European Commission

Transition Pathway for the Chemical Industry

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LEGAL NOTICE

This publication by the European Commission's Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs summarises the discussions with European chemical sector stakeholders on the twin transition of the chemical industry. The content of this document, however, does not necessarily represent the position or endorsement of all stakeholder groups nor the position of individual Member States or the European Commission. This document is without prejudice to Commission's future initiatives in the field of chemicals. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use which might be made of the information contained in this document.

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EXECUTIVE SUMMARY

The 2020 industrial strategy[1] included a list of actions to support the green and digital (twin) transition of EU industry. However, the COVID-19 pandemic affected the speed and scale of this twin transition. To address this disruption, in the **updated 2021 industrial strategy, the Commission proposed a series of transition pathways** to be developed jointly with EU Member States, industry and other stakeholders. These pathways identify the actions needed to achieve the twin transition, giving a better understanding of the scale, benefits and conditions required. A transition that will also strengthen resilience of the industry largely affected by the Russian war of aggression against Ukraine.

In the spring of 2022, the Commission launched the 'co-development' process for the **transition pathway for the European chemical industry, along with EU Member States, the chemical industry itself, social partners, NGOs and academia**. The outcome of this process is a group of topics and actions to be implemented by each of the involved actors. These most relevant ones are presented as a **roadmap** composed of:

1. An **action-oriented** component grouping the topics under three cross-cutting themes: collaboration for innovation; clean energy supply; and feedstock diversification. These actions are expected to contribute towards the transition and are set against a timeline.
2. A **technology** component identifying electrification, hydrogen, biomass, waste, Carbon Capture and Utilization (CCU) & Carbon Capture and Storage (CCS), as well as process efficiency as key technological contributors to the transition pathway.
3. A **regulatory** component that collects the existing legislation, including major research and innovation (R&I) initiatives, influencing digital and sustainable development of the chemical industry.

By implementing the actions identified under each topic, the chemical sector is expected to succeed in its twin transition and improve its own resilience, sustainability and 'circularity' (i.e. its functioning in line with the principles of the circular economy), in line with the European Green Deal.

The co-implementation of the transition pathway for the chemical industry will be the next step. This entails disseminating the pathway to all relevant stakeholders, who would then present their commitments specifying the actions and topics to which they will contribute to. The proposals in the final chapter will be discussed and agreed on during the co-implementation process expected to start in spring 2023.

[1] COM(2021) 350 final. Updating the 2020 New Industrial Strategy: building a stronger Single Market for Europe's recovery https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:350:FIN.

I/ INTRODUCTION

The chemical sector has a strategic role in the European economy. Most goods that are manufactured in Europe rely on chemicals for a wide range of various functions. Chemicals are at the heart of Europe's major value chains, including pharmaceuticals, electronics, batteries for electric vehicles, construction materials, etc. The chemical value chain is typically made up of: (i) chemicals producers; (ii) mixture manufacturers; and (iii) producers of articles. Each of these actors in the chemical supply chain has their own needs and will make their own contributions to the future objectives of the green and digital transition of EU industry and its achievement of the twin transition. It has a major focus on producers of chemicals.

The twin transition covers several dimensions for the EU chemical industry: a 'toxic-free' environment, climate neutrality, circularity (the green transition), and digitalisation (the digital transition). All these dimensions must be addressed to support the resilience of the chemical industry[2].

The EU-27 is the second largest chemicals producer in the world, with EUR 499 billion in sales in 2020. The chemical industry is also the fourth largest industry in the EU, accounting for around 7% of manufacturing output by turnover[3]. The industry directly employs 1.2 million highly skilled workers and supports 3.6 million jobs indirectly. It also supports a further 19 million jobs across all other value supply chains in the EU[4]. The EU chemical industry has 67% greater labour productivity than the average for the manufacturing sector.

Nevertheless, the chemical industry is the third emitter of carbon dioxide (CO_2) emissions in the EU (925Mt CO_2 in 2021[5]), behind only the cement and iron/steel industry. As reported by the International Energy Agency (IEA), this is largely because around half of the chemical subsector's energy input is consumed as feedstock – fuel used as a raw material input rather than as a source of energy. Immediate emission reductions are therefore necessary, as highlighted by the latest Intergovernmental Panel on Climate Change's (IPCC's) contribution to the 6th Assessment Report[6]. The IEA's 'net zero' emission scenario by 2050[7] relies on a clear reduction in CO_2 emissions from primary chemicals production[8].

In this regard, the EU chemical industry has already made progress. Despite an increase in production of more than 47% since 1990, greenhouse-gas (GHG) emissions from EU-27 chemical production have decreased by 54% in comparison to 1990 levels. Over the same period, energy consumption in the EU-27's chemical industry has fallen by 21%. **The 2030 and 2050 legally-binding EU climate targets represent the next important step for the chemical industry's emission-reduction efforts, as part of the climate component of the Green Deal.**

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[2] See https://research-and-innovation.ec.europa.eu/research-area/industry/industry-50_en.

[3] CEFIC, 2022. The European chemical industry: a vital part of Europe's future. Facts & Figures 2022.

[4] https://ec.europa.eu/growth/sectors/chemicals_en.

[5] IEA Tracking Report, September 2022: https://www.iea.org/reports/chemicals.

[6] IPCC, 2021. Sixth Assessment Report. https://www.ipcc.ch/assessment-report/ar6/.

[7] IEA Report, Net Zero Emissions by 2050 Scenario (NZE) – World Energy Model.

[8] Primary chemicals are substances obtained in its compounds in the natural state or by intensive manufacturing processes requiring massive amounts of fossil energy.

In 2020, the Commission adopted the Chemicals Strategy for Sustainability (CSS)[9], which '*strives for a toxic-free environment, where chemicals are produced and used in a way that maximises their contribution to society including achieving the green and digital transition, while avoiding harm to the planet and to current and future generations*'. The strategy identifies initiatives to support the transition, including the promotion of toxic-free material cycles and 'clean' recycling.

The EU chemical industry's investment and innovative capacity will be crucial to achieving the goals of the CSS to: (i) provide chemicals and materials that are safe and sustainable by design; and (ii) offer new ways to produce chemicals and materials. It has been reported that the chemical industry is the second largest R&I investor in the chemical industry globally, with EUR 9.4 billion invested every year[10]. This investment and innovation will support the twin transition of our economy and society. The chemical industry will also play a central role in achieving a circular economy in many value chains.

Given its size and strategic relevance, the chemical industry is therefore **at the centre of the European Green Deal** and is a major contributor to achieving its ambition and objectives. Furthermore, the digital transformation is an enabling opportunity for the industry to meet the above objectives, while retaining its competitiveness and keeping pace with societal developments[11].

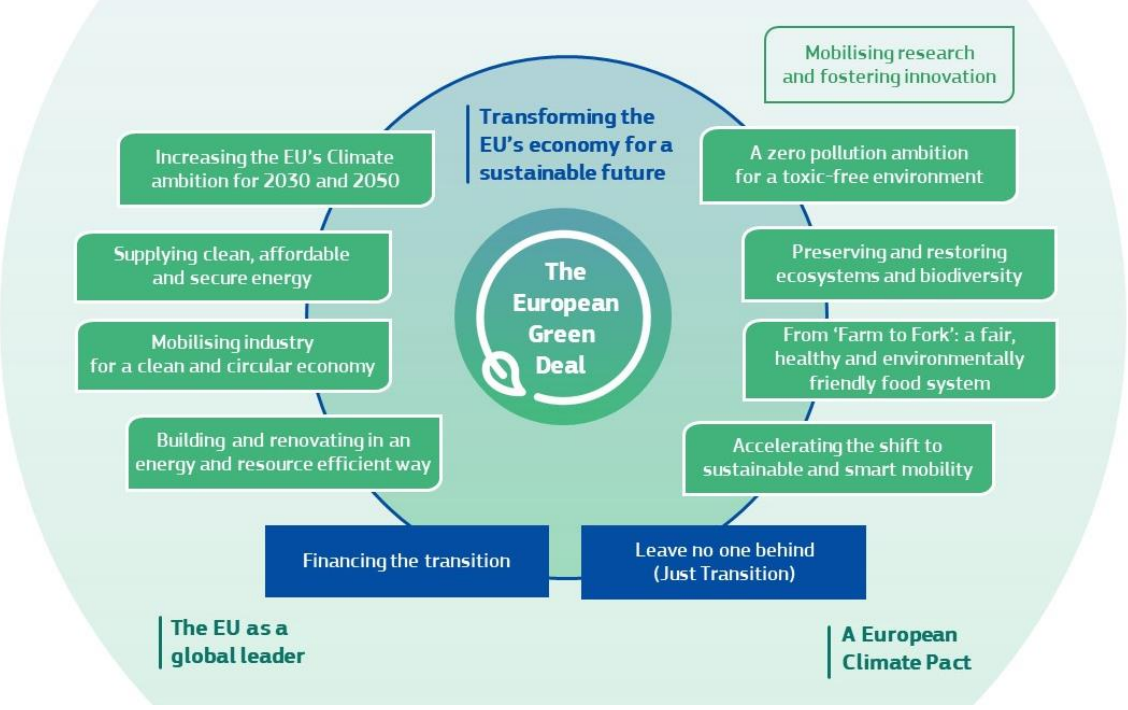

Figure 1 - The European Green Deal elements, including its ambition and objectives

[9] COM (2022) 667 final. Chemicals Strategy for Sustainability Towards a Toxic-Free Environment https://europa.eu/!Vt94Yr.

[10] OECD and Cefic Chemdata International.

[11] See Decision (EU) 2022/2481 of the European Parliament and of the Council of 14 December 2022 establishing the Digital Decade Policy Programme 2030, *OJ L 323, 19.12.2022, p. 4–26,* and in particular the digitalization of business.

The chemical industry clearly understands that it needs to do more and is greatly determined to be at the forefront of the necessary transformative process required by the twin transition. However, the industry stresses that this journey of transformation depend on its ability to stay competitive and to attract global investment.

Other relevant players in the EU's economy that have a crucial role are small and medium-sized enterprises (SMEs), which constitute 96% of European chemical companies[12]. SMEs are present at every level of a chemical supply chain. These companies have diverse roles related to chemicals, and they include manufacturers of raw materials, formulators, distributors, and users of chemicals. SMEs employ two thirds of the EU's workforce and account for 55% of added value in the EU. Furthermore, SMEs play an important part in the EU's vocational system by providing many young people with the opportunity to learn a profession. SMEs are therefore an integral part of the twin transition and resilience of the industry.

The EU chemicals industry is highly integrated into many complex international value chains that are sensitive to the geopolitical context and its sudden developments, such as the Russian war of aggression against Ukraine which started in February 2022. The new Temporary Crisis Framework for State Aid adopted by the Commission on 23 March 2022 includes the chemicals industry among the sectors and sub-sectors that are 'particularly affected' by the war. Although it is difficult to predict the longer-term impact of the war on the EU economy, its initial effects are already visible: accelerated inflation; more fragile supply chains with potential disruptions to supplies of fossil feedstocks and energy sources; temporary curtailment of the operation of chemicals plants; and a drastically weakened outlook for growth, as reported by the industry. Chemical manufacturing, using natural gas as fuel and feedstock is under unprecedented economic pressure, raising fundamental questions about the medium/long-term prospects for energy-intensive manufacturing in Europe.

The current crisis therefore brings into closer focus the objective for resilience set by the updated EU industrial strategy[13]. This strategy emphasised the benefit of increasing the resilience of the chemical industry, i.e. its capacity to absorb external shocks due to a fragile geopolitical situation and a challenging competitive environment, with surging prices of energy and raw materials. It includes a list of actions to support the green and digital (twin) transition of EU industry and its resilience, amongst which a series of transition pathways to be developed jointly with EU Member States, industry and other stakeholders. These pathways identify the actions needed to achieve the twin transition, giving a better understanding of the scale, benefits and conditions required. A transition that will also strengthen resilience of the industry.

This report presents high-level transition pathway for the chemical industry to achieve the twin transition and its resilience. The outcome of this pathway is a three-part roadmap. The roadmap is the result of a co-creation process with stakeholders who discussed with the Commission each of the building blocks that make up the transition pathway structure developed by the Industrial Forum[14]. In addition, the

[12] Cefic, 2018. Economic Outlook (July-2018).

[13] COM(2020) 102 final. A New Industrial Strategy for Europe https://europa.eu/!ghHBCV.

[14] Industrial Forum, 2022. Blueprint for the development of transition pathways.

stakeholders considered recommendations made by the High-Level Roundtable on the Chemical Strategy for Sustainability[15]. For each building block, the stakeholders identified a series of actions and initiatives that would contribute to the achievement of the twin transition and the resilience of the chemical industry. Each action also specified the timeframe for implementation as well as the main actors responsible for implementation. For example, actions being coordinated by EU institutions refer to initiatives and proposals already announced in official Commission documents that were then clustered by topics and integrated into an indicative timeline. This gave direction to some major aspects that require sequencing as part of a co-implementation process (the sequencing is presented in the final chapter).

This transition pathway and the resulting roadmap have been developed as **part of the transition pathway for** the broader group of industries (of which the chemical industry is a part of) categorised as **energy-intensive industries (EIIs)** which refers to the Masterplan for a Competitive Transformation of EU Energy-intensive Industries Enabling a Climate-neutral, Circular Economy by 2050.

