment



EUROPEANS HAVE SET THE PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT AT THE PINNACLE OF AN UNCOMPROMISING POLITICAL AGENDA.

Global sustainability standards have been successfully developed. Sustainable, bio-based and fossil-based chemistry have merged into a spectrum of solutions governed by evidence-based rules. Europe's chemical industry is recognised and welcomed as an indispensable provider of safe, sustainable and innovative solutions at the service of society as well as a reliable partner and attractive employer.

6 Industry



EUROPEAN INDUSTRY HAS BECOME MORE INTEGRATED AND COLLABORATIVE IN AN EU-WIDE NETWORK OF POWER, FUELS, STEEL, CHEMICALS AND WASTE RECYCLING SECTORS.

This interdependence has boosted the competitive advantage of the European chemical industry. It has also reinforced its role at the centre of the transformation of European industry as a whole.

7 Digitalisation



DIGITALISATION HAS COMPLETELY CHANGED THE WAY WE WORK, COMMUNICATE, INNOVATE, PRODUCE AND CONSUME AND BROUGHT UNPRECEDENTED TRANSPARENCY TO VALUE CHAINS.

Europe has embraced digitalisation and the fourth industrial revolution and invested heavily in science, technical, engineering and mathematics (STEM) education. Europe has maintained the skills to succeed.

8 UN SDGs



THE UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS AND ITS SUCCESSORS ARE AT THE CORE OF EUROPEAN BUSINESS MODELS.

They have opened business opportunities as market shares increase for those who provide solutions to these challenges.

The European chemical industry does its part to contribute to a fair transition toward greater economic, environmental and social sustainability not only in Europe but world-wide.

AN INVITATION

It is impossible to build a better future for Europe
without a successful European chemical industry.

This report is an initiative of the European chemical industry to describe a plausible path toward a prosperous, more sustainable Europe in the year 2050.

That's only two investment cycles away for an industry that thinks in decades. This vision of our industry at mid-century is offered as our invitation to discuss and debate the urgent decisions we are all facing – the prerequisites to a world that is cleaner and healthier and more inclusive, where the costly transition to climate neutrality has been socially fair and just, and in which Europe maintains its global relevance.

We serve society with products that people value and support people's natural desires for better lives, a healthy planet, peace and prosperity. We produce everything from soaps to solvents and sealants and from biofuels to plastics and vitamins and active ingredients for pharmaceuticals (to name just a few). As an 'industry of industries' we help downstream industries and value chains from construction to transportation and energy achieve their goals. We are a €650 billion industry with trillions of euros of potential. We are part of the fabric of progress, sustainably producing the raw and high-tech materials on which a modern, resource-efficient society is built.

This is our commitment in the journey ahead: Cleaner, safer, more circular. Producing more with less. Increasing fairness. Going digital. Dynamic resiliency.

As a society, we are increasingly aware of the environmental impact of human behaviour on our planet and health and we are taking unprecedented steps to mitigate it. Europe is mandating re-use and recycling. Reducing greenhouse gas emissions is at the top of the political agenda. Industry is investing in renewable energy and emission-free transport.

As an industry, we are in a constant dialogue with society concerning continuous improvements in chemical safety, the protection of human health and the environment and biodiversity. We do not own the truth, neither can we predict the future with certainty. In this spirit, in both the main report and in a series of provocative, fictional "Facets of the Future", we invite you to explore several 'What If' scenarios with us to help ensure that we are not missing new challenges and better opportunities - and don't end up with a future that nobody wants.

We want not only to continue to thrive for the next 30 years and beyond but also to lead the transition for our industry globally by offering European solutions to global challenges.

New technologies are transforming the way we live and work—for the better. That's an exciting business opportunity that we are eager to embrace—creating thousands of decent jobs and more opportunities for diversity in the workforce.

Our Vision and the whole of this report are based on a deep, year-long analysis of authoritative quantitative and qualitative research on megatrends, alternative feedstocks and circularity, climate change and the European energy mix. We consulted leading experts, thought leaders and other stakeholders. Based on those discussions we made a series of assumptions and we invited hundreds of experts from around the world to challenge us on our assumptions. They did. We listened. And the discussion continues.

**"WE ARE A €650 BILLION
INDUSTRY WITH TRILLIONS OF
EUROS OF POTENTIAL"**

"THIS REPORT
**INVITES YOU TO
HELP US BLAZE
A EUROPEAN TRAIL
FOR THE CHEMICAL
INDUSTRY**"

This report invites you to help us blaze a European trail for the chemical industry. We will not have the sheer numbers of engineers that China has. We do not have the feedstock advantage of North America or the Persian Gulf region. We will fight to keep our export markets, but we need to define our own, European way. Out of pure self-interest, the European chemical industry needs to build on Europe's strengths to have a solid future and to deliver on the expectations of investors, our employees and the communities they live in. We believe we can. It will be neither easy nor simple. But it has to be done and that means we have to think outside of our current box.

The European way means to innovate toward circular models, to lead on sustainability and to be at the forefront of new technologies. It means integrating more closely with sectors outside the chemical industry and expanding beyond our borders. And it means to be seen by our customers as leading the way.

Our report is more upbeat than you might expect given our society's many current political and economic anxieties. We believe the European chemical industry can flourish as we help Europe go carbon-neutral, reduce plastic waste, move toward a circular economy and address legitimate public concerns about health and chemical safety.

We don't claim to have all the answers, and we know that we will need to work more closely with government and society to ensure that our realistic hope bears fruit. We hope you'll join us.



Daniele Ferrari
Cefic President



Marco Mensink
Cefic Director General

OUR JOURNEY

This vision for the European chemical industry

is the result of a rigorous quantitative and qualitative consultation process that is the broadest ever undertaken by this industry.

Launch

Launched by the Cefic Board in October 2017, this vision paper is intended to stimulate a discussion about sound business, political and societal decision-making grounded in a consensus-based foresight exercise.

Foresight is a well-established practice that supports leaders and their organisations in engaging in explicit and alternative futures thinking in order to reveal and test critical assumptions and discover new options for shaping new and better outcomes.

Deep dive

The project began with a deep dive into all relevant, existing research.

Then we met consultants including McKinsey, Deloitte, DECHEMA, Accenture, ECOFYS and Korn Ferry as well as the foresight team of the European Commission. Next, working closely with the Copenhagen Institute for Futures Studies (CIFS), which monitors more than 100 different trends and megatrends, we identified those of greatest relevance to the European chemical industry and agreed on a set of 32 high-level assumptions on the forces most likely to have a major impact on the evolution of the industry.

Delphi study

To put our assumptions to the test we subjected them to a Delphi study¹, which is designed to provide strategic foresight when dealing with complex topics and a high degree of uncertainty. Our Delphi study involved a systematic, interactive examination by more than 300 reviewers ranging from chemical industry experts to academic, government and independent experts in other fields.

It has involved more than 300 stakeholders from academia, government and think tanks. They came from a range of disciplines, some in chemistry and some beyond.

Vision statement

Together, these assumptions have been used to inform a realistic and actionable vision statement as a starting point for wider dialogue on the development of the European chemical industry and its socio-political environment from now to 2050. It is only one possible future within a range of possible futures. It is subject to a wide range of external influences and uncertainties. But it is an educated, plausible estimate of the future that is neither purposely positive nor negative.

Facets of the future

In parallel to our work with CIFS and the Delphi study, we have been guided and advised by Dr. Angela Wilkinson, a well-respected foresight and scenario planning practitioner and scholar who has worked with policy pathfinding organisations such as the OECD and led other ambitious international foresight initiatives. Together, we explored different fictional “Facets of the Future” to provide wider contexts and provocative perspectives on futures that we may need to prepare for.

Thank you

We must thank many people for the hard work done to bring this vision together. They include Richard Northcote, who led the way but sadly passed away during this process. His work not yet finished, his vision will continue in the journey we now start.

WHERE WE'RE COMING FROM



Chemistry has been an essential part of our world since the dawn of time, providing the biochemical foundation for life itself.

Our industrial fabric, activities and products benefit the well-being of millions of people in Europe and worldwide. In a constant quest of discovery, whether anticipating or responding to societal needs ranging from healthy food for a growing population to caring for an ageing population and providing access to clean water, clean mobility and increased connectivity, chemists have given us medicines, sanitation, fertilisers, paints, insulation material, pesticides and plastics. Chemicals have been instrumental to using natural resources such as water and energy in efficient way.

Today, the European chemical industry is every bit as indispensable to modern life, producing the building blocks and high-tech materials on which modern societies are built. Our molecules and materials are used in every industry, from agriculture to construction, food and beverages, energy, health care, machinery, textiles, hospitals and transportation². We're developing more cradle-to-cradle business models that optimise value throughout multiple lifecycles.

The European Union's chemical sector employs 1.2 million highly qualified people directly in 28,000 companies. A recent study from Oxford Economics³ reports that the chemical sector supports around 19 million jobs across all supply chains. It generates more than €540 billion a year in sales⁴ and €170 billion in European value added⁵. We have embraced corporate social responsibility, ethical behaviour and the principles of Responsible Care⁶.

THE EUROPEAN CHEMICAL INDUSTRY IS ALSO EUROPE'S **BIGGEST INDUSTRIAL CONSUMER OF ELECTRICITY**

We are closely interlinked with many other industrial sectors and value chains in Europe. We are, in fact, the industry of industries. We will evolve as our value chains develop and our changes impact those around us. For that reason, although we believe we need to lead our transition and determine our future ourselves, we are very clear we need to do this in close dialogue with everyone involved.



In recent years the European chemical industry has increasingly been driven toward high value-added products such as lightweight materials, and insulation that improves energy efficiency, sophisticated inks and compounds for 3D printers, coagulants that help recover valuable phosphates from waste water, better laundry detergents and advanced materials for batteries, solar panels and wind turbine blades.

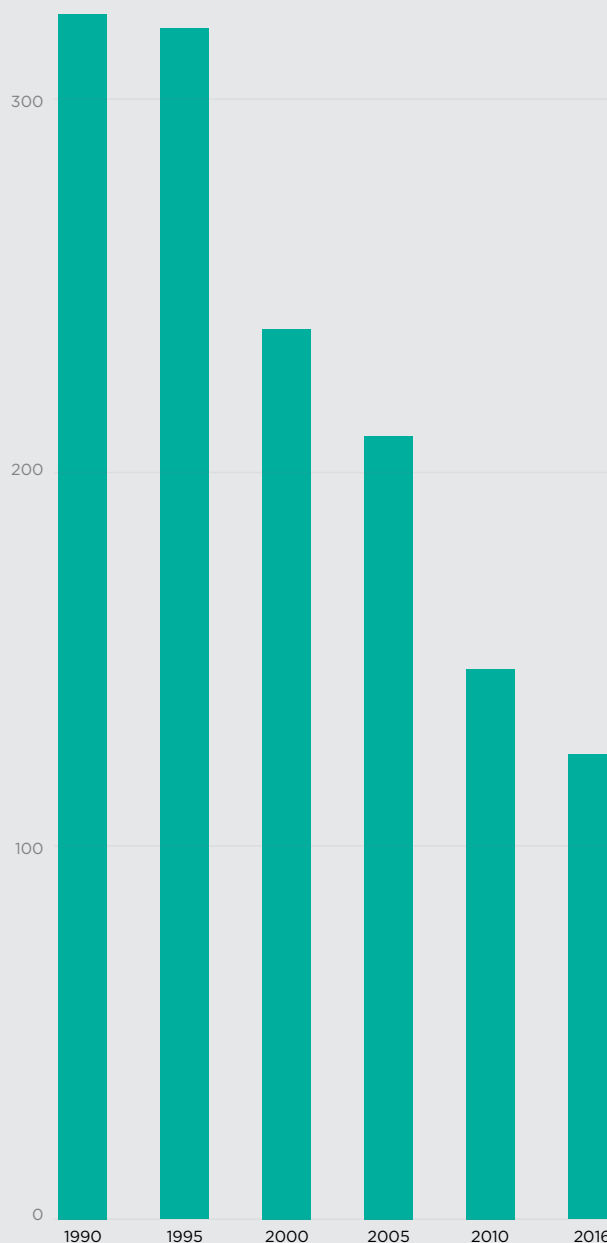
The European chemical industry is also Europe's biggest industrial consumer of electricity, giving us a big stake in the transformation of Europe's energy systems. We have already made big changes. Our greenhouse gas (GHG) emissions have fallen by nearly 61% since 1990 even as production increased by 83%⁷. By 2050, based on what we know about technology today, we think we can reduce GHG emissions a further 50% compared with today's levels⁸. However, that would require an enormous effort by industry and society and the right framework conditions. A 50% reduction in GHG emissions between today and 2050 would represent an 80% reduction from 1990 levels. All technical solutions, including carbon storage and re-using CO₂ as a feedstock, will be necessary to reduce our GHG emissions.

We understand that as a society we need to achieve more. We will engage in the debate with an open mind. The Delphi study⁹ suggested that for the European chemical industry to contribute even more would require breakthrough technologies in other sectors and increased cooperation across and along value chains.

The European chemical industry invests more than 15% of its value added in new and improved manufacturing plants and processes¹⁰—despite a doubling in the cost of complying with EU regulations in the past 10 years¹¹. Growing investments in digital technologies offer the potential for another transformation of the way the industry re-invents its internal processes, does business and relates to society. In 2017, the sector invested about €10 billion—about €25 million a day—in research and development, including in finding ways to become more energy efficient and reduce our carbon footprint.

