TOWARD GREENHOUSE GAS NEUTRALITY IN THE PRODUCTION AND USE OF CHEMICALS:

Roadmaps for shaping pathways to climate protection in the chemical sector in developing countries and emerging economies

1. Introduction

Climate Change is an overarching global challenge of our times that jeopardizes the planet and the future of mankind. As the Intergovernmental Panel on Climate Change (IPCC) points out in its latest Assessment Report (2022)[1], global emissions of green-house gases (GHG) have increased by more than 50 % from 1990 to 2019 and are still rising (Fig. 1).

Enormous efforts are needed for tackling Climate Change successfully and fighting its causes through appropriate mitigation action. According to the Paris Agreement[2], adopted in 2015, global warming should be limited to 1.5 °C or at least "well below" 2 °C. All signatory countries in the world have committed to do their share and define concretely in form of "Nationally Determined Contributions" (NDCs) their objectives for tackling climate change, including goals and actions for reducing their greenhouse gas emissions. NDCs are voluntary commitments but their level of ambition should be raised periodically. In addition to emission measurement, reporting and verification, this mechanism requires political frameworks, instruments and strategies with different time horizons. The Paris Agreement "invites countries to formulate and submit long-term low greenhouse gas emission development strategies (LTLEDS)".

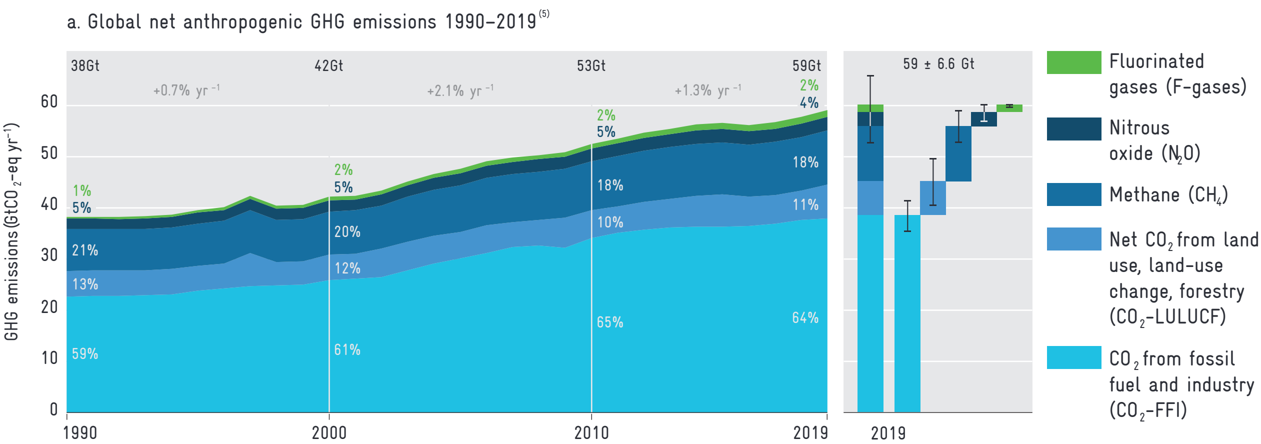


Fig. 1: Global net anthropogenic GHG emissions 1990 – 2019 (IPCC, 2022)

1: Sixth Assessment Report – IPCC
2: The Paris Agreement | UNFCCC

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

THE CHEMICAL SECTOR MATTERS WHEN IT COMES TO FIGHTING CLIMATE CHANGE

All sectors of the economy must contribute to the great transformation that is needed for achieving a climate-friendly and resilient development, not endangering sustainable development worldwide. According to the IPCC data of 2022, industry is among the sectors that emit most direct GHG emissions, together with energy and "AFOLU" (Agriculture, forestry and land use). If indirect emissions are included in the balance, industry is by far the biggest emission sector (Fig. 2). Chemical and petrochemical production accounts for 7.4 % of global GHG emissions and belongs to the 3 most relevant emission subsectors within the industry – together with cement and steel production. On the other hand, the chemical industry is also a very important supplier of almost all other manufacturing industries with chemical products and base materials, and it also provides inputs and materials that are needed for climate-friendly technologies and decarbonization[3] in other sectors.

