SUSTAINABLE CHEMISTRY FOR CLIMATE PROTECTION

Photo:®BASF

1. The way we produce and use chemicals is key for tackling climate change

Beyond their omnipresence in our daily lives, chemical products and substances constitute the basis of modern-day manufacturing activities. The chemical industry is a major economic player that produces different supplies for over 95 per cent of all industrial sectors. A point that is commonly overlooked, however, is that this industry is also pivotal to tackling one of the most paramount challenges of our times: climate change. Apart from finding solutions to reduce its own high share of greenhouse gas (GHG) emissions, the chemical industry has huge potential for contributing to climate protection across other sectors by providing innovative solutions.

Within the framework of the International Climate Initiative (IKI)[1], the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) funds a project titled the Climate Action Programme for the Chemical Industry (CAPCI). This initiative supports selected developing countries and emerging economies[2] by providing knowledge, information and action-oriented capacity-building measures related to chemistry and climate change, placing specific focus on sustainable as well as realistic mitigation pathways. Apart from having special knowledge and capacity development needs on this issue, developing countries and emerging economies are accounting for a growing share of global chemicals production as well as consumption.

Photo: Mika Baumeister, unsplash.com

1: Internationale Klimaschutz Initiative (IKI) https://www.international-climate-initiative.com/?a=login&c=index&dosubmit=1&m=admin&cHash=e12753e17359ba5e7c0ca55434a786c2
2: Developing countries have growing economies as well as a growing number of consumers. Developing economies and emerging markets are expected to continue growing relatively fast, given their growing labour force and expanding market potential. https://knowledge4policy.ec.europa.eu/foresight/topic/growing-consumerism/developing-countries-emerging-markets_en

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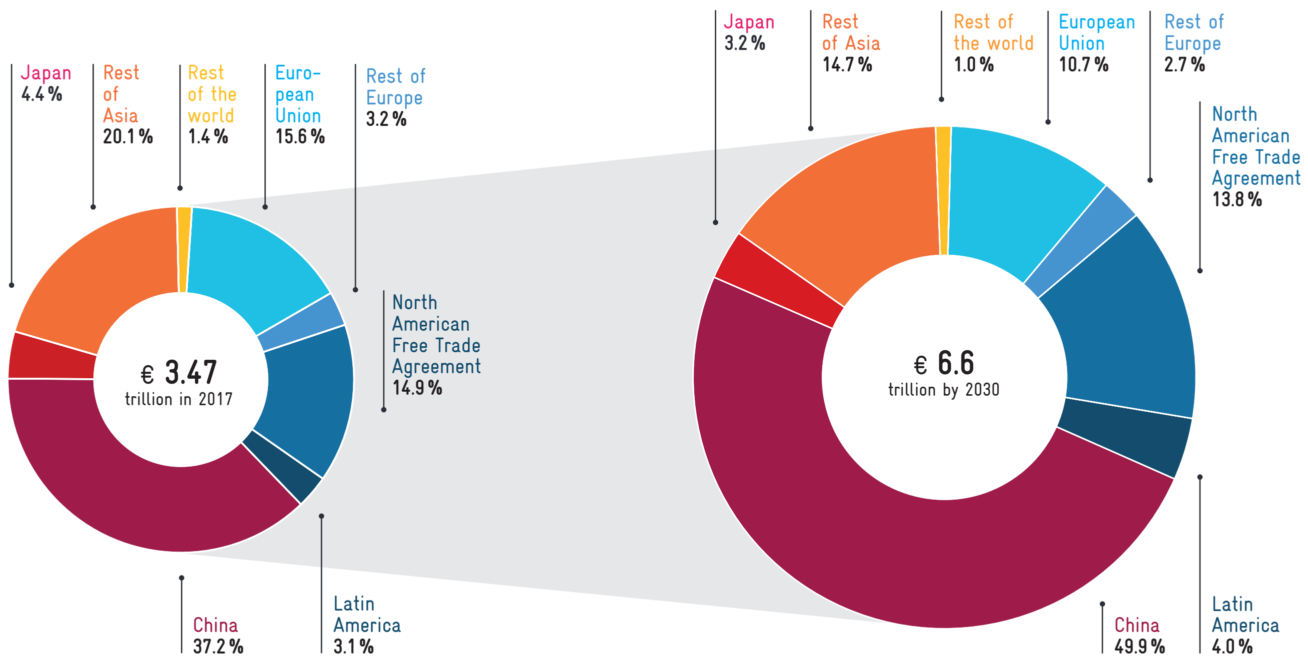
GLOBAL CHEMICALS PRODUCTION CONTINUES TO GROW

The production of chemicals worldwide is on the rise. Between 2000 and 2017, the global production capacity of this industry nearly doubled, from 1.2 to 2.3 billion tonnes of chemicals and chemical products (UNEP 2019)[3]. With global sales totalling 5.68 trillion USD in 2017 (including pharmaceuticals), the chemical industry constitutes the world's second-largest industry sector. Sales are projected to double once again between 2017 and 2030 (see Figure 1, excluding pharmaceuticals). Projected growth is highest in Asia, with China estimated to account for almost 50 per cent of global chemicals sales by 2030 (UNEP 2019).

An increasing share of chemical production is taking place in developing countries and transition economies. High growth rates are not only expected to occur in Asia and the Pacific but also across Africa and the Middle East (Figure 1). As chemicals production increases, GHG emissions will rise in parallel unless major mitigation efforts are undertaken and advances made in resource efficiency.