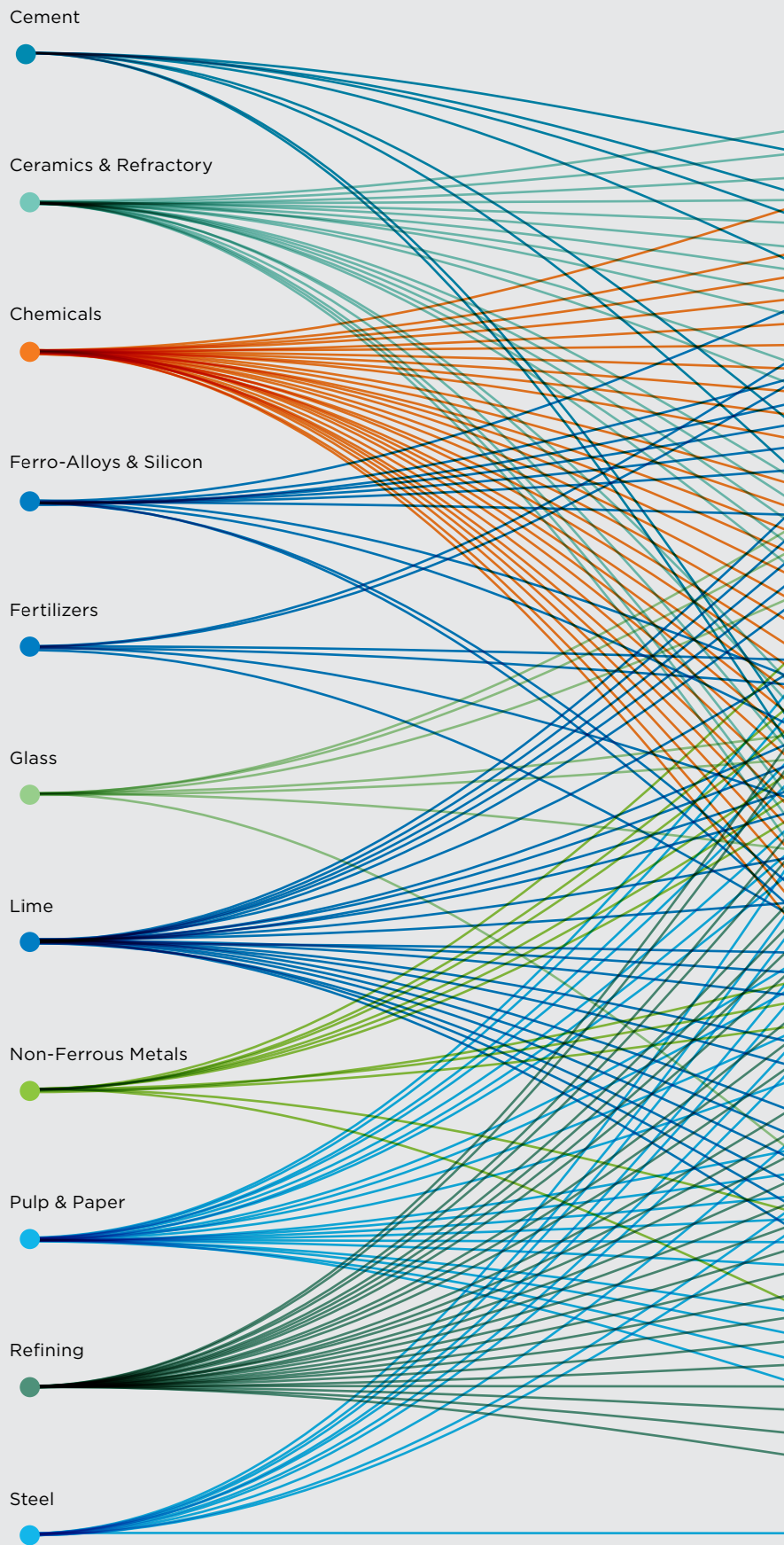
OUR GREENHOUSE GAS (GHG) EMISSIONS HAVE FALLEN BY NEARLY 61% SINCE 1990 EVEN AS PRODUCTION INCREASED BY 83%

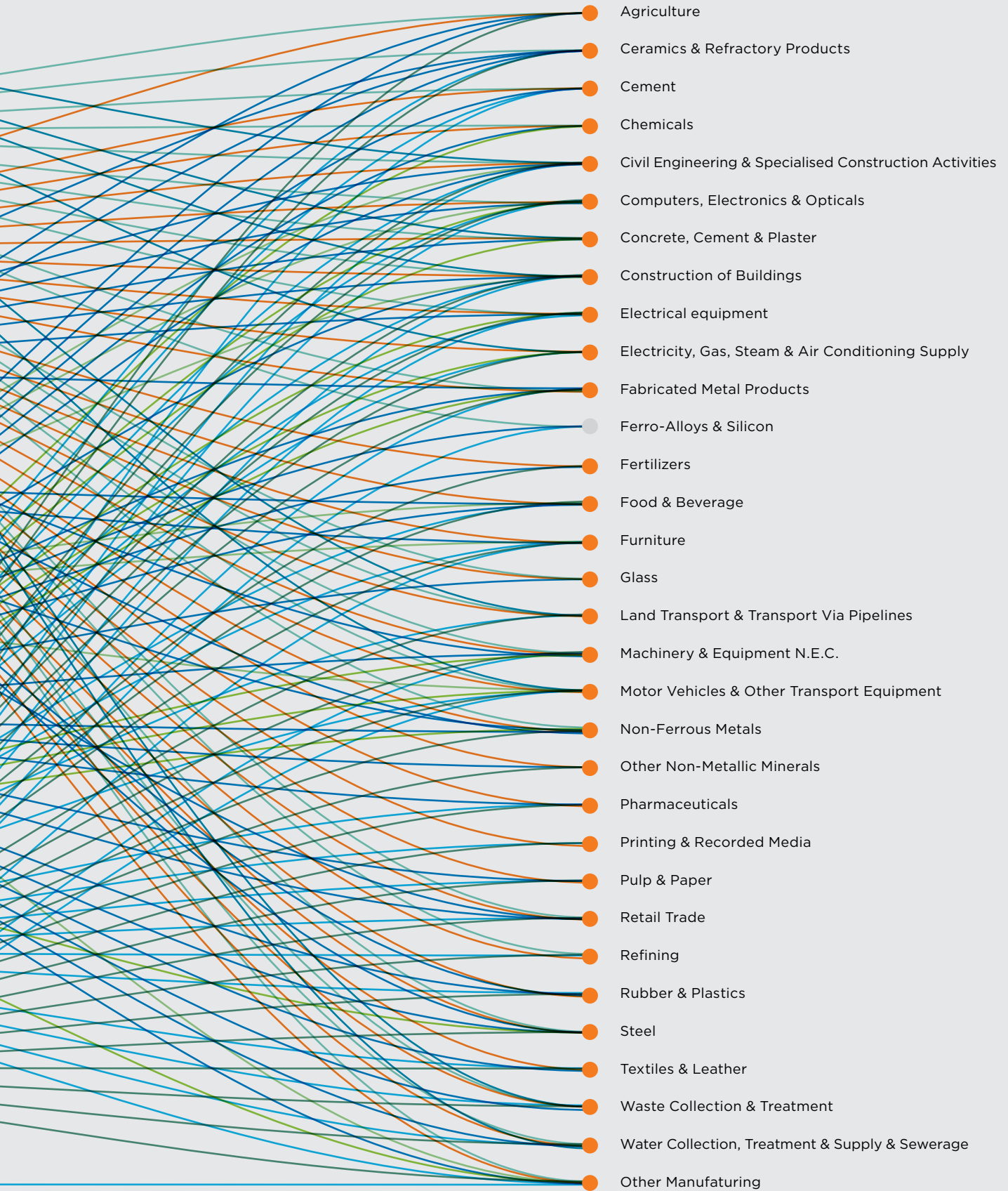
Total greenhouse gas emissions in the EU chemical industry Millions of tonnes (CO₂ equivalent). Source: European Environment Agency (EEA) and Cefic analysis 2018



The industry of industries

Value chain links between energy intensive industries





WE ARE NOT ALONE



Europe is the world's second largest chemical producing region, behind China, but that is only half of the story.

While China and North America are more focused on their own markets, Europe

has been a phenomenal export success story. Even though our relative share of the world market has fallen, Europe has by far the world's largest chemical trade surplus - €48.1 billion in 2017¹² - as a result of the European chemical industry's global performance, especially in specialty and consumer chemicals as well as in fine chemicals such as pharmaceutical ingredients.

Europe is also one of the world's biggest markets for chemical imports, making it more and more a global centre of knowledge for the transformation of basic chemicals into higher-value-added products. The EU is the second-largest export market for China, and the largest overseas market for the United States.

EUROPE HAS BY FAR THE WORLD'S LARGEST CHEMICAL TRADE SURPLUS — **€48.1 BILLION IN 2017**

European chemical producers face growing competition from manufacturers in other regions that often have less stringent rules, more favourable tax policies and access to cheaper sources of energy and feedstocks. China dominates the global ranking of chemical producers, with sales of €1.29 trillion, more than the EU's €542 billion and the United States' €466 billion combined.

China

Sales: **€1.29 trillion**
Surplus: **€1 billion**

Europe

Sales: **€542 billion**
Surplus: **€48.1 billion**

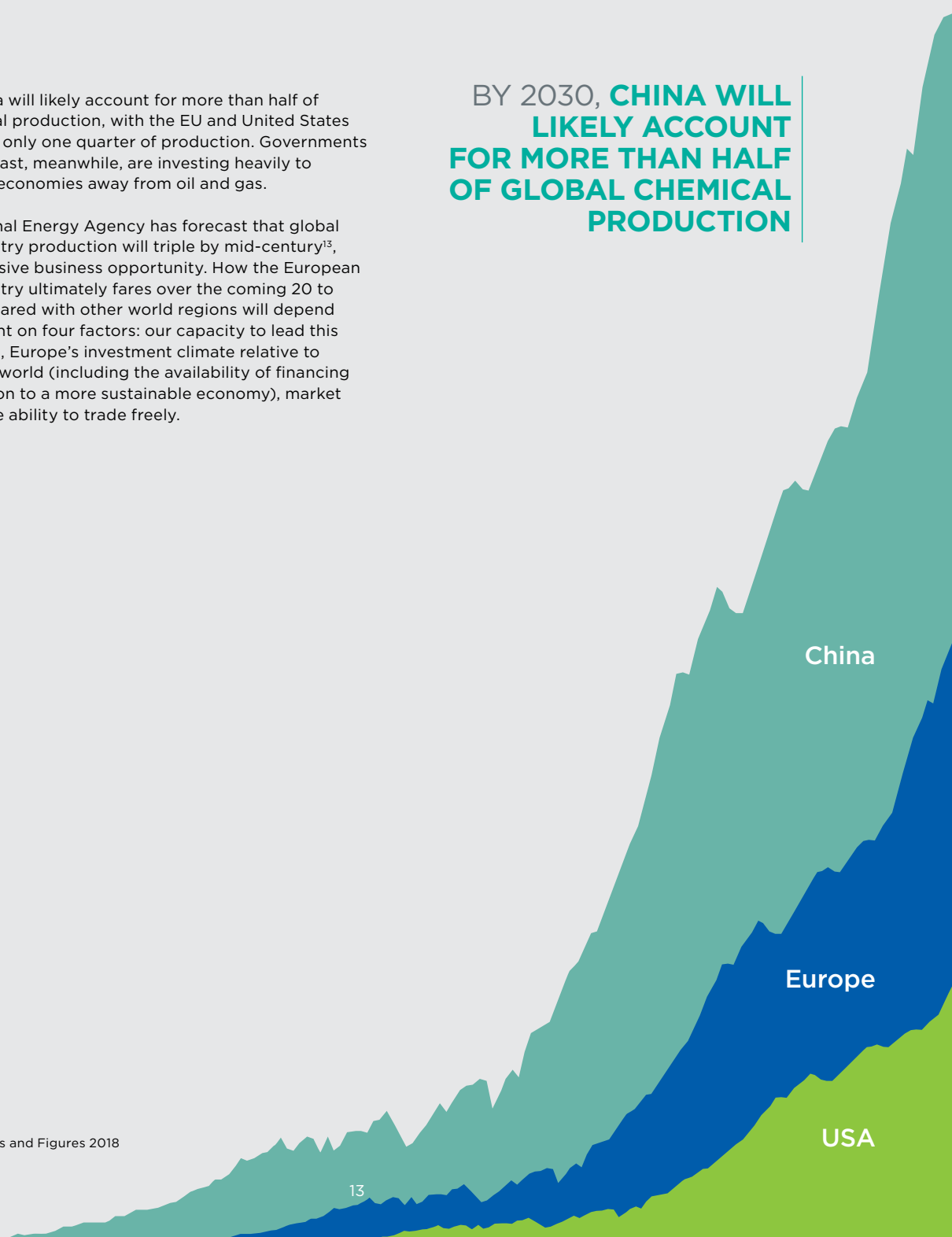
USA

Sales: **€466 billion**
Surplus: **€16 billion**

By 2030, China will likely account for more than half of global chemical production, with the EU and United States accounting for only one quarter of production. Governments in the Middle East, meanwhile, are investing heavily to diversify their economies away from oil and gas.

The International Energy Agency has forecast that global chemical industry production will triple by mid-century¹³, creating a massive business opportunity. How the European chemical industry ultimately fares over the coming 20 to 30 years compared with other world regions will depend to a large extent on four factors: our capacity to lead this transformation, Europe's investment climate relative to the rest of the world (including the availability of financing for the transition to a more sustainable economy), market growth and the ability to trade freely.

BY 2030, **CHINA WILL
LIKELY ACCOUNT
FOR MORE THAN HALF
OF GLOBAL CHEMICAL
PRODUCTION**



WHAT IF... WE HAD SUPER-SMART, SUSTAINABLE MARKETS?¹⁴

In his 20s, John hated shopping. Who really wanted to read the fine print on that barely legible calorie or cost-per-kilogram label anyway, or figure out which was better, the fair trade or organic bananas? So much drama! Nowadays, Penny, his smart digital assistant, who already knows what's important to him, does most of that thinking for him. She whitelists anything new that she thinks might interest him based on his ethical shopping criteria. She also knows that he has been going to the gym more regularly lately, so she took the liberty of adding a few more high-protein items to his shopping list and adjusted his weekly menu accordingly. **"Want to taste an organic Carmenère, today, John?"** the wine section clerk asks as he approaches, his name prompted into the clerk's ear by the store's AI, which will also process the automated payment as soon as he walks out the door. **"Penny says it will go well with that organic mushroom risotto that you'll be eating on Tuesday."**

"Love to," says John. **"You know me so well."**



If there's one thing we know for certain about the year 2050, it's that technological advancement will exceed all our current expectations.

Just as with semiconductors and smartphones, artificial intelligence is likely to evolve far faster and go further and deeper than we currently foresee, offering seamless and speedy advice and empowering better and more personalised decision-making. Computers will talk not only with us but with one another. Bots running on quantum computers will make snap decisions based on scientific consensus, big data, personal preferences and probabilities. AI and robots will replace a lot of drudgery—not only on the individual scale, but across whole cities, states and continents. That will reserve human attention for roles where creativity, flexibility and strategic decisions are required.

Many retail stores could become smaller, more experience-oriented venues because it will be possible to ship most goods straight from highly efficient, automated warehouses to homes and offices on demand. Manufacturing could be almost entirely just-in-time, and increasingly local: No more fan shortages when the temperature hits 30 degrees Celsius outside!