[15] See https://environment.ec.europa.eu/news/first-meeting-chemicals-strategy-roundtable-2021-05-05_en.

II/ BUILDING BLOCKS

The aim of this chapter is to describe the actions needed to accelerate the EU chemical industry's green and digital transitions while also making the industry resilient. It follows the structure of the blueprint developed by the Industrial Forum Task Force 2[16] on transition pathways, and is based on a building block approach, where each building block covers a key aspect of the twin transition and the desired move to greater resilience[17]. In addition to the seven building blocks defined by the Industrial Forum, stakeholders agreed to also include a building block on "access to energy and feedstock". The figure below presents them all.

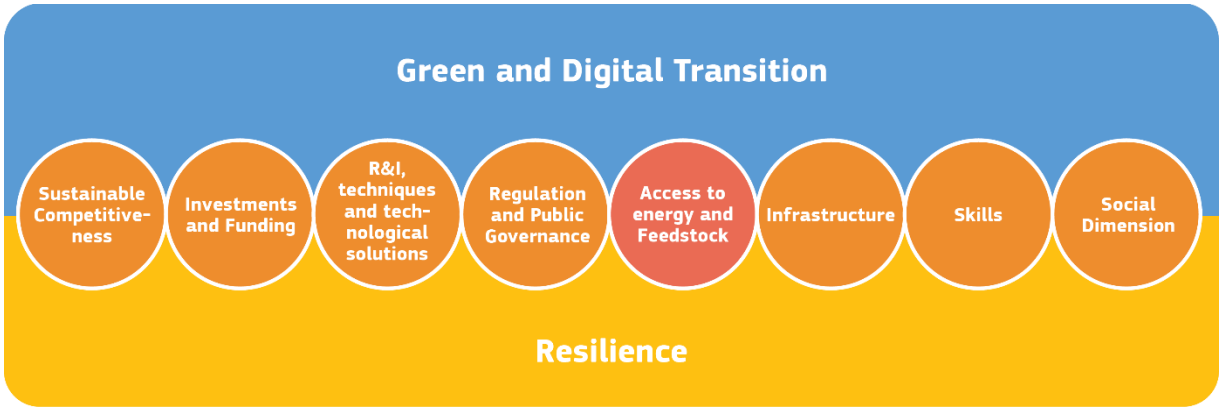

Figure 2 - The 8 building blocks considered to develop the transition pathway for the chemical industry

For each topic listed under the respective building blocks, a list of actions has been identified by stakeholders, together with a timeframe for implementation: short-term, medium-term or long-term. Indicatively, 'S' (i.e. short-term) indicates activities that should start as soon as possible; 'M' indicates activities that should start in the medium-term (i.e. by 2030); while 'L' indicates the long-term, i.e. activities that should be launched and completed by 2050. An overview of topics against a timeline is presented in the following sections.

Each action also mentions the main actor responsible for its implementation, according to the stakeholders participating to the co-development process. 'EU/MS' means that the responsible actor should be either the EU – e.g. via an EU level legislation – or the Member States with a legislative initiative at national level[18]. 'Industry' designates an action that should be coordinated and implemented by industrial actors.

1) SUSTAINABLE COMPETITIVENESS

The EU chemical industry faces unprecedented challenges that include increased international competition; skyrocketing prices of energy and feedstock; a decline in the industry's global competitiveness over recent decades; and a shift of certain activities to outside the EU would

[16] The blueprint matrix including the different building blocks for all ecosystems on transition pathways was developed by the Industrial Forum (Task Force 2 – Support to the development of transition pathways).

[17] The task force identified seven building blocks: sustainable competitiveness; investments and funding; research & innovation (R&I) techniques and technological solutions; regulation and public governance; infrastructure; skills; and the social dimension. As part of this transition pathway, stakeholders agreed to include an additional building block on 'access to energy and feedstock', which will be instrumental for the chemical industry's transformation.

[18] As stated in the disclaimer and legal notice, results of the stakeholder co-creation process presented in this report do not necessarily represent the position of all stakeholder groups nor the position of individual Member States or the Commission.

affect chemical value chains, with ripple effects across the EU's entire economy. Furthermore, some imported products not meeting the same environmental and safety standards in the production process required for goods manufactured in the EU continue to enter in the internal market. Ensuring a level global playing field is key to creating a market advantage for safe and sustainable chemicals.

Stakeholders conclude that to strengthen the competitiveness of the chemical industry, it is necessary to improve international competitiveness; to reduce existing unsustainable dependencies and supply chain vulnerabilities while avoiding new ones; to continue enhancing the safety and sustainability of chemicals and materials; to pursue the innovation and growth of SMEs; and to foster new synergies.

Improving the international competitiveness of the EU chemical industry implies a better understanding of the recent geopolitical developments and the economic consequences for the industry. To this end, stakeholders suggest undertaking an analysis of the medium-to-long-term impacts of the energy crisis caused by Russia's war of aggression in Ukraine on both: (i) the sustainable competitiveness of the EU's chemical industry; and (ii) the industry's ability to develop and innovate. The outcome could better define existing and new initiatives by the global industry[19] to further promote EU environmental and safety standards globally. Finally, stakeholders recommend setting Key Performance Indicators (KPIs) and sustainable development indicators to measure and compare the international competitiveness of the EU's objectives for the chemical industry and the progress made towards climate neutrality; and to achieve safe and sustainable by design (SSbD), processes, and derived products, followed by regular progress reports. These should be embedded with existing key performance indicators and indicator sets.

There also seems to be a need for promotion of the market for sustainable products. This implies the development, commercialisation, deployment and promotion of the uptake of SSbD substances and materials. Stakeholders suggest achieving this through financial support – especially to SMEs – under Horizon Europe, cohesion policy, the LIFE programme, other relevant EU funding and private investment instruments, and public-private partnerships. It implies also the need to develop 'market pull' measures and incentives encouraging customers (including public procurers) to purchase sustainable products, despite their higher costs.

The table below summarises actions proposed by stakeholders on international competitiveness.

Topic 1: International competitiveness		
Actions	Actors	Timeframe
1.1 Drive international competitiveness		
• Analyse medium to long-term impacts of energy crisis on sustainable competitiveness and ability to develop	Industry and EU/MS	S
• Set key performance indicators and sustainable development indicators *(Linked to Topic 3.1)*	Industry and EU/MS	S
• Global industry initiatives (new and existing) to further promote EU environmental and safety standards globally	Industry and EU/MS	S/M

[19] For example, the Responsible Care Initiative by the ICCA, the International Council of Chemical Associations.

1.2 Promote the market for sustainable products

• Develop, commercialise, deploy and promote the uptake of SSbD substances and materials	Industry and EU/MS	S
• Ensure that hazardous chemicals banned in the European Union are not produced for export including by amending relevant legislation if and as needed	EU	S
• Develop 'market pull' measures and incentives to purchase sustainable products with higher costs	EU/MS	M

For several chemicals, including chemicals essential for strategic value chains, the EU relies heavily on a limited number of suppliers located outside the EU, because manufacturers can no longer profitably produce them or because the chemical industry's customers are no longer producing in Europe. This impacts the EU's open strategic autonomy, as seen during the pandemic. To avoid further shrinkage of the market and to limit the dependence of EU value chains on manufacturers outside the EU, the chemical industry is investing in innovation in raw-material value chains. This is an area that remains untapped despite its great potential. Further information on supply chains seems therefore necessary. To this end, stakeholders suggest undertaking a strategic foresight exercise for the chemical industry with a specific focus on the EU's open strategic autonomy[20]. This exercise should also link with the EU's current activities on securing access to critical raw materials. An assessment of the need to build up and maintain strategic stocks of critical raw materials within the EU is also recommended.

The chemical industry is one of the most globalised industrial sectors in the EU and is therefore highly dependent on open and fair trade. The COVID-19 crisis and Russia's war of aggression against Ukraine have shown that the EU is still import-dependent for supplies of energy, metals, several speciality chemicals, and many raw materials, all of which are essential for strategic value chains[21]. The EU supports efficient, transparent and cost-effective approaches to chemicals management with its trading-partner countries, within a level global playing field. Stakeholders state that closer international cooperation and coordination can be promoted by the EU at a global level (e.g. via multilateral and bilateral fora) and in particular by expanding initiatives on developing and implementing global standards to ensure that the current regulatory gap and divergence do not widen between the EU and the rest of the world.

Free-trade agreements (FTAs) remain a cornerstone of EU trade policy, focusing on: (i) the elimination of tariffs and non-tariff barriers; (ii) the facilitation of cross-border trade; (iii) striving for the simplest customs procedures; (iv) rules of origin; (v) digitalisation of all required documentation; and (vi) making logistics systems as flexible as possible. Stakeholders suggest that FTAs should be ratified and ideally include a dedicated section on cooperation in the regulation of chemicals, for example in an annex.

Further integration of the EU's single market for energy, and an open single market for plastic waste and secondary raw materials will also strengthen the resilience and autonomy of the

[20] COM(2021) 750 final. 2021 Strategic Foresight Report. The EU's capacity and freedom to act https://europa.eu/!743jQV and ongoing study on foresight for chemicals by EU4Chem project.

[21] SWD(2022) 41 final. Commission Staff Working Document on EU strategic dependencies and capacities: second stage of in-depth reviews https://ec.europa.eu/docsroom/documents/48878.

EU and its chemical industry. It will also reduce the EU's dependence on chemicals from countries outside the EU.

To reduce unsustainable dependencies on countries outside the EU and the chemical industry's own vulnerability to external shocks, stakeholders suggest actions in the table below.

Topic 2: Reduction of unsustainable dependencies and supply-chain vulnerabilities		
Actions	Actors	Timeframe
2.1 Gather supply-chain information		
• Undertake a strategic foresight exercise focusing on the EU open strategic autonomy (link with critical raw materials)	Industry and EU/MS	S
• Assess the need to build up and maintain strategic stocks of critical raw materials within the EU	Industry and MS	S/M
2.2 Increased collaboration within sub-sectors		
• Secure long-term supply contracts for critical raw minerals/metals, while assessing and accounting for any environmental and socioeconomic implications of the critical raw materials and their long-term sourcing plans	Industry and EU/MS	M
2.3 Make the most of existing international partnerships, including FTAs		
• Start or strengthen international (regulatory) economic cooperation (e.g. making use of OECD and WTO mechanisms), especially with the EU's most important trading partners. Prevent potential barriers to market access (e.g. related to the use of waste as feedstock) *(Linked to Topic 1.1 and Topic 13)*	Industry and EU/MS	M
2.4 Increase resource efficiency		
• Apply 'energy-efficiency first' as a key principle and prevent losses of materials by increasing circularity according to the '3R' principle (reduce, re-use, recycle), without hampering the implementation of new low-carbon processes (e.g. electrification, CCU (carbon capture and utilisation), CCS (carbon capture and storage), etc.)	Industry	S/M
• Support the circular economy. Take into consideration whole value chains when designing 'circular' industrial processes and ensure that all raw materials are included in these processes (including plastic waste, bio-based/biomass products and CO/CO_2 emissions) to close loops, ensure resource efficiency and reduce dependencies, with public policy supporting 'end-of-waste' concept	Industry & EU/MS	S/M

To ensure the 'circularity' of chemicals, it is crucial to apply safe and sustainable by design principles and to have design principles that are safe and sustainable and to consider the specificities in each lifecycle step when developing chemicals and materials. For this purpose, the Commission is developing a detailed and workable framework and criteria to develop new chemicals and materials, optimise or redesign production processes and the use of substances currently on the market to improve their safety and sustainability for ensuring that industrial

processes are SSbD[22]. This will promote economic growth and foster innovation in substances, mixtures and materials. This in turn will advance the transition towards a circular economy, and a zero-pollution and climate-neutral society by 2050.

Finally, digital product passports can be an important enabler for the deployment of sustainable and 'circular' products. This is because digital product passports would make it possible to communicate information on chemicals and their sustainability characteristics within the value chain, while complying with competition rules and rules on the confidentiality of data. Stakeholders suggest that digital tools could provide added value for the circular economy while guaranteeing efficient implementation, considering solutions that are already available on the market.

To support the market uptake of SSbD chemicals, stakeholders recommended taking the actions in the table below.

Topic 3: Safety and Sustainability		
Actions	Actors	Timeframe
3.1 Develop a detailed and workable framework and criteria for ensuring that industrial processes are SSbD		
• Maintain an EU-wide SSbD support network to promote cooperation and the sharing of information across sectors and the value chain, and provide technical expertise on alternatives	EU/MS	S /M
• Industry and MSs should engage in the testing phase of the SSbD framework	Industry and EU/MS	S/M
3.2 Improve collaboration in value chains		
• Engage in Hubs4Circularity as well as a Circular Cities and Regions Initiative (Horizon Europe)	Industry and EU/MS	S
• Explore the potential role of digital innovation hubs in the chemical industry	EU and Industry	S
• Use data spaces to improve resource allocation, supply chain resilience and the manageability of circular processes.	EU, Industry and MS	S/M
• Promote interregional collaboration along sustainable value chains in the chemical industry through smart specialisation to accelerate the development of joint investment projects	EU	M
• Set up and invest in 'reverse logistics' to ensure that materials are not turned to waste	Industry and MS	M
3.3 Support substitution to safer chemicals as well as product design and re-design		
• Implement and enforce the Ecodesign for Sustainable Products Regulation (ESPR), as part of the new circular economy action plan (CEAP)[23]	EU/MS	S/M

[22] Commission Recommendation (EU) 2022/2510 of 8 December 2022 establishing a European assessment framework for 'safe and sustainable by design' chemicals and materials https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022H2510.