Figure 1:
Projected sales volume growth of the chemical industry by 2030 (in euro, excluding pharmaceuticals) (UNEP 2019 adapted from CEFIC 2018)



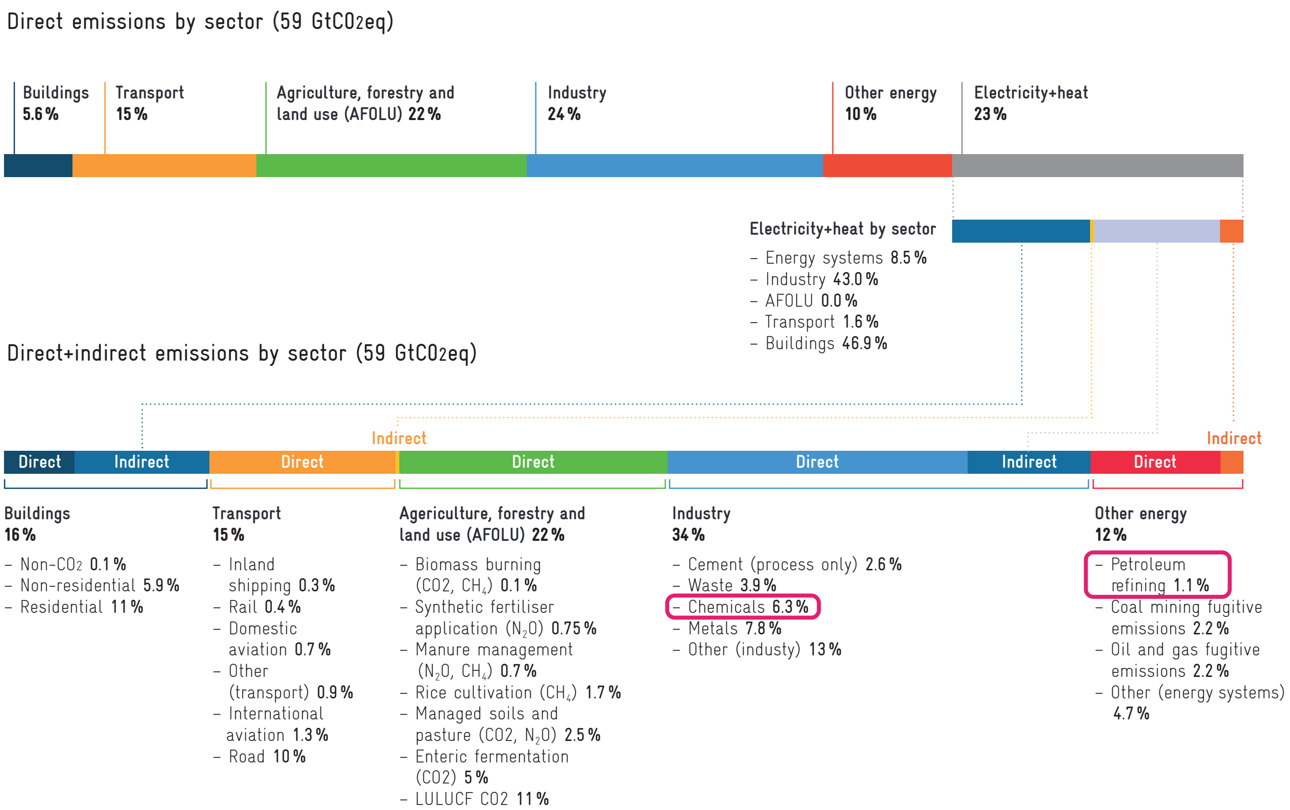
3: United Nations Environment Programme (2019) Global Chemicals Outlook II. https://www.unep.org/resources/report/global-chemicals-outlook-ii-legacies-innovative-solutions

GHG EMISSIONS FROM THE CHEMICAL INDUSTRY

According to the Intergovernmental Panel on Climate Change (IPCC), global GHG emissions amounted to 59 gigatonnes of CO2 equivalent in 2019. Given this number, the current commitment levels encompassed within the Nationally Determined Contributions (NDCs) of the signatory countries will not be sufficient for achieving the objectives set out in the Paris Agreement. Rather than keeping global warming below 1.5° C (or at least 'well below 2° C'), the current commitment levels are on track to result in a 2.4–2.6° C rise in global temperatures by the end of the century (considering conditional and unconditional pledges, respectively). This makes additional efforts imperative in order to close the 'ambition gap'.

GHG emissions from industry, which include those generated from chemicals production and use, have risen faster than emissions across all other sectors since 2000 (IPCC 2022[4]). These emissions primarily arise from fossil fuel combustion, production processes, product use and waste. In 2019, industry accounted for 14.1 gigatonnes of CO2 equivalent or 24 per cent of all direct anthropogenic emissions (IPCC 2022), second only to the energy supply sector. When we include indirect emissions from purchased power, steam, heat and cooling, industry is the leading GHG emitter, responsible for 20 gigatonnes of CO2 equivalent or 34 per cent of global emissions in 2019 (see Figure 2).