Judging by current trends, much of this innovation could come from China. Having out-invested Europe and the United States in deep learning research and STEM education, China would have a competitive advantage that converts it from an importer of technology to a major exporter.

Its huge, homogenous market could act as a giant, hyper-efficient focus group. Centralised decision making could facilitate the deployment of new technologies with unbeatable economies of scale.

Europe is expected to continue to lead on sustainability. That would ensure that the integrated value chains of the future are based on deep sustainability strategies, scientific life-cycle analysis and fair, reasonable, non-discriminatory, transparent and mandatory data exchanges. Blockchain technology should let people trace all products and even individual molecules throughout the value chain. That would enable new, more sustainable business models built on leasing products rather than owning them. AI could assign product ratings for the three dimensions of sustainability: environmental, economic and social. That would help Europe make minimising carbon footprints a top priority.

BOTS RUNNING ON QUANTUM COMPUTERS WILL MAKE SNAP DECISIONS BASED ON SCIENTIFIC CONSENSUS, BIG DATA, PERSONAL PREFERENCES AND PROBABILITIES

If this is a future we'd like, our leaders need to answer a few urgent questions, including these:

How will society ensure that there is a socially fair transition to a future dominated by super-smart, sustainable markets, a future in which no one is left behind?

How do we decide which societal decisions are made based on scientific consensus and algorithms, and which are left to individual choice?

How can we ensure that Europe leads on global sustainability standards for high tech innovation ecosystems, on AI and other digital technologies?

WHERE WE'RE GOING

Our world is shaped by multiple trends and megatrends that interact like waves, now proceeding orderly in one direction, other times colliding in unpredictable eddies.

We believe demographic, economic, environmental, technological, and geopolitical¹⁵ megatrends will have the biggest impact on the world and the European chemical industry in 2050. We consider them each in turn.

DEMOGRAPHICS

The gap between global haves
and have-nots will grow

ECONOMICS

A gradual, bumpy shift in power
to emerging economies

ENVIRONMENT

Europe blazes a sustainability
trail, other regions follow

TECHNOLOGICAL

New and disruptive technologies
drive exponential innovation

GEOPOLITICAL

A more multi-polar world
less dependent on trade,
especially in energy

DEMOGRAPHICS

The gap between global **haves and have-nots** will grow



According to United Nations forecasts, the earth's population will increase to nearly 9.8 billion in 2050, but growth will not be uniformly distributed¹⁶ (See graphic).

This ever-growing population will increase demand for natural resources, energy and food. All advanced economies, Europe included, will contend with an ageing population due to rising life expectancies and lower fertility rates. In these countries, population growth will slow, stagnate or could even decline, while more and more Europeans live in single-person households. As a region, Europe will have the world's oldest population in 2050, with more than 25% of the population over 65¹⁷.

Revolutions in automation technologies and artificial intelligence will force European workers to develop a "life-long learning" approach to skills in order to stay relevant in the labour market throughout prolonged working lives. This might boost inequality and tensions in and among societies. It will stress an already strained political environment within the EU, and prompt long-needed reforms¹⁸.

The ageing workforce and labour displacement will increase fiscal burdens as tax revenues fall and health care and welfare costs rise. On the bright side, improved healthcare (e.g. regenerative medicine, genomics) will extend the careers of ageing workers, allowing more people to have two or more careers in one lifetime¹⁹.

Some emerging economies such as China and Russia will also contend with ageing and declining populations. Africa, Southeast Asia and the Middle East, on the other hand, will see strong growth in population. This, in turn, will increase migratory pressures on Europe²⁰ but also create crucial business opportunities for Europe, especially in Africa.

Demographic and other trends in Europe are expected to drive increased competition for talent that will make it more difficult and costlier for the European chemical industry — a world leader in talent retention today²¹ — to attract and retain the scientists and engineers essential to its success. Asia—particularly India—is the only region where the supply of highly-skilled labour is growing faster than demand.

The talent crunch will begin in Europe in 2020²² and last until at least 2030, putting it at risk for "unrealised output", or the potential loss of income, compared with demand, which is attributable to a lack of skilled workers, according to research by Korn Ferry. By 2030, this hypothetical loss could total US\$8.4 trillion per year across all industries around the world, hitting Europe harder than other regions with higher birth-rates.

HELP WANTED: MULTIDIMENSIONAL CHEMISTS

As a **chemical engineer of the future**, you will need a different mix of skills than the typical organic chemistry graduate today. As a lab engineer, you will **work with artificial intelligence** and **big data** to create new chemical bond and assemble molecules much faster than we can today. Graduates will need skills in both **organic and biochemistry**, or **organic chemistry and genome editing**. With the ever-growing impact of digital tools on communication, our future colleagues will need to demonstrate **superior interpersonal skills**, along with enhanced **flexibility, managerial agility** and **international experience**.

To counter this megatrend, employers in Europe need to be more agile, adaptive, and creative. Chemical companies will need to help universities teach chemical regulation, a subject which is often neglected in curricula. They will need to hire and retain people with multiple capabilities, for example engineering and digital, or science and marketing. Increasing digitalisation in factories suggests that all employees will eventually need enhanced skills. Training and re-training need to be permanent, rapid and flexible.

EUROPE WILL HAVE THE WORLD'S OLDEST POPULATION IN 2050, WITH **MORE THAN 25%** **OF THE POPULATION OVER 65**

Artificial Intelligence will make some current job descriptions obsolete by mid-century²³, forcing people to learn new, higher-value jobs. The upside: these jobs provide an opportunity for diverse careers and re-orientation as more routine jobs get automated.

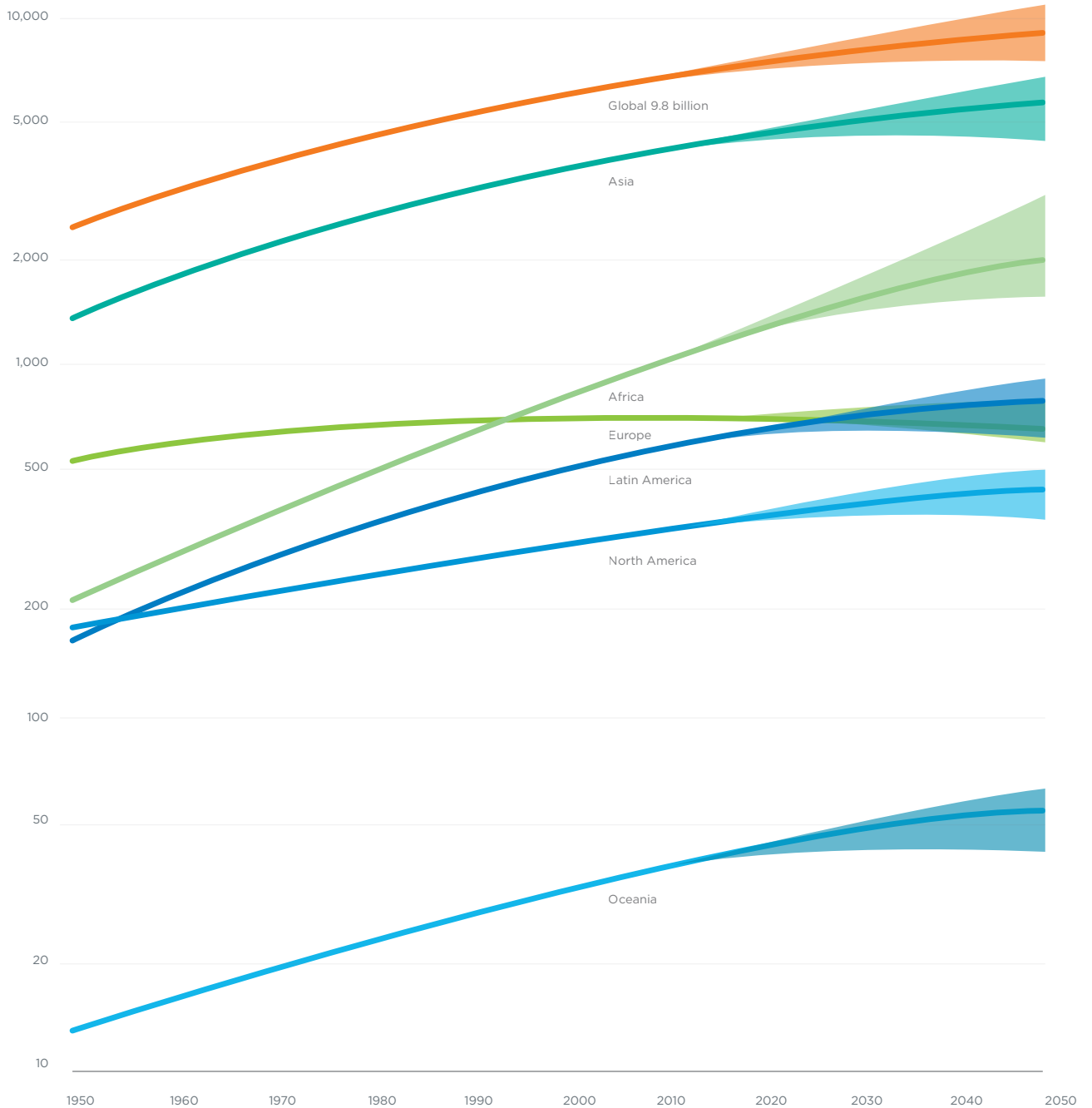
The European Commission²⁴ places investment in "education, science, technology, research, innovation and digitalisation as a prerequisite for achieving a sustainable EU economy" that meets the UN's Sustainable Development Goals.

We couldn't agree more!

Regional distribution of global population growth

Population of the world and its regions in millions 1950-2050.
 Shaded region: low to high variant. Solid line: medium variant.

Source: UN 2015



ECONOMICS

A gradual, bumpy shift in power to emerging economies



We believe the world economy will continue to grow. In the medium term, economic growth

will also be stable, but will vary by region and country. In the short term, economic growth is expected to be volatile.

For the sake of this report, we expect advanced economies to see lower average per capita gross domestic product (GDP) growth from 2015-2050. We expect that Europe's economy will grow at a moderate rate of around 1% per year on average through 2050, and the European chemical industry, as a key contributor to all aspects of life, will at least match this growth. In emerging economies, per capita GDP growth is expected to decrease, but to remain substantially above the growth rates of advanced economies. The convergence of emerging and advanced economies will continue, but at a slower rate. Relative GDP shares of advanced economies will decline.

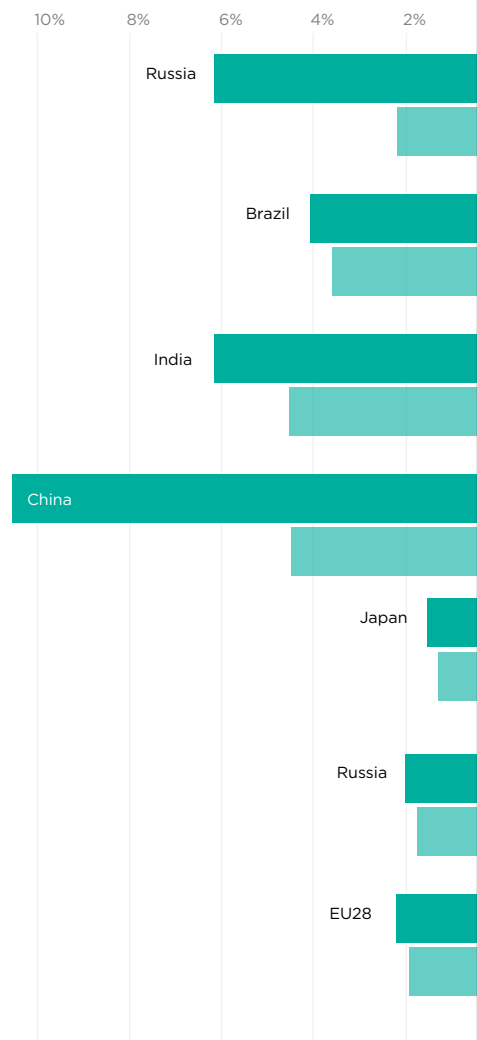
The implications of population growth for the chemical industry depend heavily on whether it is accompanied by economic growth.

EUROPE'S ECONOMY WILL GROW AT A MODERATE RATE OF AROUND 1% PER YEAR

Population growth in emerging economies requires more housing and infrastructure, as well as more consumer goods as those populations join the middle class. This will increase demand for basic chemicals (e.g., petrochemicals and general plastics) as well as for speciality chemicals (such as adhesives, coatings and ingredients). Much of that demand will be covered by local production. European producers are likely to face stiffer competition from Asian competitors as the latter's speciality chemicals competency increases²⁵.

Annual GDP per capita growth in advanced & emerging economies 2000-2007 2015-2050

Source: CIFS



THE ENVIRONMENT

Europe blazes a sustainability trail, other regions follow



In the context of an ever-growing worldwide population, society is increasingly conscious of the

need for an efficient use of natural resources.

Sustainability, once an after-thought on the path to progress, has moved to the centre of public discourse as the result of increasing pressures on the environment both locally and globally. Climate change and resources scarcity bring risks for ecosystems, crop yields, water supply, biodiversity and land use at the local, regional and global levels. The climate and resources nexus also brings business opportunities.

To address the megatrend toward more sustainable products and markets, the chemical industry is already working on version 2.0 of Responsible Care²⁶, which commits national chemical industry associations and their partners globally to continuous improvement on environment, health and safety matters including resource efficiency, transparency and ongoing dialogue with society. It also promotes stakeholder engagement and the safe management of chemicals in the supply chain and throughout their life cycle.

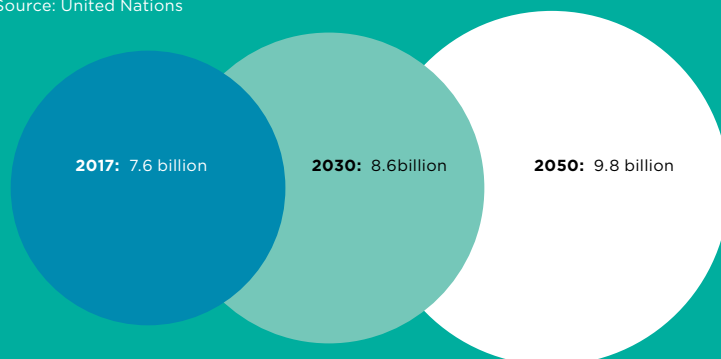
We expect a continued push toward lower emissions and even more renewable energy sources in the energy mix²⁷, which will lower the chemical industry's carbon footprint. But we believe fossil fuels will remain the most important source of feedstock, enabled by a sustainable and circular management of carbon cycles. We expect carbon pricing mechanisms—either market based or through taxation²⁸—will remain and incentivise emissions reductions. Europe as a region will go toward net-zero carbon emissions by mid-century²⁹.

