

GreenChemForCE WP2

Activity 2.1. Analysis of carbon dioxide
linear and circular

Output 2.1: Strategies for low carbon
footprint chemical industry in CE

Deliverable 2.1.1: Analysis report

2nd version

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1. Project description - main focus, goals

The aim of the GreenChemForCE project is to help reduce the negative environmental impact of the chemical industry in Central Europe.

The project aims to unify the industrial and academic sectors to achieve greener chemical production in Central Europe by developing strategies and solutions for more sustainable processes and resource management, which will result in reduced pollution and minimized environmental damage in the region. Moreover, our intention is to encourage the regional chemical companies to adopt circularity principles in production and to help a better reception of the chemical industry by the general public.

The Partners of this project are:

Charles University (CU) as Lead partner, Association of Chemical Industry of the Czech Republic (SCHP CR) and Zentiva from Czech Republic, The Servier Research Institute of Medicinal Chemistry (SRIMC) and Eötvös Loránd University (ELU) from Hungary, TU Wien (TUW) and Vienna Textile Lab GmbH (VTL) from Austria and University of Ljubljana (UL) and Chamber of Commerce and Industry of Slovenia (CCIS) from Slovenia.

The Project has the following work packages:

- WP1 Sustainable management of plastics - led by CCIS
- WP2 Carbon dioxide management in industry: emission reduction and utilization – led by SCHP CR
- WP3 Streamlining processes for the production of fine chemicals – led by UL

SCHP CR, as the Leader of WP2, prepared this Analysis based on the specific objectives for this Project. The increase of the atmospheric carbon dioxide (CO₂) concentration is an alarming issue and the consequences resulting from it already have a dramatic impact on the regional environment and beyond. The local chemical industry contributes to the production of CO₂ and the amount of the gas emission has been steadily increasing over the past years. The specific objective of this work package is to analyze the current state of CO₂ emissions in the regional chemical companies and jointly develop strategies to reduce CO₂ waste production, together with technologies for CO₂ utilization as a carbon source to produce valuable chemicals through the use of circular economy principles. The long-lasting goal of this project is to achieve a general improvement in the CO₂ management in the Central European region.

Analysis of the Current Status

Objective: The primary goal of this stage is to conduct a thorough analysis of the current state of CO₂ production across various sectors within the chemical industry in Central Europe, with a specific focus on the Czech Republic, Austria, Hungary, and Slovenia. This



analysis will be carried out through a transnational collaboration involving both academic institutions and industrial experts.

Key Activities:

Identification of Critical Points: The collaboration will identify critical points in the chemical production processes where CO₂ emissions are most significant. This includes examining processes that are energy-intensive, rely heavily on fossil fuels, or have low efficiency in resource use.

Data Collection: Partners from academia and industry will collect and share data on CO₂ emissions, including both linear (traditional) and circular (sustainable) practices currently in use. The GreenChemForCE project and initiatives like CO₂-SPICER will be instrumental in providing baseline data for this analysis.

Cross-Border Collaboration: The analysis will leverage the expertise and technological capabilities of institutions across the involved countries, ensuring a comprehensive understanding of the CO₂ emissions landscape across the region.

Expected Outcomes:

A detailed report on the current state of CO₂ emissions in the chemical industry.

Identification of the most significant sources of CO₂ emissions and inefficiencies in current production processes.

A foundation for developing strategies to mitigate CO₂ emissions in subsequent stages.



2. Introduction to „Green Chemistry“ concept

Chemicals and materials made from biomass and captured CO₂ will play a key role in the transition to a circular economy. Given the huge emphasis on climate and climate change mitigation measures, steps are being taken to transition from today's fossil fuel-based economy to a more sustainable one based on renewable energy, biomass, and recycling.

Green chemistry is one of the contributors to shift CO₂ economy from linear to circular.

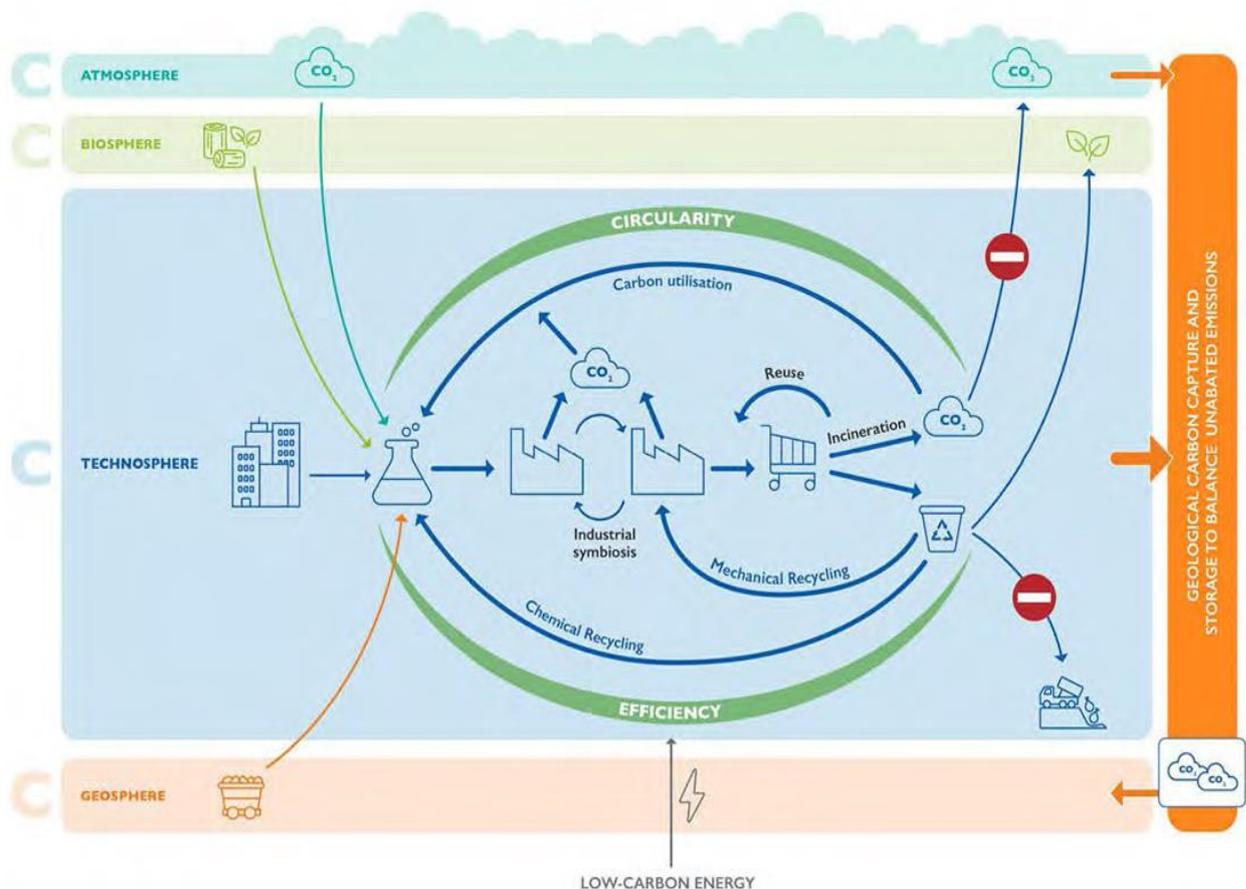


Figure 1: Sustainable carbon life cycle

(source: Cefic „The Carbon managers“, 2025)



3. Possible scenarios of industry development

Importance, probability and time horizon for the implementation of measures to achieve Carbon neutrality of the chemical industry in the EU is shown in the table below.

Carbon neutrality measures	Importance of Carbon neutrality measures	Probability of implementing carbon neutrality measures	Time horizon for implementation of measures
Increased energy efficiency	**	***	2025+
Replacing coal with low-emission fuel (NG)	**	***	2025-2035
Replacing fossil fuels with low-emission energy	***	***	2035+
Heat energy recovery	**	***	2025+
CO ₂ capture, storage and processing	***	**	2035+
Electrification (buying electricity on the market)	**	**	2030+
Production of own electricity from Renewable Energy Solutions (RES)	**	**	2025+
Generation of own electricity from SMR	**	*	2045+
Replacing fossil hydrogen with low-emission hydrogen	*	***	2035+
Material recovery of waste	**	***	2030+
Energy recovery of waste	*	**	2025+
Use of renewable raw material (incl. bio-based)	**	***	2025+
Use of biomethane as fuel	*	**	2025+
Using hydrogen as fuel	*	*	2035+
Decommissioning of existing energy sources	**	***	2025+

Source: own expert assessment



Transformed chemical industry is characterized by a high degree of energy efficiency, use of secondary raw materials, and a very minimal negative impact on the environment. The chemical industry effectively helps the use of waste CO₂ and comes up with technological innovations for the transformation of CO₂ into chemical products for further processing. The transformation of the chemical industry is supposed to take place according to the scenario described below, gradually achieving full carbon neutrality by 2050.