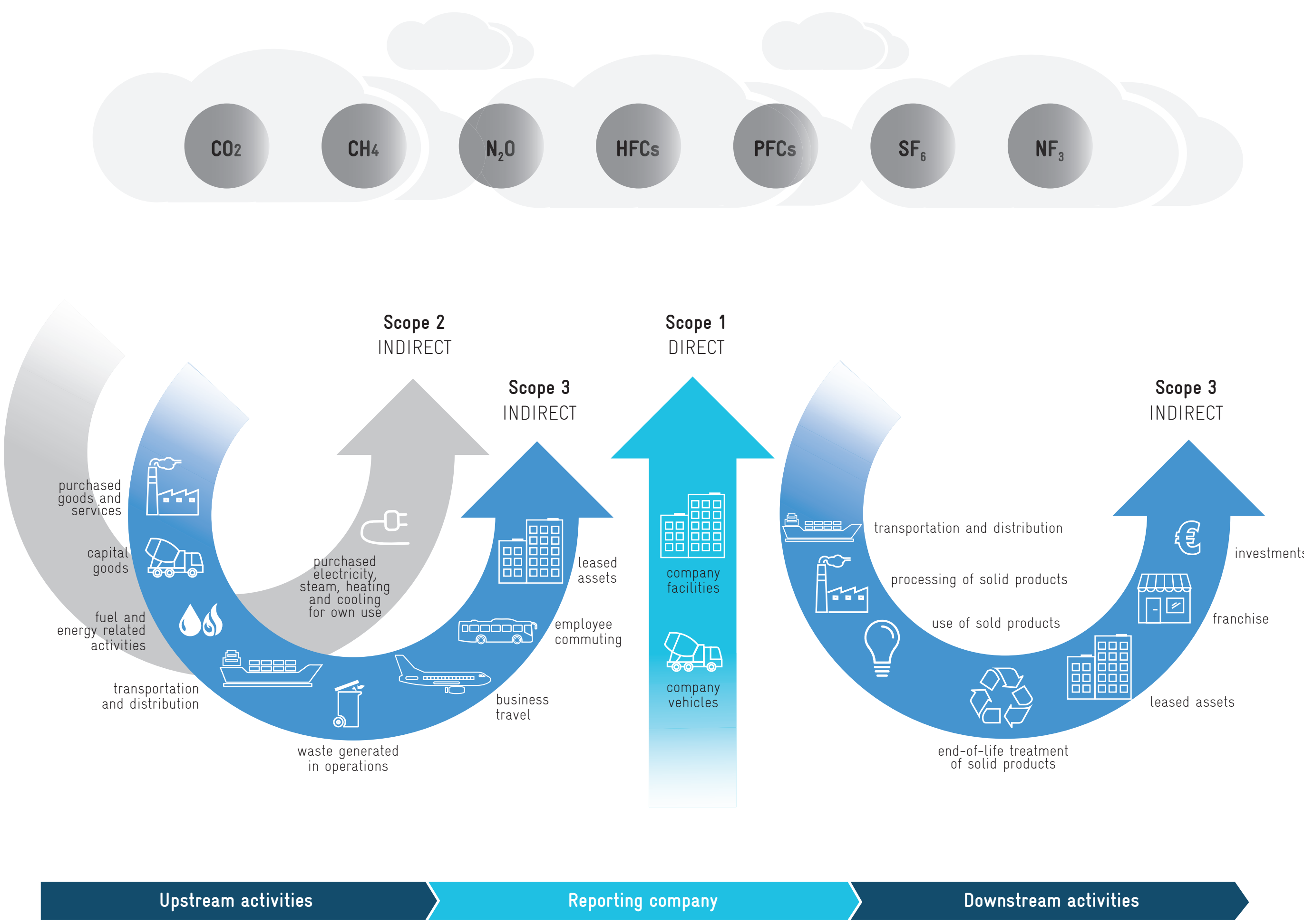
Figure 2:
Contribution to total GHG emissions (direct and indirect) by sector and sub-sector in 2019 (IPCC 2022)



4: Intergovernmental Panel on Climate Change (2022 b) Working Group III contribution to the Sixth Assessment Report of the IPCC, full report. https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Full_Report.pdf

According to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2022), when considering emissions directly controlled by companies (scope 1) as well as those associated with purchased electricity, heat, steam or cooling (scope 2), the chemical and petrochemical industry account for 7.4 per cent of GHG emissions. One factor underlying this considerable contribution is the sector's high energy demand, particularly the extensive and continued use of fossil hydrocarbons as an energy source. This makes the chemical and petrochemical sector responsible for around 10 per cent of global energy demand and constitutes the main reason for the high GHG emissions (scopes 1 and 2) of the sector. When including emissions along the value chain (scope 3), the sector's importance for climate protection proves to be even higher: scope 3 emissions (Figure 3) occur upstream, such as through the extraction and transport of raw materials and feedstocks, as well as downstream, such as from substances with high global warming potential. The latter includes fluorine-containing substances such as so-called F-gases, which still see widespread use for cooling and foam-blowing.

Figure 3:
Overview of the scopes, sources and types of greenhouse gases (GHG) considered by the Greenhouse Gas Protocol
(source: https://ghgprotocol.org)



THE INNOVATIVE POWER HELD BY THE CHEMICAL INDUSTRY

While the chemical industry is one of the top-three industrial sectors in terms of greenhouse gas emissions along with cement and steel, it also represents a major source of innovative solutions and materials for reducing GHG in other sectors such as energy and transport. Tapping into the potential of the chemical industry to advance mitigation efforts and provide low-emission technologies holds significant possibilities for tackling climate change in general.

Chemical parks are one such promising area with the potential to improve energy and resource efficiency while reducing GHG emissions. This approach promotes joint low-carbon infrastructure and linkages between different chemical plants housed within a certain industrial area. Operating on the concept of **Verbundstandorte**[5], industrial parks offer excellent opportunities for implementing circular economy solutions and piloting innovative technologies, such as green hydrogen and Power-to-X (P2X).

Achieving a climate-friendly transformation in the chemical industry will demand significant innovation efforts as well as unprecedented levels of long-term investment into new technology. One barrier we see to this today, however, is an overarching lack of awareness related to the importance of the chemical industry and the potential it holds along with capacity gaps. Effecting real change requires knowledge, qualified professionals and sensitised decision-makers across the public, private and academic sectors. This implies that developing countries and emerging economies need to strengthen their technical, scientific, managerial and political capacities in order to successfully compete in the market and tackle climate change while concurrently improving their abilities for environmental and resource management.

Photo: BASF Ludwigshafen, ©BASF SE

5: CAPCI Factsheet: Verbundstandorte, https://www.isc3.org/cms/wp-content/uploads/2023/01/Factsheet_Verbund_060123.pdf

2. Sustainable chemistry: A new paradigm for chemicals production and use

From science, research and development to processing, production, distribution and downstream uses, chemistry is indispensable for promoting high standards of living and health. Its various facets represent one of the most essential building blocks in the transformation toward a more sustainable future. To effectively leverage the multitude of opportunities offered by chemistry as a sector, a number of challenges must be tackled, such as those associated with the countless chemical substances produced and distributed that require special care to protect human health and the environment.

Photo: OCG, unsplash

Environmental pollution in our rivers, groundwater, soil and air caused by chemicals emerged as a wide-spread problem in the second half of the twentieth century. In response, extensive legislation to control and prevent pollution was introduced across many industrialised countries. A series of serious accidents connected to different chemical companies (with Schweizerhalle/Basel, Bophal and Seveso being among the most well-known) placed the chemical industry under a high degree scrutiny and pressure. Existing legislation was tightened and, in 1985, the Responsible Care programme was launched, serving as 'the global chemical industry's voluntary initiative', which – beyond legislative and regulatory compliance – commits companies, national chemical industry associations and their partners to:

- Continuously improve the environmental, health, safety and security knowledge and performance of our technologies, processes and products over their life cycles so as to avoid harm to people and the environment.
- Use resources efficiently and minimize waste.
- Report openly on performance, achievements and shortcomings.
- Listen, engage and work with people to understand and address their concerns and expectations.
- Cooperate with governments and organisations in the development and implementation of effective regulations and standards, and to meet or go beyond them.
- Provide help and advice to foster the responsible management of chemicals by all those who manage and use them along the product chain[6].