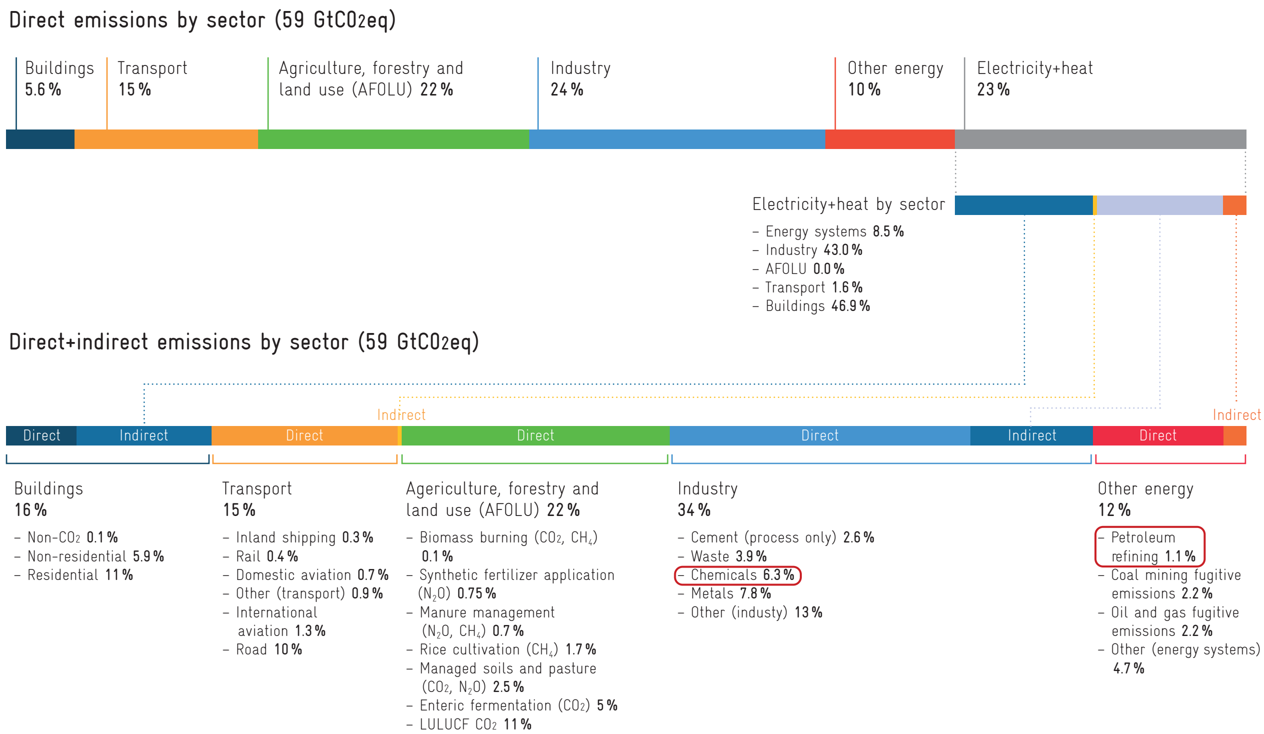


Fig. 2: Origin of global GHG emissions by sector. Whereas the upper part shows direct emissions (scope 1 – emissions under direct control of a reporting company), the lower part includes additionally indirect emissions under scope 2 (e.g. GHG emissions associated with electricity, heat, steam or cold, purchased by a reporting company from third parties). The classification into emission scopes is a wide-spread approach used for emission accounting and reporting by companies (Greenhouse Gas Protocol[4]).

3: The term "decarbonization" is used here because it is so common and widespread in the climate context – despite the fact, that it is somewhat misleading if one understands it literally particularly in chemistry: In the chemical industry the element carbon (C) is fundamental for a large portion of processes and products. Sometimes the term defossilization is proposed as a better alternative, because it refers to reducing, replacing and, finally, phasing out carbon from fossil sources for both, energy and material inputs. Probably, this term is more adequate; but it is less common than decarbonization, and, in addition, it does not cover all types of relevant GHG emissions from chemical production, e.g. laughing gas (N2O) with its high global warming potential (GWP) or sulphur hexafluoride (SF6) that has the highest GWP of all technically important chemicals.

4: https://ghgprotocol.org

In recent times, it seems, that the industry due to its high share of global GHG emissions is receiving increased attention on the international climate agenda and especially when it comes to mitigation action and strategies. A schematic pathway towards climate-neutrality of the industry, as proposed in the 6th assessment report of the IPCC, is represented in Fig. 3. It includes major building blocks such as emission-free electricity and heat, energy efficiency, fuel switch, feedstock switch, material efficiency, circular material flows and waste reduction as well as carbon capture and use (CCU) and storage (CCS). The chart also suggests a possible sequence of these mitigation options over time with short to medium and medium to long-term horizons. It should be pointed out here that this pathway for the industry is schematic and may hopefully inspire; but there are no blueprints! Each mitigation pathway or transformation roadmap must correspond to the specific situation and characteristics of a company or sector as well as the framework conditions in the country or region and so on. One conclusion highlighted in this paper is that transition pathways should go beyond GHG mitigation und strongly reflect additional aspects, such as economic efficiency and competitiveness, social acceptance and environmental sustainability, including sustainable management of chemicals. With regards to developing countries and emerging economies, it is suggested that the often still significant potentials for co-benefits and cost-efficient mitigation action should be tapped in an early stage. They are often associated e.g. with energy and material efficiency, waste and loss reduction, circular economy etc.

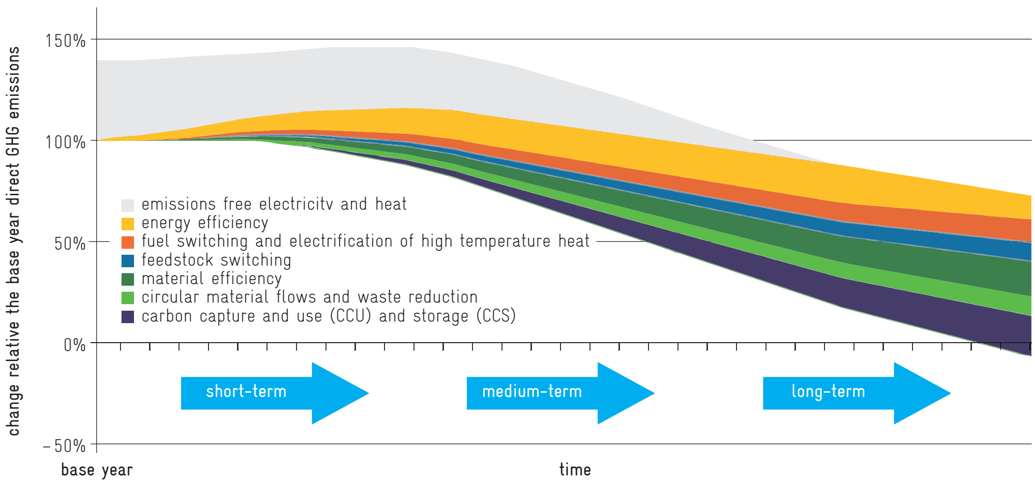


Fig. 3: Schematic pathway towards climate-neutrality of the industry (IPCC, 2022)

THE CLIMATE ACTION PROGRAMME FOR THE CHEMICAL INDUSTRY (CAPCI)

The present paper focuses specifically on the situation and challenges of developing countries and emerging economies. It is based on the experiences of an international cooperation project CAPCI (Climate Action Programme for the Chemical industry). CAPCI has been funded by the German Ministry for the Environment (BMUV[5]) through the International Climate Initiative (IKI). The objective is to enhance capacities of key stakeholders in selected developing countries and emerging economies for designing and implementing effective measures for climate protection in the chemical sector. The conceptual approach corresponds to the conclusion that developing countries and emerging economies have particular needs in terms of information, awareness creation, access to knowledge and capacity building. CAPCI has pursued this objective in cooperation with relevant government organizations and associations of the chemical industry with participation of stakeholders of the civil society and academia.

CAPCI started cooperating with 5 countries – Argentina, Ghana, Peru, Thailand and Vietnam. At the beginning, special emphasis was given to information, knowledge sharing, awareness creation and stakeholder dialogues. This was necessary because the significant role of the chemical industry for tackling climate change was usually not on the agenda of relevant public and private stakeholders, and even among stakeholders of the chemical industry there was only little knowledge about climate change and mitigation options, particularly in smaller companies, whereas bigger companies or branches of multinational companies usually have their corporate strategies and organizational units that cover climate aspects. In the second part of project implementation, CAPCI focused on capacity development and training as well as advice for climate action and roadmap development. Adequate capacities must be considered as a fundamental prerequisite for effective climate action and finding socially, economically and environmentally adequate solutions.