Description of possible scenario of chemical industry development.

Green and Digital transformation is introduced.

Resilience to energy self-sufficiency and access to strategic raw materials and products is built continuously.

Raw materials for chemical industry

The raw material base of the chemical industry underwent a rapid transformation, during which the consumption of fossil raw materials for chemical production was minimized and optimized. The introduction of new technologies for the production of synthetic hydrocarbons significantly contributed to the transformation of the raw material base of the chemical industry and reduction of CO₂ emissions. However, these technologies have been very expensive and, given the slight and gradual rise in fossil fuel prices, investment in these technologies has a very long return. Depreciation of these investments reduces the profitability of the chemical industry as a whole. There has been another shift in the reuse of critical raw materials from recycling.

Energy for chemical industry

The chemical industry is still one of the most energy-intensive branches of industry but thanks to a smart energy mix and increased energy efficiency of chemical production, CO₂ and other greenhouse gas emissions have been significantly reduced. The chemical industry has thus become the driving force behind the decarbonization of EU industry. Natural gas as an energy source (prices range between 35 and 100 EUR / MWh) is significantly more expensive than in other parts of the world (2-3 times), so the chemical industry will rely heavily on the use of electricity. Although the price of electricity on the market is in the reasonable cost-range between 45 and 100 EUR / MWh, the availability of electricity for full electrification is sufficient having access to the low carbon electric energy as prevailing part of the national energy mix. The large chemical companies use also their own energy source, such as the recovery of thermal energy generated during chemical production, and their own sources of electricity production, such as small modular nuclear reactors (SMR). Energy technologies based on low-emission hydrogen are introduced.

Demand for chemical production

Revenues in the chemical industry are constantly growing, mainly due to an increase in demand for the main chemical commodities and active approach in recycling and CO₂ utilisation. Thanks to this, it is possible to gradually balance and depreciate the enormous costs of the transformation of chemical production invested in the last 15 - 20 years. The demand for polymers and specialty chemicals is also gradually growing.



Regulation of production processes and chemical production

The European Commission's original intentions to rapidly transform European industry into a carbon-neutral economy have been modified over the years towards a more gradual transition. This is reinforced by rise in prices of emission allowances EU ETS over 150 EUR /t and possibly stabilizing them at extremely high levels up to EUR 250 /t. Pressure from society and EU governments on strict regulations on emissions policy, the use of fossil fuels (especially natural gas) and circularity has also eased. Nevertheless, thanks to the successful transformation, the chemical industry is ready to meet stricter limits and requirements for production processes than the ones set by regulations.



4. SWOT Analysis on Decarbonization Efforts in the Chemical Industry

4.1. Czech Republic

Strengths

- **Coal Phase-Out Commitment:** The Czech Republic has committed to phasing out coal by 2033, primarily for energy use. However, coal and other fossil fuels will still be used as raw materials in chemical processing, allowing for a gradual reduction in their usage. Both approaches align with broader national decarbonization goals ([Balkan Green Energy News](#)).
- **Technological Transition:** Investments in renewable energy sources, essential for advancing technologies in the chemical industry (e.g., renewable hydrogen production, electric heating in chemical processes), are expected to replace coal. This transition is further driven by the rising EU Emissions Trading Scheme (ETS) prices ([McKinsey & Company](#)).
- **CO₂-SPICER Project:** This project, funded by Norway Grants and the Technology Agency of the Czech Republic, focuses on the storage of CO₂ in carbonate reservoirs. It represents a significant effort to incorporate carbon capture and storage (CCS) as part of a circular carbon economy ([CO₂-Spicer](#)).

Weaknesses

- **High Reliance on Fossil Fuels:** A significant portion of energy production still comes from coal. The question of nuclear power as a low-carbon energy source is still under discussion. These are making the transition challenging ([Balkan Green Energy News](#)). The Czech Republic continues to rely heavily on coal, particularly for electricity generation, which complicates its decarbonization efforts ([McKinsey & Company](#)).
- **Investment and Financial Requirements:** Achieving decarbonization goals in chemical industry requires substantial investments, estimated at around CZK 500 billion by 2030 ([McKinsey & Company](#)).

Opportunities

- **EU Support:** Access to the EU's Just Transition Fund and other EU incentives can help finance the transition ([Balkan Green Energy News](#)).
- **Innovation in Automotive Sector:** Decarbonization presents opportunities for technological advancements and economic growth, particularly for suppliers in the automotive industry (e.g., polymers, composite materials) ([Europeum](#)).
- **Renewable Energy Expansion:** The potential for significant growth in renewable energy, particularly solar and wind power, offers an opportunity to reduce reliance on fossil fuels ([McKinsey & Company](#)).
- **Biomass and Fermentations processes:** These technologies provide a viable pathway to negative emissions in the chemical industry, especially in sectors where alternative low-carbon technologies are not yet feasible due to high capital and operational costs. Biomass and fermentation can also serve as sources of raw materials for the chemical industry.



- **EU Funding and Support:** Access to EU funds through initiatives like the Just Transition Fund can help finance the transition from coal to renewable energy sources, chemical recycling or biomass technologies ([McKinsey & Company](#)).

Threats

- **Economic Cost and Risks:** The high cost of transitioning from coal to renewable energy may impact economic stability ([Balkan Green Energy News](#)).
- **Global Competition:** Czech industries face stiff competition from countries with less stringent environmental regulations, potentially affecting competitiveness of chemical industry ([Balkan Green Energy News](#)). In opposite, if other countries in the region advance their decarbonization efforts more rapidly, the Czech Republic could face competitive disadvantages ([McKinsey & Company](#)).

4.2. Austria

Strengths

- **Strong Renewable Energy Base:** Austria has a well-developed renewable energy infrastructure, particularly in hydropower, which supports decarbonization efforts.
- **Government Initiatives:** Austria's government is proactive in promoting decarbonization through various policies and subsidies for green technologies.
- **C2PAT Initiative:** Austria's C2PAT (Carbon to Product Austria) project is a cutting-edge initiative converting captured CO₂ into methanol, which is used in the chemical industry. This project plays a key role in Austria's circular carbon economy ([EuropaWire](#)).

Weaknesses

- **Dependency on Natural Gas:** Despite progress in renewables, Austria still relies heavily on natural gas, especially in the industrial sector, which may slow down its overall decarbonization efforts ([KPMG](#)).
- **High Energy Costs:** The cost of energy in Austria remains high, which could hinder the pace of decarbonization efforts ([KPMG](#)).

Opportunities

- **EU Green Deal:** Austria stands to benefit from the EU's Green Deal, which provides funding and regulatory support for decarbonization ([KPMG](#)).
- **Innovation in Circular Economy:** There is potential for Austria to lead in circular economy initiatives, particularly in chemical recycling and sustainable materials, particularly through projects like C2PAT that emphasize recycling carbon for industrial use ([EuropaWire](#)).

Threats

- **International Competition:** Austria's industries could face challenges from countries with lower environmental standards and costs.
- **Economic Impact:** The financial burden associated with the transition to a low-carbon economy might strain Austria's economic resources ([KPMG](#)).
- **Regulatory Compliance:** Adapting to rapidly changing EU regulations on carbon emissions could present challenges for Austrian industries if they are slow to comply ([KPMG](#)).



4.3. Hungary

Strengths

- **Government Commitment:** Hungary has shown commitment to the EU's climate targets, with plans to increase renewable energy usage.
- **OMV Petrom Projects:** Hungary benefits from OMV's efforts to utilize captured CO₂ in chemical processes, contributing significantly to the country's decarbonization strategy ([EuropaWire](#)).
- **Nuclear Energy Utilization:** Hungary's reliance on nuclear power, which produces minimal carbon emissions, provides a stable foundation for further decarbonization efforts ([KPMG](#)).

Weaknesses

- **Slow Adoption of Renewables:** The pace of renewable energy adoption in Hungary is slower compared to other EU countries, particularly in wind energy. ([KPMG](#)).
- **Energy Dependency:** Hungary's reliance on energy imports, particularly from Russia, poses risks to its energy security and decarbonization efforts ([KPMG](#)).

Opportunities

- **Solar Energy Expansion:** There is significant potential for expanding solar energy in Hungary, which could play a crucial role in reducing the country's carbon footprint ([KPMG](#)).
- **EU Funding:** Hungary can leverage EU funds to support renewable energy projects and infrastructure development, facilitating its transition to a low-carbon economy ([KPMG](#)).