[23] COM(2020) 98 final. A new Circular Economy Action Plan for a cleaner and more competitive Europe https://europa.eu/!Tg93Ug.

• Proposals to extend the generic approach to risk management to ensure that consumer products do not contain chemicals that cause cancers, gene mutations, affect the reproductive or the endocrine system, or are persistent and bioaccumulative and toxic; assess the modalities and timing to extend the same approach to further chemicals including those affecting the immune, neurological or respiratory systems and chemicals toxic to a specific organ; proposal to restrict PFAS under REACH for all non-essential uses including in consumer products	EU	S
• Support the uptake of new business models (e.g. facilitate the chemical 'leasing' concept within public tendering; engage and/or support projects on digital product passports that aim at passing along information on chemicals and other sustainability assets within the value chain)	Industry	S/M
• Develop digital infrastructure for data spaces to share high-quality data on products' environmental footprint, including the GHG footprint of products and applications (up to 'scope 3' emissions) and chemical-hazard profiles	Industry and EU/MS	S/M

Although the EU chemical industry includes many well-known large companies, most chemical companies are SMEs. Although both large companies and SMEs face common challenges, SMEs face particular difficulties when confronting both the twin transition and the war in Ukraine. SMEs often depend on single chemical products and limited portfolios in their offering of products for sale. They are also often deeply rooted in the region where they operate and cannot easily move production or swiftly re-design products, or introduce completely different business models. Accessing EU funding for research and innovation is also more complex for SMEs, as they often lack the time, experience and skilled staff necessary to successfully apply for this funding. As they typically have few employees, SMEs rarely have dedicated staff to manage regulatory changes. Furthermore, SMEs face particular challenges to digitalisation, including a lack of knowledge about which technologies to adopt and who should provide them, where to get digitalisation advice and support and how to access finance for digitalisation. They also often lack the (digital and managerial) skills needed to digitalise the business and make the necessary organisational changes to accommodate them. To address these challenges and support the digitalisation of SMEs, the European Commission and the Member States are jointly investing EUR 1.5 billion (e.g. Digital Europe Programme/RRF/ERDF) over the next 7 years in a network of European Digital Innovation Hubs (EDIH). The EDIH are one-stop-shops providing SMEs (and public sector organisations) with tailor-made advice and support (training, "test-before-invest", access to financing, match-making services etc.) to aid their successful digital transformation. "Test-before-Invest" opportunities are particularly important to support digitalisation in the Chemical industry as it allows companies to see first-hand if and how technologies can benefit their business. Therefore, reducing uncertainties and risks associated in investing in expensive new technologies. The network, which is just starting its work, will cover all EU regions and address the digitalisation needs of SMEs in all sectors, including chemicals.

Data spaces are not only used in mechanical engineering, but also in the process industry. The benefits of data spaces are similar in the different industrial sectors; they are about increased transparency and efficiency of processes. The European Data Spaces provide the necessary infrastructure and governance models, which also allow for effective and fair

involvement of SMEs. Through cross-company data exchange, the participants of Catena-X, for example, expect to improve the predictability, plannability and resilience of supply chains as well as the manageability of circular processes and the cost-efficient fulfilment of regulatory requirements. The table below summarises actions that could unleash the innovation and growth potential of SMEs according to stakeholders.

Topic 4: Innovation and growth of SMEs		
Actions	Actors	Timeframe
4.1 Strengthen cooperation with the start-up ecosystem		
• Develop tools and policies to promote cooperative buying in compliance with competition rules	Industry and EU/MS	S
• Support SMEs in their supply chains also by connecting to EIT Knowledge and Innovation communities	Industry	S
• Improve communication by fostering information exchange to promotion success stories	Industry and EU/MS	S
• Strengthen the Enterprise Europe Network	EU/MS	S
• Develop modular production processes to enable local and regional chemical economies	Industry	M
4.2 Support the successful implementation of the network of European Digital Innovation Hubs (EDIH)		
• Provide information to and encourage SMEs to make use of the digitalisation support services provided by the EDIH network.	Industry/MS	S/M
• Ensure the EDIH are appropriately funded	EU/MS	S/M
4.3 Strengthen initiatives with SMEs under the European Innovation Council (EIC)		
• Encourage SMEs to make use of open innovation test beds[24], which can bring both co-development and the testing of new substances and advanced materials within the reach of companies and users	Industry/MS	M
• Further support access for SMEs to national funding opportunities, which can complement funding received from the EIC programme	EU/MS	M
4.4 Support compliance with legislation and funding for new technologies		
• Communicate on funding opportunities *(Linked to Topic 7.1)*	Industry (trade federations)	S
• Assess the need for – and develop, if needed – regulatory sandboxes for regulatory testing and learning	Industry/MS	S
• Promote access to risk finance, in particular for SMEs and start-ups, and consider facilitating industrial research, e.g. through increased building of skills at local and regional level	EU/MS	S/M

[24] Sustainable production processes. See https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/sustainable-production-processes_en

(Linked to Topic 7.1)		
• Develop and promote 'plug-and-play' technologies with an appropriate regulatory framework and standards, and support from Member States	Industry/EU/MS	M

Maintaining existing synergies and developing new synergies will contribute to the sustainable competitiveness of the chemical industry. These synergies can be promoted by activities such as: (i) encouraging a high level of integration in chemical plants and within the sector more broadly; and (ii) further integrating projects in the chemical industry with projects in other sectors that contribute directly to resilience and the twin transition. In particular, greater integration between the chemical industry and the waste sector, (or other energy-intensive industries such as the steel, cement and energy sectors,) will be key to further increasing circularity, resource efficiency and energy efficiency.

Additionally, stakeholders suggest there is a need to improve the processes for designing chemicals and a need to adopt a full 'lifecycle' approach from the start, by increasing cooperation among the different value chains with manufacturers of end-products. The table below summarises actions suggested by stakeholders for the creation of new synergies.

Topic 5: New synergies		
Actions	Actors	Timeframe
5.1 Facilitate the exchange of information		
• Maintain the Euroclusters initiative, which aims to create partnerships of cluster organisations	EU/MS	S
• Facilitate cooperation in value chains and sectors through the ongoing revision of antitrust rules	EU/MS	S
5.2 Increase collaboration to de-risk investments		
• Increase the number of joint projects to de-risk investments (e.g. joint projects on CCS and the electrification of crackers)	Industry	S
• Increase cross-border projects on the generation and supply of energy and feedstock, such as grids, pipelines, renewable carbon, and CO_2 transport	EU/MS	M
• Consider incentivising processes that would increase the value of industrial waste and the CO_2 emissions it generates	EU/MS	M
5.3 Support the development of partnerships for innovation		
• Ensure shared access to the research and technology infrastructures as part of the European Research Area	EU/MS	S
• Undertake joint cross-sectoral projects that could qualify as important projects of common European interest (IPCEIs)[25]	Industry	S
• Strengthen and develop synergies with all players in the chemicals value chain[26]	Industry	M

[25] E.g. chemicals and waste, chemicals and steel, etc. to reduce emissions in the chemical industry in line with EU objectives. IPCEIs are a State aid instrument and have to comply with State aid rules, in particular the Communication from the Commission on criteria for the analysis of the compatibility with the internal market of State aid to promote the execution of important projects of common European interest (C/2021/8481 final) https://europa.eu/!NWcVp3.

[26] Producers of chemicals and materials, manufacturers of end-products, and the waste sector (e.g. in construction, textiles, transport, electronics, digital, renewables, aerospace, and defence).

• Support new data-driven business models based on Common European Data Spaces	Industry & EU/MS	M

2) INVESTMENTS AND FUNDING

The transition to a climate-neutral, safer, zero-pollution, and 'circular' chemical industry, including the development of safe and sustainable alternatives for substances of concern, will require major R&I investments (see textbox below). The development of new products and the implementation of the supply chain for their manufacture can easily take 5 years or more, especially for complex formulations.

Industry reports that one of the key hurdles for investing in the chemical industry's transformation is the risk linked to 'first-of-a-kind' solutions, and the risk of not being able to scale up. These two risks are driven by a changing regulatory context and the uncertain financial return from making these investments. The chemical industry requires high CAPEX for initial investments, combined with significantly higher OPEX to modify its production processes and to purchase energy and feedstock from alternative sources. Increasing the industry's confidence that these investments will produce a positive return would boost funding for innovative products and/or processes, and also foster the market for new products. In this respect, additional attention must be paid to the international competitiveness of EU companies.

Estimations by Process4Planet

The Processes4Planet Partnership (P4P) under Horizon Europe estimates that EU-wide investments needed to develop the first of a kind commercial low-carbon and circular technologies in the chemical industry are in the region of EUR 218-238 billion[27]. It also estimates that additional investments in the order of trillions[28] are needed to fully deploy these technologies across Europe including also electric-power production, supply chains and transport. The P4P partnership also estimates that ensuring the operation of industrial plants based on low-carbon technologies will require an average additional investment of EUR 3.9-5.5 billion per year[29]. The gradual transition from one system to another will require some degree of parallel production systems, with dual investments required in both systems for a period as a result (transition costs). From the mid-2030s, a need for increased investments will be expected driven by higher intrinsic CAPEX associated with some low-carbon processes and with CCS (Carbon Capture and Sequestration).

The chemical industry possesses significant physical assets, but investments are needed to secure the long-term sustainability of these assets. Major equipment or plant retrofitting demand long-term planning (including an R&I plan) and large capital investments.

The dismantling, retrofitting or rebuilding of existing assets may be opposed by shareholders if existing assets are not fully depreciated and still generate revenues (stranded assets). 'Drop-in' solutions may allow the prolonged use of existing assets and thereby enable fast retrofitting and minimise stranded assets. An action plan should be developed with the authorities to manage these existing assets and convert them or replace them with more sustainable

[27] See Processes4Planet SRIA, October 2021, p. 96 "*A more accurate estimation of investment needs for deployment would require more detailed analysis, and the overall figure will depend on the investments included"* […].

[28] See Processes4Planet SRIA, October 2021, p. 97 and 18.

[29] See: European Commission, 2021. ERA industrial technology roadmap for low-carbon technologies in EIIs, p. 5, Figure 26. Investments needs across the 3 pathways to net-zero.

alternatives. Investment timelines must take into consideration the industry's long investment cycles and the need for pilot and demonstration plants. New business models will have to be scaled up and proven to win the confidence of investors.

Summary of discussion on chain-of-custody principles emerged during the co-development meetings

Industry also points out the lack of officially acknowledged chain-of-custody principles. Industry stakeholders say that these principles would be an effective instrument in helping to finance the extra cost of sustainable feedstocks and energy. There is already strong existing consumer demand for more sustainable products, and products produced according to chain-of-custody principles could help to attract consumers to pay a premium. Chain-of-custody models, such as the mass-balance-credit method, may enable new sustainable and circular industrial models to emerge, making it possible to process different raw materials (fossil feedstock, CO2 from industrial emissions, biomass and recycled waste) in the same installation or plant. These are typically installations that already exist, and chain-of-custody principles makes it possible to allocate different raw materials to specific products that can bear the extra cost. This gradual feedstock shift would allow the timely conversion of chemical production plants to environmentally sustainable production processes. The mass-balance-credit method could become the key enabler for a significant demand-driven and consumer-financed step in the transition to a sustainable chemicals industry. Some stakeholders and civil-society representatives note that, for the mass-balance approach to be honest, transparent, traced and credible when applied to the chemicals industry: (i) there must be a physical connection between the waste and the desired end-product; and (ii) the claimed percentage of recycled content must correlate to the actual content. Consumers could be misled if there are no standards on traceability and transparency[30]. The application of the mass-balance-credit approach to chemicals remains controversial and under discussion at EU level, notably as part of Renewable Energy Directive (RED) revision.

National energy and climate plans, which Member States are currently updating[31], have a crucial role to play in increasing both investor confidence and the predictability of investments. They provide a good framework for planning and encouraging reductions in the use of fossil fuels and resources, thus providing more certainty and predictability overall. The table below summarises actions supporting funding for green investments proposed by stakeholders.

Topic 6: Fund for Green Investments		
Actions	Actors	Timeframe
6.1 EU Taxonomy to support the CSS		
• Consider drawing up delegated acts and FAQs to support the Taxonomy Regulation implementation ensuring the consistent interpretation of the relevant economic activities	EU	S

[30] E.g. see ZeroWasteEurope, 2021. Determining recycled content with the 'mass balance approach'.

[31] In accordance with the Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action; Member States have to update their national plans for 2021-2030 in a draft version by June 2023 and in their final version by June 2024.