The support of CAPCI for the development of roadmaps for climate protection in the production and use of chemicals is meant as an explicit contribution to the achievement of national climate goals (and NDCs). A significant number of developing countries and emerging economies have committed to ambitions climate goals and even climate neutrality (e. g. by 2050).

KEY QUESTIONS DISCUSSED IN THIS PAPER

Based on the cooperation experiences of CAPCI, the following questions will be discussed in this paper:

> How important is the production and use of chemicals for fighting climate change successfully, and is the sector adequately reflected in the international climate agenda?

> What are the characteristics of feasible mitigation pathways in the production and use of chemicals, and how should roadmaps for GHG mitigation be designed so that they provide guidance particularly for developing countries and emerging economies?

> What can be learned from mitigation roadmaps and emission trends of the chemical sector in industrialized countries?

> How should environmental sustainability, societal acceptance, economic efficiency and competitiveness be reflected in mitigation roadmaps?

> What is the role of enabling policies and frameworks for accelerating the transition towards sustainable and climate-friendly chemistry?

5: Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz

2. Chemistry and Climate Change on the International Agenda

The fundaments of international climate policies are the UN Framework Convention on Climate Change (UNFCCC)[6] from 1992 and the Paris Agreement with the common goal of limiting global warming to a maximum of 1.5 °C or at least well below 2 °C. It also defines the obligations of the signatory states to define, communicate, measure and periodically update their climate-related objectives and strategies (NDCs).

The chemical sector is at the base of far most industrial value chains and produces a wide variety of chemical substances and products, probably some hundreds of thousands. Many of them have toxic properties and pose risks to human health and/or the environment, but in many cases, closer investigations and analysis are still missing. Therefore, sustainable management of chemicals is an important and complex task for the authorities that are responsible for environmental and health protection. On international level, a series of multilateral environmental agreements has been created that cater for certain groups of relevant chemical substances (or hazardous wastes):

- **Montreal Protocol (MP)** on Substances that Deplete the Ozone Layer[7], adopted in 1987, and the **Kigali Amendment**[8] from 2016
- **Basel Convention**[9] on the Control of Transboundary Movements of Hazardous Waste and their Disposal, adopted in 1989
- **Rotterdam Convention** on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (PIC Convention)[10], adopted in 1998
- **Stockholm Convention** on Persistent Organic Pollutants (POPs) adopted in 2001[11]
- **Minamata Convention**[12] on Mercury agreed upon in 2013

In conclusion, it shall be stated here that coherence and interrelations of the international agreements on climate change and on chemicals management remain a big challenge, while the Montreal Protocol and its Kigali Amendment remain a remarkable exception because they regulate concretely defined climate-relevant chemical substances. The Montreal Protocol should also be regarded as an outstanding example of an effective multilateral environmental agreement as it shows how the international community can resolve a global problem with clear-cut regulations, financing and implementation mechanisms. Scientists expect that the ozone layer will recover in the coming decades[13], when the corresponding efforts are continued and not counteracted.

As a recent development it should also be mentioned here that 175 countries agreed in 2022 at the United National Environment Assembly (UNEA) to “forge a legally binding agreement” for ending plastics pollution[14] that “addresses the full lifecycle of plastic, including its production, design and disposal”. In addition to the intended reduction of plastic pollution, this is of high relevance for both, the chemical industry and global climate protection. Plastics production does not only represent a big portion of chemical production, it also accounts for around 3.5 % of world-wide greenhouse gas emissions along its lifecycle according to the Global Plastics Outlook (OECD, 2022[15]). The overwhelming part of the feedstock used for plastics production consists of fossil hydrocarbons, while only less than 10 % of the more than 350 million tons of the plastic waste, generated annually, are recycled. While the new plastics treaty addresses primarily the urgent problem of plastics pollution and marine litter, the cited data strongly make the case for holistic approaches rethinking the entire lifecycle.

6: conveng.pdf (unfccc.int)
7: About Montreal Protocol (unep.org)
8: The Kigali Amendment is remarkable as it stipulates for the first time a phase-down of a defined group of fluorinated chemical substances because of their high global warming potential (and not because of ozone-damaging properties according to the original scope of the MP). See: The Kigali Amendment (2s016): The amendment to the Montreal Protocol agreed by the Twenty-Eighth Meeting of the Parties (Kigali, 10-15 October 2016) | Ozone Secretariat (unep.org)
9: Basel Convention › The Convention › Overview › Text of the Convention
10: Text of the Convention (pic.int)
11: Text of the Convention (pops.int)
12: The Minamata Convention on Mercury | UNEP - UN Environment Programme
13: Scientific-Assessment-of-Ozone-Depletion-2022-Executive-Summary.pdf (unep.org)
14: Historic day in the campaign to beat plastic pollution: Nations commit to develop a legally binding agreement (unep.org)
15: Global Plastics Outlook: Policy Scenarios to 2060 | en | OECD

INTEGRATED APPROACHES AND COHERENT POLICIES REMAIN A BIG CHALLENGE

The need for coherent and integrated approaches to the nexus chemistry – climate change is high – at international level but also for the countries that have to implement the above cited multilateral agreements nationally. This is particularly challenging for developing countries and emerging economies. In many cases the responsibility for both, climate and chemical policies relies on the environmental ministries (though often institutional arrangements for the participation of other ministries and/or stakeholders in formulating and implementing climate policies are in place). Nevertheless, coordination between departments responsible for chemical policies and those responsible for climate policies is weak or almost missing. This was also observed in some cases in the implementation of CAPCI as a starting situation; nevertheless, the proposed dialogue for a of the project were welcomed, and the different actors generally accepted engagement in inter-institutional discussion and cooperation.

In 2021, the United Nations addressed Climate Change, Biodiversity Loss and Pollution as the 3 main environmental emergencies in their report “Making Peace with Nature”[16] emphasizing their interlinkages. The “Triple Crisis” also framed the discussion on the future of the Strategic Approach to Chemicals Management (SAICM) before and at the 5th session of the International Conference on Chemicals Management (ICCM5) at the end of September 2023 in Bonn. Its main outcome was the “Global Framework on Chemicals – for a Planet Free of Pollution from Chemicals and Waste” that also considers the interlinkages with climate change and biodiversity loss. Nevertheless, coherent policies and their well-coordinated implementation remain a huge and complex challenge for many countries, particularly developing and emerging economies.