Threats

- **Geopolitical Risks:** Hungary's energy security is vulnerable to geopolitical tensions, particularly due to its reliance on Russian gas, which could impact its ability to decarbonize effectively ([KPMG](#)).
- **Regulatory Challenges:** The evolving EU regulatory landscape may impose additional pressures on Hungary's energy sector, potentially slowing down progress ([KPMG](#)).

4.4. Slovenia

Strengths

- **Public and Private Sector Collaboration:** Strong collaboration between government, industry, and local communities in the transition process.
- Best practices in sustainable solutions within the construction industry are still in the development phase, but they are already being actively tested in various companies. Among them are companies such as Wienerberger, GIC Gradnje, Goriške opekarne, Termit, and Melamin, which are conducting tests and pilot projects to assess the effectiveness of these approaches and contribute to the introduction of more sustainable and environmentally friendly solutions in the industry.
- **Commitment to Coal Phase-Out:** Slovenia's clear strategy to phase out coal by 2033 reflects a strong commitment to reducing carbon emissions and transitioning to cleaner energy sources ([Balkan Green Energy News](#)).



Weaknesses

- **Slow Renewable Energy Development:** The development of renewable energy sources, particularly wind and solar, has been slower in Slovenia, which could hinder its decarbonization goals ([Balkan Green Energy News](#)).
- **Economic Impact of Transition:** The economic impact of transitioning away from coal, particularly in regions dependent on coal mining, poses significant challenges ([Balkan Green Energy News](#)).

Opportunities

- **EU Support for Transition:** Slovenia can access substantial EU funding to support the transition from coal to renewable energy, particularly through initiatives like the Just Transition Fund ([Balkan Green Energy News](#)).
- **Expansion of Nuclear Energy:** Slovenia has the opportunity to expand its nuclear energy capacity, which could provide a stable and low-carbon energy source to support its decarbonization efforts ([Balkan Green Energy News](#)).

Threats

- **Stranded Assets:** Investments in coal infrastructure could become stranded assets as the country phases out coal ([Balkan Green Energy News](#)).
- **Social and Economic Disruption:** The transition away from coal could lead to economic and social disruption, particularly in regions heavily reliant on coal-related jobs and industries ([Balkan Green Energy News](#)).



5. Identification of critical points - CZ, H, A and SI

5.1. Czech Republic

Energy Intensity

- Dependence on fossil fuels, particularly natural gas and coal, for energy-intensive chemical processes.
- Limited integration of renewable energy sources and green hydrogen.

Technological Lag

- Insufficient implementation of carbon capture and utilization (CCU) technologies.
- Inadequate support for research and development in advanced recycling of plastics and other materials.

Integration of Circular Principles

- Low levels of recycling and material reuse in the chemical industry.
- Lack of circular design in manufacturing and untapped potential for industrial symbiosis.

Economic Barriers

- High costs of implementing low-carbon technologies and long investment payback periods.
- Limited financial incentives for innovations and recycled materials.

Legislative Gaps

- Absence of specific legislation and targets to support CCU technologies and circular economy practices.
- Weak alignment of the chemical industry with national decarbonization plans.

5.2. Hungary

Energy Intensity

- Dependence on fossil fuels, particularly natural gas, for energy-intensive chemical processes.
- Limited integration of renewable energy sources and green hydrogen.

Technological Lag

- Lack of technological background and infrastructure: costly to develop, slow to adapt, costly investments needed.
- Need for a skilled workforce capable of introducing and operating green technologies.

Integration of Circular Principles

- Limited use of renewable energy sources - in Hungary, around 20-25% of energy production comes from renewable sources. This makes "green energy" less accessible to industry.

Economic Barriers

- Lack of adequate capital to enable investments that facilitate the green transition.
- Slow return on investment in green technologies, not only in financial terms, which is not always a sufficient incentive for industry to go green.



- Insufficient maturity and awareness of society - There is insufficient demand for products using green technologies.

Legislative Gaps

- Regulatory environment not effectively supportive of the transition.
- Precise definition of criteria for a "green industry" - with well-defined metrics.
- Lack of appropriate incentives: financial instruments, regulatory support, tax credits, simplified administrative procedures
- Lack of certificates, trademarks - To certify green technologies to consumers or other partners (marketing and other benefits).

5.3. Austria

- **Energy Intensity**
 - Energy is 20-30% more expensive in Austria than neighboring EU countries. One factor for high prices is missing competition in the power sector. If not regulated, Austria will become less attractive as business location which could hinder the development of decarbonization technologies and implementations. (Energie Österreich)
- **Technological Lag**
 - Insufficient implementation of carbon capture and utilization (CCU) technologies.
- **Integration of Circular Principles**
 - Geological CO₂ storage is still banned by law in Austria, despite the potential to store significant amounts of CO₂ in former hydrocarbon- and saline reservoirs. (Hochmeister et al., 2024)Even though it is mentioned, there is no clear definition of the term "climate neutrality" in the current governmental program, which poses the risk of misunderstandings and inefficient implementations of decarbonization strategies (governmental program 2020 - 2024).
 - The general population has a reserved and reluctant attitude towards climate change. More communication and financial incentives to convince the public and implement decarbonization strategies are needed.
- **Economic Barriers**
 - The investments required for Austria's climate targets for 2030 would require an annual budget of 2.6 bn. €. It remains to be seen if regulators are willing to invest this amount of money in times when politics is shifting towards austerity. (Österreichs Energie, accessed 19.01.2025)
- **Legislative Gaps**
 - Lengthy procedures and strict regulations for the establishment of renewable energy plants like wind parks (obtaining the required land, electricity regulation laws, nature conservation etc...). (Windfakten)



- The new far-right political landscape in Austria shows restrictive tendencies in climate change related topics. During recent government negotiations, the coalition parties put forward a proposal to reduce environmental subsidies by 500 Mio. € (-20%). Additionally, they proposed to eliminate tax relief for electric cars and VAT exemption for solar systems.
- Austria's neocorporate and federal political system has made it easier in the past for industrial, agrarian as well as trade unions to block climate change policies that would threaten their interests. (Brad et al., 2024)

5.4. Slovenia

The entry into the concept of green chemistry in Slovenia faces numerous challenges that can be identified as critical points influencing the successful implementation of sustainable practices in the chemical industry. Identifying these points is crucial for developing strategies that will enable a faster and more efficient transition to environmentally friendly processes.

Lack of appropriate regulations and incentives

- The current legislative framework in Slovenia does not provide strong enough incentives for companies to transition to green chemical processes.
- Complex administrative procedures for obtaining permits to introduce sustainable technologies.
- Absence of specific tax reliefs or subsidies for green chemistry projects.
- Insufficient alignment with EU goals, such as the European Green Deal and Fit for 55, slowing down the adoption of sustainable practices.

High costs of implementing green technologies

- Transitioning to green chemical processes requires high initial investments in new equipment and technologies.
- Limited access to financing and non-repayable funds that would facilitate the transition for companies.
- Long payback periods for investments in sustainable solutions, which discourages companies from making the switch.
- Lack of opportunities for collaboration with foreign investors in the field of sustainable innovations.

Lack of knowledge and expertise

- Low awareness of the green chemistry concept among companies, the public, and educational institutions.
- Shortage of professionally trained personnel to implement advanced sustainable chemical processes.
- Absence of specialized educational programs and training to support companies in the transition.
- Insufficient connections between academic institutions and industry for knowledge and experience transfer.



Limited access to renewable raw materials and energy sources

- Despite the potential for utilizing renewable energy sources (solar, wind, geothermal) in the chemical industry, their availability remains limited.
- Lack of infrastructure for the supply of sustainable raw materials, such as biodegradable materials and bio-based chemicals.
- Insufficient implementation of the circular economy, which would allow for greater use of recycled and renewable resources.

Low market awareness and demand

- Absence of clear market demand for products manufactured in accordance with green chemistry principles.
- Consumers and business partners are often unwilling to pay higher prices for sustainable products.
- Lack of certificates and labels to assure consumers of the transparency and quality of green products.
- Absence of a strong marketing strategy to promote sustainable chemical products.

Technological challenges and lack of research projects

- Low level of research and development in the field of green chemistry in Slovenia.
- Lack of pilot projects for testing and demonstrating new green technologies.
- Absence of collaboration with international research institutions, which could accelerate technological development.
- Challenges in developing competitive green chemical processes that could replace conventional methods.

Lack of systemic support and strategic direction

- Absence of a long-term national strategy to promote green chemistry in the industry.
- Insufficient involvement of key stakeholders (government, businesses, academia) in joint sustainability initiatives.
- The need for greater synergy between different sectors to develop sustainable solutions.