• Continue fostering global dialogue and coordination on sustainability taxonomies through the International Platform on Sustainable Finance	EU	M
6.2 Develop hub structures		
• Develop hub structures to increase investment in the development and uptake of cross-sectoral low-carbon industrial technologies[32]	Industry and EU/MS	M
• Consider drawing up meaningful, harmonised and applicable sustainability-assessment methodologies and tools to stimulate collaborative innovation, with hubs as the entity charged with promoting these methodologies and tools (e.g. Hubs4Circularity [Horizon Europe], Circular Cities and Regions Initiative) *(Linked to topic 3.2 and 5.2)*	EU/MS	M
6.3 Manage and convert existing assets		
• Adopt a transition plan on the conversion or replacement of existing assets, while taking investment cycles into account *(Linked to Topic 11.2)*	Industry	S
• Facilitate and accelerate permitting procedures for plant investments and participate in communities of practice on permits[33] *(Linked to Topic 10.2)*	EU/MS	S
• Support (incl. financial) for retrofits and transformation that aim at effective and innovative low-carbon technologies and sustainable solutions	EU/MS	M

Public funding can be an efficient way to limit the risk of investment and can also be a useful complement when market incentives and regulation are not sufficient to drive investments. For instance, the EIC supports breakthrough and transformative innovation under the Horizon Europe programme. Through its tailored approach for start-ups and SMEs[34]; the EIC addresses innovators regardless of the maturity of the technology that they are developing. The overall funding of the EIC for 2021-2027 is EUR 10.1 billion. Industry associations stress that access to those funding mechanisms should generally be made easier and that all subsidies linked to the European Green Deal should be increased. Additionally, the ETS Innovation Fund[35] supports the commercial demonstration and de-risking of innovative low-carbon technologies, including projects in the chemicals sector. The fund will provide around EUR 38 billion of support from 2020 to 2030 (at a carbon price of EUR 75 per tCO_2). Resources for industrial transformation are also available through other funds, as the Just Transition Fund, the Recovery and Resilience Fund and the Modernisation Fund. Finally, the European Social Fund is well suited to focus on reskilling of the workforce for such a transition.

SMEs play a significant role in creating further synergies at industry level to develop and promote the widespread use of new industrial technologies. They should continue to do so in the future while driving the transition of energy-intensive industries to climate neutrality.

[32] See: European Commission, 2022. ERA industrial technology roadmap for low-carbon technologies in EIIs, p. 144.

[33] See: European Commission, 2022. ERA industrial technology roadmap for low-carbon technologies in EIIs.

[34] At least 70% of EIC budget shall be dedicated to SMEs, including start-ups.

[35] See https://climate.ec.europa.eu/eu-action/funding-climate-action/innovation-fund_en

The consultations carried out by the Commission[36] reveal that excessively high investment costs are the most frequent barrier preventing SMEs from adopting new environmental technologies, followed by a lack of finance[37]. SMEs tend to access less favourable borrowing terms than larger companies in the same industry and are often exposed to greater risk of failure, particularly when they attempt to pioneer new products and processes. The reporting requirements necessary to secure such funding can also be onerous. Improved assistance from local and regional authorities could enable a greater success rate for access to public funding by SMEs. Stakeholders also proposed the creation of a bespoke chemical SMEs fund, backed by a consortium of all major EU commercial banks, to be able to support investment by SMEs. To improve access to public and private funding, stakeholders suggest the following actions.

Topic 7: Access to Funding		
Actions	Actors	Timeframe
7.1 Strengthen communication channels for European funding		
• Communicate on funding opportunities *(Linked to Topic 4.3)*	Industry	S
• Increase skills-building at local and regional levels to support SMEs in funding opportunities *(Linked to Topic 4.3)*	Industry and MS	S
• Help industry to become frontrunners in sustainable innovations	Industry and EU/MS	S
• Keep informing Member States on the existing funding opportunities and conditions[38]	EU/MS	S/M
7.2 Provide a coordinated platform for funding		
• Cooperate with the public sector to complement public-private partnerships for R&I. Provide a broad and open platform to draw up strategic roadmaps and efficiently coordinate research, development and innovation investment plans for technologies in particular ecosystems (see updated industrial strategy), including national use of Recovery and Resilience Facility.	Industry	S
• Consider cutting red-tape (at EU and national level), and improve coordination to facilitate access to funding for industry through a 'single window' approach[39]	EU/MS	S

[36] DG R&I has run a series of consultations targeting SMEs. See Annex 1 of ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries, 2022, https://data.europa.eu/doi/10.2777/92567.

[37] *Idem.*

[38] Such as the EIC, the European Institute of Innovation and Technology, InnovFin (EIB), the European Structural and Investment Fund, the Just Transition Mechanism (JTM), InvestEU, the Innovation Fund, the European Fund for Strategic Investments, React-EU, Horizon Europe, and the Digital Europe Programme. See extensive overviews in ERA industrial-technology roadmaps on low-carbon technologies and (end of 2022) circular technologies and business models: ERA Common Industrial Technologies Roadmaps (europa.eu).

[39] A 'single window' means that companies and other users of official IT systems only have to submit their data once.

3) SUPPORT TO R&I, TECHNIQUES AND TECHNOLOGICAL SOLUTIONS

According to the International Energy Agency (IEA), if the right technologies reach the market in time for the next 25-year retrofitting cycle – due to start around 2030 – they can prevent nearly 60 Gt CO_2 – or 38% of projected emissions – from existing equipment in energy-intensive industries[40]. This is a once-in-a-generation opportunity to shape the future.

To boost its sustainability – including safety, circularity and resilience – the EU chemical industry also needs to adopt new techniques and technological solutions developed and scaled up through a well-supported policy agenda for R&I and development. The principles of co-creation, diffusion, updating, transformation and directionality should guide this R&I agenda[41]. However, there are barriers to the development of this agenda[42]. Specific actions are therefore required to address these barriers at different stages of R&I.

The manufacturing and transport of chemicals is energy intensive, but the industry is constantly innovating to become more energy efficient and to use more low-carbon technologies. Industry representatives report that the EU chemical industry is investing in innovation in advanced materials where the EU must maintain its lead position. They demand regulatory certainty, predictability and incentives to prioritise investments to Europe.

Essentially, there are actions fostering a better conceptualisation of new techniques and technical solutions. Once the conceptualisation is finalised, the development phase follows before the full deployment of new techniques and technological solutions.

A better conceptualisation includes sharing expertise in the implementation of SSbD frameworks considering existing criteria initiatives (e.g. among the IRISS project, the PARC partnership, the OECD, and the World Business Council for Sustainable Development)[43] and innovating safety testing and chemical-risk assessment to reduce dependence on animal testing while improving the quality, efficiency and speed of chemical hazard and risk assessments[44]. This should make it possible to promote assessments early on in a chemical's design cycle. Better conceptualisation is also a result of sharing knowledge on and encouraging the use of digital maturity assessment frameworks, such as the European Commission's Digital Maturity Assessment[45], to support the successful digital transformation of businesses in the chemical industry.

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[40] IEA, 2021. Net Zero by 2050. A Roadmap for the Global Energy Sector.

[41] These principles refer to 'Science, Research and Innovation performance of the EU, 2022 (SRIP) Report':
- Co-creation, working and acting together for a better society;
- Diffusion, sharing knowledge across society, territories and people;
- Uptake, turning research into sustainable solutions with social and economic value;
- Transformation, changing the way we consume and produce; and
- Directionality, with R&I leading the way.

[42] Stakeholders suggest classifying barriers as: (i) financial; (ii) related to legislation; (iii) related to knowledge and digital gaps (e.g. not sufficiently reflecting scientific progress or missing a balanced consideration of gains and risks); (iv) related to technologies; or (v) as related to high barriers to entry.

[43] One stakeholder suggests also including the sharing of experiences: (i) on sustainability assessment (including lifecycle assessments); and (ii) on the use of ProScale and UseTOX to assess the toxicological potentials of product systems.

[44] E.g. predictive toxicology based on improved data and algorithms and increased 'super-performance' or 'high performance' computing power (e.g. leading to the development of virtual human platforms; p.21 Chemicals Strategy for Sustainability).

[45] The Digital Maturity Assessment (DMA) framework was developed by the European Commission to support and monitor the digitalisation of businesses using the services of the European Digital Innovation Hubs network. The questionnaire which has

The development of industrial technology roadmaps could also support the conceptualisation of new techniques and technical solutions. This tool promoted by the Commission aims to accelerate the transfer of research and innovation results into the market for the green and digital transformation of industries across the EU. The roadmaps will address the way forward for research and innovation in the industry in key areas at European and national level. They will have a particular focus on closing the innovation divide between EU countries and making better use of research and innovation results. Stakeholders propose therefore to publish additional technology roadmaps on the circular economy, including roadmaps that focus on the specific needs of the chemical industry as part of ERA; and to develop national roadmaps for a low-carbon or circular chemical sector, where not existing[46].

A summary of the actions suggested by stakeholders is available in the table below. These actions are grouped by Technology readiness levels (TRLs); which scales the maturity of technologies[47].

Topic 8: Better conceptualisation of new techniques and technical solutions (TRL 1 to 5)		
Actions	Actors	Timeframe
8.1 Promote safety and sustainability-assessment approaches		
• Share expertise in the implementation of SSbD frameworks considering existing criteria initiatives	Industry and MS	M
• Innovate safety testing and chemical-risk assessment	Industry and EU/MS	S/M
8.2 Promote the use of Digital Maturity Assessment Frameworks		
• Share knowledge on and encourage the use of digital maturity assessment frameworks	Industry and EU/MS	S/M
8.3 Development of an industrial technology roadmap		
• Publish additional technology roadmaps on circular economy	Industry and EU/MS	S
• Consider developing national roadmaps for a low-carbon or circular chemical sector, where not existing	Industry and MS	S

The next significant stage is the development of new technologies, especially for energy and feedstock sourced from renewable sources and the circular economy. Stakeholders suggest fostering collaboration and partnerships, while also receiving support for the development. For example, by receiving appropriate financial and regulatory support between high TRLs – in particular demonstration and first-of-their-kind plants (e.g. via Innovation Fund) – and lower TRLs (e.g. via Horizon Europe), needed for the development of new breakthroughs.

The table below summarises the conclusions agreed among stakeholders.

been developed, enables the assessment of an SMEs state of digital development before and after the support of the Hub, therefore enabling an identification of the businesses service needs prior to an intervention and the subsequent impact of the support received.

[46] See executive summary in ERA Industrial technology roadmap for low-carbon technologies in EIIs.

[47] See https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

Topic 9: Developing new techniques and technological solutions (TRL 6 to 7)		
Actions	Actors	Timeframe
9.1 Foster collaboration and partnerships		
• Increase cooperation between research institutions and universities and industry, fostering applied research and targeting key enabling technologies for industry	Industry	S
• Engage in public-private partnerships (e.g. Processes4Planet, Circular Bio-based Europe) to develop and demonstrate energy efficiency and climate neutral, circularity and zero pollution chemical industry processes *(link with topic 5.3.)*	Industry and EU/MS	M
• Develop Chemical Data Spaces with the support of the Data Spaces Support Centre to leverage the potential of data exchange for more transparency and manageability	Industry	S
9.2 Support for development		
• Appropriate financial and regulatory support between different levels of technology readiness, including by establishing a community of practice to facilitate the authorisation for first-of-a-kind installations for low-carbon industrial technologies[48]	EU/MS	S
• Co-implement the strategic research and innovation plan (SRIP) for safe and sustainable chemicals and materials to guide future R&I priorities	Industry and EU/MS	S

Once technical solutions are demonstrated on an industrial scale, these solutions will need to be efficiently deployed across the industry to meet the objectives of the twin transition. Stakeholders highlighted the role of permitting and commercialisation to this end. In particular, this includes active contribution of the chemical industry in the information exchange organised by the Innovation Centre for Industrial Transformation and Emissions (INCITE) set-up under the revised Industrial Emissions Directive (IED). The Centre will identify emerging techniques worldwide for decarbonisation, depollution and/or increasing circularity in large agro-industrial installations. INCITE will evaluate these new processes and techniques and, if they are deemed ready for use at an industrial scale within a short timescale, will incorporate them in the Best Available Techniques Reference documents drawn up under the Sevilla Process to establish environmental norms for those installations.

Then, stakeholders suggested to assess the potential for cooperation among future potential users to address the investment gap so that innovative low-carbon technologies can timely be brought to the market[49]. Support the development, commercialisation, deployment and uptake (including through 'market pull' and pre-commercial procurement[50]) of new techniques and technological solutions. A summary of the actions suggested by stakeholders is available in the table below.

[48] As indicated in the ERA Industrial technology roadmap for low-carbon industrial technologies in energy-intensive industries, mentioned above.

[49] See ERA Industrial technology roadmap for low-carbon technologies in EIIs, action 7.2. ('broad and open platform') above, and the German proposal at COMPET 29 September 2022 to set up a 'platform for transformation technologies'.

[50] Pre-commercial procurement (PCP) is an approach to public procurement of research and development (R&D) services that is outlined in the PCP communication.

Topic 10: Deployment of new techniques and technological solutions (TRL 8 to 9)		
Actions	Actors	Timeframe
10.1 Permitting and commercialisation		
• Active involvement of INCITE on emerging processes or techniques for decarbonisation, depollution and/or increasing circularity in the sector	Industry and EU/MS	S
• Assess the potential for – and design the scope of – cooperation among future potential users to address the investment gap so that innovative low-carbon technologies can timely be brought to the market	Industry and EU/MS	M
• Support the development, commercialisation, deployment and uptake (including through 'market pull' and pre-commercial procurement) of new techniques and technological solutions	EU/MS	M/L

4) REGULATION AND PUBLIC GOVERNANCE (LEGISLATION)

The new legislation adopted and soon to be adopted under the European Green Deal covers all aspects of the industry's operating environment. It is an example of how, for the twin transition to be successful and to lead to increased resilience for the EU chemical industry, legislation plays a fundamental enabling role. The 'better regulation' agenda already ensures evidence-based and transparent EU law-making that considers the views of those that may be affected by new legislation. The Commission continuously evaluates and improves EU laws, focusing on changes to laws that will have the greatest impact. Existing and future legislation can address some of the major barriers that currently prevent the twin transition from proceeding. Stakeholders say that these barriers include: (i) the lack of predictability for the timelines of new legislative proposals; (ii) the lack of coherence and consistency between EU legislation and national legislation ('vertical' coherence); and (iii) the lack of legislative harmonisation across entire economic/industrial sectors or across entire value chains ('horizontal' coherence).