While this was a solid step in the right direction, the voluntary nature of the programme meant it often failed to be taken seriously by companies, with some using it as an argument that no further legislation would be needed. The legislative framework has, however, developed on other fronts. One important milestone was the Council Directive 96/61/EC on 'Integrated Pollution Prevention and Control (IPPC)' enacted on 24 September 1996. The IPPC directive addressed unwanted side effects of chemical (and other industrial) production, based on a more integrated view as well as the use of 'best available techniques' (BAT).

The IPPC directive, that was succeeded by the Industrial Emissions Directive (IED) in 2010, laid the foundations for an integrated approach to reducing pollution and the negative side effects of chemicals. Its main points are outlined in Box 1.

6: Responsible Care Programme Responsible Care®
https://cefic.org/responsible-care/

BOX 1:
POINTS FOR REDUCING THE NEGATIVE EFFECTS OF CHEMICALS AND THEIR PRODUCTION LISTED IN ANNEX IV OF THE EU DIRECTIVE COUNCIL DIRECTIVE 96/61/EC FROM 24 SEPTEMBER 1996 CONCERNING INTEGRATED POLLUTION PREVENTION AND CONTROL

1.
The use of low-waste technology

2.
The use of less hazardous substances

3.
The furthering of recovery and recycling of substances generated and used in the process, and of waste, where appropriate

4.
Comparable processes, facilities or methods of operation which have been tried with success on an industrial scale

5.
Technological advances and changes in scientific knowledge and understanding

6.
The nature, effects and volume of the emissions concerned

7.
The commissioning dates for new or existing installations

8.
The length of time needed to introduce the best available technique

9.
The consumption and nature of raw materials (including water) used in the process and their energy efficiency

10.
The need to prevent or reduce to a minimum the overall impact of the emissions on the environment and the risks to it

11.
The need to prevent accidents and to minimize the consequences for the environment

12.
The information published by the Commission pursuant to Article 16 (2) or by international organisations.
(Note: this point refers to an obligation on the part of the European Commission to organise an exchange information between Member States and the industries concerned on best available techniques – BATs)

In addition to legislative, 'command-and-control' approaches and the management-focused Responsible Care programme, attempts were also made to establish a different conception of chemistry.

The 12 Green Chemistry (GC) principles (Box 2) were introduced in 1998. While these have gained momentum since then, they are yet to be fully implemented in science or industry. The green chemistry principles address the design, processing and manufacturing of chemicals in order to reduce directly connected waste, energy demand and safety risks. The green chemistry principles represent another step forward, but they are far not sufficient for chemistry to satisfy the requirements of a circular economy and those of the Sustainable Development Goals (SDGs) while avoiding negative trade-offs.

BOX 2:
THE PRINCIPLES OF GREEN CHEMISTRY
(source: https://www.epa.gov/greenchemistry/basics-green-chemistry#twelve

1. Prevention of waste:
It is better to prevent waste than to treat or clean up waste after it has been created.

2. Atom economy:
Synthetic methods should be designed to maximise the incorporation of all materials used in the process into the final product.

3. Less hazardous chemical syntheses:
Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. Designing safer chemicals:
Chemical products should be designed to affect their desired function while minimising their toxicity

5. Safer solvents and auxiliaries:
The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.

6. Design for energy efficiency:
Energy requirements of chemical processes should be recognised for their environmental and economic impacts and should be minimised. If possible, synthetic methods should be conducted at ambient temperature and pressure.

7. Use of renewable feedstocks:
A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.

8. Reduce derivatives:
Unnecessary derivatisation (use of blocking groups, protection/de-protection, temporary modification of physical/chemical processes) should be minimised or avoided, if possible, because such steps require additional reagents and can generate waste.

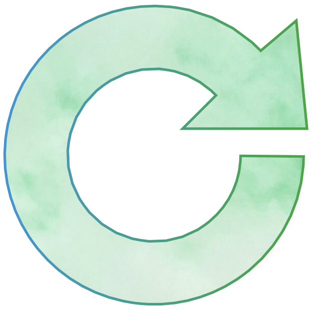
9. Catalysis:
Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

10. Design for degradation:
Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.

11. Real-time analysis for pollution prevention:
Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.

12. Inherently safer chemistry for accident prevention:
Substances and the form of a substance used in a chemical process should be chosen to minimise the potential for chemical accidents, including releases, explosions and fires.

The use of renewable resources, for example, may satisfy one or more of the principles, but this does not necessarily translate into products that can be circulated or recycled. Instead, to avoid unwanted social or environmental impacts, a broad set of circular economy and sustainability criteria should be applied at the early stages of product design and technology development.



Circulating and recycling materials and products also requires energy and generates waste, albeit generally in lesser quantities compared to the 'flow-through-economy'. Product streams also need to be depolluted even in a circular economy, regardless of their origin. Another consideration is that renewable energy also relies on different types of materials, including critical raw materials that can turn into future waste. The (unavoidable) dissipative loss of metals and other chemical elements must be kept to a minimum as these cannot be synthesised due to their non-renewable nature.

Green chemistry primarily addresses pollution prevention on the level of the individual product but does not address explicitly the reduction of the increasing total volume of material and product flows. Moreover, many chemical products cannot be recycled at all, including those found in personal care products, pharmaceuticals and products released in the environment such as pesticides, biocides and detergents. The same applies to abrasion from surfaces, e. g., paint applied to building façades, rubber particles from tires and the like – which all end up in the environment as an unavoidable consequence of their use. Such products must be designed differently for fulfilling their purpose, in a way that reduces harmful impacts on the environment throughout their lifecycle and end-of-life.