European prices for CO₂ and other externalities are expected to increase and end up higher than in other regions in the world. There will be a great deal of variety in projected prices around the world due to different political agendas.

EUROPE WILL GO TOWARD NET-ZERO CARBON EMISSIONS BY MID-CENTURY

World population projected to reach 9.8 billion in 2050

Source: United Nations



TECHNOLOGICAL DEVELOPMENT

New and disruptive technologies drive exponential innovation



New technologies create new opportunities, new markets and new business models.

They give us new ways to handle important challenges, while also introducing new and sometime unexpected problems.

The technologies with the biggest impact on the world and the European chemical industry are expected to be digitalisation, electrification, renewable electricity, recycling, low-carbon synthesis processes from circular feedstocks including CO₂ and carbon storage.

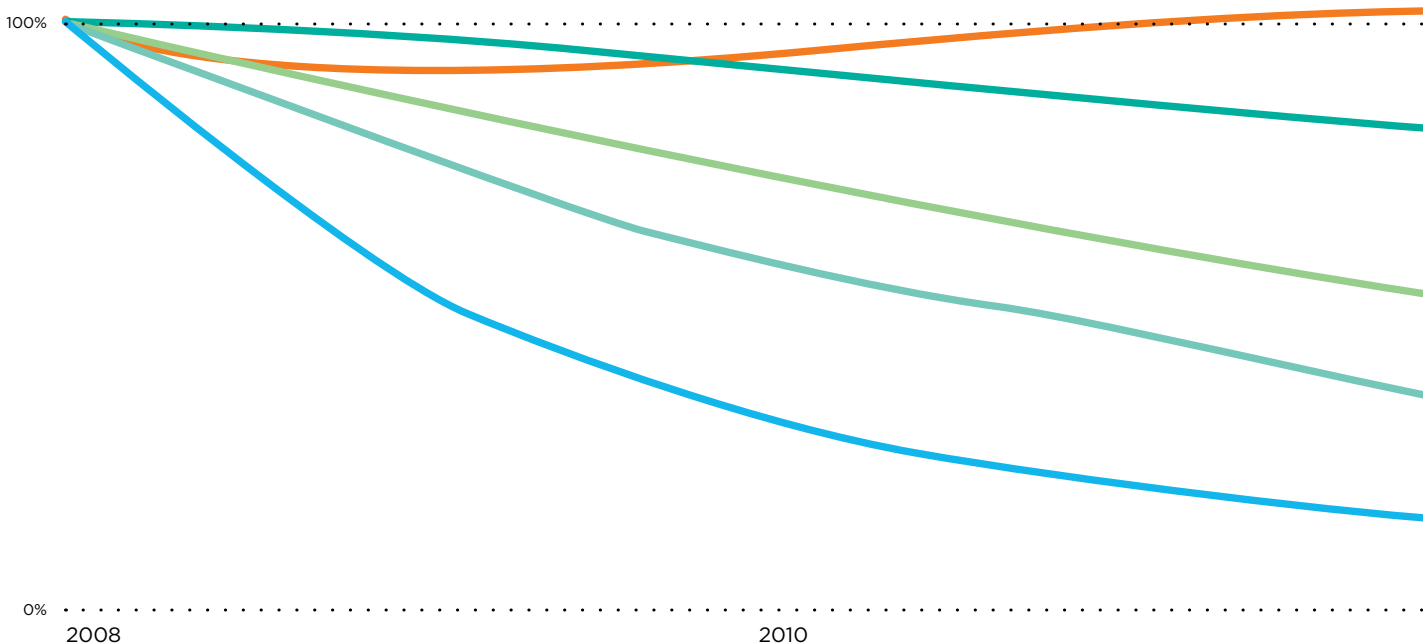
On the digital front, big data, analytics, 5G mobile telephony, the “Internet of Things”, blockchain, advanced production technologies and low-cost sensor connectivity, among other emerging technologies, are all poised to have a major impact.

Renewable energy will continue to become more competitive and more readily available—a key condition for the energy-intensive chemical industry to reduce its carbon emissions significantly³⁰. Energy storage will improve and spread. Technical progress will also be made in lignocellulose extraction, as well as “white industrial biotechnology” - i.e. fermentation of chemical compounds by genetically engineered hosts such as bacteria, fungi or yeast.

Improved chemicals recycling technology for plastics and polymers will also create new sources of raw materials to feed European crackers, the industrial sites that break complex organic molecules into simpler molecules. This will foster the emergence of new value chains for recyclable polymers and plastics and promote the circular economy in Europe.

Cost deflation across diverse energy technologies

Source: IEA World Energy Investment 2016

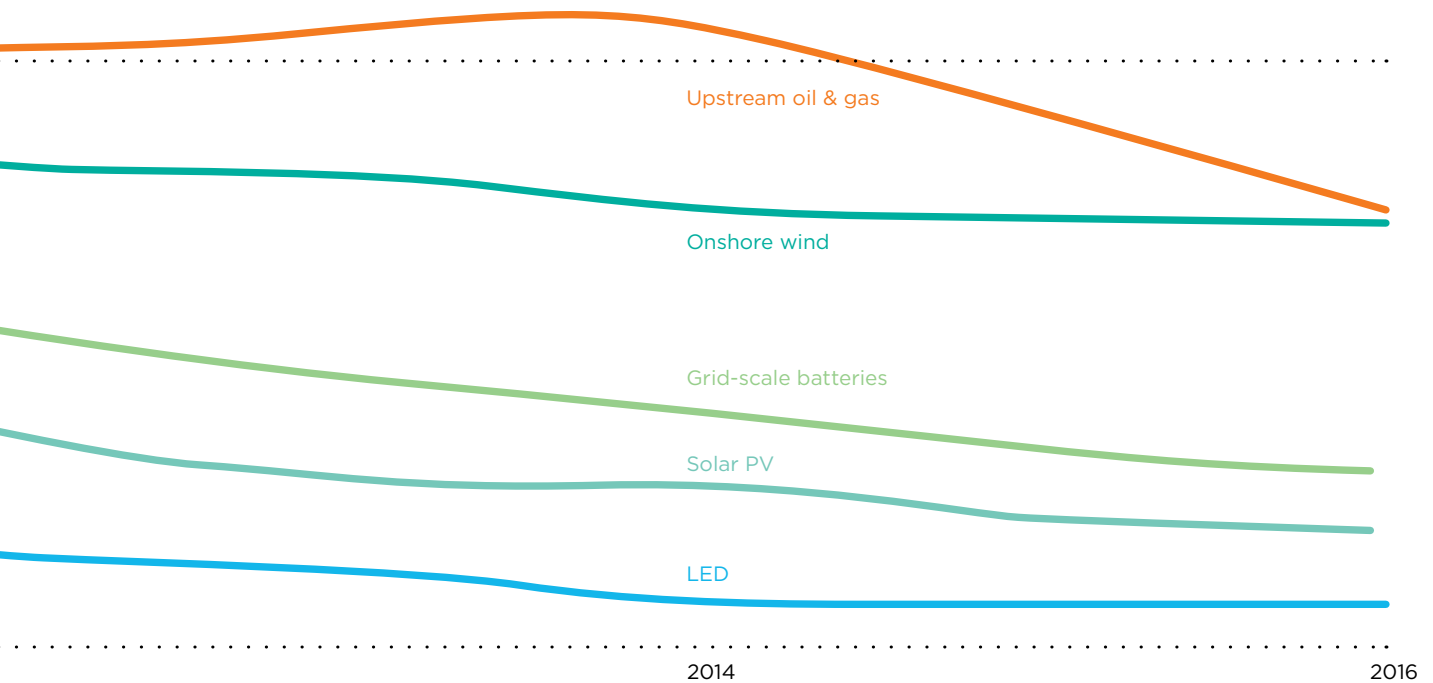


**NEW TECHNOLOGIES
CREATE NEW OPPORTUNITIES,
NEW MARKETS
AND NEW BUSINESS MODELS**

BACKBONE TECHNOLOGIES FOR LOW-CARBON PRODUCTION OF CHEMICALS

Source: DECHEMA 2017

Biomass to chemicals	Cellulosic and lignocellulosic biomass and biomass waste streams are converted through biotechnological and conventional processes to chemicals and fuels. Alternatively, biomass is gasified into syngas (CO ₂ , H ₂ and CO), which is used for chemical synthesis.
CO ₂ and hydrogen-based synthesis of chemicals	Low-carbon electricity is used for hydrogen production. Obtained hydrogen is reacted with CO ₂ or CO sourced from industrial plants or fossil-fired power plants to produce chemicals. Also known as Power-to-X technologies.
Power to heat	Low-carbon electricity is used to generate steam for chemical processes (steam cracking) or steam decomposition, thus replacing natural gas fired steam production.



GEOPOLITICAL

A more multi-polar world

less dependent on trade, especially in energy



Politics are perhaps the most difficult area in which to predict trends, but we nonetheless identified a consensus around a few important trends. First, the North

Atlantic dominance of international relations will continue to decline. China and India could overtake the United States and Europe in economic importance and play an increasingly influential role in regional and global politics³¹.

The longest period of peace in recent history, globalisation, free trade, investment—and yes, the chemical industry—have contributed to unprecedented levels of human health, wealth and quality of life, yet they are increasingly under fire (See the fictional “Facet of the Future” titled “What if our world continues to fragment?” on page 48 to see where this might lead). Because of growing protectionism, the 4th industrial revolution and societal preferences for local production, more manufacturing might happen locally than in the past—which in turn will reduce trade intensity. This would contribute to a shift away from decades of increasing international co-operation and economic globalisation (which previously lifted millions of people out of poverty and into the global middle class). There is a risk of greater nationalism and protectionism driven by populism, public unhappiness with the political establishment and rising economic and social inequality. In such an environment, it will become harder to reach a consensus on common global standards, protocols and treaties on issues such as sustainability, data, information security and cybersecurity. Many countries will turn to bilateral or regional cooperation and institutions³² instead.

Overall the world is at risk of becoming more complex as new threats emerge while global security structures weaken. In an increasingly heterogeneous geopolitical environment, global businesses will be exposed to more geopolitical conflicts, necessitating stronger bilateral and multilateral institutions and engagement to ensure that the benefits of globalisation are more equally distributed³³.



THERE IS A RISK OF **GREATER NATIONALISM AND PROTECTIONISM** DRIVEN BY **POPULISM, PUBLIC UNHAPPINESS WITH THE POLITICAL ESTABLISHMENT** AND **RIISING ECONOMIC AND SOCIAL INEQUALITY**



WHAT IF... WE HAD A SUPER- CIRCULAR ECONOMY?¹⁴

The carbon plant was cranking up the volume. The sun was shining brightly across northern Europe and the wind was blowing. Result: a big surplus of renewable energy in the grid that was immediately put to use extracting CO₂ out of the atmosphere and converting it into renewable fuel and chemical feedstock. **The introduction of a global carbon price, combined with a massive scaling up in wind, wave and solar power, had made it possible to take the world's biggest problem—CO₂ build-up in the atmosphere—and turn it into part of the solution.** Ever since, the circular economy, which began with recycling things like paper and batteries, had extended to the invisible realm of the gases that are ubiquitous in the atmosphere.



WHETHER ONE'S TALKING ABOUT PAPER, BATTERY OR PLASTICS **RECYCLING, THE PROCESS IS FUNDAMENTALLY CHEMICAL**

Chemistry is central to the ideal of the circular economy. Whether one's talking about paper, battery or plastics recycling, the process is fundamentally chemical. It includes polymer recycling loops (e.g. PET into polyester fibre for fabric, recycled PE/PP blended with new polymer for high-performance applications), depolymerisation (plastic bottles and polystyrene), chemical recycling (lower grade mixed plastic waste to chemical plant feedstock for olefins and aromatics), bio-based chemicals and CO₂/H₂ to synthetic gases and chemicals.

The 20th Century mandated recycling for wastes that were filling up landfills and polluting the landscape. Today, the focus is on plastics – especially in the ocean.

The only material difference between CO₂ and other raw materials such as aluminium and steel is price. If a universal carbon tax on one-way carbon is introduced, “waste” carbon would suddenly become a valuable commodity and chemical engineers would trip over themselves inventing new and ingenious ways to scrape it out of the atmosphere and the oceans and sell it back to industry. The cool thing is, they wouldn't even have to create a whole new infrastructure because it would already exist in the form of pipelines and storage tanks.

For physical goods, powerful recycling incentives, recyclability-by-design, blockchain and new business models based on leasing would make it infinitely easier to manage valuable raw materials in products throughout their life-cycles. Suddenly, manufacturers would have an incentive to keep better track of their products after they were sold and incentivise everyone to give or sell stuff back at the end of their life cycle. Molecule-level pricing schemes would help facilitate chemical leasing and recycling.

IF A UNIVERSAL CARBON TAX ON ONE-WAY CARBON IS INTRODUCED, 'WASTE' CARBON WOULD SUDDENLY BECOME A VALUABLE COMMODITY

Massive European Union investments in non-fossil energy sources would be critical to making the economy climate -neutral. They would also help dramatically reduce Europe's dependence on some imported raw materials.

This potential future invites us to address the following leadership questions:

<p>Is our current economic model fit for a circular economy and, if not, what policy innovation is needed to make it fit for purpose?</p>	<p>How should we manage the presence of chemicals of concern in a circular economy?</p>	<p>Who would be the natural winners and losers in a circular economy, and how can we better manage the transition for a more equitable sharing of benefits and costs?</p>	<p>How can Europe maintain and increase its leadership role in setting global sustainability standards for the circular economy?</p>	<p>What if the world doesn't agree on global standards?</p>
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EUROPE AND ITS CHEMICAL INDUSTRY IN 2050

What will **Europe look like in 2050?**

Predicting the future is perilous, but with foresighting methodology we can make a few reasonable projections based on what we know about trends in technology, economics and politics today. The result is a cautiously optimistic view of the future.



Our homes and offices will be carbon neutral, or even carbon-negative.

Our personal transportation sector will have been largely transformed by autonomous, electrical vehicles, car-sharing and other new forms of mobility.



Aeroplanes, trucks and ships will be shifting to alternative fuels or fuel cells.