To successfully embrace the concept of green chemistry in Slovenia, it is necessary to:

- Strengthen government support with clear legislative guidelines and financial incentives.
- Establish educational programs to develop competencies in sustainable chemical processes.
- Encourage research and innovation, with a focus on collaboration between industry and academia.
- Enhance infrastructure for renewable energy sources and sustainable raw materials.
- Increase market awareness by better informing consumers and promoting the benefits of sustainable products.



6. Current status

6.1. Overview of most important EU legislation

The European Union has recently implemented several regulations and initiatives to support the development and deployment of Carbon Capture and Utilization (CCU) technologies as part of its broader strategy to achieve climate neutrality by 2050.

Green Deal is the main starting point:



One of the key developments is the **Net-Zero Industry Act (NZIA)**, which came into force in 2024. This regulation aims to establish a Union market for CO₂ storage services, with the objective of making 50 million tonnes of annual CO₂ injection capacity available by 2030. The NZIA also simplifies permitting procedures for net-zero projects and encourages Member States to prioritize these projects to accelerate the deployment of CCU technologies.

In addition to NZIA, the **Renewable Energy Directive** has been amended to include provisions for CCU-based fuels, ensuring that these fuels can be considered as renewable when they meet specific criteria. This is particularly important for sectors like aviation and maritime, where synthetic fuels produced through CCU are expected to play a significant role.

Moreover, the EU is fostering innovation in CCU through funding mechanisms like the **Innovation Fund** and **Horizon Europe**, which support large-scale CCU projects. These initiatives are helping to bring forward technologies that can convert captured CO₂ into valuable products like synthetic fuels, chemicals, and building materials, thus contributing to the circular economy and reducing reliance on fossil feedstocks.

Overall, these regulations and initiatives demonstrate the EU's commitment to integrating CCU into its climate strategy, enhancing the circularity of CO₂, and promoting sustainable industrial practices across Europe ([Renewable Carbon](#)) ([Climate Action](#)) ([Research and innovation](#)).



Transition pathway for carbon neutrality – main measures for chemical industry

In order to accelerate the current (digital and green) transformation, the European Commission has proposed an updated industrial strategy in 2021, focusing on 14 industrial sectors. These transformation plans were to offer "a **better understanding of the scope, costs, long-term benefits and conditions of the actions needed to accompany the simultaneous transformation**" for the most important industrial ecosystems, leading (according to the Commission) to "a feasible roadmap for sustainable competitiveness". ...which we must trust and actively engage in (following the example of other EU countries)... One of the 14 defined sectors is the **chemical industry**. On 27 January 2023, the European Commission published the document "Transition Pathway for the Chemical Industry".

The EU Chemicals Transition Pathway consists of eight building blocks:



The original EU crossing proposal consists of 187 measures listed in 8 building block (pillars) chapters. Some measures will be addressed by Member States and/or the EU. Some will be relevant for specific Member States, others will be less relevant for them. The measures are identified in a breakdown for EU, MS, Industry.

Together with the **green and digital transformation** of the chemical industry, this increases its resilience and sustainable competitiveness as the main objective.

6.2. Regional Collaboration

Here are examples of **collaborations between academic and industrial experts** in the analysis of carbon dioxide (CO₂) management, both linear and circular, in the Czech Republic, Austria, Slovenia, and Hungary:

Czech Republic

- **CO₂-SPICER Project:** The CO₂-SPICER project is a significant collaboration between academic institutions like the Czech Geological Survey, VSB - Technical University of Ostrava, and industrial partners such as MND a.s. This project focuses on the storage of CO₂ in carbonate reservoirs, integrating expertise from geology, engineering, and industrial applications to develop effective carbon capture and storage solutions ([CO₂-Spicer](#)).



Austria

- **C2PAT Initiative:** The "Carbon to Product Austria" (C2PAT) project is a collaboration between Austrian universities and industrial companies like OMV and Borealis. This initiative focuses on capturing CO₂ emissions and converting them into useful products like methanol, which can be used in the chemical industry. This project showcases the synergy between academic research on carbon capture technologies and industrial applications in creating a circular carbon economy ([EuropaWire](#)).

Slovenia

- **BELINKA PERKEMIJA:** Their passion lies in the production of high-quality peroxide compounds, essential for various industries. With over 70 years of expertise, Belinka Perkemija is a leading manufacturer of hydrogen peroxide, sodium perborate, and peracetic acid, serving industries such as paper, textiles, and food. Strongly committed to sustainability, they focus on reducing energy consumption and environmental impact. As part of the KANSAI HELIOS Group, they ensure innovation and high standards in chemical production.
- **AQUAFILL:** It is the leading producer of polymers and synthetic fibers in Slovenia and a center for research and development in circular economy solutions. The company is part of the Aquafil Group, a pioneer in circular economy practices and a global benchmark for product quality and innovation. Its flagship product, ECONYL® nylon, enables circular economy practices in the fashion, automotive, and interior design industries. AquafilSLO serves as a hub for innovative technologies that recover materials from end-of-life products and pre-consumer waste, regenerating them into new ECONYL®. ECONYL® is a premium nylon made entirely from various types of nylon waste. It is polyamide 6 and is available in polymer chip or yarn form. Moreover, it can be infinitely recycled. By using regenerated nylon, designers have endless possibilities to create new products without consuming new resources.

Hungary

- **OMV Petrom and Academic Research:** OMV Petrom, which operates in Hungary, collaborates with local universities and research institutions on projects aimed at utilizing captured CO₂ in chemical processes. These collaborations focus on integrating academic research into practical applications, such as converting CO₂ into useful chemicals, thereby reducing overall carbon emissions and supporting circular economy practices ([EuropaWire](#)).

Here are **examples of cross-border projects** that involve the Czech Republic, Austria, Hungary, and Slovenia, particularly in the field of carbon dioxide management and decarbonization:

1. GreenChemForCE Project (Bringing Green Chemical Production Forward in Central Europe)

- **Countries Involved:** Czech Republic, Austria, Hungary, Slovenia
- **Project Overview:** GreenChemForCE is a collaborative project under the Interreg Central Europe program. It aims to reduce the environmental impact of the chemical industry in Central Europe by focusing on the circular economy, particularly in the area of carbon management. The project involves academic institutions and industrial partners from these four countries working together to minimize CO₂ emissions, optimize waste management, and implement sustainable chemical production processes.



- **Key Activities:** Within Work Package 2, the project includes analyzing the current state of CO₂ emissions, developing strategies for CO₂ capture and utilization, and promoting green chemistry principles across the region. The collaboration is critical in pooling resources, knowledge, and expertise from multiple countries to tackle common environmental challenges (WP2 _ MEETING1_12.6.202...).

2. C2PAT (Carbon to Product Austria)

- **Countries Involved:** Austria, with implications and partnerships in neighboring countries including the Czech Republic, Slovenia, and Hungary.
- **Project Overview:** While primarily an Austrian project, C2PAT involves collaboration with research institutions and industrial partners across borders. The initiative focuses on converting captured CO₂ into valuable products like methanol, which can be used across the chemical industries in these countries. The cross-border implications are significant as the technology and processes developed can be implemented across Central Europe, enhancing regional decarbonization efforts ([EuropaWire](#)).

3. CO₂-SPICER Project

- **Countries Involved:** Czech Republic, Norway
- **Project Overview:** The CO₂-SPICER project is a cross-border initiative funded under the KAPPA program, which involves the Czech Republic in collaboration with Norwegian. The project focuses on the storage of CO₂ in carbonate reservoirs, aiming to establish a model for carbon capture and storage that can be replicated across the region.
- **Key Activities:** This project integrates geological, technical, and industrial expertise from multiple countries, focusing on cross-border collaboration to enhance the effectiveness and scalability of CCS solutions in Central Europe ([CO₂-Spicer](#)).

4. Danube Transnational Program (Interreg)

- **Countries Involved:** Austria, Czech Republic, Hungary, Slovenia, among others
- **Project Overview:** The Danube Transnational Program, part of the broader Interreg initiative, involves multiple projects aimed at promoting sustainable energy and decarbonization across the Danube region. This program includes collaborative efforts in renewable energy development, energy efficiency, and CO₂ reduction technologies that benefit all involved countries.
- **Key Activities:** The program funds and supports projects that promote cross-border cooperation in the field of decarbonization, with a focus on integrating sustainable practices into energy production and industrial processes across the Danube region ([Cambridge University Press & Assessment](#)).