INDUSTRY IS A KEY PLAYER

The industry is a key player when it comes to a climate-friendly and sustainability-oriented transformation of the chemical sector and the associated value chains. It implies fundamental changes in production processes, products and infrastructure. The idea of undertaking such a big transformation is embraced by some actors of the chemical industry, while others are more skeptical or even reluctant; and especially many small and medium-sized enterprises in developing countries and emerging economies do not yet see it as relevant for them and have no clear strategies. Associations and other organizations representing the chemical industry have therefore a crucial role to play in informing and sensitizing companies.

As a “global voice of the chemical industry”, the ICCA[17] (International Council of Chemical Associations) has issued a statement on climate neutrality in 2017, expressing its full support for the Paris Agreement and the commitment to be “part of the solution to global climate change in two ways:

- By working to reduce our own greenhouse gas GHG emissions associated with our own operations; and
- by enabling the entire manufacturing value chain including the building and construction, energy, transportation and consumer goods sectors and even individual consumers, to reduce their own GHG footprints, through the use of energy-saving and emissions-reducing technologies and materials, produced or made possible by chemical innovations.”

In the project implementation, ICCA has played a very helpful role in CAPCI cooperation activities with developing and emerging countries, e. g. establishing contacts with national chemical associations or providing expertise and proposing speakers for project events. In addition, ICCA has engaged in valuable studies on technology roadmaps, e.g.:

- “ICCA Building Technology Roadmap. The Chemical Industry’s Contributions to Energy and Greenhouse Gas Savings in Residential and Commercial Construction.”[18]

16: Making Peace With Nature | UNEP - UN Environment Programme
17: ICCA Statement on Climate Neutrality October 2021 (icca-chem.org)
18: ICCA-Building-Technology-Roadmap-Executive-Summary.pdf (icca-chem.org)

- “Technology Roadmap. Energy and GHG Reductions via Catalytic Processes” (2023).[19] And together with the International Energy Agency (IEA) and the DECHEMA.

In 2021, the World Economic Forum (WEF) launched its report “Implementing Low-Carbon Emitting Technologies in the Chemical Industry. A Way forward.”[20] The study has identified 5 main „Building blocks toward net zero: Technology innovations“:

- Electrification of existing processes with renewable and carbon-neutral energy,
- Use of renewable feedstock by using biomass for feed and/or for fuel. The demand for biomass as a renewable source of feedstock and fuel is increasing in various sectors such as aviation and shipping,
- Combination of electrification and renewable feedstock within alternative hydrogen production via electrolysis,
- Use of renewable feedstock by increasing circularity via improved waste processing
- Carbon capture, use and storage (CCUS) and CO_2 sequestration by reforestation.

Obviously, technology and innovation play a decisive role for the WEF just like for the ICCA for making a “net zero” perspective feasible. In the next part, we will have a closer look at the European Union and Germany as an example of an industrialized country. With regards to developing countries and particularly small and medium-sized enterprises, it must be admitted that the starting points for such types of decarbonization pathways may be quite different in industrialized and developing countries. Though there may be a lot to learn from experiences and example of other countries, the respective pathway and roadmap must cater to the specific situation and starting point of the chemical industry or company in question.

3. Selected trends and approaches in industrialized countries

THE CASE OF THE EU

Before dealing with the future perspectives for decarbonization of the EU’s Chemical Industry, it is helpful to have a look at past developments. The European Chemical Industry Council (CEFIC) provides charts with the emission trends from 1990 to 2021[21], based on materials from the European Environment Agency (EEA). As shown in Fig. 4, the GHG emissions decreased by around 50 % in that period from more than 250 millions of tons CO_2 eq. to less than 125 millions of tons CO_2 eq. The decrease is more marked for process-related emissions than for those related with the combustion of fossil fuels.

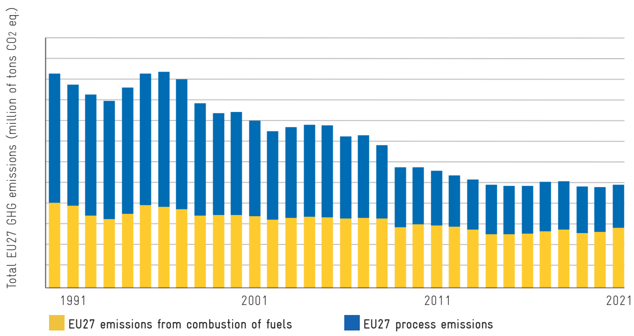


Fig. 4: Total scope 1 emissions (direct process- and energy-related emissions) of the chemical industry in the EU from 1990 – 2021 (Source: CEFIC with materials from EEA)

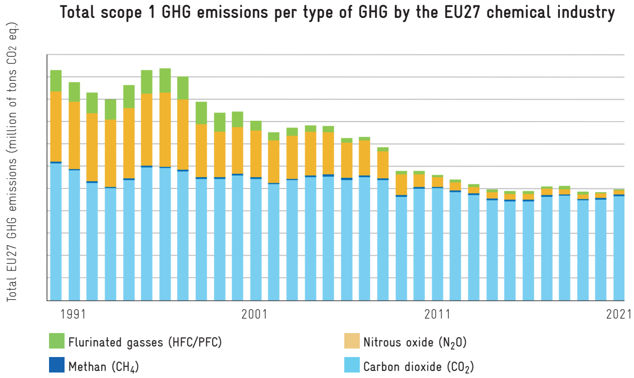


Fig. 5: Total scope 1 emissions (direct emissions) by type of GHG of the chemical industry in the EU from 1990 – 2021 (Source: CEFIC with materials from EEA)

19: Chemical_Roadmap_2013_Final_WEB-called_by-dechema-original_page-136220-original_site-dechema_eV-view_image-1.pdf
20: WEF_Implementing_Low_Carbon_Emitting_Technologies_in_the_Chemical_Industry_A_ Way_Forward_2021.pdf (weforum.org)
21: Environmental Performance - cefic.org

Fig. 5 confirms that the strongest GHG reductions have been achieved for process-related emissions, particularly laughing gas (N2O) e.g. released in the production of nitric acid that are eliminated through catalyzer technologies. But the decrease of emissions of fluorinated gases (F-gases) is also significant. Less reduction has been achieved for CO_2 emissions from fossil fuel combustion. Nevertheless, as CEFIC also emphasizes on its homepage under "Environmental Performance" it must be considered that the volume of chemical production rose by 52 % in the same period. Hence, energy intensity has also decreased significantly (though less then carbon intensity); the energy consumption fell by 20 % and GHG emissions by 52 % between 1990 and 2021 according to CEFIC.