Our environment—at least in Europe—will be even cleaner than it is today. People will live longer and better. Renewable and other low-carbon energy sources will have replaced around two-thirds of fossil fuel combustion globally. Almost everything will be recyclable by design, and everything that can be recycled will be recycled.



Data will have replaced oil as the most valuable commodity.

Data mining, artificial intelligence, predictive maintenance and data-based process management will transform industry. Blockchain technology will power radical transparency and track the path of molecules in our economy from production through to recycling. Europe will have cut its greenhouse gas emissions to net zero.



Carbon that is still used in industrial processes will be largely captured, re-used and recycled as a valuable feedstock in the circular economy.

Europe will be the world leader in sustainable technologies. Each of these visions is highly plausible and highly desirable on its own. Each becomes even more plausible and even more desirable as part of a coherent system.

EUROPE AND ITS CHEMICAL INDUSTRY IN 2050



This report on a Mid-Century Vision for the European chemical industry is our way of saying that we'll be here to help every step of the way — for the next 30 years and beyond.

The truth is, we need to change if we want to thrive, both as an industry and as a healthy, wealthy and ageing society. To tackle the risks of climate change we must slash greenhouse gas emissions and become more circular. To do that, we need to revolutionise our energy, transportation, construction and industrial sectors —among others. To do that, we'll need new materials —semiconductors for solar panels, carbon-fibre reinforced composites for windmill blades, better batteries, lightweight materials for transportation, and better insulation and coatings, to name just a few. To recycle them all at their end of life affordably, they will need to be recyclable by design, and the necessary infrastructures will need to be built and the necessary processes put in place. To do that, Europe will need to invest tens of billions of euros in research, development and production of new recyclable materials. That, in turn, implies huge demand for a highly skilled workforce.

THE CHEMICAL INDUSTRY IS AN INDISPENSABLE CATALYST OR ACTOR IN ALMOST EVERY ASPECT OF THE FUTURE THAT WE ALL WANT

The chemical industry is an indispensable catalyst or actor in almost every aspect of the future that we all want. The next ten years will be crucial to determine if we can make it.

Getting there

The question is, how can the European chemical industry continue to grow in a world of increasing global competition for investments? As one of Europe's biggest industrial sectors, the European chemical industry invests more than €21 billion a year³⁴ in new and better factories and fixed assets. Those need to pay a return on investment over many years—often measured in decades. If they don't, companies will have no means to re-invest in improved products or processes.

To make the right investments, companies need to have clear signals from customers, governments, regulators and ultimately society as a whole. How much is society willing to pay for a cleaner environment? Where will we get all the chemists, engineers and materials scientists we need? How can the European chemical industry continue to compete and be an engine for exports and change?

Here are a few of the most important issues we need to confront and our thoughts on the prerequisites for success. We do not claim to have all the answers. We do share the same goals and the same fundamental values as our stakeholders.

WE CAN BE CERTAIN THAT THE CHEMICAL LANDSCAPE WILL LOOK VERY DIFFERENT IN 2050

Helping Europe win with a fair transition

As this report goes to press, we see a geopolitical situation marked by increasing fragmentation.

The geopolitical balance of power that was dominant for decades has given way to new powers and new winners and losers. Global trade flows have shifted considerably as the result of both technological development and increasingly insular, regional politics that hamper multilateralism and disrupt historical supply lines. There is more economic and political integration within most regions, but more fragmentation between regions. We believe that the successful transformation of our economies requires a transition that is fair to all actors in society.

We can be certain that the chemical landscape will look very different in 2050. We firmly believe that Europe can lead this transformation and set sustainability standards that will ensure fair trade and competition both around the world and on the European market. The insistence on fair competition, combined with enlightened policies on sustainable finance and significant investments in the production and distribution of low-carbon electricity, will go a long way toward ensuring that the right investment climate and business environment prevail.

Appeal #1: **Use chemicals to strengthen the EU – economically and diplomatically**

2050 is only two industrial investments cycles away. More than ever, there is an urgent need for a policy framework to help the European chemical industry stay competitive in the context of less ambitious policies among Europe's global competitors. The urgency for a long-term, stable EU industrial strategy will continue to grow as other regions implement plans to promote their own industries.

MORE THAN EVER, THERE IS AN **URGENT NEED FOR A POLICY FRAMEWORK TO HELP THE EUROPEAN CHEMICAL INDUSTRY STAY COMPETITIVE** IN THE CONTEXT OF LESS AMBITIOUS POLICIES AMONG EUROPE'S GLOBAL COMPETITORS

The chemical industry will continue to provide value to society. We need to better articulate and showcase our contribution to the European economy and the UN SDGs and track developments in terms broader than GDP.

Europe in return should avoid environmental dumping and unfair competition by ensuring import compliance and promoting European environmental, chemical and circularity standards in international agreements³⁵. In the longer term, Africa should be a key priority as it represents a huge business opportunity for Europe. The aim: to help develop African economies while creating opportunities for European industry on our geographic doorstep.

Appeal #2: **Help us innovate in sustainable solutions**

European authorities should look for a new societal deal that fosters leadership in breakthrough innovations by streamlining the "Innovation Principle"³⁶ across all policies and in particular those enabling a climate-neutral economy, circularity of material streams and an efficient use of resources via—among other means—chemical recycling of plastics, polymers and composites and low-carbon electricity. With EU support, the chemical industry could develop a series of large-scale projects across the EU that showcase the new technologies the industry needs to transform.

Europe needs to become the best place to invest in new breakthrough technologies, for example by enabling EU state aid rules to cover refurbishment, deploying cost-effective alternative feedstock (e.g. CO₂, biomass, wastes) and innovative electricity storage technologies and including using liquid ammonia or hydrogen for electricity storage.

The European chemical industry needs to refurbish ageing facilities and install best-in-class technologies as they become available over the next 10 years. Our industrial fabric, coupled with its innovation engine, are strongly needed in Europe to achieve the European political agenda of circularity and net-zero emissions. New forms of sustainable financing³⁷ and development such as the external investment plan must be reinforced and must be technology neutral and not discriminate against any sector.

EUROPE NEEDS TO BECOME THE **BEST PLACE TO INVEST IN NEW BREAKTHROUGH TECHNOLOGIES**

EUROPE AND ITS CHEMICAL INDUSTRY IN 2050

Appeal #3:

Foster an ambitious, market-based framework

Policymakers, industry and civil society need to develop a post-2030 harmonised EU-wide policy framework for acknowledging, measuring and pricing externalities such as greenhouse gases, water consumption, air pollution, etc., based on life-cycle analysis as a first step toward ensuring a level playing field globally.

Europe also needs to encourage demand for more sustainable products³⁸ via, for example, an economy-wide pricing mechanism that incentivises the use of chemicals which minimise environmental impacts over the whole life cycle, that streamlines a value-chain approach in all new policies, and that drives a behavioural shift toward optimal circularity and lower greenhouse gas emissions at a competitive cost. That would have a positive impact on markets, driving the technology-neutral selection of solutions.

Going circular

Worldwide, more than 55% of people live in urban areas, a figure that the United Nations expects to rise to 68% by 2050³⁹. Those cities are also where most of waste is generated.

It is technically possible to recycle almost every type of waste, especially if products are designed with a view to reuse and recycling. This provides the European chemical industry with a massive opportunity to not only be a producer of products but also lead the way in preserving value through multiple life cycles, including the chemical recycling of valuable waste through processes such as pyrolysis and depolymerisation as well as improved separation technologies. The chemical industry is the catalyst in a circular society.

Today's chemistry still depends heavily on fossil feedstock and will continue to do so in the future, so we either need to find ways to increase carbon productivity—e.g. keep it flowing through our economies longer—or to enable its recyclability. We also need to use more circular feedstocks such as biomass, waste materials and industrial CO₂ and CO emissions.

Less but better, with breakthrough technologies

We are optimistic that Europe will develop its own, different but successful place in the world based on European values and a focus on sustainability. Chemistry contributes to new technologies and improved performance in the fields of health and nutrition, access to water, connectivity and mobility, as well as contributes to a climate-neutral economy, increased circularity of material streams and a more efficient use of resources.

The European chemical industry will grow at least at the same rate as the European economy each year. The value of European chemicals will increase through specialised, higher-value-added, sustainable products even if volumes stabilise. Consolidation will encourage the development of efficient, well-maintained, state-of-the-art and clustered assets in Europe.

The European chemical industry will further flesh out the principle of carbon productivity that will be instrumental to charting an optimal approach to carbon emission reductions and invest in sustainable chemistry, chemical recycling, sustainable manufacturing and education.

IT IS TECHNICALLY POSSIBLE TO **RECYCLE ALMOST EVERY TYPE OF WASTE**, ESPECIALLY IF PRODUCTS ARE DESIGNED WITH A VIEW TO REUSE AND RECYCLING

LET'S TALK ABOUT CIRCULARITY.

The term is based on the simple concept of recycling, applied to the whole of an economy. The point is to maximise the value of materials in circulation by keeping them in value chains longer, re-using and recycling as many materials as physically and economically sensible into new raw materials. Circularity has numerous positive knock-on effects, including reduced dependence on imported raw materials, less waste and increased life-cycle productivity of valuable raw materials.

WE EXPECT
EUROPEAN
LEGISLATION TO
BAN LANDFILLING
AND **RECOGNISE**
CHEMICAL
RECYCLING AS A
VALUABLE WASTE
MANAGEMENT
OPTION

Appeal #4: **Make Europe the global leader in circularity**

The European chemical industry aims to help prevent environmental damage, reduce waste, and develop technologies necessary to enable recycling, including chemical recycling, and cost-effectively sort materials from plastics to polymers in large volumes. We support collaboration with value chain and government partners to avoid letting recyclable end-of-life plastics⁴⁰ end up in the environment and to develop solutions that help achieve a higher circularity in plastic value chains. We also aim to develop an industry-wide strategy for managing the risks of substances of concern⁴¹ in a circular economy, through and beyond recycling; and to innovate with value-chain partners in new products designed to be recyclable. To harvest the full potential of a circular economy, we need help from everyone, including individual European citizens for whom sorting household waste will be as natural as breathing.

Under the right prerequisites, industry will invest in chemical recycling across Europe that can absorb the many valuable materials that are currently wasted, including plastic and polymers. We can transform these materials back into hydrocarbon feedstock while taking care of substances of concern. Enhancing vertical integration with waste recyclers, these sites may become the recycling hubs of European economy – sites where molecules that are no longer needed or which hamper further recycling can be transformed into new or better uses or be removed from the system.

In order for a maximum of recyclable materials to actually be reused, we expect European legislation to ban landfilling and recognise chemical recycling as a valuable waste management option in addition to mechanical recycling and energy recovery.

To fully benefit from the potential of biomass to be a valuable feedstock and establish the right market incentives for a sustainable economy, the EU should implement its strategy for the bio-economy.

Europe also needs to optimise waste transport legislation to facilitate the flow of waste products and allow a truly functional, pan-European market for waste sorting and recycling.

EUROPE AND ITS CHEMICAL INDUSTRY IN 2050

Climate change mitigation and adaptation

According to the Intergovernmental Panel on Climate Change, our world will become more hostile as global temperatures rise. More frequent and powerful droughts and storms will transform our environment and likely lead to unprecedented numbers of climate refugees. Climate change mitigation and adaptation are key focus areas for the European chemical industry.

According to DECHEMA⁴², a massive amount of renewable electricity will be required in the next 20 years to enable the transition to a lower industrial carbon footprint. DECHEMA has calculated that the demand for low carbon electricity may even exceed the projected installed capacity in the EU by 2050. In some scenarios, and only for 60% of the European chemical production to-date, it could reach the equivalent of more than three times Germany's 2017 production capacity.

We will have to help Europe achieve its goal of net-zero greenhouse gas emissions by ensuring that virgin fossil carbon is used selectively and productively. Companies also will need to consider adapting their operations to the growing effects of climate change, for example by investing in flood control measures and reducing their reliance on rivers that could run low for cooling and transportation.

LET'S TALK ABOUT CLIMATE NEUTRALITY.

Climate neutrality — achieving a net-zero emission balance in the economy — is currently the subject of lively discussions among European policy-makers. In practical terms it means that remaining emissions in some sectors can be offset by carbon removals in others, for example through increased carbon uptake in the biosphere or carbon capture and storage (CCS). The chemical industry as a whole will need to focus on reducing its carbon footprint as well its products' total life-cycle emissions. This will largely depend on the availability of affordable, carbon-neutral electricity sources.

SOME OBSERVATIONS ON THE EUROPEAN COMMISSION'S COMMUNICATION ON "A CLEAN PLANET FOR ALL"

The European Commission Communication "A Clean Planet for All" lays down a number of potential pathways for lower-carbon energy transformation, both for individual business sectors as well as for the economy as a whole.

We believe the chemical industry has a significant role to play in all of these scenarios. As their realisation requires significant investments, our common challenge in the coming years will be to develop the right policy framework and business models to support the industrial transition. In fact, we feel that the Commission needs to assess in more detail the economic impact of two scenarios that aim to achieve climate-neutrality for industry.

All the scenarios presented foresee a relatively stable rate of emissions reductions by industry until 2030 and a steep decline afterwards. This is the result of the time needed to pilot potential technological solutions before scaling up the most promising solutions. This confirms Cefic's view that the next 10 years will be crucial for scaling up cost effective low-carbon technologies.

Some of the Commission's scenarios put the emphasis on a single type of solution (e.g. electrification, circularity, hydrogen, etc.). Although these scenarios provide useful bases for comparison, we believe that the EU's long-term strategy needs to be based on a combination of such measures rather than just one or the other.

Another scenario, which combines all leveraging solutions (the COMBO scenario), provides an illustration of how supply- and demand-side measures can be combined in a balanced manner.

The two scenarios which aim to achieve net-zero GHG emissions in 2050 may rely too heavily on either politically sensitive demand-side measures or costly negative emissions technologies and their use by the chemical industry. The most ambitious scenarios would require the chemical industry to double the rate of CO₂ abatement that prevailed between 1990 and 2015, but abatement becomes more expensive as the potential of 'low-hanging fruit' such as energy efficiency and smokestack measures is exhausted.

It could be useful to design additional scenarios, aiming for climate-neutrality, which combine all supply- and demand-side measures in a balanced way.

Appeal #5:

Lead on global standards towards net-zero greenhouse gas emissions

As an industry, our goal is to work on the technologies needed to enable the transformation toward greater carbon productivity, seek an EU-wide agreement on internal CO₂ cost accounting (in strict compliance with European competition law), and develop and communicate a clear and progressive industry position on carbon pricing.