These cross-border projects highlight the importance of regional cooperation in addressing the challenges of decarbonization and carbon management. By pooling resources and expertise, these countries are better equipped to develop and implement effective strategies for reducing CO₂ emissions and promoting sustainable industrial practices.



6.3. CO₂ emission status by countries

Since 2012, total coal power generation has dropped by almost a third in the EU. The declining use of coal has caused mines to close down and power plants to be decommissioned in a number of regions across Europe. The graph below depicts the current state of play of national coal phase-out commitments in the EU.



* Member States with peat and oil shale in their energy mix.

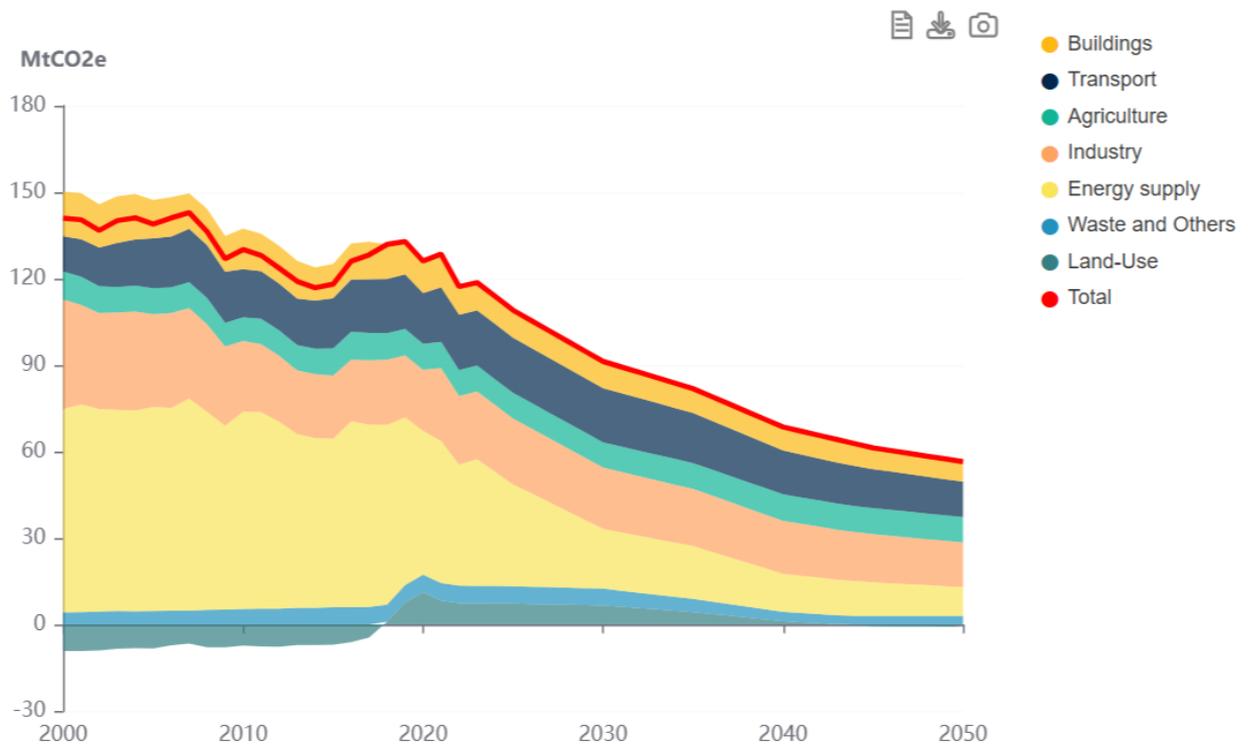


6.3.1. Czech Republic

The Czech chemical industry has achieved a greenhouse gas emission decrease of 32% in 2022 compared to 1990, which is much lower compared to 55% in the EU. We still have a long and arduous road ahead in decarbonization or carbon neutrality.

Since 2010, CO₂ (CO₂ eq.) emissions of chemical companies in the Czech Republic per tonne of products produced have fallen by about 80% and have stabilized at a total of about 11 million tonnes of CO₂ per year. The highest decreases were realized until 2015, since then we observe stagnation.

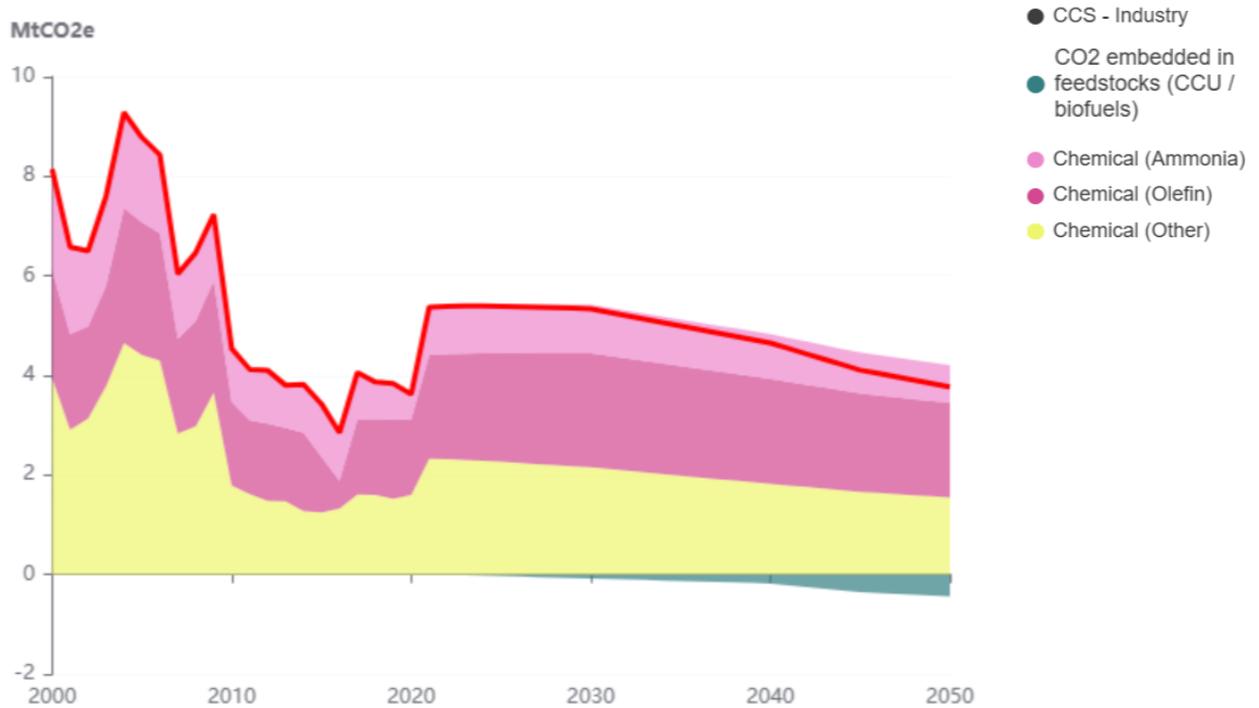
Total GHG emissions by sector (Scope 1 territorial)



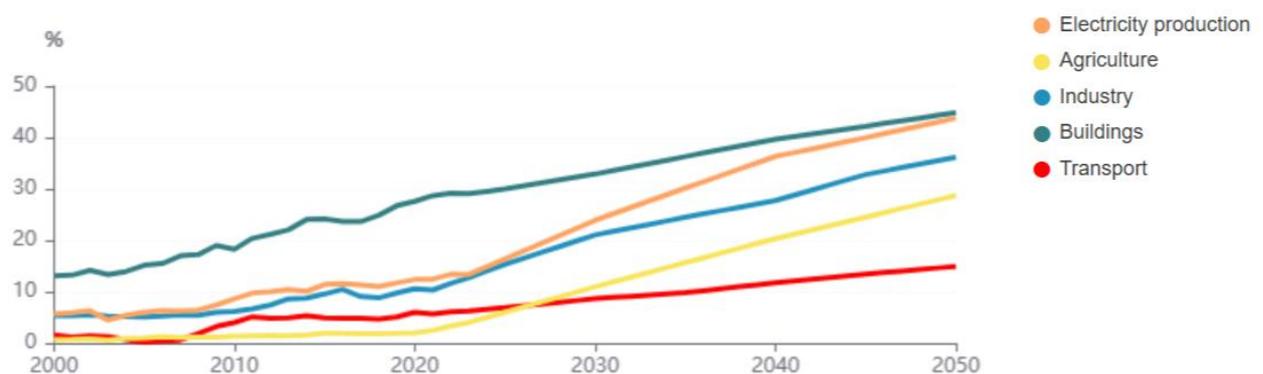
CO₂e (CO₂equivalents) emission of the Czech 2000-2050. Source: Pathway Explorer: <https://pathwayexplorer.climact.com/pathways?visualisation=0®ion>