More effective and predictable legislation could address these barriers, according to stakeholders. To this end, policymakers and the industry could act on definitions, concepts, and methods. For example, stakeholders appreciated the information on chemical legislation available in the EUCLEF portal[51] and suggested to continuously update the information. Industry also pledges to continue to actively engage in the work of EU public authorities, such as the participation to public stakeholder consultations and expert groups, so that definitions of new concepts recently introduced in the EU legislation can be made available and applied. Meanwhile, stakeholders invited EU and national policymakers to define and explain new concepts introduced by recent EU legislation and policy documents. Finally, stakeholders proposed to develop a sectoral roadmap towards achieving the climate-neutrality objective[52]. Specific actions on more effective and predictable legislation that stakeholders suggested are presented in the table below.

Topic 11: More effective and predictable legislation		
Actions	Actors	Timeframe
11.1 Definitions and concepts		
• Continuously update the EUCLEF portal with information on chemicals legislation	EU	M/L
• Continue to engage actively in the work of public authorities proposing the definition of key concepts mentioned in recent EU legislation and policy documents (CSS, IED, etc.)	Industry	S
• Define and explain new concepts introduced by recent EU legislation and policy documents[53]	EU/MS	S

[51] The EU Chemicals Legislation Finder (EUCLEF) is a tool funded by COSME and powered by the ECHA (European Chemicals Agency) that helps to identify which pieces of legislation apply to each substance. It consists of a search engine for regulatory information on chemicals enabling companies, and especially SMEs, to find out how their substances are being regulated in the EU and what their legal obligations are: https://echa.europa.eu/legislation-finder.

[52] In line with Article 10 of the European Climate Law: 'The Commission shall engage with sectors of the economy within the Union that choose to prepare indicative voluntary roadmaps towards achieving the climate-neutrality objective set out in Article 2(1). The Commission shall monitor the development of such roadmaps. Its engagement shall involve the facilitation of dialogue at Union level, and the sharing of best practice among relevant stakeholders'. https://europa.eu/!b9jcXm.

[53] A stakeholder suggested some examples: definition of 'recycled content' and definition of 'end-of-waste'.

• Develop a sectoral roadmap towards achieving the climate-neutrality objective	Industry and EU	S
• Take note of the proposals suggested by stakeholders on future chemicals legislation listed in Annex 4	EU	M
11.2 Methods		
• Propose targeted amendments to the REACH Regulation as per the CSS, including reform of the REACH authorisation and restriction processes based on key findings from its practical implementation	EU/MS	S
• Continue to consider the 'think-small-first' principle giving full consideration to SMEs at the early policy development stage	EU/MS	S/M

Stakeholders formulated actions that could improve the coherence and consistency between EU legislation and national legislation (the so-called 'vertical' coherence). For example, the industry proposes drawing up a comprehensive and integrated overview of the regulatory framework applied to the EU chemical industry at EU and national level. This overview should include a comparison with key competing regions to suggest to policymakers' options to harmonise regulations and remove obstacles to circularity. Similarly, stakeholders proposed actions improving the legislative harmonisation across entire economic/industrial sectors or across entire value chains (the so-called 'horizontal' coherence). For example, the industry wishes to contribute to the development of technical guidance that promote harmonised implementation and better enforcement of legislation on occupational safety and health.

The table below collects actions identified by stakeholders as being likely to increase coherence and clarity about how different pieces of EU legislation and national legislation interact with each other.

Topic 12: Vertically and horizontally coherent legislation		
Actions	Actors	Timeframe
12.1 Horizontal coherence of legislation		
• Propose to remove legislative obstacles for the re-use of data. Better streamline the flow of chemical data between EU and national authorities. Extend the principle of 'open data' and the relevant transparency principles from the EU's food-safety sector to other pieces of chemical legislation	EU/MS	S
• Propose drawing up a comprehensive and integrated overview of the regulatory framework applied to the EU chemical industry at EU and national level. This overview should include a comparison with key competing regions to suggest to policymakers' options to harmonise regulations and remove obstacles to circularity	Industry	S
• Consider revisiting legislation on occupational safety and health to ensure it is future-proof and promotes the safe use of chemicals in professional and industrial settings [COM(2021) 323 final]	EU/MS	S

12.2 Vertical coherence of legislation

• Continue to update PACT (the Public Activities Coordination Tool) to provide an up-to-date overview of all planned and ongoing initiatives on chemicals by authorities across different pieces of legislation	EU/MS	S
• Suggest technical guidance to promote harmonised implementation and better enforcement of legislation on occupational safety and health	Industry	M

Finally, stakeholders reflected on means to improve the enforceability of existing legislation; focusing in particular on imported products allowing authorities to detect when these products do not comply with EU standards; especially for online sales of consumer products. Under the Market Surveillance Regulation, the Commission proposes to lay down uniform conditions and frequencies of checks for certain products where specific risks or serious breaches of applicable EU harmonisation legislation have been continuously identified. It also wishes to explore the use of digital tools to support market-surveillance and customs authorities and to improve the compliance of products containing chemicals that are sold online to European consumers. Implementation of legislation can also be improved by fully deploying existing synergies and further developing existing public-private partnerships or by creating specific support to help SMEs implement legislation. Technical guidance may also help to explain regulatory requirements and harmonise interpretation and implementation.

The table below summarises proposals made by stakeholders on enforcement.

Topic 13: Effective and efficient enforcement		
Actions	Actors	Timeframe
• Consider developing analytical methods to support enforcement. Increase available resources for enforcement	Industry and EU/MS	S
• Share for Member States consideration, successful non-regulatory enforcement measures (e.g. voluntary actions, schemes and stewardship initiatives) that make the enforcement of legislation more efficient and more effective	Industry	S
• Lay down – under the Market Surveillance Regulation – uniform conditions and frequencies of checks for certain products where specific risks or serious breaches of applicable EU harmonisation legislation have been continuously identified	EU	S
• Explore the use of digital tools to support market-surveillance and customs authorities and to improve the compliance of products containing chemicals that are sold online to European consumers	EU	S/M
• Encourage MS to use the Recovery and Resilience Facility to invest in strengthening market-surveillance infrastructures and digitalisation	EU/MS	S/M
• Extend the scope of action of the European Anti-Fraud Office in coordination and investigation, so it can help to tackle the circulation of illicit chemical products in the EU	EU	S/M

During the co-development process, stakeholders expressed their willingness for the Commission to develop a comprehensive and integrated overview of the legislation applied to the chemical industry at EU level. This could provide industry with a better understanding of the upcoming regulatory framework, as well as the opportunities available at European level.

The resulting regulatory roadmap became a third component of the transition pathway for the chemical industry. This overview of existing legislation and major R&I initiatives relevant to the chemical industry has been developed using the best available knowledge at the time of writing. It includes the latest publicly available information and best-scenario assumptions about the ongoing legislative and non-legislative procedures. However, the timeline of this roadmap remains purely indicative; especially for those proposals whose content is still under development.

The overview does not include all financial opportunities supporting the implementation of the legislation (where it exists) and/or the transition of the industry. It also does not include all supportive EU documents, such as the guidance on boosting circular business models referred to in the ESPR. However, it aims to be a tool to help decision-makers in the chemical industry and other stakeholders.

5) ACCESS TO ENERGY AND FEEDSTOCK

Around half of the chemical subsector's energy input is consumed as feedstock with fuel used as a raw material input rather than as a source of energy. Upstream processes are the most emissions intensive but in a 'linear' economy (i.e. an economy that uses new raw materials which are then discarded as waste and not recycled), the carbon embedded in products also creates substantial emissions at the products' end of life. To reach the EU's climate goals, the chemical industry should move progressively away from primary fossil-based feedstocks. The European gas-demand-reduction plan, published in response to sanctions against Russia, greatly affects the chemical sector, as it is heavily reliant on gas consumption both as a fuel and as a feedstock. This reliance on Russian gas makes the transition to greener alternatives even more important. Furthermore, the EU objective to be climate-neutral by 2050 will need to address the challenge of both direct and indirect emissions (e.g. 'scope 3' emissions[54]).

Products from the chemical industry that are used in a variety of applications can help consumers and end-users to support EU actions. For example, products from the chemical industry are used for wind energy, solar energy, electromobility, energy efficiency in buildings, etc. However, the production of these chemicals necessary for the twin transition relies on: (i) cheap and readily available energy (which should be renewable and/or clean); and (ii) alternative feedstocks. Alternative fuels such as renewable hydrogen or e-ammonia and e-methanol have much lower energy density than fossil fuels. Producing these alternative fuels will require massive amounts of electricity sourced from clean energy. However, converting renewable electricity to renewable fuels may also result in a loss of energy. There could be a risk that the industry's transition to climate neutrality results in higher levels of final energy consumption. Moreover, because of the trend towards electrification of boilers and furnaces (as argued below), the sector's electricity demand is expected to grow significantly.

According to the industry's initial estimations as part of the iC2050 modelling project[55], annual electricity demand from the chemical industry will be well above 200TWh in 2030 and could reach up to 700TWh in 2050, which is a level four times higher than today. Some stakeholders stress the need to reconsider our energy needs and move towards a 'sufficiency' approach. According to the same iC2050 modelling estimations, total demand for biomass is also set to increase significantly over the coming years and decades, reaching 22Mt in 2030 and 88Mt in 2050. Several other sectors (e.g. transport and heating) will depend on the same limited resource, and if sustainably available biomass is scarce, prices risk becoming uncompetitive.

The 2022 progress report on the EU's bioeconomy strategy[56] reflects on the increased importance of the bioeconomy in the new policy context and in the context of the EU Green Deal. It outlines the need for policy coordination and action areas to address the demand for – and availability of – biomass for different applications, ensuring biomass is used in a way that contributes to addressing the biodiversity and climate crises.

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[54] 'Scope 1' indicates direct greenhouse gas (GHG) emissions that are from sources owned or controlled by the reporting entity. 'Scope 2' indicates indirect GHG emissions associated with the production of electricity, heat, or steam purchased by the reporting entity. 'Scope 3' indicates all other indirect emissions, i.e., emissions associated with the extraction and production of purchased materials, fuels, and services, including transport in vehicles not owned or controlled by the reporting entity, outsourced activities, waste disposal, etc. (source: IPCC, 2014. Glossary. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change).

[55] CEFIC, 2021. Towards implementing the Climate Law.

[56] European Commission, 2022. EU Bioeconomy Strategy Progress Report.

To ensure the supply of energy and feedstocks, long-term needs have to be anticipated as suggested by stakeholders and presented in the table below.

Topic 14: Anticipate long-term needs for the supply of energy and feedstock resources		
Actions	Actors	Timeframe
• Estimate the future needs for energy and alternative feedstock to ensure continued production of chemicals	Industry and EU/MS	S
• Evaluate the impact of increases in energy prices	Industry and EU/MS	S
• Consider developing a strategy for the competitive supply of clean energy and strategic raw materials to the EU that takes geopolitical factors into consideration. (REPowerEU). Consider evaluating the potential role of eliminating tariffs for supplies of key resources *(Linked to Topic 2.3 and 15.2)*	EU/MS	S

The sixth strategic energy and technology (SET) action plan[57] intends to record the agreements between stakeholders on actions to '*increasing efforts to make EU industry less energy, resource and emissions intensive and more competitive*'. It prioritises R&I activities with the highest potential for reducing both carbon emissions and the consumption of energy/resources. The bullet points below outline in more detail two out of the six policy areas in which the action plan identifies a pressing need for R&I activities.

- **Electrification**

Chemical industry requires the possibility to purchase cost competitive climate-neutral electricity. In chemical processes, electricity can be introduced either directly or indirectly. This indirect use of electricity can be considered for generating heat and steam or low- and high-temperature processes (e.g. e-crackers). Direct use of electricity can be done via electrochemistry[58] or alternative forms of energy (e.g. ultrasound and plasma).

- **Integrated production of hydrogen with a low-carbon footprint**

Large supplies of electricity will also be essential for hydrogen production. The chemical industry is both a major producer and a major consumer of hydrogen. The hydrogen-production method most commonly used in the EU is the reforming of natural gas or the bottom fraction of crude oil. This method emits significant quantities of CO_2. Meanwhile, technologies such as methane pyrolysis or photo-electrocatalysis are under development for cost competitive production of hydrogen, in addition to water electrolysis.

Renewable hydrogen[59] must be affordable and should be prioritised when replacing unabated fossil-based hydrogen[60]. It should be seen as part of a broader set of options leading the chemical industry towards climate neutrality. Stakeholders stress that regulatory barriers to the procurement of green electricity for hydrogen self-production should be avoided, and that

[57] SET-Plan ACTION n°6 - Declaration of Intent '[Continue efforts to make EU industry less energy intensive and more competitive]'.