The chemical industry needs a policy framework that combines climate objectives with measures to ensure European industry's continuing competitiveness. This industrial climate strategy should create the right enabling framework to support industry on its path toward climate neutrality by:

- Rewarding and creating demand for low-carbon and circular value chains, for example by developing a standardisation framework based on measuring carbon cycle productivity and raising sustainability standards and assigning the right monetary value to sustainability.
- Identifying solutions to mobilise the necessary financial resources. Europe needs to invest in energy storage and other infrastructure, for example by implementing an EU-wide investment plan modelled on the "Juncker Plan" of 2014.
- Securing access to and availability of sufficient low carbon and renewable resources (energy and feedstock).
- If Europe wants to promote a hydrogen economy, it will need to develop a framework to promote the emergence of a working hydrogen-based infrastructure in Europe where hydrogen could be used both as an energy carrier and as electricity storage and a feedstock for the chemical industry.
- Accelerating the transformation of European ageing assets requires a new approach to state aid and depreciation, including national tax credit schemes.

WHAT IF... WE HAD A NEW GREEN DEAL?¹⁴

The climate breakthrough took a crisis, of course. **Europe had had droughts before, but the rolling droughts that destroyed harvests globally for several years running led to such sharp spikes in food prices and food riots—not to mention the forest fires—that they convinced even the most reluctant countries to approve The New Green Deal.** The pact institutionalised a draconian tax on CO₂ emissions, and at the same time incentivised CO₂ recycling and carbon circularity. The first years were tough as coal-fired power plants were shuttered for good. Prices for almost everything went up as ships, aeroplanes, lorries and automobiles were converted to new fuels. But public investments in energy efficiency and infrastructure, including The Great Clean Power Grid, paid off even faster than many people expected. This helped Europe regain a competitive edge as other countries, struggling to reduce their own carbon footprints, turned to Europe for clean-tech support.

The difference between Europe today and Europe in the future may just be a question of two degrees.

First, the Paris Accord threshold of a global average temperature rise of 2 degrees Celsius above pre-industrial levels is almost certain to be shattered. Passing this point could lead to runaway climate change as polar ice melting accelerates, sea levels rise, and political and military conflicts multiply in sync with unprecedented waves of human migration.

Then there's the degree to which Europe and the rest of the world are willing to take drastic action to make climate the absolute first priority, judging every other policy, existing and proposed, by its impact on climate change. Experts agree that one of the greatest risks to avoiding massive climate disruption is incrementalism, or a series of half-measures that ultimately fail to fully address the scale of the challenge. Unfortunately, economic and political inertia may well prevent government and industry alike from doing what they know needs to be done. It may take a crisis—or several of them in quick succession—to convince governments of the need to pay for more sustainable goods, models and behaviours. But is Europe willing to “drop everything” else to fight climate change?

IS EUROPE WILLING TO
“DROP EVERYTHING” ELSE
 TO FIGHT CLIMATE CHANGE?

These are some of the questions our leaders need to ponder:

<p>What trade-offs is Europe willing to make in order to create an entirely CO₂-neutral economy?</p>	<p>What policies and policy adjustments would be needed to provide a just transition to a more sustainable economy that ensures equitable sharing of costs and benefits?</p>	<p>How should we calculate the costs of carbon, taking account of sustainability co-benefits and synergies, in order to stimulate and incentive consumers to recycle?</p>	<p>How can we integrate with global trade and global policies to avoid unilateralism while developing added value for all?</p>
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EUROPE AND ITS CHEMICAL INDUSTRY IN 2050

Safe and transparent chemical management

Safety is in the DNA of the European chemical industry, and yet according to a recent Eurostat poll, 84% of Europeans are concerned about the impact of chemicals on their health or the environment⁴³. The same report shows that citizens who live closer to chemical manufacturing sites are better informed about chemical risks and tend to have a better perception of our industry than others.

The European chemical industry recognises the disconnect between the desire for a hazard-free environment and industry's focus on minimising risks and preventing harm related to chemicals, whether they are natural or synthetic.

We continue to invest in the development of products that address societal needs as well as in improved education and transparency on the safe use of chemicals and the products that contain them. We continue to improve our own knowledge and expertise about the health, safety and environmental impacts of our products and operations. We lead the development of advanced, intelligent safety testing strategies, new modelling tools and in-vitro technologies.

Artificial intelligence and quantum computing offer unprecedented potential to improve such tests. We continue to develop chemicals that transform our lives for the better, helping nourish and provide potable water for a growing population, and offer more sustainable solutions for mobility, to cite just two examples.

LET'S TALK ABOUT "SUBSTITUTION".

This word is often used outside the chemical industry to describe the regulatory phasing out of hazardous substances or even an entire class of chemicals in favour of substances perceived to be less harmful. In fact, substituting problematic substances is an innovation opportunity that the European chemical industry wholeheartedly embraces. Companies base their substitution decisions on objective criteria such as functional requirements, full safety and economic assessment of alternatives, life-cycle environmental impact analysis, scientific assessments of comparative real-world risks and economic impact assessments. Each of these elements is essential to avoid "regrettable substitution"⁴⁴.

The European chemical industry will continue to improve transparency about the presence of chemical substances in products and about our drive to promote their safe use. With due consideration to potential exposure, substitution of problematic substances by those with a lower impact on human health or the environment is and should remain a daily activity that contributes to better and safe products."

LET'S TALK ABOUT RISK MANAGEMENT.

We all manage risks in our daily lives. For the European chemical industry, managing risks is a key competence as essential as innovation. Performing an in-depth risk assessment, including consideration of potential mixture effects and exposure levels, followed by the appropriate risk management where needed, is part of the day-to-day activities of the chemical industry.

Once risks are identified, risk management measures need to be communicated, understood and implemented throughout the value chain to ensure that chemicals are used safely and as intended. Reducing exposure, reducing emissions, reviewing chemical uses critically and substituting as needed and as feasible are all routine risk management options.

We also work with governments and social partners to continue to reduce occupational exposure to chemicals. Managing chemical risks well is a top priority for the chemical industry.

Appeal #6: **Let's focus on chemical safety, innovation, transparency and education**

Chemistry provides the solutions that we use in the world today. Looking at the bigger picture, the chemical industry is an enabler of health and safety for a growing and ageing population. It improves access to sustainable and nutritious food, for example via micronutrients and vitamins. It provides new medicinal solutions that increase life expectancy. It helps reduce food waste through smart packaging and with antioxidants that keep food nutritious and safe. It also contributes to better animal nutrition.

Our industry manages the risk of those chemicals in manufacturing. It also aims, together with business partners in the value chain, authorities and society, to manage risks in use. The world of 2050 faces many new challenges for which new solutions and new chemistry are needed. Industry, governments and stakeholders will need to cooperate within the existing legal framework to enable this development.

The chemical industry will continue to provide the European Chemicals Agency and European Food Safety Authority with reliable safety data and will develop a framework to increase transparency of scientific evidence while protecting confidential business information and intellectual property rights, for example via greater use of blockchain technology. People need to know that they can find the safety information they want and that the presence of legacy and new chemicals in the environment is governed by clear and well enforced rules across their entire life cycle. Although it is hard to see today how animal testing could be fully replaced with alternatives, artificial intelligence (AI) may ultimately allow us to fully and reliably predict the safety profile of a chemical or of a mixture of chemicals, thereby enabling innovation at a greater pace, as well as help us better manage their impact on human health or the environment. For example, a combination of sensors and AI could help people deemed to be exposed better manage their exposure to chemicals.

As the European chemical industry develops new, innovative products and technologies, we will engage in a public debate on how to further make facts and evidence available in order to build greater confidence in chemicals.

We appeal to European policymakers to create a supportive framework for innovation. Horizon Europe and other EU R&D programmes should include more support for chemical substance innovation. For the future of our industry, we need an EU-wide dialogue among governments, the chemical industry and civil society to ensure that debates and decisions in an increasingly digital world are based on facts and scientific consensus. We need Europe to further strengthen reliance upon evidence-based risk assessments.

We still need full implementation of the UN's Globally Harmonised System⁴⁵ and beyond that, more international regulatory cooperation generally. For example, mutual recognition for substance-related data and risk assessments would help safeguard the principle of "one molecule, one safety message", especially in an increasingly digitalised world in which data are easily accessible everywhere⁴⁶.

CHEMISTRY PROVIDES THE SOLUTIONS THAT WE USE IN THE WORLD TODAY

In addition, EU member states need to step up enforcement of EU rules at the borders to prevent non-compliant substances and articles access to the EU market.

The chemical industry, Europe and international organisations need to help society better value the difference between hazards and risks and the benefits chemicals can provide, whether natural or synthetic. In cooperation with those organisations, for example via public-private partnerships, we need to actively re-connect with society on these issues, including via social media.

EUROPE AND ITS CHEMICAL INDUSTRY IN 2050

Going digital

Digitalisation has been described as the key to the 4th industrial revolution. Data mining and analysis, combined with artificial intelligence, promise better, faster decisions and greater efficiency in every sector by enabling processes such as sustainability modelling, predictive maintenance and digital services, along with whole new digital business models.

Digitalisation could unlock up to €550 billion⁴⁷ of value over the next few decades while enabling lower greenhouse gas emissions; lower injury rates; higher environment, health and safety standards and predictability; greater value chain transparency and improved public trust. While the digitalisation of operations and commercial functions might have the largest potential for immediate value creation, the acceleration of digitalisation into new business models, product development and collaborative innovation might eventually prove to be more disruptive over the next decades.

Blockchain and distributed ledgers (see also the Disruptive Technologies chapter in this report) promise a radical improvement in transparency and traceability of individual molecules throughout their life cycle. At the moment, Europe is already behind in critical technologies dominated by the US and China, while those regions and others also have an edge in science, technical, engineering and math education for the next generation.

With the right policy environment, the European chemical industry will invest in the frontier sciences of chemical computing and digital management. The sector also envisages open innovation projects to map, develop and expand the use of blockchain as a tool for transparency on chemicals across value chains and life cycles.

Appeal #7:

Support digitalisation and the 4th industrial revolution

The European chemical industry has started its own digital transformation, and developments in digitalisation will have a booster effect on transparency. A solid policy framework will still be needed to protect intellectual property rights and formulations for products. We need the right political framework to promote investment, deployment and entrepreneurship in some of the new technologies driving innovation including data mining, artificial intelligence, distributed ledger technology, with the highest possible cyber security. European authorities and the chemical industry need to work together to foster this transition.

We plan to invest in improved digital logistics and launch value chain outreach projects. In order to deploy the full potential of the digital revolution, Europe should build and strengthen its digital infrastructure. To develop artificial intelligence tools for improved chemical data management, the European Chemicals Agency (ECHA) could work with industry to promote a joint approach to chemical data in the context of global standards.

Data analytics is based on the premise the industry has access to affordable data sources. As data becomes an ever more important resource in the future, Europe needs to secure access to data in a global trade situation where the biggest data companies hark from the US or China.

To protect intellectual property across open data transactions and breakthrough technologies, Europe needs to complete the digital single market with effective data protection rules and develop a strong intellectual property (IP) framework for industrial data.

BLOCKCHAIN AND DISTRIBUTED LEDGERS (...) PROMISE A **RADICAL IMPROVEMENT IN TRANSPARENCY AND TRACEABILITY OF INDIVIDUAL MOLECULES** THROUGHOUT THEIR LIFE CYCLE

Working together

Civil society and social media are demanding greater transparency, accountability and sustainability from companies and governments alike. That requires an expanded dialogue between all stakeholders, including non-governmental organisations, to ensure a better mutual understanding that is a prerequisite to a smooth transition to a more sustainable future. We know that we can do more, better, faster, if we work together with government and civil society—as well as with other industries.

Today, the power, fuel, steel, chemicals and waste recycling sectors work largely independently of one another, sometimes for historical and geographical reasons. By mid-century, they will have largely integrated.

Our vision is to work towards the creation in Brussels of platforms for strategic dialogue between businesses, national governments, European policy makers, academia and civil society to embrace the cross-sectoral character of the 4th industrial revolution in the context of the UN SDGs. Such consensus-building platforms are critical to enabling agile, adaptable and acceptable solutions towards an ambitious, common vision. A successful transition can only be achieved by persistence, experimentation and cooperation. We envision permanent, transparent, cross-sectoral, technology-neutral and science- and facts-based dialogue that accelerates product optimisation and decision-making as well as socially acceptable solutions.

Appeal #8: Let's break down silos

Europe needs to fundamentally rethink the cooperation between academia and industry in order to better prepare education and life-long learning to meet the demand for future skills. As a growing industry that creates good jobs, the chemical sector will continue to create a steady demand for STEM trainees and employees with a focus on digital technologies and artificial intelligence⁴⁸. We will work together with governments and society to raise awareness of the potential benefits to society of recruiting top talent globally. We plan to develop an industry-wide inclusiveness agenda to boost diversity in the industry and thereby contribute to a more inclusive European society overall. Together, let's design policies for value chains, not individual sectors. If we scan the legal boundaries and obstructions to cross-industry collaborative projects, we can remove these boundaries in a new generation of regulatory proposals. Let's design an EU-wide approach to address critical skilled labour shortages, including efforts to attract workers from other regions.

LET'S DESIGN AN **EU-WIDE**
APPROACH TO ADDRESS
SKILLED LABOUR SHORTAGES

WORDS ARE IMPORTANT. SCIENCE IS CRITICAL. DIALOGUE IS ESSENTIAL.

Policy makers, industry and other stakeholders often speak different languages. Some words have already been embraced by society, while our industry, even when we agree on what the words mean, is fundamentally at odds with the way the words are used. For example, people sometimes talk about “decarbonisation.” We talk about “emission reductions” and “carbon productivity” because many products will always contain carbon, and industry will continue to use, produce and optimise the use of carbon molecules. Likewise, you will not find any references to a “non-toxic” environment in this report. Scientifically speaking, there is no such thing as zero toxicity. We talk about the “safe use of chemicals” and “risk management.” That is why we need to work harder to understand each other, using the right words, explaining what we mean without jargon.

CHEMICALS AT THE CENTRE OF TECHNOLOGICAL DISRUPTION

2020

2030

Chemical recycling of plastics (large scale demonstration) 2020-2022

CO₂ as feedstock for polymers (commercial scale) 2020-2025

Widespread, large scale valorisation of biowastes (eg Enerkem technology, Rotterdam) 2020-2025

Steel mill flue gas valorisation for chemicals 2020-2025

Large scale production of advanced materials for EV batteries 2020-2025

Recycling of CFR-Composites (e.g. wind blades) (large scale demonstration) 2020-2022

CO₂ valorisation with low carbon H₂ (large scale demonstration) 2025-2030

Large scale recycling of EV battery materials 2020-2025

Large scale demonstration of alternative route to H₂ 2025-2030

Some of what science can do today might have passed for magic as recently as 50 years ago. Converting sunlight into electricity. 3D “printing” entire buildings out of concrete and steel, or critical parts of air-crafts. Artificial joint implants. Self-healing materials. Drones. Flying cars.