GHG emissions per sector in Industry



CO₂e (CO₂equivalents) emission of the Czech chemical industry 2000-2050. Source: Pathway Explorer: <https://pathwayexplorer.climact.com/pathways?visualisation=0®ion>



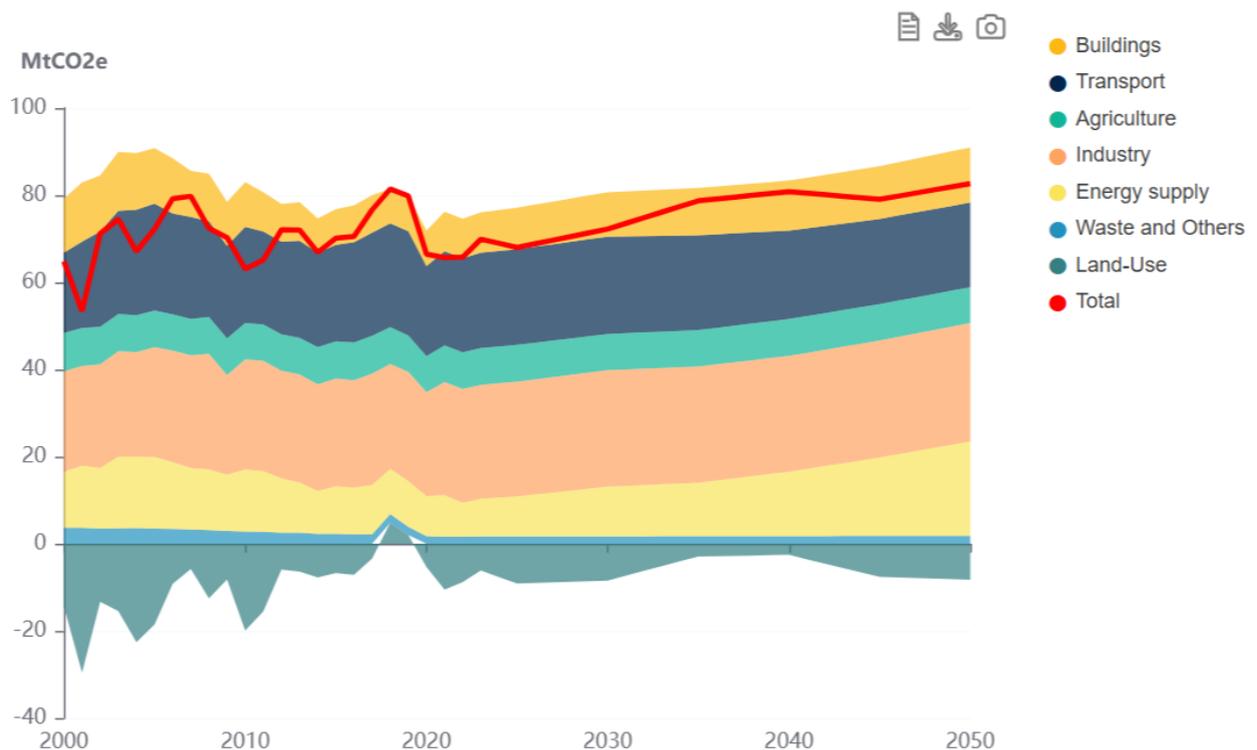
Share of RES energy demand by sectors – Czech Republic. Source: Pathway Explorer: <https://pathwayexplorer.climact.com/pathways?visualisation=0®ion>



6.3.2. Austria

In 2022 the chemical industry in Austria reduced their CO₂ equivalent (CO₂ eq.) emission by 54% compared to 1990. A strong factor for this reduction was the introduction of NO₂ abatement technologies in 2004 and 2009.

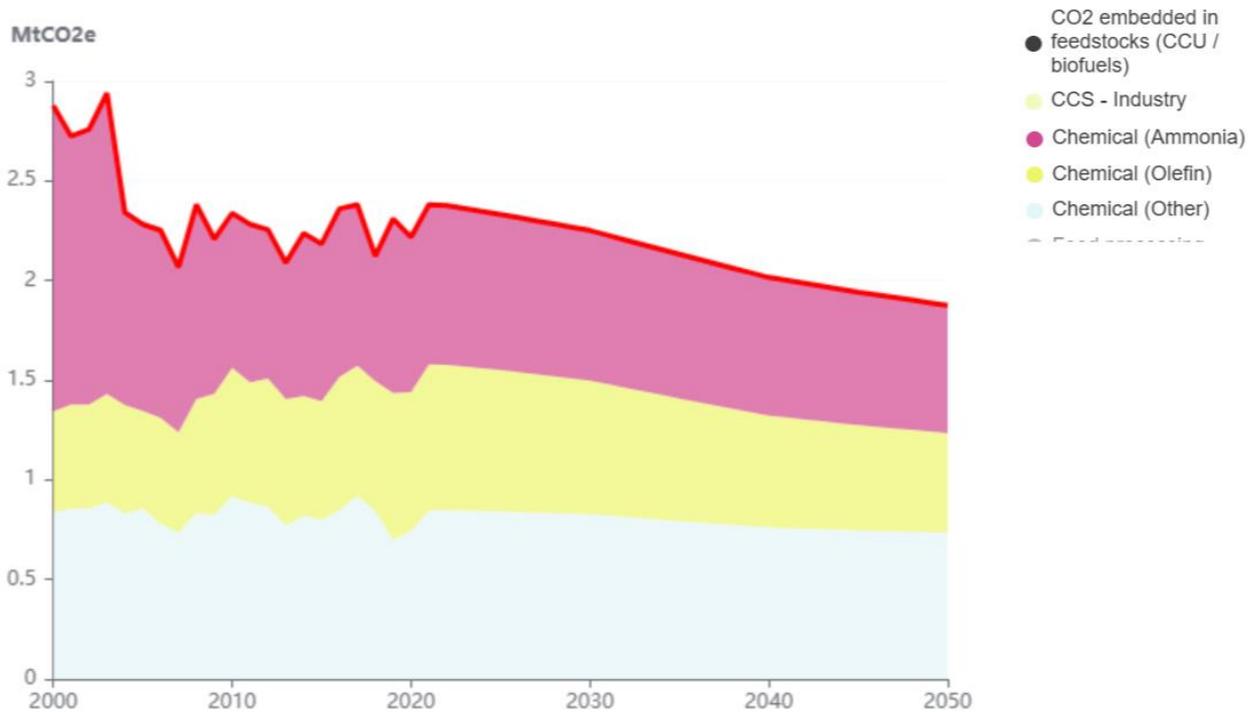
Total GHG emissions by sector (Scope 1 territorial)



CO₂e (CO₂equivalents) emission of the Austrian 2000-2050. Source: Pathway Explorer: <https://pathwayexplorer.climact.com/pathways?visualisation=0®ion>

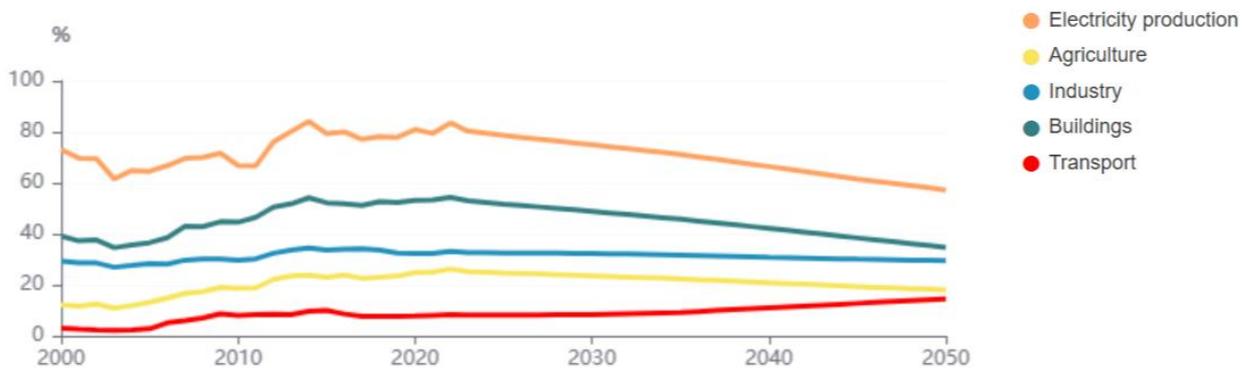


GHG emissions per sector in Industry



CO₂e (CO₂equivalents) emission of the Austrian chemical industry 2000-2050. Source: Pathway Explorer: <https://pathwayexplorer.climact.com/pathways?visualisation=0®ion>

Austria has a lot of room for improvement in this sector. Measures to reduce CO₂ emissions are, however, on the way.