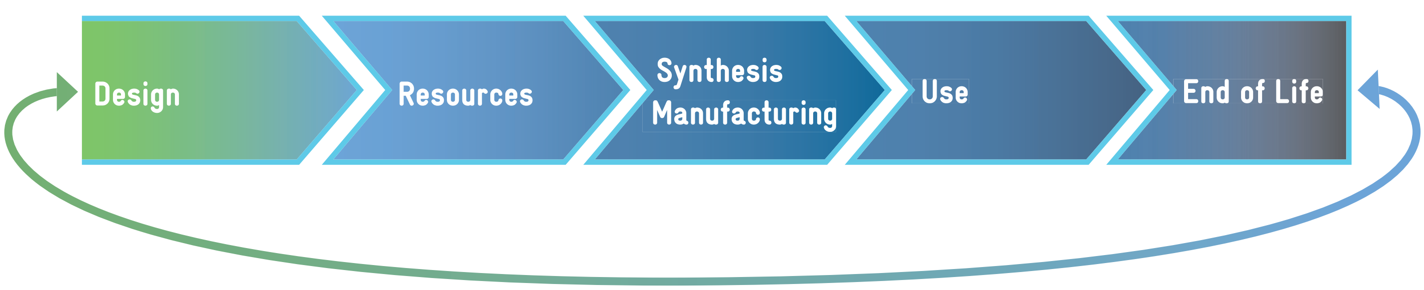
Photo: Bee Naturales, unsplash.com

Additionally, these two approaches do not necessarily solve the issue of shifting of problems to other places, countries, environmental media (e. g., from the air to the soil) or the future. Sugar cane used as a renewable resource serves as a prime example, where the plantations are often subject to poor working conditions and inadequate safety measures. Most are located in developing countries. As is the case for many other products, this raw material is extracted with high energy and water consumption, environmental pollution and precarious social and environmental conditions and subsequently exported with little or no further processing, meaning that the added value is captured in countries that are economically more developed. Practices such as these are unfair and contradict the principles of sustainable development as well as many of the SDGs.

Sustainable chemistry is a conceptually broader approach, and one that explicitly addresses the environmental, economic and social dimensions of sustainable development. In order to operate within the planetary boundaries and respect precautionary principles along all stages of their processes and product lifecycles, current and future chemical production practices and those of associated industries[7] need to apply three crucial sustainability strategies: sufficiency, consistency and efficiency. Doing so has been shown to result in benefits for the planet as a whole as well as for societies across the globe, thereby contributing to the United Nations Sustainable Development Goals.

This approach should be applied across the board, including the entire chemical sector as well as downstream users – from resources and manufacturing to applications and end-of-life solutions. Promoting sustainability – as the fulfilment of present needs without compromising the ecological, social and economic needs of future generations – means that all stakeholders across chemical sector value chains need to be incorporated. Sustainable chemistry (SC, Box 3, page 11) serves as a guiding principle for aligning the practices involved in the chemistry sector with the principles of sustainability. This broader framework aimed at the production and use of chemicals is urgently needed to enable the transformation of the sector toward a sustainable, climate and environmentally friendly future.

Sustainable chemistry demands that stakeholders such as chemists, product designers and end-users first consider the needed service and function – before recommending that a certain chemical product be applied: What for, for whom and why? Alternative business models present an opportunity here, including schemes such as chemical leasing, payment for services and knowledge-sharing, to first assess a chemical application before coming to a conclusion or recommendation. Additional opportunities lie in promoting changes to consumers behaviour, the way infrastructure is designed, construction practices and products. This entails applying measures at the source or inception (e. g., pollution prevention) rather than at the end (e. g., treatment or depollution).



7: Generally, sustainable chemistry is not limited to chemical-producing industry but also include downstream sectors using chemicals and chemistry-based materials, e. g., the chemistry-associated fields of pharmaceuticals, home and personal care, construction, mobility, energy, electronics, management, law and IT. It takes into consideration the full lifecycle form the very beginning and all the interdependencies along the different stages of it.

BOX 3:
KEY CHARACTERISTICS OF SUSTAINABLE CHEMISTRY[8]

Holistic

Guiding the chemical science and the chemical sector towards contributing to sustainability in agreement with sustainability principles and general understanding and appreciating potential interdependencies including long-distance interactions and temporal gaps between the chemical and other sectors.

Precautionary

Avoiding transfer of problems and costs into other domains, spheres and regions at the outset, preventing future legacies and taking care of the legacies of the past including linked responsibilities.

System thinking

Securing its interdisciplinary, multidisciplinary, and transdisciplinary character including a strong disciplinary basis but taking into account other fields to meet sustainability to its full extent. Application as for industrial practice including strategic and business planning, education, risk assessment and others including the social and economic spheres by all stakeholders.

Ethical and social responsibility

Adhering to value to all inhabitants of plant earth, the human rights and welfare of all live, justice, the interest of vulnerable groups and promoting fair, inclusive, critical, and emancipatory approaches in all its fields including education, science, and technology.

Collaboration and transparency

Fostering exchange, collaboration, and right to know of all stakeholders for improving the sustainability of business models, services, processes and products and linked decisions including ecological, social, and economic development on all levels. Avoiding all "green washing" and "sustainability washing" by full transparency in all scientific and business activities towards all stakeholders, and civil society.

Sustainable and responible innovation

Transforming fully the chemical and allied industries from the molecular to the macroscopic levels of products, processes, functions and services in a proactive perspective towards sustainability including continuous trustworthy, transparent and traceable monitoring.

Sound chemicals management

Supporting the sound management of chemicals and waste throughout their whole life cycle avoiding toxicity, persistency and bioaccumulation and other harm of chemical substances, materials, processes, products and services to humans and the environment.

Circularity

Accounting for the opportunities and limitations of a circular economy including reducing total substance flows, material flows, product flows, and connected energy flows at all spatial and temporal scales and dimensions especially with respect to volume and complexity.

Green chemistry

Meeting under sustainable chemistry application as many as possible of the 12 principles of green chemistry with hazard reduction at its core when chemicals are needed to deliver a service or function whenever and wherever this complies with sustainability.