Several technologies in development today will generate even more excitement tomorrow as they progress from the early, exploratory stage to fully commercial products. Some of them may even be lifesavers, such as technologies that can help mitigate epidemics and climate change.

Chemistry is an essential component of all existing and new technologies. The chemical industry delivers the products and materials that enable other sectors to innovate and produce new generations of products and solutions for consumers and businesses alike. Even as data becomes an increasingly valuable commodity, the chemical industry will continue to fulfil its essential mission to modern society by using new feedstocks and alternative energy sources (including renewable electricity) in completely re-designed production processes.

Two disruptive developments hold particular promise to help address some of society’s biggest challenges: 1) the recirculation of molecules across value chains; and 2) the exponential evolution of new business models based on digitalisation, including Big Data mining, AI and blockchain technology. We focus on those areas below, but also highlight some additional innovations in the “cool boxes”—examples of technologies that we think are exciting—that accompany this section.

2040

2050

Electrification of large chemical processes such as crackers 2030-2040

Artificial Photosynthesis from CO₂ and sunlight (large scale demonstration) 2040-2050

What if we could recycle everything?



Today, recycling is limited to a small number of goods and substances not only by technology, but also by cost and infrastructure. The two are linked. To be cost-effective, you need to recycle large volumes of the same material; and for that, you need a solid infrastructure for collecting the end-of-life products and substances and getting them to a recycling centre. As we've seen from reports about European waste being shipped to Africa and China, there's no point forcing everyone in Europe to sort their waste if there's no cost-effective, local way to recycle it. The further we have to transport things, the higher the CO₂ footprint of the whole process.

Recycling will be significantly more common in the future than it is today. In a 2017 report for Cefic, Accenture estimated that up to 60% of all molecules that the European chemical industry delivers to its customers—mainly plastics—can be recycled⁴⁹. Today the figure is just 10%⁵⁰.

The European chemical industry is increasingly involved in creating solutions for the entire life cycle of many products. As illustrated in the accompanying infographic on plastics in a circular economy, circularity could be based on:

- 1) Replacing linear and/or hard-to-re-use materials where possible
- 2) Redesign for ease of re-use or recycling
- 3) Renewable feedstocks, such as food waste and biomass
- 4) Re-use of products
- 5) Mechanical recycling, such as PET bottles
- 6) Chemical recycling to re-use molecules such as plastic automobile parts as new feedstocks; and
- 7) Energy recovery and re-use of CO₂ – most important for limiting the human impact on climate.



Artificial photosynthesis

Artificial photosynthesis is one the most promising research areas. It is a biomimetic chemical process in which energy from the sun is captured in chemical bonds or used to split molecules such as water (H₂O) into its constituent hydrogen and oxygen atoms. Researchers in Europe are also studying artificial photosynthesis as a way of sequestering atmospheric CO₂ and creating oxygen and energy-rich chemicals including biofuels⁵¹.

If you consider that the “photovoltaic effect” that is the basis for all the solar panels in the world today was only discovered in the 19th Century, it's not hard to imagine that we will soon be making clean fuels from air and sunlight⁵²!



Hydrogen and fuel cells

Hydrogen will play an important role in the transition to low carbon electricity and low carbon industrial processes. It can be used to store and transport renewable electricity. Although water electrolysis is often mentioned as a means of producing hydrogen, there are alternatives, including methane pyrolysis – producing elemental carbon next to hydrogen – and methane reforming coupled with carbon capture and storage. Hydrogen has potential uses not just in fuel cells for clean-burning transportation but also for chemical and steel production.

Self-healing polymers

Imagine a plastic that, when cracked, re-seals the crack⁵⁷. Self-healing polymers may provide the solution. These are smart materials that essentially repair themselves in response to a stimulus such as a crack, pressure or current⁵⁸. Similarly, self-healing cement and other construction materials can prolong the lives of buildings, bridges and critical infrastructure by decades or more. Self-healing lithium-ion batteries could prolong the lives of electric cars and even smartphones⁵⁹. All these examples, which depend on advanced chemistry, are currently being developed in laboratories today.



3D printing

Born in design labs to make precision prototypes, three-dimensional printing is rapidly becoming an alternative to traditional construction of everything from spare parts to bridges and buildings. The technology allows bespoke “printing” using almost any substance, including polymers, metals, cement and even cellular tissue for organ transplants. Customisation is one of the main attractions of 3D printing because it allows the client to add features for individual products that wouldn’t be feasible in mass manufacturing. The potential implications are huge: on-site printing of bespoke products can reduce demand for materials and labour and eliminate much of the energy-intensive distribution of centrally produced products.

CO₂—the ultimate feedstock

CO₂ may well be the ultimate feedstock for the chemical industry and play an important role in the feedstock mix of the future. Carbon remains an essential element of most chemical products and of a large variety of products from food to materials, in addition to being a basic building block of life. Every tonne of CO₂ we can recycle represents gases that don’t contribute to the greenhouse effect and carbon that doesn’t need to be dug or pumped out of the ground. Several different chemical processes⁵³ can take CO₂ captured at the point of emission and convert it into other valuable molecules including methanol, organic acids, aspirin,

solvents, detergents and cosmetics. A few demonstration plants have even already been built in Europe that convert CO₂ into high-quality plastics⁵⁴ and convert CO₂ into methanol⁵⁵. The key to transforming CO₂ without emitting more greenhouse gases is to use advanced catalytic processes and low-carbon energy sources. The same holds true for the circular economy in general: If Europe needs to burn fossil fuels to power energy-hungry collection, sorting, cleaning and recycling processes, it will end up emitting more CO₂, not less. The only way to make circularity carbon-neutral and resource efficient is to power it all with carbon-neutral

power sources. The scale of the challenge is enormous: according to quantitative research by DECHEMA⁵⁶, the chemical industry would require an additional amount of renewable power equivalent to 3.5 times Germany’s current total electricity supply in order to reduce its emissions by about 100 million tonnes of CO₂ per year. For comparison’s sake, the industry’s greenhouse gas emissions in 2015 were the equivalent of 128 million tonnes of CO₂.

Pushing boundaries with new materials

New materials are the key to many of the coolest innovations today. For example, the biggest waste of energy in most forms of transportation is hauling around heavy steel and aluminium and other structural elements. Lighten the load, and you dramatically reduce the amount of energy needed to move it. Without lightweight materials, super-efficient electric vehicles and drones would not be possible. New materials can also enable unique insulation opportunities, recycling by design and flexible displays, wearable or foldable screens⁶⁰ and artificial limbs, joints and organs—to name just a few applications.



Artificial intelligence

AI promises to relieve people from routine tasks and to promote better decision-making. The investment is already huge. In all, according to the European Commission, private industry invested more than €30 billion in AI around the world in 2016 alone. For the European chemical industry, AI can make industrial processes safer and cleaner and help invent new molecules for specific objectives, including increased circularity. Precision agriculture powered by Big Data, meanwhile, can pinpoint the exact, optimum level of fertilisers and crop protection products needed for every individual square meter of a field, eliminating excess ploughing and application of agrochemicals.

Advanced Analytics and the Internet of Things (IOT), combined with the additions of millions of sensors and AI (i.e. machine learning, neural networks, etc.) into all aspects of operations (descriptive, predictive and prescriptive), are poised to boost productivity, energy efficiency, emissions reductions and overall environment, health and safety metrics, including circularity. It will also support and enhance traceability, predictive maintenance and workplace safety, for instance using sophisticated robots and drones in complex turnaround operations and confined spaces.

Going Digital

Digitalisation is expected to drive transformational change across all industries, ushering in new, more efficient ways of delivering products and services across the entire business model, from sourcing to production and sales and after-sales service and recycling.

In the chemical industry, digital technologies such as data mining and automated data analysis will make manufacturing plants and operations more resource and energy efficient, contributing to CO₂ emission reductions. This in turn will make a major contribution to the achievement of Europe's long-term policy goals. Digital technologies can be implemented in enhanced production processes, in improved management systems (e.g. data-based plant operation and monitoring) and in new digitally-enabled supply chain structures (e.g. sharing & recycling platforms). In addition, the chemical industry is developing new business models such as chemical leasing based on data-based services.

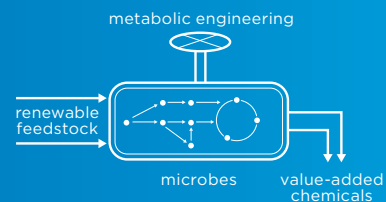
End-to-end process digitalisation, first within a chemical site, then across entire firms and ultimately across the whole value chain, is poised to deliver greater customer satisfaction and value creation.

Industrial Biotechnology

Biotechnology offers many opportunities to apply life sciences to chemical synthesis and has made significant advances in recent years. Imagine a future in which colonies of genetically engineered bacteria will become new chemical factories that can be programmed to produce a range of products from bulk chemicals and biofuels to pharmaceuticals and nutraceuticals.

The concept of metabolic engineering is at the heart of advancements in this field. Metabolic pathways can be compared with production lines in which enzymes are used to assemble specific products. Advances in computational technology, protein science and genetic modification tools enable the safe, efficient and sustainable production of chemicals and fuels⁶¹.

In a recent study, scientists reported on the optimisation of biosynthetic pathways⁶² that promise accelerated



production of chemicals as well as a significant increase in production output while relying on evolution to naturally eliminate under-performing cells. Other recent research even focused on designing a 'translator' that could allow different communities of bacteria to communicate with each other (quorum sensing mechanism deployment)⁶³.

This breakthrough could unlock the engineering of new complex systems, with multiple bacteria coordinating their activity to carry out a number of complex tasks and processes to produce from chemicals to composite biomaterials⁶⁴.



Blockchain and distributed ledgers

Blockchain can be every bit as revolutionary as AI. Blockchain is a digital, distributed ledger technology used to verify transactions and contracts without the need for middlemen such as financial institutions. The technology offers several potential benefits to the chemical industry by increasing traceability, safety and security and improving compliance while lowering transaction costs.

For example, European regulations requiring the tracking of chemicals are currently limited by complex paper trails that can be broken as a substance moves from producer to consumer. Blockchain could allow secure, tamper-proof transmission of all relevant data, including the complete molecular composition of every substance in a product, throughout its life-cycle, facilitating better risk management and end-of-life recycling. That, in turn, could facilitate the spread of circular business models such as chemical leasing and services.

WHAT IF... OUR WORLD CONTINUES TO FRAGMENT?¹⁴

The end of the 20th Century marked the peak of global economic integration.

Climate change, non-tariff barriers, export restrictions and then all-out trade wars disrupted supply chains and investment strategies even before the World Trade Organisation was dismantled, Brexit reversed decades of closer integration within Europe and climate change sparked an unprecedented number of droughts, storms and famines that led to wars and mass migrations. Some countries' response was to scrap global trade and immigration pacts altogether, worsening the problem for everyone. In Europe, a core group of countries continued to integrate economically, politically and socially while another group, mostly along the EU's external borders, splintered away. Pretty much the only thing everyone still agreed on was the need to continue decarbonising their economies for the sake of the planet.



An increasingly fragmented world is the undesirable dark side of a 2050 with its super-smart markets and super-circular, low-carbon economy.

Even as technology and climate-smart policies might transform Europe into a clean-tech powerhouse, the EU and national governments may continue to struggle with the centrifugal forces of nationalism, populism and protectionism. Businesses that used to bank on the free movement of goods, services, capital and people would be left scrambling to find ways to survive with less.

An avant-garde of integration-minded European member states could continue to integrate by fits and starts while other member-states could turn further inward. Years if not decades could go by before EU carrots and sticks reverse the trend.

The hard-core EU states might do a good job integrating legal migrants into their healthy economies, reversing decades of demographic stagnation and social cost inflation in countries that account for more than two-thirds of Europe's economic output. The availability of more skilled labour would help accelerate the construction of a Great Clean Power Grid and other new infrastructure projects and increase those countries' agricultural self-sufficiency.

THE END OF THE 20TH CENTURY MARKED THE PEAK FOR GLOBAL ECONOMIC INTEGRATION

The price for that progress, however, would likely be restricting free movement of some goods and people with their neighbours until all countries agreed to stronger pan-European policies on immigration and other matters.

European leaders face a number of urgent questions, including:

How can Europe better promote global free and fair trade in the face of growing public scepticism?

How could **better industrial policies** help Europe mitigate and/or reverse the trend toward growing economic nationalism?

How can Europe work more closely with Africa to create a hemispheric economic area that leverages the strengths of both regions for mutually beneficial synergies?

TIME TO ACT!

As you have read, the European chemical industry in 2050 will be at the heart of the circular and climate-neutral economy — a daunting responsibility.

The goal of this report is not to paint a one-off picture of our future. The goal is to engage you in dialogue and travel this journey together. We will reach out, listen and adapt this paper in a few years again.

It will be an exciting journey.

Throughout this report, we have sought to project a grounded assessment and an upbeat narrative of what is achievable by 2050 —for the European chemical industry, for society, and for the planet as a whole. We firmly believe that everything we have described is at least possible, and often quite probable. As the industry that manages many of the materials and processes on which our society depends, we can do a lot on our own even if the world changes around us. We can do a lot more—and stand a better chance of helping to meet our common objectives—if we all work toward those objectives together.

The achievement of the UN's Sustainable Development Goals, especially in the mitigation and adaptation related to climate change, require an unprecedented mobilisation of investment funds and society as well as every sector of the European economy. They have implications for everything from energy supply to development aid and immigration policies, all of which need to reinforce one another toward a common goal of a just transition toward a more sustainable future.

With the right political alignment and support, the European chemical industry stands ready to do its part, investing in new technologies and molecules, restructuring, providing good jobs, embracing greater transparency on chemicals throughout their life cycle and recycling valuable raw materials at products' end of life.

In order to navigate a world reshaped by geopolitics, demographic trends, climate change and other megatrends, the four fictional “Facets of the Future” included in this report can help shape the debate.