What we can notice from these trends is a significant reduction of GHG emissions in the chemical industry over the last more than 3 decades, mainly due to the reduction of specific greenhouse gases with high global warming potential (N2O and F-gases) in combination with continuous improvement of energy supply and use. Nevertheless, it must also be stated that emissions from the chemical sector have still a very relevant dimension. And the figures shown in Fig. 4 and 5 do not even include emissions under scope 2 and 3 (especially purchased electricity under scope 2 should be relevant).

In conclusion, emission reduction in the chemical sector remains an important field of action. This is also reflected in the publication "Transition Pathway for the Chemical Industry" of the European Commission (EC) from 2023[22]. The chemical industry is the 4th largest manufacturing sector in the EU and a supplier of more than 90 % of all other industries. The EC strategy is based on the European Green Deal and the associated goal of climate-neutrality of the EU by 2050. Climate neutrality is one of four dimensions of the transition pathway – making clear that the climate-related goals are integrated together with other goals in a broader initiative of modernization, innovation and enhanced competitiveness:

- **Going circular** to reduce the use of non-renewable resources during production and ensure the materials produced can be recycled
- **Going digital** to make processes more transparent and efficient towards the overall green transition
- **Going climate neutral** to reach climate neutrality by 2050, breakthrough innovations and major changes in production processes are needed
- **Transition to safe and sustainable chemicals** to phase out the most harmful substances which means to significantly boost its research & innovation activities to develop and bring to the market safe and sustainable chemicals

Furthermore, 8 building blocks with more than 200 actions have been identified:

1. **Sustainable Competitiveness**: EU Chemicals Strategy for Sustainability (CSS) create a business environment that allows the industry to develop sustainable solutions in Europe and beyond
2. **Investment and funding**: Action plan to support the conversion or replacement of existing assets with more sustainable alternatives
3. **R&I, Techniques and technological solutions**: Right technologies available to the mark that could reduce 38 % GHG from energy intensive industries
4. **Regulation and public governance**: Improving the consistency and predictability of legislations
5. **Access to energy and feedstock**: Move from primary fossil-based feedstock to alternatives like biomass, captured CO_2 and waste; deploy renewable energy and access to raw materials and feedstock.
6. **Infrastructure**: To access clean energy sources and circularity of resources supporting industrial symbiosis and improve integration within industrial clusters
7. **Skills**: Significant pool of talent with the right skills to accelerate the development of safe and sustainable chemicals and materials and deploy digital technologies such as AI, blockchain and robotics into industrial processes and product design
8. **Social**: transition to a circular economy must be fair and inclusive, putting people first and supporting those who will face the greatest challenges

22: Transition pathway – European Commission (europa.eu)

Germany is the biggest economy of the EU and has also a strong and well-developed chemical industry. Perspectives for climate-neutrality were analyzed in the study "Working towards a greenhouse gas neutral chemical industry in Germany" commissioned by the association of the German chemical industry (VCI –Verband der Chemischen Industrie)[23].

The study analyzes 3 scenarios with different levels of ambition:

Scenario 1 – the "Reference pathway" is a baseline scenario, that would yield a 27 % GHG reduction by 2050 through minor improvements and efficiency gains as well as coal power phaseout in Germany.

Scenario 2 – called "Technology pathway" would lead to a 61% reduction of GHG by 2050 through the introduction of low-GHG emission technologies, but implying a much higher demand of electricity from renewable sources.

Scenario 3 – the GHG neutrality pathway would require a massive introduction of low GHG emission technologies, including electrification with renewable power of so far combustion-based processes in order to achieve climate neutrality.

As shown in Fig. 6, enormous amounts of renewable electricity would be needed, estimated at 628 TWh per year just for carbon-neutrality of the chemical sector in scenario 4. This quantity is in the order of the total energy consumption of Germany around 2020. This is just one key issue, but innovative technologies and fundamental process changes would also be needed in many other areas. Table 1 (see page 9) gives an overview of the technologies associated with scenarios 2 and 3.

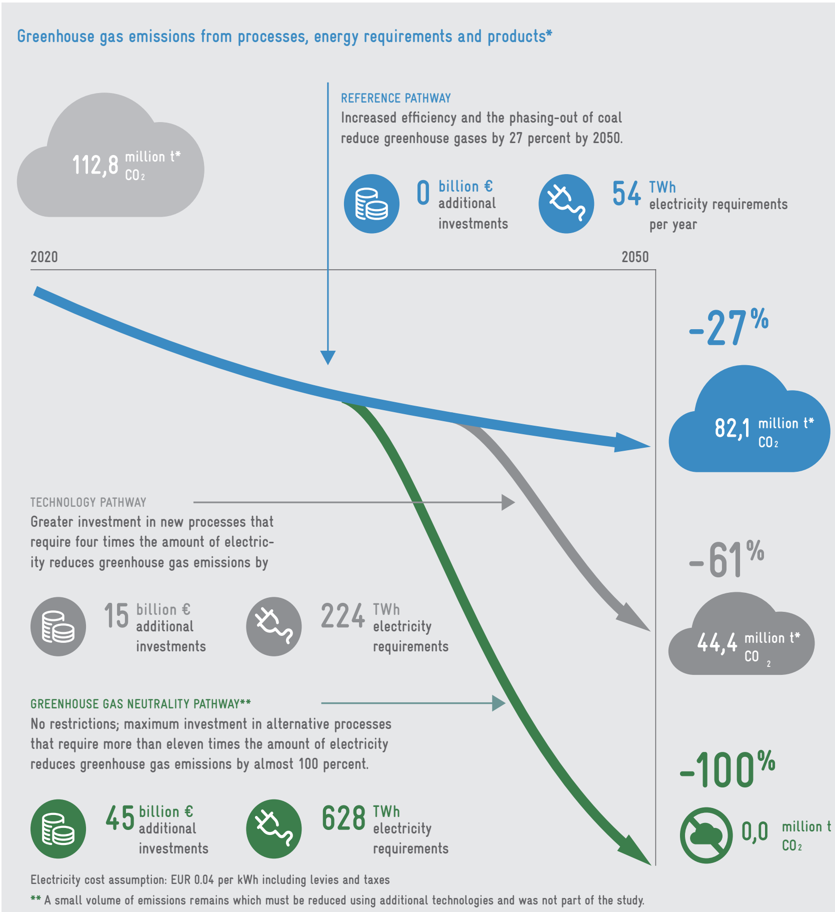


Fig. 6: 3 scenarios for the development of the chemical industry in Germany with different pathways and implications for technologies, energy and GHG emissions (FutureCamp & DECHEMA, 2019)