Life cycle

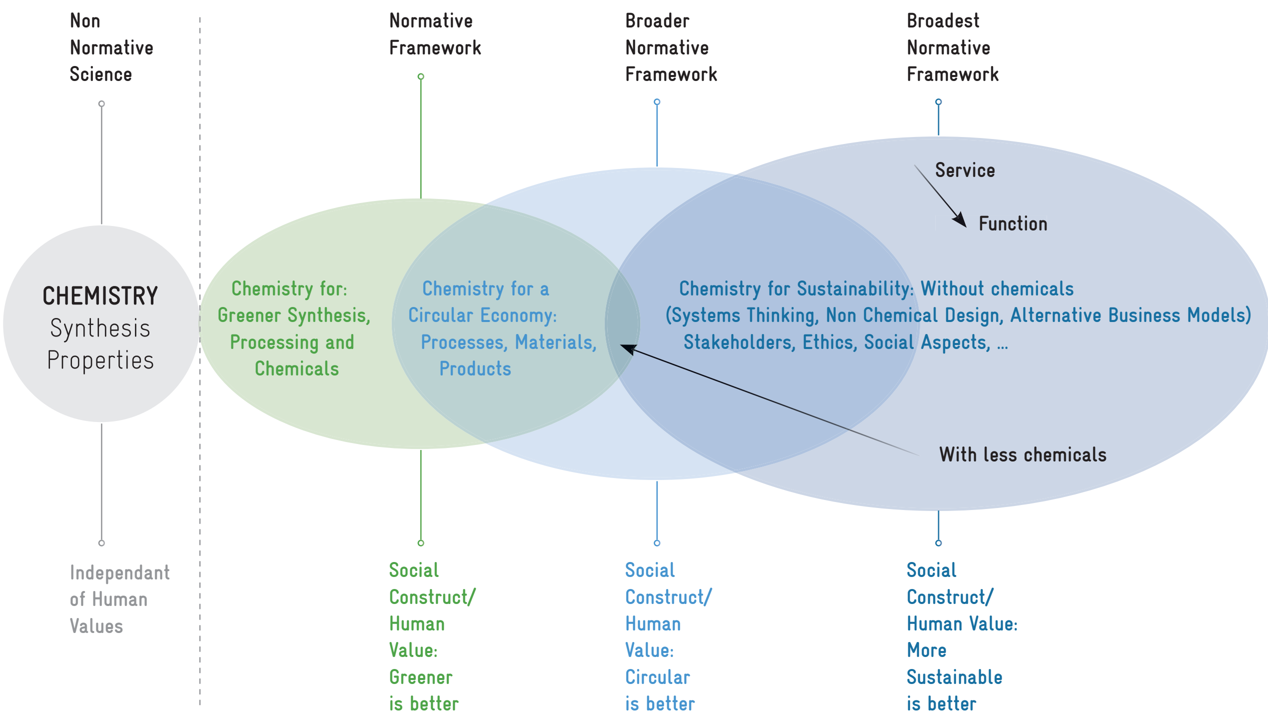
Application of the above-mentioned key characteristics for the whole lifecycle of products, processes, functions and services on all levels, e.g. from molecular to the macroscopic levels and all sectors in a pro-active perspective towards sustainability.

8: International Sustainable Chemistry Collaborative Centre (2021) Key characteristics of sustainable chemistry https://www.isc3.org/page/key-characteristics-of-sustainable-chemistry

While the chemical economy has long been supply-driven, the future must be demand-driven, based on the principle of 'knowledge instead tonnage'. This can allow countries and stakeholders to reduce the total volume of substances, material and product flows all along their entire life cycle, leading to a reduction of resource use, energy input, pollution and toxic substances.

While chemistry as a science is non-normative and remains free of human value propositions (Figure 4), its application is different. Green chemistry, chemistry for a circular economy and sustainable chemistry are normative approaches that respond to our human value propositions regarding environmental protection, resource use and sustainable development in general. This opens a path for opportunities to create better products and applications while allowing the chemical sector to substantially contribute to the SDGs. However, we must also understand that not all processes and products that satisfy the principles of green chemistry fit within the circular economy, nor any product that fits into a circular economy can automatically be considered greener or more sustainable.

Figure 4:
The relationship of greener chemistry[9], chemistry in a circular economy, sustainable chemistry and sustainability
(Source: Kümmerer)



9: In fact, we cannot judge in an absolute sense what is green or sustainable – we can only compare to identify which products, syntheses, applications, etc. are greener or more sustainable.

3. Advancing low-carbon economies through sustainable chemistry

The pathway towards sustainable chemistry is complex and challenging. It implies a fundamental transformation. Advancing in this direction would represent a major contribution to sustainable development, leading to positive impacts on numerous industrial sectors as well as our daily lives. Tackling climate change constitutes an important area of sustainable chemistry. The chemical sector has the potential to reduce its own considerable direct and indirect GHG emissions, including from the sector's substantial energy demand as well as along the entire product value chain. At the same time, the chemical industry provides many of the materials needed for developing renewable energy, green mobility and other climate-friendly technologies. This potential for offering innovative low-carbon solutions have not yet been fully tapped. According to the vision of Sustainable Chemistry, integrated approaches are needed to maximise synergies and minimise trade-offs, particularly between climate protection and chemical safety.

The transformation to a climate-friendly chemical industry requires action on different levels, from technological and political solutions to smart organisational, managerial and educational structures. Concurrently it requires agreement and commitment on the part of governments, industry and other stakeholders, united in view that a climate-neutral chemical industry is possible and serves as a common goal. Through its vision of a climate-neutral chemical industry, the position paper from the International Council of Chemical Associations as Statement on Climate Neutrality published in 2021 (ICCA 2021)[10] provides good starting points.

Photo:Jeffrey Hamilton,unsplash.com

The European chemical industry managed to reduce its direct GHG emissions by 55 per cent between 1990 and 2019 while increasing production by 43 per cent[11]. This has gone hand in hand with process optimisation, increased energy and resource efficiency and the abatement of process-related N_2O emissions – mainly from fertiliser production. In future, moving closer to net zero will require the large-scale phase-in of renewable energy, the electrification of fossil-fuel based processes, alternative feedstocks and green hydrogen. This pathway poses a number of major challenges, from enormous quantities of renewable energy to material resources such as metals.

For fighting climate change successfully according to the Paris Agreement, all relevant emission sectors are requested to develop mitigation strategies. The most important industrial subsectors have started to develop detailed roadmaps for climate-neutrality, such as the Association of the German Chemical Industry (Verband der Chemischen Industrie, VCI)[12]. Some developing countries and emerging economies including Thailand and Vietnam have also committed to climate-neutrality by 2050 and are now establishing detailed plans with emission reduction targets for all relevant sectors. Against this background, CAPCI supports the development of roadmap studies for the chemical industry in its partner countries. It does so with the awareness that realistic pathways must be designed according to the specific situation, conditions and needs at hand, knowing that these will look different in developing countries and emerging economies as compared to industrialised countries.