[58] Electrochemistry refers to the relationship between electrical and chemical energy and the conversion of one to the other.

[59] JRC, 2021. [Cleaning up hydrogen production with local renewables].

[60] According to the EU hydrogen strategy, unabated hydrogen is hydrogen produced through a variety of processes using fossil fuels as a feedstock, mainly the reforming of natural gas or the gasification of coal.

regulation should prioritise renewable hydrogen for the chemical industry. On energy supply, direct electrification (when possible) should be prioritised over hydrogen, which is by nature less energy efficient for the moment.

These sources of hydrogen must be economically viable and priced at a level that the chemical industry can afford. Thus, chemicals produced with low-carbon methods or renewable hydrogen should be supported and priced so that they reflect robust GHG-accounting rules. The difference in cost between zero-emissions chemicals-production technologies and other more polluting alternatives in global market prices are still significant. This difference could be bridged through several options, such as carbon contracts for difference (where the EU would subsidise producers so that it would pay for any covering the difference in cost between zero-carbon technologies and more polluting ones) and entering into long-term contracts for clean energy. REPowerEU sets up an action plan for a massive scaling-up and speeding-up of this clean energy in power generation.

To support the economically viable purchase of clean energy, the actions set out in the following table could be taken.

Topic 15: Economically viable purchases of clean energy		
Actions	Actors	Timeframe
15.1 Channel investments for clean energy		
• Adopt a social climate fund to support small business in the transition (REPowerEU)	EU/MS	S
• Channel investments to players committed to the green transition and to becoming 'frontrunners' in the use of novel sustainable technologies *(Linked to Topic 6.1)*	Industry and EU/MS	S/M
• Strengthen the funding and de-risking measures (e.g. contracts for difference, robust investment-protection policies) to support the deployment of green and smart technologies and the sourcing of clean energy up to demonstration plants and first-of-their-kind plants – e.g. via the Innovation Fund	EU/MS	M
15.2 Ensure the competitive supply of clean energy		
• Reassess electricity-market rules with the aim of making electrification cost-competitive for energy-intensive industries	EU/MS	S
• Implement the EU solar strategy to double solar photovoltaic capacity	EU/MS	S/M
• Consider setting up 'go-to' areas for renewables with shortened and simplified permitting processes *(Linked to Topic 4.3, 6.3, 10.2, 11.2 and 14.2)*	MS	S/M
15.3 Improve power-purchase agreements (PPAs)		
• Publish guidance to Member States on PPAs	EU/MS	S
• Set up EU certifications and standards for feedstock (addressing energy and chemicals, including hydrogen)	Industry and EU/MS	S

• Set up risk-sharing facilities to support micro-firms & SMEs *(Linked to Topic 4.3)*	EU/MS	S
• Introduce an electricity-price system for industry that ensures internationally competitive energy prices and supports the transition towards climate neutrality. Consider increasing the number of renewable-energy PPAs	EU/MS	M/L
• Ensure diversification of sources and the strategic autonomy of the EU for essential power supply while safeguarding competitive supply	EU	M/L

The production of chemicals and materials still relies heavily on fossil-based feedstocks, and therefore solutions for substitution need to be implemented alongside the management of demand for these alternatives.

- **Biomass as an alternative feedstock**

Various types of biomass can be considered for producing chemicals (e.g. from sugars, sustainably sourced vegetable oils, residues, and agricultural or forest-based lignocellulosic biomass and residues). The value chains being created to make bio-based chemicals and materials include a large portfolio of technologies roughly categorised into pre-treatment, conversion, and downstream processing. These technologies make possible the processing of a broad range of biomass feedstocks into an array of high-value products. Actors in the bioeconomy seek to extract value from all fractions of the biomass raw material, including those that might formerly have been considered as waste or residues (secondary biomass). Innovative process technologies are promising in that they raise the possibility of using residual biomass to produce commodity chemicals.

The challenge is firstly to ensure that this biomass is sustainably sourced, in line with the approach of the EU Bioeconomy Strategy and the Green Deal. The next challenge is to link all bio-based processing steps into integrated value-chain networks while ensuring that production is resource efficient, energy efficient, cost efficient, and contributes to the zero-pollution ambition. In this context, R&I is key to contribute to the sustainability of bio-based processes.

The design and production of bio-based chemicals, along with dedicated infrastructure for supply and production (e.g. bio-refineries, bio-based supply chains) should support the production of chemicals and materials, creating quality jobs and added value. This added value should come by turning responsibly and sustainably sourced biomass into high-value products (cascading use of biomass). Nonetheless, future scenarios of biodiversity loss and climate change mean that the forecasts for biomass availability (for both energy and chemical uses) remain a key challenge in transitioning away from fossil-based feedstocks. According to some stakeholders, facilitating imports of biomass may help overcome any potential biomass shortages. However, the impact of biomass sourcing in non-EU countries would need to be fully sustainable and should not aggravate environmental degradation nor promote unsustainable practice or increase strategic dependencies.

The prospect of the chemical sector becoming largely bio-based remains challenging. It will be difficult to achieve given: (i) the limited availability of sustainable primary biomass in the EU; (ii) the fierce competition for biomass resources from other sectors (in particular, the energy and transport sectors); and (iii) the sheer scale of demand. Increased pressure on

biomass demand therefore requires careful assessment of trade-offs[61] by adopting the biomass-use prioritisation principle on the national or EU level[62]. The 'cascading' principle for biomass as proposed in RED III (the revised version of the Renewable Energy Directive, which has yet to become law) ensures that biomass is used first where it has the highest economic added value and the lowest environmental impact.

- **Waste as an alternative feedstock**

Organic and inorganic waste[63] can be used as an alternative feedstock for chemicals. For instance, some petrochemical companies collect used cooking oil as organic waste to generate biofuel. The re-use of inorganic waste (e.g. plastics, iron, steel, and aluminium[64]) is of strategic importance to environmental protection and to achieving the circular economy. Chemical-recycling[65] technologies break down the chemical structure of polymeric waste and other input materials such as plastic or textile waste into monomers and chemical building blocks. These technologies then transform the monomers and chemical building blocks into valuable secondary raw materials, and dedicated and drop-in intermediates for manufacturing new products. Outputs include chemicals and other products, some of which are fuels. Stakeholders state that fuel use is excluded from the definition of 'recycling' in the Waste Framework Directive. These new products include chemicals and plastics (but do not include the use of these products for energy recovery and incineration)[66]. Chemical-recycling processes each have their own requirements regarding the inputs used and result in different outputs. These processes are typically depolymerisation, pyrolysis and gasification. These three techniques offer a solution for best dealing with the deteriorating quality of the polymer chains after each cycle of mechanical recycling. A fourth technique is solvolysis, which makes it possible to separate polymers from other materials.

Certain breakthrough upcycling' technologies are now commercially scalable. These technologies involve recycling with a high yield a broad range of plastic waste, including hard-to-recycle plastics, into high-purity products (such as waxes, oils and solvents) that can be used across a variety of different industries. These innovative and sustainable business cases only require plastic waste as a feedstock, thereby enabling the circular production of fossil-free chemicals.

Despite these promising niche applications of chemical-recycling processes, some stakeholders report significant hurdles to scaling up these technologies. They stress the need for more transparency and evidence around mass flows, chemical use, and the viability of processes in real-life waste-management circumstances. Moreover, clear standards for

[61] See action on 'Integrated Bioeconomy Land Use Assessments' in COM(2021) final https://europa.eu/!9xCx8D.

[62] COM(2022) 283 final. EU Bioeconomy Strategy Progress Report: stocktaking and future developments europa.eu/!dGJMKR.

[63] EEA Glossary: Waste composed of material other than plant or animal matter, such as sand, dust, glass and many synthetics https://www.eea.europa.eu/help/glossary/eea-glossary/inorganic-waste.

[64] The Commission is preparing a set of end-of-waste criteria for priority waste streams under the Waste Framework Directive.

[65] ISO, 2008 Definition: Chemical recycling: 'conversion to monomers or production of new raw materials by changing the chemical structure of plastics waste through cracking, gasification or depolymerization, excluding energy recovery and incineration'.

[66] Article 3(17) of the Waste Framework Directive: 'recycling' means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

environmental sustainability and safety should be set for the energy required for these transformation processes.

To meet the ambitious European objectives for sustainability and circularity, increased volumes of plastic waste must be recycled and a broader range of markets need to be served with plastic products containing higher recycled content. However, stakeholders say that the chemical industry faces increasing barriers to intra-EU cross-border shipments of waste and that there is a need for harmonised application of 'end-of-waste' criteria. Some stakeholders point out that the EU framework is not yet applicable to local and regional waste laws and directives in individual Member States. They also argue that waste-as-feedstock technology is not being implemented on a large scale and still partly involves the use of large amounts of energy.

- **CO_2 as an alternative feedstock[67]**

Carbon from CO_2 captured from concentrated sources (e.g. industrial sources, biogenic gaseous carbon) is a potential alternative to virgin fossil feedstock. In the longer-term, CCU technologies may mitigate climate change by removing CO_2 from the atmosphere or using carbon-containing (not only from CO_2, but also from CO for example) flue gases (industrial off-gases, including from fermentation processes from food, beverages, etc.). These flue gases are captured directly at point sources so that they do not enter the atmosphere and can instead be converted into chemicals. In December 2021, the Commission adopted the Sustainable Carbon Cycles[68] communication, which sets out an action plan on: (i) how to develop sustainable industrial solutions to increase carbon removals (using direct air capture and bio-based products with long lifetimes); and (ii) key actions to support the industrial capture, use and storage of CO_2 (CCU and CCS). Carbon capture (CCS/CCU) technologies are key technological pathways for the decarbonisation of energy-intensive industries, including the chemical industry. Their application potential has been identified as particularly high for the chemical sector (both CO_2 and CO)[69]. However, these technologies still face some challenges. The two main challenges are listed in the bullet points below.

- It is complex and costly to collect and purify CO_2 directly from the air.
- There is not a lot of carbon-free renewable energy (e.g. to produce green hydrogen required to produce chemical feedstocks from CO_2).Transforming CO_2 via electrolysis for CCU requires a lot of energy, preferably from renewable sources.

The CO_2 captured can also be stored either permanently in geological sites or in long-lasting products.

Today the industry is already working on four fronts to play its role in the circular economy. These four fronts are set out in the four bullet points below.

- Firstly, the industry is seeking to improve processes (e.g. optimisation of mechanical recycling) including by using fewer resources and less energy (e.g. through energy recovery, waste recovery, and innovative recycling technologies).
- Secondly, the industry is seeking to design and re-design chemical products and materials to reduce waste from the outset, improve circularity, and improve recycling

[67] Including CO capture from 'industrial waste gases'.

[68] COM(2021) 800 final. Commission communication on Sustainable Carbon Cycles, p.19 https://europa.eu/!9xCx8D.

[69] See chapter 2 (p. 28) in ERA Industrial technology roadmap for low-carbon technologies in EIIs.

end-products (e.g. using new recyclable composites for windmill blades). It is possible to develop a circular model for chemicals that pose certain risks to health and ecosystems.

- Thirdly, the industry is making progress towards turning second-generation, primary, secondary and waste biomass into valuable inputs for bio-based chemistry.
- Fourthly, the industry is making progress towards using CO_2 from industrial off-gases and fermentation as a valuable input for chemical feedstocks. The industry is also working on the direct air capture of gaseous effluent chemicals to turn them into a valuable feedstock input.

Based on these elements, stakeholders presented a series of actions aimed at identifying and developing new and sustainable sources of feedstock; as well as at further developing alternative feedstocks such as biomass, waste and CO_2. The table below summarises these actions as suggested by the stakeholders.

Topic 16: Feedstock Substitution		
Actions	Actors	Timeframe
16.1 Identify and develop new and sustainable sources of feedstock		
• Consider setting targets for renewable/non-fossil content to stimulate demand	EU/MS	S
• Consider harmonising EU and international certification systems for the sustainable sourcing of biomass feedstock (including secondary biomass) and standards irrespective of the feedstock's end-use	EU/MS	S
• Assess further the economic and technical potential of aquatic biomass (third-generation biomass)	Industry	S
• Provide a detailed definition of 'non-fossil sources' and a methodology to calculate the share of total feedstock in carbon sources. Make statistical data more detailed to support the calculation of this share[70].	Industry and EU/MS	S
• Increase reporting of scope-3 GHG emissions and explore opportunities to use feedstock from waste and recycled materials	Industry	M
• Consider promoting projects on turning alternative sources into valuable feedstock inputs, partly through joint agreements & interdisciplinary cooperation; ensuring SMEs participation	EU/MS	S/M
• Harmonise criteria and methodologies – and make sure they also apply to SMEs – to assess the environmental and socioeconomic performance of bio-based systems (integrating biodiversity for example). Ensure that these criteria and methodologies are aligned with the future SSbD framework.	Industry and EU/MS	S/M

[70] See 'Industrial Sustainable Carbon challenge' in COM(2021) 800 final. Sustainable Carbon Cycles https://europa.eu/!9xCx8D.