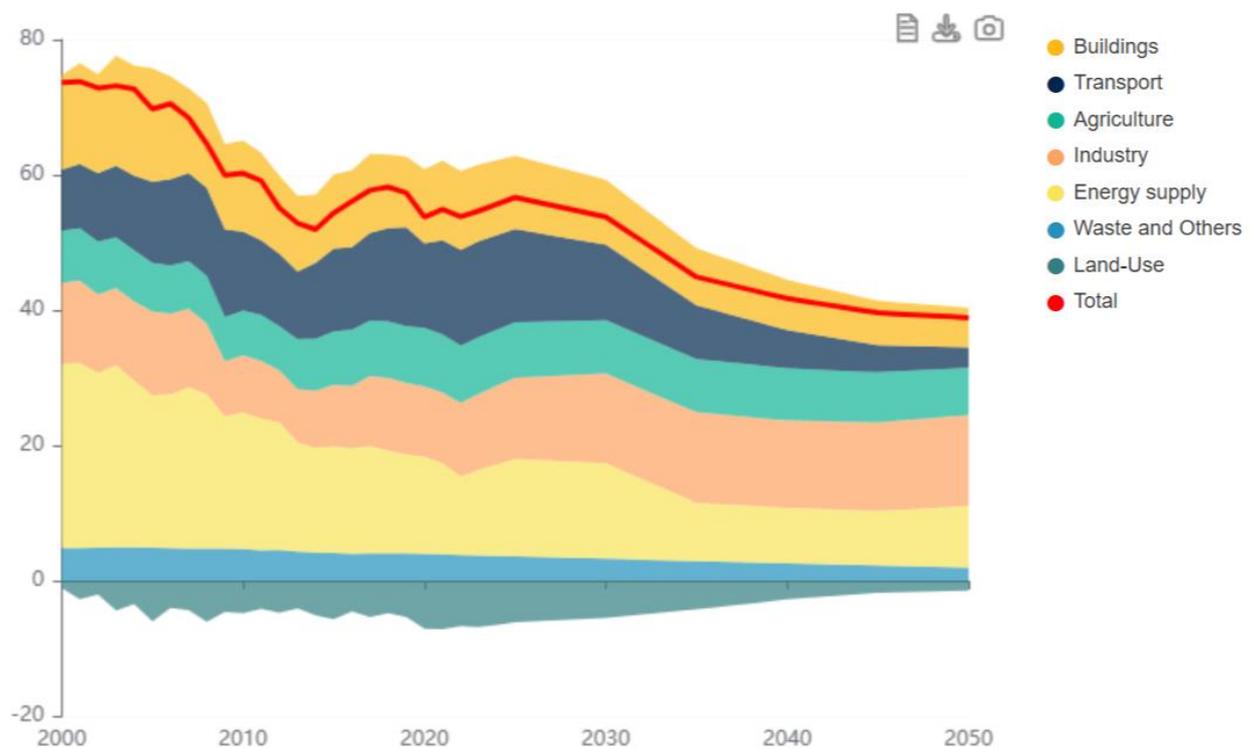
Share of RES energy demand by sectors – Austria. Source: Pathway Explorer: <https://pathwayexplorer.climact.com/pathways?visualisation=0®ion>



6.3.3. Hungary

Hungary has achieved its 2030 objective by recording a more than 40% reduction of the 1990 greenhouse gas emission. With this it is in the top third of countries in Europe. While industrial production and the energy industry recorded a significant decrease in greenhouse emission from 1990 (from 25Mt to 14 Mt and 25 Mt to 13 Mt respectively by 2019) the emission from transportation increased over time (from 9 Mt to 16 Mt). Renewable energy makes up around 18% of the gross amount.

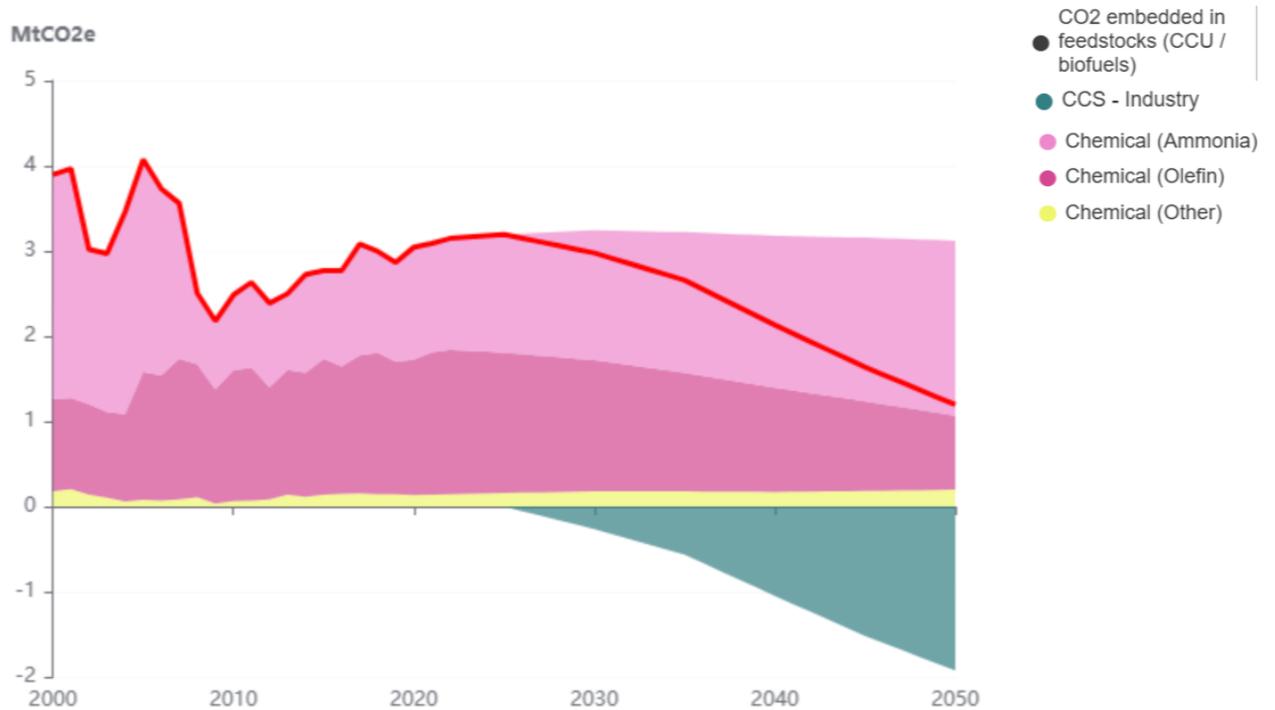
Total GHG emissions by sector (Scope 1 territorial)



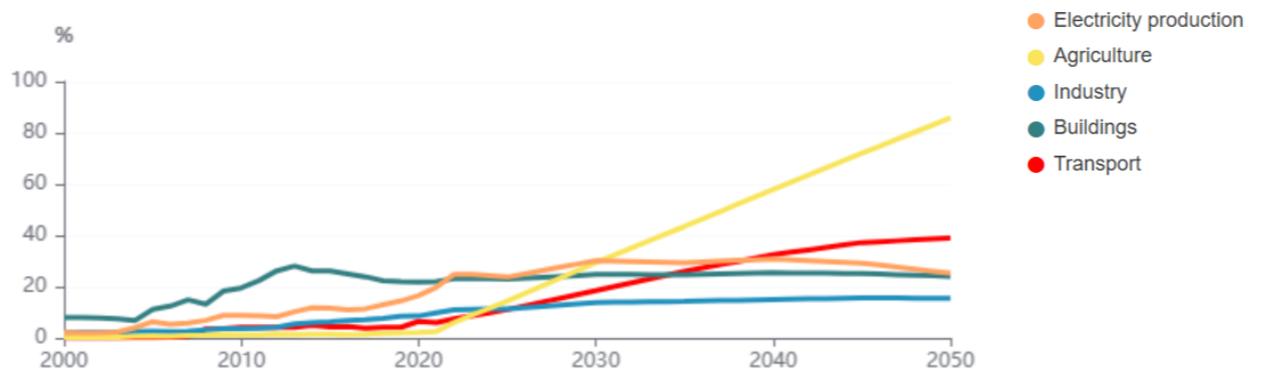
CO₂e (CO₂equivalents) emission of the Hungarian 2000-2050. Source: Pathway Explorer:
<https://pathwayexplorer.climact.com/pathways?visualisation=0®ion>