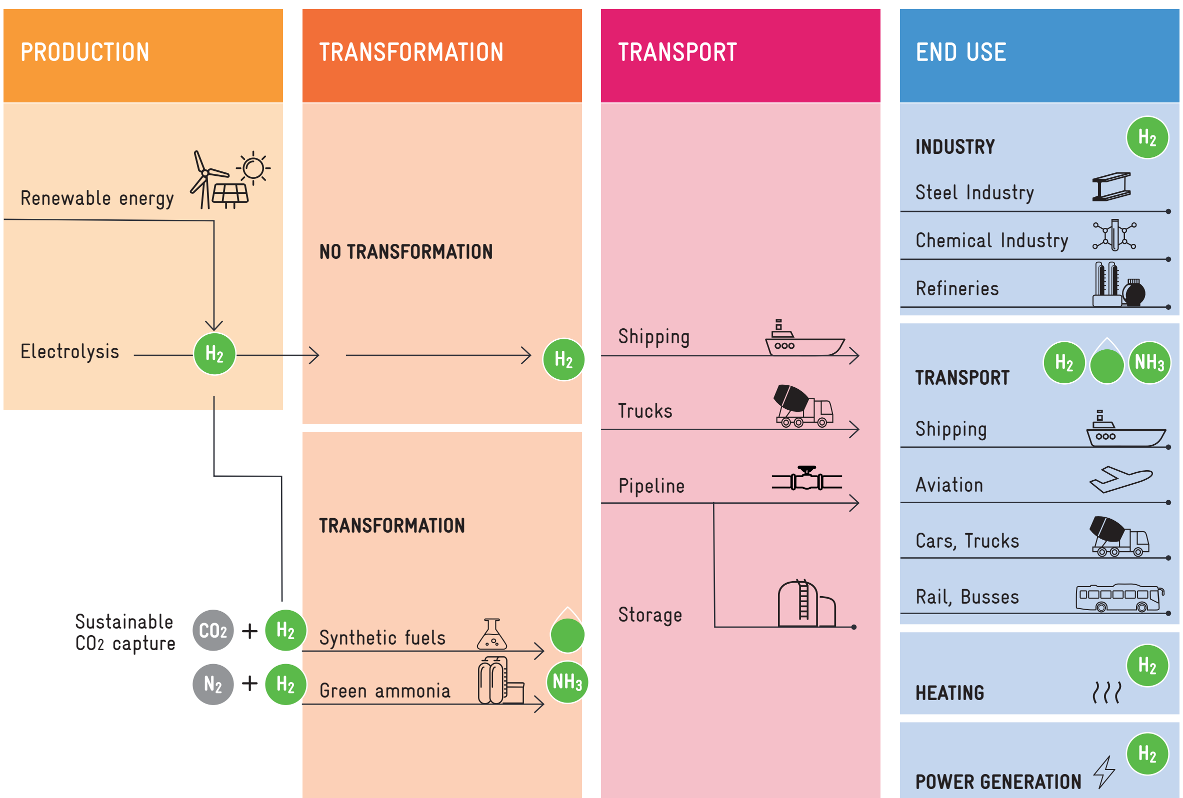
10: International Council of Chemical Associations (2021) Statement on Climate Neutrality. https://icca-chem.org/news/icca-statement-on-climate-policy/
11: European Chemical Industry Council Total EU 27 scope 1 GHG Emissions 2020 Environmental Performance - cefic.org
12: Verband der Chemischen Industrie VCI (2019 a) Roadmap 2050 Treibhausgasneutralität Chemieindustrie VCI-Broschüre.indb

Harvesting low-hanging fruits first

Undertaking an ambitious transformation to climate-neutrality within an important industrial sector will invariably require a long-term strategy with significant investment into new technologies. Nevertheless, the first steps can also leverage a variety of low-cost or even zero-cost initiatives (so-called 'no regret measures'). These may include improving energy and resource efficiency, reducing losses or taking advantage of synergies between different production plants via waste materials, waste heat etc.

In developing countries and emerging economies in particular, potential for these sorts of mitigation measures with low payback periods and co-benefits may be quite high. However, long-term strategies aiming at net-zero will also demand more sophisticated technology options that imply significant investment.

Figure 5:
Green hydrogen production, conversion and uses across the energy system (IRENA 2020)[13]



13: International Renewable Energy Agency (2020) Green Hydrogen: A guide to policy making. Green hydrogen: A guide to policy making (irena.org) Green hydrogen: A guide to policy making (irena.org)

Green hydrogen and Power-to X for a net-zero pathway

When renewable energy is used for water electrolysis to generate green hydrogen and oxygen, zero greenhouse gases are emitted. As a climate-neutral (intermediate) product, this is an ideal path for substituting fossil fuels and chemicals within industrial processes and other applications. Besides being well suited for storing discontinuously generated renewable energy, green hydrogen opens a wide spectrum of additional benefits. The chemical industry uses green hydrogen as a feedstock and it can serve as a basis for other basic chemicals in Power-to-X (PtX) approaches, e. g., for green ammonia, green methanol and substitutes for fossil based chemicals (see Figure 5, page 14).

In the long run, green hydrogen and PtX hold immense potential for contributing to the sustainable energy transition and creating a viable net-zero perspective for the chemical industry. Applying this solution does not, however, mean that sustainability criteria can be ignored. Green hydrogen strategies must be designed and implemented in a way that avoids critical trade-offs, e. g., regarding the resources needed to construct and maintain green energy harvesting facilities and power plants. The same holds true for captured carbon dioxide used as a starter material for organic chemicals.

Enhancing circularity

Nearly all circular economy solutions contribute to mitigating greenhouse gas emissions: waste, waste heat and steam generated by one company or plant is used or recycled as an input by another company or plant in a chemical park – or even by the same company at the same facility. Intelligent waste management and recycling as well as certain waste-to-energy technologies also offer mitigation benefits, e. g., power generation from refuse-derived fuels or the energetic use of biogas from anaerobic wastewater treatment, just to name a few examples.