• Accelerate the market deployment of existing circular and bio-based solutions (whether they are mature or innovative) – e.g. via the Innovation Fund	Industry and EU/MS	S/M
16.2 Biomass as an alternative feedstock		
• Create a balance and prioritisation between the different uses of biomass by providing a set of sustainability criteria (e.g. considering deforestation risk) and develop concrete incentives for the use of these criteria	Industry and EU/MS	S/M
• Further improve methodologies to monitor the environmental performance of biomass as a feedstock	Industry and EU/MS	S/M
• Increase the efficiency and transparency of biomass supply chains	Industry and EU/MS	M/L
16.3 Waste as an alternative feedstock		
• Promote setting targets for recycled and bio-based content in order to stimulate demand	Industry	S
• Suggest improvements on transparency – and ending restrictions on transparency – in the use of 'substances of concern' to clean up material cycles (ESPR) at national level	Industry	S
• Advocate for promotion of early international cooperation on standards to prevent potential barriers to market access barriers from arising	Industry	S
• Advocate for chemical recycling as a complementary option for waste that cannot be recycled mechanically, if it causes less environmental burden than incineration and virgin plastic production	Industry	S
• Increase the recyclability of products to boost the use of upcycled resources instead of virgin materials	Industry	S/M
• Phase out the most harmful substances from consumer products, unless they are essential for society, as per the CSS	Industry	S/M
16.4 CO_2 as an alternative feedstock		
• Consider using circular carbon sourced from CO_2 as a feedstock	EU/MS	S/M
• Support the economic and technological development of CO2 as a feedstock	EU/MS	S/M
• Consider developing an impact assessment on the CO_2 footprint of the increased demand for strategic metals *(Linked to Topic 2.1)*	Industry and EU/MS	S/M
• Consider harmonising the EU regulatory framework for cross-border CO_2 transport	EU/MS	M

New business models and more efficiently produced materials could help reduce emissions by about 65Mt CO_2 per year across the value chain[71]. The opportunities in this area include: (i) improving design; (ii) reducing waste during the production of chemicals; (iii) having higher-performance materials; (iv) reducing over-specification; and (v) encouraging higher intensity use of chemicals. The chemical industry must also consider new business models. Chemical leasing[72] for instance, could address the over-consumption of chemicals by charging customers based on functions performed by the chemicals rather than by the volume of chemicals purchased.

Process intensification (e.g. by changing reactor designs, or by developing new catalysts) can also provide major opportunities for resource and energy efficiency. With these new processes, chemical reactions can be achieved at optimal conditions with significantly fewer side reactions, creating fewer by-products, and using fewer auxiliary materials. As catalysts are key enablers for higher selectivity and reduced energy consumption, novel catalysts must be designed to accommodate more complex feedstocks and/or more variable feedstock quality (e.g. biomass, waste, CO_2). Intensified separation technologies and their control technologies must complement higher selectivity of the reactions. Further innovation in this area is required to significantly reduce energy consumption and costs. However, the development of a new generation of catalysts relies on the availability of certain raw materials[73]. The increased demand for energy infrastructure (electricity, hydrogen), transport, and deployment of digital technologies will require large volumes of several strategic metals. These raw materials needed for the transformation of EU industries will mostly come from mining and refining.

Process efficiency can be complemented at plant and site level with the implementation of other optimisation measures such as energy recovery, including energy recovery from low-temperature energy streams. Industrial symbiosis will make it easier to implement some of the above-mentioned options, for example through exchange of material or energy flows for heat integration. Digital technologies could also play a role in efficient production processes, starting as early as the virtual planning and simulation phase of new production-line processes. The table below summarises actions stakeholders suggest on process and resource efficiency.

Topic 17: Process and resource efficiency		
Actions	Actors	Timeframe
• Re-think business models and identify potential enablers for these new business models	Industry and EU/MS	S
• Support the development of advanced and alternative separation technologies	Industry and EU/MS	S/M
• Promote industrial symbiosis as a commonplace approach for advancing the circular economy *(Linked to Topic 18.1)*	Industry and EU/MS	S/M
• Invest in the development of novel catalysts	Industry	M/L

[71] Materials Economics, 2019. Industrial transformation 2050: Pathways to Net-Zero Emissions from EU Heavy Industry, p. 26.

[72] Chemical leasing is a business model that intends to shift the focus from increasing sales volume of chemicals towards a value-added approach.

[73] See SRIA: Innovation Priorities for EU Global Challenges. Priorities include the design and scalable production of catalysts with reduced consumption of critical raw materials and preferably starting from abundant and accessible raw materials.

6) INFRASTRUCTURE

Access to energy and feedstock and the corresponding infrastructure is of essential importance. The necessary infrastructure will need to be built or scaled up to secure the chemical industry's access to energy and feedstock, and in particular to electricity, hydrogen, waste, CO_2, and biomass. Infrastructure will also support both industrial symbiosis[74] and better integration of processes within industrial clusters (e.g. capturing, storing and transporting CO_2 from an emitting plant to the chemical industry). The development of such structures is being slowed down by: (i) the lack of infrastructure around certain industrial sites, especially on inland locations and in central and eastern Europe; and (ii) the slow approval procedures at Member State level for energy and industrial processes. The necessary permits and infrastructure for energy transition and feedstock diversification must still be put in place.

Expanding the gas and electricity grid is necessary to access low-carbon energy from all sites, not only those sites close to electricity-generation plants. Bottlenecks in the gas grid must be abolished, and cross-border interconnectors must be put in place to enable the free flow of energy between countries. Existing sources of gas must be adapted so that they respond to demand and provide flexible generation units and storage. Progress must be made in new sources of flexibility such as power to-X[75] and new types of storage (e.g. for renewable or low-carbon hydrogen and ammonia).

Finally, the availability and deployment of ample CCS and CCU capacity are essential enablers for climate neutrality. For this reason, bilateral agreements could be concluded between countries that ship captured CO_2 and those that receive it to facilitate the access of landlocked production sites to CO_2 storage sites.

Industry stakeholders speak of both the stringent safety standards requirements for hydrogen infrastructure and the public protests against these large-scale developments. In October 2021, a report[76] was published on barriers to – and mitigation measures for – clean hydrogen projects.

To overcome these barriers, the European Clean Hydrogen Alliance supports the large-scale deployment of clean hydrogen technologies by 2030 by bringing together: (i) renewable and low-carbon hydrogen production; (ii) demand from industry, mobility and other sectors; and (iii) the transmission and distribution of hydrogen. Together with ammonia producers, the chemical sector is projected to be one of the EU's industrial champions in the use of clean hydrogen, as shown by an analysis[77] of around 1 052 specific investment projects which have been submitted as part of the European Clean Hydrogen Alliance. In addition, the industry already produces vast amounts of hydrogen that is completely used in internal manufacturing processes.

[74] Industrial symbiosis is the process by which waste or by-products from an industry or industrial process become the raw materials for another.

[75] Technology that converts renewable electricity from solar or wind farms into other forms of energy (e.g. renewable hydrogen, renewable methanol).

[76] European Hydrogen Alliance, 2021. Reports of the alliance roundtables on barriers and mitigation measures https://ec.europa.eu/growth/document/download/5b759bcc-db55-49ad-b0d4-bf0e16255aab_en.

[77] European Commission, 2021. 'European Clean Hydrogen Alliance: Overview of projects collected' presentation at the Hydrogen Forum, 17-18/06/2021 https://prod5.assets-cdn.io/event/6779/assets/8375992644-bc85860f7c.pdf.

If the RED III is adopted as proposed by the European Commission, it will mandate a 50% share of green hydrogen (RFNBO) in the total hydrogen consumption of the chemical industry. The EU and Member States should ensure the necessary infrastructure is in place to supply this hydrogen to each point of consumption (e.g. each plant) to make this target attainable. The hydrogen and decarbonised-gas market package[78], published in December 2021, puts forward policy measures required to support the creation of: (i) optimal and dedicated infrastructure; and (ii) efficient markets. This package aims to remove barriers and create the conditions for a more cost-effective transition. In her 2022 State of the Union speech, President of the Commission Ursula von der Leyen also announced the creation of a market for hydrogen through a new European Hydrogen Bank, dedicated to investing EUR 3 billion to power the economy of the future.

To improve the development of large-scale electricity and hydrogen infrastructure, the actions set out in the table below should be taken.

Topic 18: Large-scale electricity and hydrogen infrastructure		
Actions	Actors	Timeframe
18.1 Enable the free flow of energy between countries		
• Identify preliminary hydrogen-infrastructure needs by March 2023, based on the TEN-E Regulation (REPowerEU)	EU / MS	S
• Set up a dedicated workstream on joint, renewable hydrogen purchasing under the EU Energy Platform[79]	EU/MS	S
• Develop an infrastructure outreach programme to non-EU countries via the EU global gateway strategy[80]	EU/MS	S/M
• Abolish electricity-grid bottlenecks and increase the number of cross-border interconnectors	Industry and EU/MS	M
18.2 Develop separate hydrogen infrastructure at EU level		
• Re-dedicate current gas pipelines and refineries and construct new pipelines dedicated to hydrogen infrastructure	Industry and EU/MS	M
• Invest in new harbour-storage capacity in key EU ports or in relocating industrial harbours to more suitable locations	Industry and EU/MS	M
• Support and drive investments in appropriately sized dedicated hydrogen grids (including local grids, highly interlinked grids, high-capacity grids and digitalised grids) with an extended electricity grid to support hydrogen	EU/MS	M
• Develop a certification system for the import of low-carbon hydrogen	Industry and EU/MS	M

[78] Hydrogen and decarbonised gas market package https://europa.eu/!YPpd33 .

[79] https://energy.ec.europa.eu/topics/energy-security/eu-energy-platform_en.

[80] https://ec.europa.eu/info/strategy/priorities-2019-2024/stronger-europe-world/global-gateway_en#key-areas-of-partnership.

Designing and building a demonstration plant and deploying solutions on an industrial scale are major challenges for developing many abatement technologies and solutions. It also often requires collaboration between different industries and partners on a regional level and across borders. The investment returns from building a demonstration plant and deploying solutions on an industrial scale are uncertain and there is the risk of technological 'lock-in' and stranded investments. Security planning is also often hampered by long and complex permitting procedures, which create uncertainty around new infrastructure projects. This issue of uncertainty affects both questions about the viability of the chemical facility itself and questions about how to guarantee the supply of resources to it.

To support the development of new sustainable and decentralised production models to ensure resilience, the actions set out in the table below should be taken.

Topic 19: Development of new and sustainable production facilities		
Actions	Actors	Timeframe
19.1 Develop recycling facilities and bio-refineries (and exploit synergies with the chemical industry)		
• Launch pilot projects to develop sustainable infrastructures	Industry and EU/MS	S/M
19.2 Accelerate and improve permitting		
• Facilitate and accelerate approval procedures for production plants and products, notably via the ongoing revision of the IED	EU/MS	S/M
• Publish an annual comparative report to identify Member States' best practices in planning and permitting law; create an exchange of best practices	EU/MS	S

A pan-European rail infrastructure would enable a significant modal shift from roads to rail for the transport of feedstock and chemical products. The development of such infrastructure is currently being held back by: (i) the lack of an integrated system for managing international rail-freight traffic and capacity; and (ii) the poor quality of rail transport in general. Regulations have been put in place to support: (i) the development of energy interconnections and energy infrastructure (the Trans-European Networks for Energy TEN-E); and (ii) the Green Deal ambitions for modal shift and improvements in freight-transport efficiency (Trans-European Networks for Transport TEN-T).

To support the development of sustainable transport of raw materials and chemical products, the actions set out in the table below should be taken.

Topic 20: Sustainable transport of raw materials and chemical products		
Actions	Actors	Timeframe
20.1 Increase the availability and capacity of multi-modal terminals that are close to industrial clusters		
• Support investment in rail and inland waterway transport through public-private partnerships	Industry	S

• Develop a framework for trusted, secure and resilient B2B transport and logistics for data sharing (DTLF)	EU/MS	S
• Set up sustainable and resilient value-chain logistics for the sustainable supply of alternative feedstock (e.g. following the 'Hubs4Circularity' concept (Horizon Europe) and the EU global gateway strategy)	Industry	M
• Support the development of a multi-modal single European transport area through the Cohesion Fund (TEN-T)[81]	EU/MS	M
20.2 Improve use of rail transport		
• Adopt in 2023 a legislative package on greening freight transport (REPowerEU)	EU/MS	S
• Improve reliability, rail punctuality, and rail-infrastructure coordination between different national railway systems	MS	S

The digital transformation of the chemical industry and the deployment of available technologies for production and distribution will accelerate the industry's path towards the digital, green and resilience objectives.

The chemical industry must increase its deployment rate of digital technologies (e.g. the 'internet of things', big data, artificial intelligence, automation, smart sensors, digital twins and robotics) for product design, process design, production and logistics (e.g. paperless transport; real-time logistics planning and steering; and reducing idle transport capacity).

To take full advantage of the enabling power of digitalisation, the industry requires high-speed and reliable digital infrastructure. Industry associations say that there is a need for new standards for digital platforms to make possible the exchange of information on chemicals. These standards must be set in a way that promotes greater technical and semantic interoperability, while the governance systems for these digital platforms should also be designed in a way that ensures the protection of confidential business information. The Commission's new standardisation strategy[82] aims to support these goals by focusing on standardisation needs in strategy areas and improving the overall governance and integrity of the European standardisation system. This digital shift brings with it both cybersecurity risks and the problem of human resistance to change. The Commission fosters innovations – such as this one in standards – by creating investment programmes such as the InvestEU or the Digital Europe Programme.

To support the development and deployment of new and available technologies for the digitalisation of chemical manufacturing, the actions set out in the table below should be taken building upon in particular the policies, measure and actions set in the European Strategy for data[83].