GHG emissions per sector in Industry



CO₂e (CO₂equivalents) emission of the Hungarian chemical industry 2000-2050. Source: Pathway Explorer: <https://pathwayexplorer.climact.com/pathways?visualisation=0®ion>



Share of RES energy demand by sectors – Hungary. Source: Pathway Explorer: <https://pathwayexplorer.climact.com/pathways?visualisation=0®ion>



Between 2004 and 2022 the share of renewable energy in Hungary increased from 4.4% to 15.2%. Renewable energy sources were used mainly for heat and electricity production and, to a lesser extent, as biofuels. The dominance of biomass in the Hungarian renewable energy production is very significant, although it has decreased in recent years. Its share of total renewable production decreased from 91% in 2005 to 62% in 2021. The largest increase over the period was in biofuel production, which increased from 0.1 PJ to 20.4 PJ, and its share from 0.1 to 14.4%. Since 2005, the share of biogas-based energy production has increased from 0.4 to 2.9%, and that of solar energy from 0.1 to 12.5%. However, the shares of geothermal (from 5.1% to 4.9%) and hydro (from 1.0% to 0.4%) have decreased, although their production has increased in terms of volume. The amount of electricity generated from renewable energy sources has increased from 243.6 gigawatt-hours in 2000 to 7662 gigawatt-hours in 2022. Solar energy is the most important source of electricity generation with a share of 61.8%. Biomass came second with 22.1% and wind energy third with 8%.

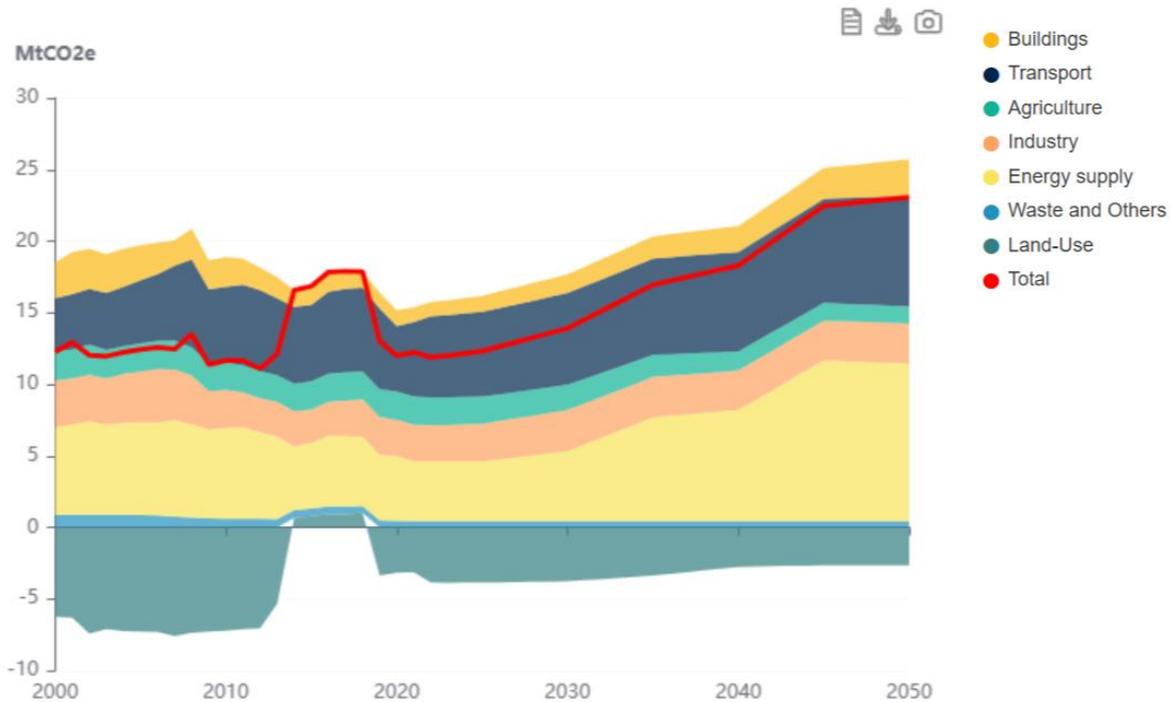
6.3.4. Slovenia

The amount of CO₂ emission decreased by 3.2% compared to 2021, from 13.1 million tons to 12.7 million tons. Households generated 6.6% more emission. Among economic activities, emissions particularly decreased in electricity, gas, and steam supply (by 18.8%) and manufacturing (by 6.3%), while they increased the most in transport and storage (by 33.0%).

The majority of CO₂ emission came from manufacturing and service activities, with the highest emissions in electricity, gas, and steam supply (3.5 million tons or 27.2% of the total), followed by manufacturing (2.6 million tons or 20.1%) and transport and storage (1.3 million tons or 10.0%). In all other activities, a total of 2.2 million tons or 17.1% of the total emissions were generated. Households accounted for 3.2 million tons or 25.6% of the CO₂ emissions in 2022.



Total GHG emissions by sector (Scope 1 territorial)

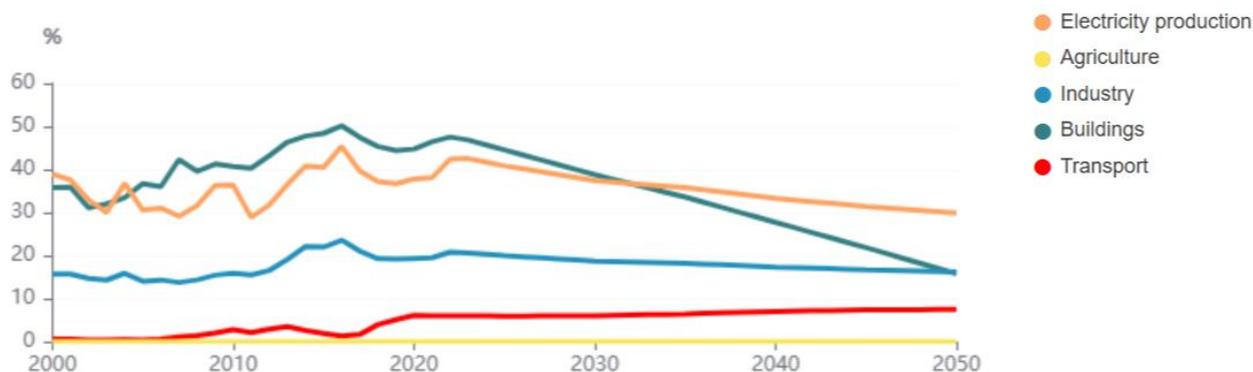


CO₂e (CO₂equivalents) emission of the Slovenian 2000-2050. Source: Pathway Explorer: <https://pathwayexplorer.climact.com/pathways?visualisation=0®ion>

GHG emissions per sector in Industry



CO₂e (CO₂equivalents) emission of the Slovenian chemical industry 2000-2050. Source: Pathway Explorer: <https://pathwayexplorer.climact.com/pathways?visualisation=0®ion>



Share of RES energy demand by sectors – Slovenia. Source: Pathway Explorer: <https://pathwayexplorer.climact.com/pathways?visualisation=0®ion>

7. Conclusions

Analysis of Carbon dioxide linear and circular for elaboration of Strategy for low carbon footprint chemical industry in CE

„In Sustainable Carbon Cycles, most of the carbon used in production stays within the economy. The carbon goes through various transformations in the chemical value chain. Some of it is burned as fuel during production or incinerated at the end of a product’s life. The CO₂ released during these processes is captured and reused as raw material through CCU. Products containing carbon are kept in the cycle through reuse and recycling, either mechanically or chemically, as much as possible. Biodegradable products can also be recycled or processed through composting or fermentation, returning their components to the biosphere. Minimising landfill use helps keep carbon in the loop. Capturing CO₂ and storing it underground can offset unavoidable emissions. Carbon captured directly from the air can be used as additional raw material, helping to reduce atmospheric carbon to levels that meet the Paris Agreement goals. Any extra carbon needed can be extracted from underground (fossil carbon) but should be balanced by an equal amount of carbon removal. To positively impact climate change, all processes should use low-carbon energy.“¹

Green chemistry is one of the contributors to move CO₂ from linear to circular.

WP2 is focused on CO₂ utilisation and consequent strategy is to define main prospective technology streams to be further considered for further analysis and development.

This is ANALYSIS which will be followed by STRATEGY document GreenChemFORCE WP2, Activity 2.1: Analysis of Carbon dioxide linear and circular; Output 2.1: Strategy for low carbon footprint chemical industry in CE; Deliverable 2.1: Strategy document.

¹ Cefic „The Carbon managers“, 2025