23: Roadmap Chemie 2050 | VCI (FutureCamp & DECHEMA, 2019)

ELECTRICTY-BASED PROCESSES	ALTERNATIVE RAW MATERIALS / PROCESSES	DOWNSTREAM PROCESSES
• Methanol from electrolytic hydrogen and CO_2 • Ammonia and urea from electrolytic hydrogen and CO_2 • Electrically heated cracking • Electrically heated steam reforming • Synthetic naphtha / methane from electrolytic hydrogen and CO_2	• Chemical recycling of plastics (pyrolysis, gasification, depoly-merization) • Thermo-catalytic biomass conversion into BTX • Synthetic naphtha / methane from biomass • Co-firing with biomass • Methane pyrolysis	• Ethylene / propylene via methanol-to-olefins (MtO) • BTX via methanol-to-aromatics (MtO) • Olefins from synthetic naphtha and cracking • Olefins from synthetic methane + oxidative coupling of methane

Table 1: Technology portfolio for scenarios 2 and 3 of the roadmap for the German chemical industry

Following up and based on the cited study of a possible roadmap towards GHG neutrality, the German chemical association VCI initiated a broad analysis and discussion process of how such a transformation could be achieved concretely. The initiative was called "Chemistry for Climate" (C4C)[24] and included experts and representatives from an important number of different public, private sector and academic organizations. From 2021 to 2023, working groups were formed, in order to deepen the analysis, verify underlying assumptions and examine different scenarios, based on detailed fact-finding, for 3 key areas:

- Energy supply and infrastructure of the future (incl. renewables, H_2 etc.)
- Circular economy and raw material supply of the future (recycling, biomass, circular carbon)
- Regulatory framework (enabling policies and regulations etc.)

Instead of the former timeline of 2050, 3 scenarios were defined for achieving climate-neutrality already by 2045[25]:

- Scenario 1: Focus on direct maximum use of electricity
- Scenario 2: Focus on green hydrogen and PtX products (e-fuels and raw materials / chemicals)
- Scenario 3: Focus on secondary raw materials (plastic waste and biomass)

While the above-mentioned study of 2019 had found a demand of (renewable) electricity in the order of 628 TWh, the three new scenarios implied lower energy demands of 464 TWh, (Scen. 1), 508 TWh (Scen. 2) and 325 TWh (Scen. 3) respectively. In the final report of C4C the following approaches were emphasized as critical success factors:

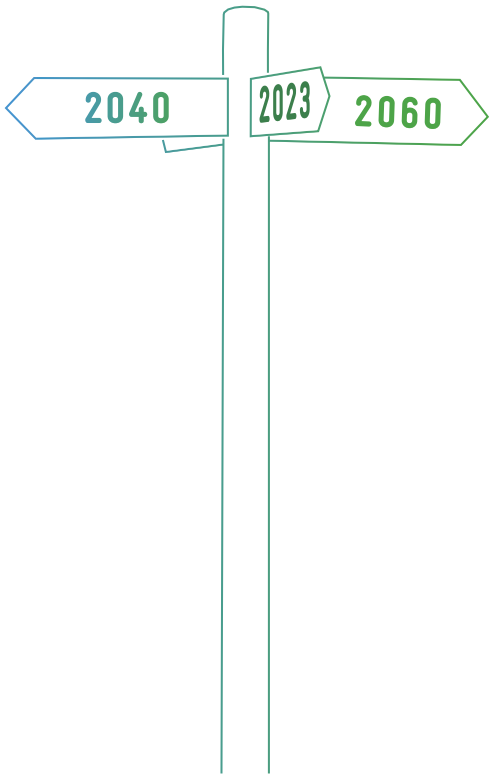
- Circular economy for plastics as a secondary raw material
- Use of biomass as an alternative feedstock (with sustainability criteria)
- Use of CO_2 as alternative carbon source ⇢ carbon capture und utilization (CCU)
- Power from renewable sources
- (Green) hydrogen
- Financing mechanisms for the transformation: low electricity prices, infrastructure, funding etc.

The last conclusions regarding necessary infrastructure, financial incentives and price conditions are critical and imply that a favorable overall framework must be provided by the public sector and the society.

24: Chemistry4Climate | VCI
25: This corresponds to the updated German objective of being climate neutral by 2045, established in 2021; see: Climate Change Act: climate neutrality by 2045. (bundesregierung.de)

4. Exploring pathways in developing countries and emerging economies

The experiences and approaches of industrialized countries can be helpful when analyzing feasible pathways for climate protection in the production and use of chemicals in developing countries and emerging economies. Economic feasibility will play a crucial role – maybe an even bigger role than in industrialized countries. As the case of the EU shows, specific measures like eliminating N2O emissions through catalyzer technologies and phasing out fluorinated gases in cooling, refrigeration and foam-blowing can form relatively cost-efficient building blocks and reduce GHG emissions significantly. Efforts for increasing energy and resource efficiency are often "no-regret" measures with significant co-benefits, while investments into renewable energy sources should be considered right from the beginning. Nevertheless, such a transformation has a huge dimension, and in many cases, it will be wise to combine GHG mitigation efforts with other elements of modernization, regarding technologies, digitization among others (see EU Transition Pathway for the Chemical Industry).



As mentioned above, CAPCI experiences strongly suggest that there are no blueprints for pathways and roadmaps for GHG mitigation in the sense of "one size fits all"; they must respond to the specific situation of the industries considered and the framework conditions. In many developing and emerging economies, the situation of the chemical industry is more heterogeneous than in industrialized countries in the sense of co-existence of big enterprises or branches of multinational companies with an important sector of small and medium-sized enterprises. While the big players usually have their corporate strategies, sometimes with ambitious objectives such as climate neutrality worldwide by the middle of the century, the smaller ones are often missing basic knowledge and capacities. Sectorial mitigation strategies have to take these different starting points into account and should be accompanied by information, awareness creation, dialogue and training offers.