Considering the broader picture, we should emphasise that avoiding any sorts of waste is, ultimately, the most environment and climate-friendly option and should therefore be given priority. Other circular solutions discussed in the context of the chemical industry's low-emission transformation offer possibilities for replacing fossil fuels as a feedstock by using alternative sources such as plastic waste, biomass or carbon capture.

Photo: istockphoto.com

Avoiding trade-offs and hazardous substances

One of the core goals pursued by CAPCI in addition to raising awareness of climate-friendly solutions in the chemical industry is to identify synergies and trade-offs. It is imperative that chemistry innovation seeking to mitigate greenhouse gas emissions does not lead to negative trade-offs.

For instance, the use of hazardous substances with adverse effects on human health and the environment needs to be decreased to a minimum. Unwanted side-effects associated with using renewable energy in the cases outlined above have to be taken into account, as well, e.g., the environmental and social impact of large-scale hydropower facilities. Environment and climate-friendly technologies must therefore be assessed in consideration of the entire system, beyond one-off solutions. This means defining and applying criteria and conditions that outline their sustainable use.

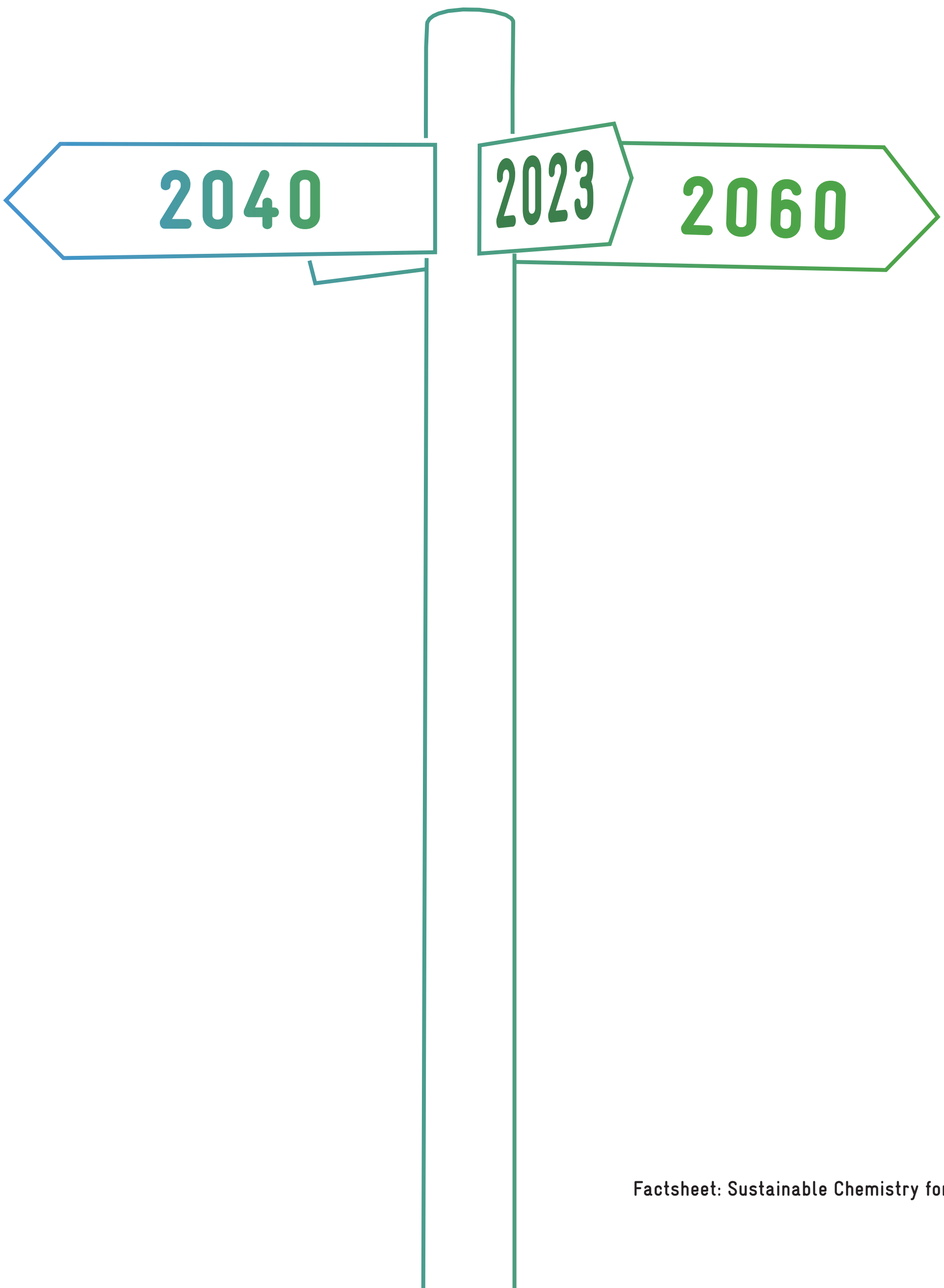
One example is the intentional or unintentional presence of hazardous substances in recycled or reused materials and products that undermine environmentally sound recycling and pose a challenge for the circular economy. Contaminated recycled materials include flame retardants e.g. in children's toys made of recycled plastic and rubber as well as polycyclic aromatic hydrocarbons that contaminate rubber playgrounds made of recycled tires. Key elements of this involve promoting sustainable materials management, fully disclosing data on the materials used and improving knowledge sharing and cooperation beyond selling and buying along the entire supply chain (including recyclers). Additionally, expanding sustainable product design based on green and sustainable chemical innovations goes a long way in minimising and avoiding the presence of hazardous substances in products.

Photo: lanxess.com

Photo: Markus Spiske, unsplash.com

Conclusion

Chemistry has a decisive role to play in promoting sustainable development around the globe and for the transformation toward a climate-friendly economy. The chemical sector can do so by reducing its significant share of global greenhouse gas emissions and by enabling other sectors to meet their climate goals. Climate-friendly processes, materials and products are an important building block of sustainable chemistry and should be reflected in integrated approaches that exploit synergies and avoid trade-offs for the activities, services and products throughout their lifecycle.



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(2) Developing countries and emerging markets / https://knowledge4policy.ec.europa.eu/foresight/topic/growing-consumerism/developing-countries-emerging-markets_en

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