WE FIRMLY BELIEVE THAT
**EVERYTHING WE HAVE
DESCRIBED IS AT LEAST
POSSIBLE, AND OFTEN
QUITE PROBABLE**

We need European governments and regulators to fully embrace the goals of carbon neutrality, ensure a socially fair transition for the people most affected by the changes, and to help accelerate the transformation by doing the things that we can't.

We look forward to discussing this report with both policymakers and society.

ANNEXES



Annex 1:

Key assumptions

This vision is based on a number of initial assumptions—many related to megatrends described earlier—that were identified, tested, tweaked and Delphi-tested⁶⁵ for more than a year on their path toward the operating assumptions described below. The complete process is described in greater detail in the Methodology section.

Our assumptions fall into five categories: economic, geopolitical, societal, technological and environmental. We summarise each of them briefly below and indicate the areas—there were only four of them—where divergent results from the Delphi panel forced us to revise our initial assumptions.

Economic:

- **The global economic balance shifts as China gains importance and new growth comes from India and Africa.** China continues transforming from an economy led by investment and exports to one driven by imports and consumption. India struggles with its transformation, while Africa's growth potential is challenged by overreliance on natural resources and inefficient institutions. Trade regionalisation is increasingly likely. *(The Delphi report, on which this report is based, was slightly more pessimistic about the prospects of India than the original CIFS study).*
- **The 4th industrial revolution affects trade in goods and moves production closer to consumption.** Global trade in primary goods increases at the expense of intermediate and finished goods. For the chemical industry, this may mean finished goods become more important in domestic and regional markets, and (possibly) decline in overseas exports. Likely exceptions are top-competitive, unique European products that are not matched by global competitors.
- **Protectionism continues to hamper trade and subdue growth through tariffs and non-tariff barriers.** Non-tariff barriers – mostly imposed by high-income countries – significantly impede global trade (since the 2008 crisis, they have caused more than 15% of the global trade slowdown). Key instruments are currency manipulation, subsidies and state aid such as state loans, bailouts, and “buy-local” public procurement requirements.
- **Digital technology advances drive cost deflation.** Digitalisation advances continue to deflate costs in many areas of the economy, due to lower production and distribution expenses and better insight on consumer needs. In Europe, this means new business models emerge in fast-moving tech markets, conducive to growth in small and medium sized enterprises and in partnerships with multinational companies.
- **The regulatory environment shapes competitiveness.** In 2050, the leading companies provide significantly greater transparency on the different molecules in their products and focus on the environment and labour conditions, primarily driven by consumer demand. Europe's regulatory environment drives the chemical industry in Europe to be first movers, in some cases gaining a competitive edge on other regions. *(The European chemical industry participants in the Delphi panel, which included political actors, were less optimistic than the panel as a whole concerning the net benefits of regulation for the competitiveness of the European chemical industry.)*
- **Efficiency driven by automation supplants 50-60% of manually intensive jobs by 2050⁶⁶.** Redeployment is key to solving these massive changes to the workforce. And while history shows that this scale of redeployment is possible, as when industry displaced agricultural manual labour, automation may change the rules of the employment game, especially for low-skilled workers.
- **Network effects characterise the global economy.** Individual consumers' participation in the global economy via digital business models become increasingly cost-effective. The economy is increasingly based on business models driven by distributed ledger technology such as blockchain, which toward 2050 will deliver many different solutions that benefit users.
- **The circular economy grows.** Circular economic models grow in prominence within industry. They are driven in part by innovations in digitalisation of industry, with artificial intelligence increasing industry-wide integration.

Geopolitics:

- **Geopolitics will shape the business environment for chemical industries globally.** The chemical industry needs a strong EU to ensure a coordinated, competitive energy policy, regulatory stability and consistency, open markets and continued access to skills and people mobility. Not only do these ensure a strong internal market, but also pave the way for equal access to markets and resources in Asia, Africa and the Americas. *(The Delphi panel expressed uncertainty about the EU's further integration as a political, economic and social union.)*
- **Four major regional powers protect their own spheres.** China, the United States, Europe and India are the four key regional powers by 2050, each protecting its own sphere of influence. No sole guarantor of the international economic and political order exists. Regulatory frameworks and harmonisation across regions require significant effort and mutual benefits to succeed.
- **Competition over access to critical resources (energy, materials, food, water, etc.) raises diplomatic and geopolitical stakes for some, while increasing the leverage for others.** Development of alternative material technologies and enhanced input reuse can help mitigate frictions by reducing industry and consumer dependence on scarce resources.
- **Greater focus on sustainability supports tighter regulatory standards and spurs innovation, such as bio-based and flexible feedstock.** The evolving geopolitical environment is conducive to technology being deployed for recovering and reusing materials, as well as to limiting use of raw materials and bringing production systems closer to a circular economy. This creates an opportunity for the chemical industry to establish alternative materials manufacturing and to reduce its own and consumers' reliance on scarce raw materials.

Society:

- **Demographic transition tracks globally.** Economic development, a growing middle class, technological advances and better opportunities for women all transform societies. Together, they promote low birth rates and long life expectancies.
- **Support to STEM (Science, technology, engineering and mathematics).** Concerns that Europe lacks an adequate supply of STEM skills is mitigated by a strong focus on increasing the supply of STEM graduates and attracting more STEM professionals from abroad.

- **Peer-to-peer networks.** Technological development creates a strong role for peer-to-peer networks, permitting freedom from ownership via short-term rental models through third-party, digital platforms enabled by blockchain technology. Crowd-funding of new digital platforms accelerates their formation and usage.
- **Autonomous and shared vehicles are accepted by consumers and legislators.** By 2040, more than 50% of new cars sold are expected to be at least level 4 autonomous (level 5 is fully autonomous). The implications for the chemical industry are that increased utilisation decreases the volume of cars produced and sold. This is partly off-set by an increase in electric vehicles' share in the global car fleet, which in turn increases demand for materials for the lithium-ion batteries that are vital for the electric car.

Technology:

- **The chemical industry reduces its greenhouse gas emissions by a further 50% compared with today's (2015) levels** through a combination of feedstock shift toward renewables, introduction of recycling processes and a switch to low-carbon electricity for processes and synthesis, opening the door to a massive transformation of European industry.
- **Biomass is an important raw material source for the industry and continues to be explored as a sustainable solution.** Industry potentially uses twice as much biomass in 2050 as in 2018.
- **The capacity continuously expands to generate low-carbon electricity in large amounts and at affordable prices.** This is generated from renewable energy sources as well as nuclear energy. The European energy sector expands its low-carbon electricity production to a level of over 3000 Twh in Europe (as foreseen in IEA, 2-degrees scenario). Low-carbon electricity is in high demand across industries, as well as in the transportation and housing sectors.
- **Electrified conversion** of CO₂, CO and H₂-based synthesis to methanol and other chemicals is scaled up to industrial levels in the 2050s.
- **Industrial symbiosis enables access to end-of-pipe CO₂ and CO emissions for chemical synthesis in 2050.** These gases are sourced from other industries, such as steel manufacturing, cement production and power plants burning waste, coal and natural gas.

- **Production volume growth of the European chemical industry from 2018 to 2050 is comparatively low** but strong value growth will take place in specialty chemicals.
- **Substantial amounts of chemicals are recycled** through a combination of product reuse, mechanical recycling, chemical recycling or combustion with subsequent recovery of energy and CO₂.
- **Digital technologies such as blockchain are used widely in industry** to manage and document transactions in the circular business models.
- **Chemical leasing and service models become widespread.** Blockchain transaction volumes and speed will be high, due to more-powerful computers in 2050. Digital transactions supported by blockchain will rely on industry standards and the presence of a single digital market in the European Union.
- **Technology development is essential for the chemical industry to grow, compete and reduce its GHG emissions.** Several technologies shape the future of the industry. Examples include next generation nuclear fission reactors, thorium reactors, fusion reactors, superfast computing, quantum computing, 2D materials (graphene, fullerene, etc.), genome editing, artificial intelligence and additive manufacturing.
- **A long-term focus on harmonising policies to reduce greenhouse gas (GHG) emissions.** The European Commission and national governments push for homogenous and harmonised GHG policies.
- **Sustainable finance legislation supports investment in reducing emissions.** The EU ensures that sustainable finance legislation supports investments in carbon productivity and recycling, as well as in commercialising circular economy practices.
- **Climate change and environmental challenges fuel social unrest.** Environmental degradation as a result of climate change, pollution and inadequate land management, exacerbated by basic resource scarcity, fuels social tension and unrest, potentially leading to increased immigration to Europe.
- **Environmental issues stay high on the agenda.** European initiatives to reduce pollutants intensify over coming decades, including a focus on reducing plastic waste. Similarly, the debate over the environmental impact of chemical products persists, presenting a changing and challenging regulatory framework for the chemical industry.
- **Pollution and waste remain sources of public concern.** Environmental pollution, especially through plastic waste, challenges freshwater, maritime and terrestrial ecosystems alike. It requires significant effort from the public and private sectors not only to limit new waste but also to address the old waste already accumulated.

Environment:

- **The EU remains a leader in sustainability, emissions/pollution reduction, renewable energy and recycling technologies.**
- **Climate change increases average temperatures by more than 1.5 degrees Celsius.** Savings on emissions from renewable technologies, nuclear power, and increased efficiency are not deployed widely enough to keep temperatures in control. (The Delphi panel was less optimistic about the prospects of staying below the 2-degree threshold than chemical industry participants.)
- **CO₂ prices in Europe continue to climb and reach a level of up to €100 per tonne in 2050 in real terms and possibly more if regulators set such price globally.** High prices are crucial to offset the economic gap between fossil chemical routes and new low-carbon synthesis processes.

Annex 2:

Endnotes

- 1 Delphi study report on The European Chemical Industry in a 2050 Perspective, 2018.
- 2 VUB chemical value chain study (see Figure 1).
- 3 The global chemical industry: An Enabler for growth – a report commissioned by ICCA in February 2019.
- 4 Cefic Facts & Figures 2018.
- 5 Eurostat.
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- 7 Cefic Facts & Figures 2018.
- 8 Cefic forecast based on Delphi study. (tier 1 and 2 emissions).
- 9 Delphi study report on The European Chemical Industry in a 2050 Perspective, 2018.
- 10 Feri Chemdata.
- 11 EU Commission Report, “Cumulative Cost Assessment (CCA) for the EU Chemical Industry” (11 July 2016).
- 12 Cefic Facts & Figures 2018.
- 13 IEA World Energy Outlook 2018.
- 14 Please note that the four Facets of the Future in this report are fictional possible futures included to provide challenging perspectives for public debate, not Cefic’s predictions for the future. They were the result of an extensive foresighting exercise described in the Methodology section.
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- 16 http://www.un.org/en/development/desa/population/events/pdf/other/21/21June_FINAL%20PRESS%20RELEASE_WPP17.pdf
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- 34 Cefic Facts & Figures 2018
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- 36 <http://www.riskforum.eu/innovation-principle.html> and <https://www.consilium.europa.eu/en/press/press-releases/2016/05/26/conclusions-better-regulation/>
- 37 Consistent with the European Commission scenario of the future #3 of the Commission Reflection Paper “Towards a sustainable Europe by 2030” issued on January 2019.
- 38 Coherent with UNEP Global Chemicals Outlook 2019/ UNEP/EA.4/21- “From Legacies to Innovative Solutions – Implementing the 2030 Agenda for Sustainable Development”- summary to Policy Makers finding #9.
- 39 <https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html>
- 40 We support the Global Alliance to End Plastic Waste- 2019 global campaign and the Circular Plastics Alliance led by DG GROW.

- 41 As defined in Cefic's position on the interface between chemical, product and waste legislation and identification of policy options, accessible at: <https://cefic.org/app/uploads/2018/10/Interface-btw-chemical-product-waste-legislation.pdf>
- 42 DECHEMA Technology Study on Low carbon energy and feedstock for the European chemical industry.
- 43 Eurobarometer 468, Oct. 2017.
- 44 The ultimate decision to substitute one substance for another is for each company to make on an individual basis and according to their own decision-making process, in compliance with competition law.
- 45 Coherent with UNEP Global Chemicals Outlook 2019- UNEP/EA.4/21- "From Legacies to Innovative Solutions - Implementing the 2030 Agenda for Sustainable Development"- summary to Policy Makers finding #5, #6 and #7.
- 46 This would contribute to solve the knowledge gap identified as Finding #10 in the UNEP Global Chemicals Outlook 2019-UNEP/EA.4/21-"From Legacies to Innovative Solutions - Implementing the 2030 Agenda for Sustainable Development"- summary to Policy Makers.
- 47 World Economic Forum, Digital Transformation in Chemicals and Advance Materials.
- 48 In line with the European Commission Reflection paper "Towards a sustainable Europe in 2030" - Jan 2019.
- 49 The report assumed that sufficient and cost-competitive energy is accessible, the necessary logistics infrastructure is in place, and abundant capital is available for the necessary investments.
- 50 Material Economics report.
- 51 <http://www.a-leaf.eu/project/>
- 52 <http://www.rsc.org/learn-chemistry/resource/res00001143/solar-fuels-and-artificial-photosynthesis?cmpid=CMPO0002252#!:cmpid=CMPO0002179>
- 53 Thermochemical, photochemical, electrochemical, biochemical or catalytic.
- 54 <https://www.covestro.de/en/projects-and-cooperations/co2-project>
- 55 <https://www.chemicals-technology.com/projects/george-olah-renewable-methanol-plant-iceland/>
- 56 DECHEMA Technology Study on Low carbon energy and feedstock for the European chemical industry.
- 57 <https://www.self-healingmaterials.com/self-healing-plastic/>
- 58 <http://www.vub.ac.be/MACH/FYSC/topics/self-healing-polymers>
- 59 <https://omnexus.specialchem.com/news/industry-news/acs-self-healing-polymeric-material-000188209>
- 60 <https://ihsmarkit.com/research-analysis/q22-flexible-displays-throwing-a-technology-curve.html>
- 61 Some successful examples include the production of 1,3-propanediol in *Escherichia coli* and engineering *saccharomyces cerevisiae* for the production of antimalarial drug precursor artemisinic acid.
- 62 <https://doi.org/10.1073/pnas.1409523111>
- 63 <https://www.nature.com/articles/s41467-018-05046-2>
- 64 <https://onlinelibrary.wiley.com/doi/abs/10.1002/biot.201500106>
- 65 Delphi study report on The European Chemical Industry in a 2050 Perspective, 2018. <https://cefic.org/library-item/delphi-study-report-the-european-chemical-industry-in-a-2050-perspective>
- 66 CIFS/Delphi.

Annex 3:

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On behalf of the Cefic Board,

Daniele Ferrari.

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