CAPCI has supported studies for the elaboration of roadmap proposals in three partner countries that will be briefly presented here: Argentina, Ghana, and Thailand[26]. The structures of the chemical industry and the political and economic context in these 3 countries are quite different. In some cases, the government partners were more in the lead and in others the cooperating private sector organization. But in all 3 cases the roadmap development was accompanied by a public-private stakeholder dialogue and involvement of academia or specialized technical institutions.

26: For baselines regarding the chemical industry in these countries see: www.isc3.org/page/capci

ARGENTINA

The roadmap proposal for Argentina is based on a study of the regional centre of the Basel Convention, based in Buenos Aires. It was undertaken on behalf of the national association of the chemical and petrochemical industry (CIQyP – Cámara de la Industria Química y Petroquímica) with the support of CAPCI and the backing of the Ministries for Industry and Environment.

The main characteristics of the roadmap proposal are shown in Fig. 7. Three areas of work have been defined: (1) energy, (2) circular economy and raw materials and (3) policy framework. In addition, three scenarios characterized by different complexities and time horizons are considered, with impacts to be achieved by 2030, 2040 and 2050 respectively.

The work with different time horizons and scenarios of growing complexity is essential for structuring an endeavor of comparable dimensions. Energy is of course a crucial area, comprising efficient use and introduction of significant amounts of renewable energy. But raw materials are also important, e. g. the use of alternative feedstocks such as plastic waste and secondary biomass instead of fossil hydrocarbons. The experiences of CAPCI indicate that circular economy approaches can contribute significantly to efficient resource use (and economic feasibility of such changes) and GHG mitigation, particularly in industrial parks or chemical parks, organized as "Verbundstandorte"[27].

Last but not least, enabling policy frameworks have a critical importance; the low-carbon transformation requires adequate infrastructure, incentives, reliable and positive legal structures, a solid public-private partnership and a high degree of innovation.

Scenario	Energy	Circular economy and raw materials	Policy framework
Low complexity (impact to 2030)	• Energy efficiency • Renewable energies	• Mechanical and chemical recycling • Resource efficiency strategies • Reduction of emissions in specific sectors	• Adequacy of promotion instruments • Political-institutional support for transformation
Medium complexity (impact to 2040)	• Blue Hydrogen • Power to Chemicals	• Use of biomass	• Innovation tools • Infrastructure for CCU • Public / Private R+D Partnerships
High complexity (impact to 2050)	• Green Hydrogen	• ccu	• Emission rights • Regulated carbon market

Fig. 7: Overview of the mitigation roadmap proposal for the Argentinian chemical and pet-rochemical industry

27: A factsheet elaborated by CAPCI shows examples of synergies between different companies and plants in a chemical park, e.g. using residual material, waste heat and steam generated by one company in another one and in joint infra-structure. The German term "Verbundstandorte" indicates that these chemical parks work in an inter-connected man-ner in order to create synergies, reduce waste, use energy and materials efficiently etc.: https://www.isc3.org/cms/wp-content/uploads/2023/01/Factsheet_Verbund_060123.pdf

GHANA

The development of a roadmap for Ghana's chemical industry was realized upon the request of the Environmental Protection Agency (EPA), the Association of Ghana Industries and the CAPCI network group. The EPA and the AGI are the implementing partners of CAPCI and provided support to the contracted national expert for the execution of the assignment. The chemical sector contributes to about 6 % of the national GDP and about 11% of Ghana's manufacturing GDP. Considering chemical use, mainly in the sectors of fertilizers, aluminum smelting, light manufacturing, furniture, paints, steel, cement, food processing and textiles, Ghana is an attractive country for chemical trade. One of the important sectors that contributes to the high economic values as well energy consumption and greenhouse gas emissions is the chemical industry. The industry has complex processes resulting in a broad range of products.

The chemical imports include chemicals such as activated carbon, caustic soda flakes, sodium hypochlorite, vinyl ether, sodium isobutyl xanthate and Mono-Dicalcium Phosphate 21%. Some chemicals exported by Ghana are Natural Menthol Crystals (USP/BP/JP/IP), spice oils, aromatic chemicals, herbal extracts, 100 % natural essential oils, flavours & castor oil[28]. A broad range of products, manufacturing processes, and supply chains from feedstocks to end products are contained in the chemical industry.

The five (5) product categories generally focused on are basic chemicals and petrochemical products, agricultural chemicals, specialty chemicals, pharmaceuticals and consumer products.

The study reveals the main sources of emissions in the chemical industry, establishes the trajectory of the emission reduction approaches and proposes mechanisms to ensure that national targets are met.

The emission sources are categorized into process-related and those that are related with energy use or energy production. The chemical industry has a long history of reducing energy consumption and emissions while also providing innovative solutions. An energy mix dominated by natural gas and biomass is the basis for the development of alternative and domestic energy sources, while the options of an enhanced use of other renewable energy sources and, eventually, nuclear power complementation are also considered.

This roadmap has been developed in reference to relevant national policies, legislative frameworks and the global commitments expressed in Ghana's NDC. It has set the national context of a pathway towards Net Zero, highlighting guiding principles, commitments and roles for government and industries in the period from 2030 to 2070. It further proposes solutions for decarbonizing the chemical industry, emphasizing the opportunities presented by a Net Zero Transition.

Proposed Projections	Energy	Circularity of Resource Use	Enabling Environment	Production Technology
Low Complexity (by 2030)	Energy Audits for enhanced energy efficiency Distribution of green energy sources	Enhance natural source of production inputs Awareness on waste segregation	Enabling regulatory framework Capacity building Incentives for greening	Financial Support New Technologies Green labeling
Medium Complexity (by 2040)	Renewable sources of energy Grey energy base for clusters	Increased recycle/re-use of resources (waste) Commitment to circular economy models	Grant scheme for industries Financial institutions offer green grants	Zero high-carbon production Commitment to new technologies
High Complexity (by 2050)	Green energy production and use Transition to renewable energy	Green supply chain linkages Industrial cluster systems Incentives for CCU	Research and development Regulated carbon market	Green resource system Carbon market participation

Fig. 8: Summary of the mitigation actions towards Net Zero as presented in the Roadmap for Ghana

28: https://ghanatrade.org/chemicals

THAILAND

The roadmap proposal for Thailand is based on a study conducted by the Center of Excellence on Hazardous Substance Management (HSM) Chulalongkorn University in Bangkok. Its primary objective is to establish a framework for stakeholders in the chemical industry, outlining strategies to curtail greenhouse gas (GHG) emissions from their manufacturing operations with waste and energy management into consideration. This initiative is aligned with broader efforts towards achieving Carbon Neutrality by 2050. The roadmap study focuses on proposing mitigation measures for GHG reduction in the chemical industry, addressing aspects such as electricity and thermal energy consumption, feedstock and production changes, technological adjustments, and waste management within production facilities.

The implementation of GHG mitigation measures is structured into three phases: the preparation phase (2024–2025), mid-term phase (2026–2030), and long-term phase (2031–2050). These measures span six categories:

1. Energy efficiency
2. Fuel switching, electrification, and the use of renewable and bio-based energy
3. Chemical/feedstock switching
4. Technological adjustment/change
5. Circular material flow and waste utilization
6. Carbon Capture and Utilization (CCU), Carbon Capture and Storage (CCUS), and Direct Air Capture

Implementing all six categories of interventions within the time frame specified in the preliminary road map is expected to reduce greenhouse gas emissions by more than 3 million tons in 2050 and 0.46 million tons in 2030. And by implementing measures specific to production processes (chemical/feedstock switching and technological adjustment/change) as accounted for under IPPU (2B), greenhouse gas emissions are expected to be reduced by 0.15 million tons in 2030 and 1.21 million tons in 2050, compared to the baseline year of 2025.

The successful implementation of these mitigation measures requires appropriate support mechanisms, categorized into four groups:

1. Mechanisms related to finance and economics
2. Mechanisms related to legal frameworks, regulations, and standards
3. Mechanisms related to knowledge, skills, and capacity development, along with awareness-raising programs for all stakeholders
4. Mechanisms related to research and development (R&D).

5. Conclusions and discussion: The way forward

The chemical sector is a key sector for tackling global climate change due to its high GHG emissions (7.4 % under scopes 1 and 2, IPCC 2022) and its significant potential to contribute to climate-friendly solutions for mitigation also in other sectors. When it comes to national climate objectives and implementation strategies in developing countries and emerging economies, the chemical sector also matters. It must be taken into account that the need for information, knowledge and capacity building is often very high, particularly in the segments of small and medium-sized enterprises.

In general terms, it can be stated that achieving climate neutrality for the chemical industry by 2050 is possible, but it requires big efforts. Economic viability is crucial, also for ensuring competitiveness in the markets – where climate-friendly production methods are supposed to be a positive factor or even prerequisite in future.

As shown above in section 3 (but also in Fig. 3 – "schematic pathway to climate-neutrality of the industry" of the IPCC, 2022), many different mitigation options are available at technological level. It shall be underlined here that for developing countries, in addition to specific mitigation technologies with high impact, it seems crucial to start with cost-effective measures such as optimization of existing processes, loss reduction, energy and resource efficiency. In many cases, the potential of synergies between plants and companies has not yet been explored. Therefore, the focus should also be put on circular economy options in industrial parks in the sense of "Verbundstandorte" with shared infrastructure and the use of waste materials, waste heat or steam from one plant or company in other plants or companies.

Such well-organized industrial areas also offer the chance to initiate renewable energy projects and explore innovative technology options such as Power-to-X, green hydrogen or Carbon Capture and Utilization (CCU). Fuel switch, electrification and feedstock switch are also parts of the menu of mitigation options. Investing into innovative solutions, alternative business models, and, of course, renewable energy will often constitute an important opportunity.

Roadmaps at sector level as well as company level can be a good starting point of a transition pathway (not its end); regular assessments of progress and periodic updates are necessary. It was found essential that their development and implementation is accompanied by public-private dialogue.

Roadmaps must be individually designed according to the specific demand of the sector in a country and of a company; there is no blue-print or one-size-fits-all for all regions of the world. On the other hand, it was found in the implementation of CAPCI that South-South cooperation, especially knowledge sharing and learning from each other is very helpful. International cooperation should provide these types of opportunity. For instance, it proved useful to summarize the basic ideas such a roadmap in a comprehensive structure with defined areas of action and different scenarios, time horizons and levels of complexity.

Clear-cut mitigation action pathways are needed that should include not only technologies but also soft success factors, such as collaboration between value chain partners, big and small companies, suppliers and clients. A lifecycle approach is important, also considering emissions in the value chain, upstream and downstream.

Of course, as the example of the EU Transition Pathway shows, GHG mitigation could be just one major pillar together with others like digitization, circular economy and chemical safety. If transformation efforts are needed in different areas, an integrated strategy implies synergies and will probably be more efficient. For the chemical sector the concept of Sustainable Chemistry offers a holistic vision. In any case, coherence of mitigation efforts with other goals is indispensable, e.g. with sustainable chemicals management; and trade-offs should be avoided.

Roadmaps for GHG mitigation in the production and use of chemicals should generally take the national climate policies as a reference; and they should be designed in a way that they can form a contribution to national climate objectives or NDC's and their sectorial implementation strategies. On the other hand, ambitious roadmaps can only be implemented with favorable political framework conditions and adequate financing. Governments have to do their part, e. g. providing economic incentives, creating the necessary infrastructure (e.g. renewable energy) and promoting capacity development.

As the experiences of CAPCI show, international cooperation can play a crucial supportive role for initiating and accompanying the process, providing advice and technical studies, capacity development, knowledge sharing and South-South cooperation opportunities. ■

Published by:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany
Climate Action Programme for the Chemical Industry – CAPCI

Address
Friedrich-Ebert-Allee 32+36
53113 Bonn, Germany
T +49 228 44 60-0
F +49 228 44 60-1766
E capci@giz.de
I www.giz.de/en

Factsheet:
Toward greenhouse gas neutrality in the production
and use of chemicals

Responsible:
Dr. Detlef Schreiber, Paola Bustillos

Editors:
Ezequiel Gaspes, George Johnson, Pimpilas Nuntiphon

Contact:
Paola Bustillos, Project Manager CAPCI
E paola.bustillos@giz.de

Design:
Visuelles Design Andrea Groß, Darmstadt

On behalf of:
Federal Ministry for the Environment, Nature Conservation, Nuclear
Safety and Consumer Protection (BMUV)

Bonn, March 2024