[81] Trans-European Transport Network (TEN-T) https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en.

[82] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_661.

[83] See COM(2020)66 final. A European strategy for data. https://europa.eu/!BB46Mq.

Topic 21: Deployment of digital technologies		
Actions	Actors	Timeframe
21.1 Deploy safe, high-speed and reliable digital infrastructure		
• Development of an open data platform data space for chemicals to ensure seamless access and combination of data and tools complying with GDPR, IP, confidential business information and access rights (CSS and SRIP)	Industry and EU/MS	S
• Consider drawing up standards for both data interoperability and governance to protect confidential business information based on the developments in the context of common European Data Spaces	Industry and EU/MS	S
• Provide data on product carbon footprints for chemicals, and feed-in data for wider sectoral KPIs being developed within the CSS in alignment with the Digital Product Passport	Industry and EU/MS	S/M
21.2 Deploy technologies to improve chemical manufacturing processes and data gathering		
• Extend partnerships with innovative actors offering digital solutions *(Linked to Topic 8.1)*	Industry	S/M

To develop infrastructure for the recycling and re-use of materials, it will be necessary to invest in organic and inorganic waste collection, sorting, and value chains. This will improve access to important alternative sources of feedstock. Local and regional legislation must also be updated to avoid the landfilling, incineration and export of waste. Nonetheless, there remain strong economic barriers to this circularity project, in particular: (i) the price competitiveness of virgin materials compared to material recycled via mechanical recycling processes (virgin materials are often cheaper); and (ii) the lack of support for creating post-consumer recycled end-markets. Outdated 'linear' support for waste incineration, landfilling and shipment will have to be changed, and this change should be incentivised by law – including at municipal level – to engage the full circular value chain. The new circular economy action plan shows the path to a climate-neutral competitive economy by changing the way we produce and consume along with initiatives to modernise and transform our economy while protecting the environment.

The deployment of CCU and CCS[84] technologies also require the scale-up of reliable infrastructure for transporting and storing CO_2. The main barrier preventing the chemical industry from deploying these technologies is insufficient access to CO_2 pipes and storage as well as the lengthy and complex implementation process, especially in this phase of the transition. The ETS Innovation Fund provides support to small- and large-scale projects focusing on scaling up the construction of CCU and CCS technologies and infrastructure. In addition, through local industrial symbiosis (the Hubs4Circularity concept), the CO_2 produced

[84] Carbon capture and storage (CCS) is a set of technologies aimed at capturing, transporting, and storing CO_2 emitted from power plants and industrial facilities.

See: https://energy.ec.europa.eu/topics/oil-gas-and-coal/carbon-capture-storage-and-utilisation_en#:~:text=Carbon%20capture%20and%20storage%20(CCS,Strategy%20(2020%2D2024).

by an energy-intensive industry (e.g. the steel industry), can be used by a chemical facility nearby, avoiding the need to scale up infrastructure for transporting and using CO_2.

To increase the development of infrastructure that promotes recycling and re-use, stakeholders recommend that the actions set out in the table below should be taken.

Topic 22: Circularity: recycling and re-use of infrastructure		
Actions	Actors	Timeframe
22.1 Set a regulatory framework for the transport of waste		
• Ensure the harmonised EU implementation of the Basel Convention through the Waste Shipment Regulation	EU/MS	S
22.2 Improve the management of logistics for waste feedstock		
• Increase the coordination of waste-management infrastructure with Hubs4Circularity (Horizon Europe) (e.g. mechanical treatment of waste management) *(Linked to Topic 3.2.)*	EU/MS	S
• Use the Innovation Fund to support the deployment and upscaling of CCS technologies and infrastructure, aimed at capturing, transporting, and storing CO_2 emission	EU/MS	S
• Implement the Waste Framework Directive and Waste Shipment Regulation; encourage cooperation between municipalities	MS	S
• Enforce the regulation of illegal imports to avoid contamination of the recycling loop *(Linked to Topic 13)*	MS	S
• Consider participating in infrastructure projects[85]	EU/MS	S
• Invest in the management of waste feedstock	Industry	M

[85] e.g. Porthos, Antwerp at Sea, North Sea Port.

7) SKILLS

Some SMEs have only limited capacity to upskill and reskill their workforce in-house. At the same time, other SMEs are an integral part of the vocational educational system, where most of the EU's retraining, upskilling and re-skilling opportunities occur. Nevertheless, SMEs are especially vulnerable to the risk of employees leaving the workplace after completing the vocational education, which is often a significant investment for a company. Skills partnerships for stakeholders in the chemical industry (and skills partnerships under the Pact for Skills) will provide opportunities to investigate the existing and emerging skills needs across the chemical industry, including the skills needs for people working in or managing SMEs. The EU's Pact for Skills, for example, could provide common support, leadership and monitoring for the development of skills in the chemical industry among stakeholders in the EU chemical industry. This would help to reskill and upskill the workforce for the twin transition in line with the targets set in the Digital Decade Policy Programme. Moreover, the SRIP[86] for safe and sustainable chemicals and materials identifies the skills that will be critical for: (i) training a new generation of researchers; and (ii) improving sustainability management in industry, and specifically in R&I. Additional sources for skills support are set out in the two bullet points below.

- The digital education action plan aims to support the sustainable and effective adaptation of the education and training systems of Member States to the digital context. This action plan could be used to help identify the main gaps and necessary actions in the chemical industry.
- The European strategy for universities provides actions that also contribute to the transition pathway for the EU chemical industry since the strategy aims to help universities adapt to changing conditions, and to contribute to Europe's resilience and recovery.

To support the re-skilling and upskilling of the chemical workforce, stakeholders suggested the actions set out in the table below.

Topic 23: Education (re-skilling/upskilling the workforce)		
Actions	Actors	Timeframe
23.1 Develop skills with a sustainability focus		
• Develop a roadmap for skills, including the social dimension	Industry and EU/MS	S
• Set up sector-specific training, including training on green and sustainable chemistry, chemicals regulation, and safety	Industry	S
• Identify and address SSbD skills mismatches and skills gaps in the field of SSbD in the chemical industry. Ensure appropriate skills at all levels – including in vocational and tertiary education, in research, in industry, and among regulators	Industry and EU/MS	S
• Increasing awareness of the European Digital Innovation Hubs in the sector and digital technology training they offer	EU	S

[86] COM, 2022. Science, Research and Innovation Performance of the EU (SRIP) report.

• Participate in the EU blueprint for sectoral cooperation on skills, including the Blueprint Alliance on energy-intensive industries/industrial symbiosis	Industry	S
• Develop a more effective compensation scheme for SMEs that contribute to vocational education	Industry and EU/MS	S/M
23.2 Adapt secondary, post-secondary and university education		
• Contribute to the activities of the European Year of Youth in cooperation with national associations of chemical employers	Industry	S
• Adapt university curricula to industry needs, by adding courses on regulation, sustainable chemistry, green chemistry and the principles of SSbD to university programmes in chemistry. Adapt apprenticeships and vocational education and training programmes to teach future-proof knowledge	EU/MS	S/M
• Develop and ensure broad science, technology, engineering and mathematics (STEM) education across all education sectors	EU/MS and social partners	M
• Make use of tools and initiatives under the European Skills Agenda, such as the EU Pact for Skills	EU/MS	M

New, effective and inclusive training approaches are essential in swiftly integrating new workers into the job market. It is also important that workers benefit from training opportunities combined with actual work tasks. This will require the modernisation of teaching methods and training programmes. Considering their great importance in vocational education, SMEs should play a central role in achieving these objectives. Stakeholders report that the chemical industry will lack skilled workers, in particular in technical fields, digital/IT fields, R&I, production, logistics, chemical safety, chemical regulation, etc. This lack of skilled workers is especially acute in the area of digital skills. Re-skilling workers should be a priority to avoid overall job losses and to benefit the chemical sector. Specific attention should be given to training university students on the regulatory and safety aspects of the chemical industry.

To ensure sufficient high-quality jobs at technical level, the actions in the following table should be taken.

Topic 24: Sufficient supply of jobs at technical level		
Actions	Actors	Timeframe
24.1 Increase corporate training		
• Foster/organise regional training programmes and centres where in-company training is difficult (e.g. in small companies), in line with existing programmes	EU/MS and Industry	S
• Further promotion of lifelong learning	EU/MS	S
• Forecast and address the challenges connected to skills needed to introduce new technologies, with full contribution from workers' representatives (including digital skills)	Industry	S/M

• Provide company-based training, and reskill workers so they are prepared for the professions of the future. Link this training to job-to-job transition plans	Industry	S/M
• Provide in-company training opportunities, career paths, and apprenticeships	Industry	S/M
• Invest in the re-skilling of workers, especially by ensuring financial support for SMEs	Industry	M

24.2 Increase the attractiveness of the sector

• Ensure good communication by company managers with their workers, notably about the risks linked to the transition. This will reduce existing uncertainties and help workers to embrace the transformation of the industry in which they work	Industry	S
• Provide attractive employment conditions, such as flexible working hours, digital technologies, job sharing, etc.	Industry	S
• Increase the exposure of young scientists to R&D carried out in industry as well as in academia. 'Industry led' research is also science that should be given equal value/status in education	EU/MS	M

8) SOCIAL DIMENSION

The European Green Deal and the EU digital strategy pay particular attention to supporting those regions, industries, workers, households and consumers that will face the greatest challenges coming from the social impact of the twin transition. This impact varies according to sector, occupation, region and country, and will entail job changes within industrial sectors, and changes to investment patterns and staff numbers across these sectors.

This requires appropriate anticipation of change and socially responsible restructuring where necessary[87]. Through the responsible care initiative, the EU chemical industry has already demonstrated its focus on workers' health. For the industry, particular attention should also be paid to regional cohesion, the industry's impact on workforce and consumers, and improving gender equality and diversity in the sector. The twin transitions will likely shift jobs away from some places and towards others, creating job losses in some sectors, but increasing staff numbers in others.

The green transition must be fair and inclusive, putting people first, and paying particular attention to supporting those workers, households and consumers that will face the greatest challenges. Social dialogue should play an important role in this context.

Sustainable products will soon become the norm, and this will make it easier for consumers to take 'sustainable' decisions. Higher production costs will ultimately be borne by consumers but are expected to be minimal, as they will be spread very broadly. In any case, potential negative social consequences should be avoided. To avoid negative impacts on workers and consumers, stakeholders suggested that the following actions be taken.

Topic 25: Impact on workers and consumers		
Actions	Actors	Timeframe
25.1 Regional cohesion		
• Monitor and assess the environmental and economic impact of chemical production in the region	Industry	S
• Inform the public about the impacts and risks linked to the transition. This will reduce existing uncertainties and help encourage the public to embrace the transition	Industry	S
• Conduct a detailed investigation of employment in industries at NUTS 2 and 3 levels to identify where jobs are being created, transformed and lost in order to target support and cohesion policies	EU/MS	M
• Support active regional labour market policies, including policies to increase workers' skills	EU/MS	M/L
25.2 Safety and social security of workers		
• Continue to adapt safety protocols before introducing new technologies.	Industry	S

[87] Industrial Forum, 2022. Blueprint for the development of transition pathways.

• Develop 'job transition plans' (based on social lifecycle assessments (e.g. SEE balance[88]), and dialogue at company, local and sectoral levels)	Industry	S
• Take business decisions with workers' representatives involved to ensure that the decisions incorporate occupational safety and health, work organisation, training needs etc.	Industry	S
• Ensure social dialogue at company, sectoral and regional/national levels through an appropriate legal framework (EMPL Committee 2013 Cercas report) and make public funding for transition projects dependent on the involvement of workers and their representatives in these projects	EU/MS	M
• Share best practices and develop synergies among sectors on clean and smart production processes	Industry and EU/MS	S/M

Gender equality, inclusion and diversity are among the EU's founding values. In a sector that has historically been gender unbalanced such as the chemicals sector, actions and initiatives to address this shortcoming and lack of diversity are therefore necessary to increase the proportion of women in the sector. As reported by the EIB[89], more investment in women entrepreneurs is the right thing to do socially and ethically. When eliminating barriers for women to access the chemical industry and develop a career path within it, due attention must be paid to the principle of fairness: one size does not fit all.

Measures should also be taken to address the existing knowledge gap on certain aspects of the chemical industry. For example, there is a need to: (i) increase the collection of data on the differentiated risks affecting working women; and (ii) provide an exhaustive assessment of such data. It is also important to address the lack of extended data on exposure to chemicals that are detailed enough to show the risks that women in particular face when exposed to certain chemicals.

The following table summarises actions proposed by the stakeholders on improving gender equality and diversity in the sector.

Topic 26: Improve gender diversity and equality in the sector		
Actions	Actors	Timeframe
• Follow-up on the outcomes of the 2022 report on equal participation of women in the EU chemical industry and on the e-platform 'Children – Care – Career'	Industry	S
• Further implement the EU gender-equality strategy, with policy objectives and actions to make significant progress by 2025 towards a gender-equal Europe	EU/MS	S
• Encourage women into chemistry and chemical engineering programmes and raise awareness of careers for women in the chemicals industry at high schools	Industry and EU/MS	M

[88] A methodology designed by BASF to measure all the three pillars of sustainability – environment, society and economy.

[89] EIB, 2022. Women entrepreneurs are our best opportunity.

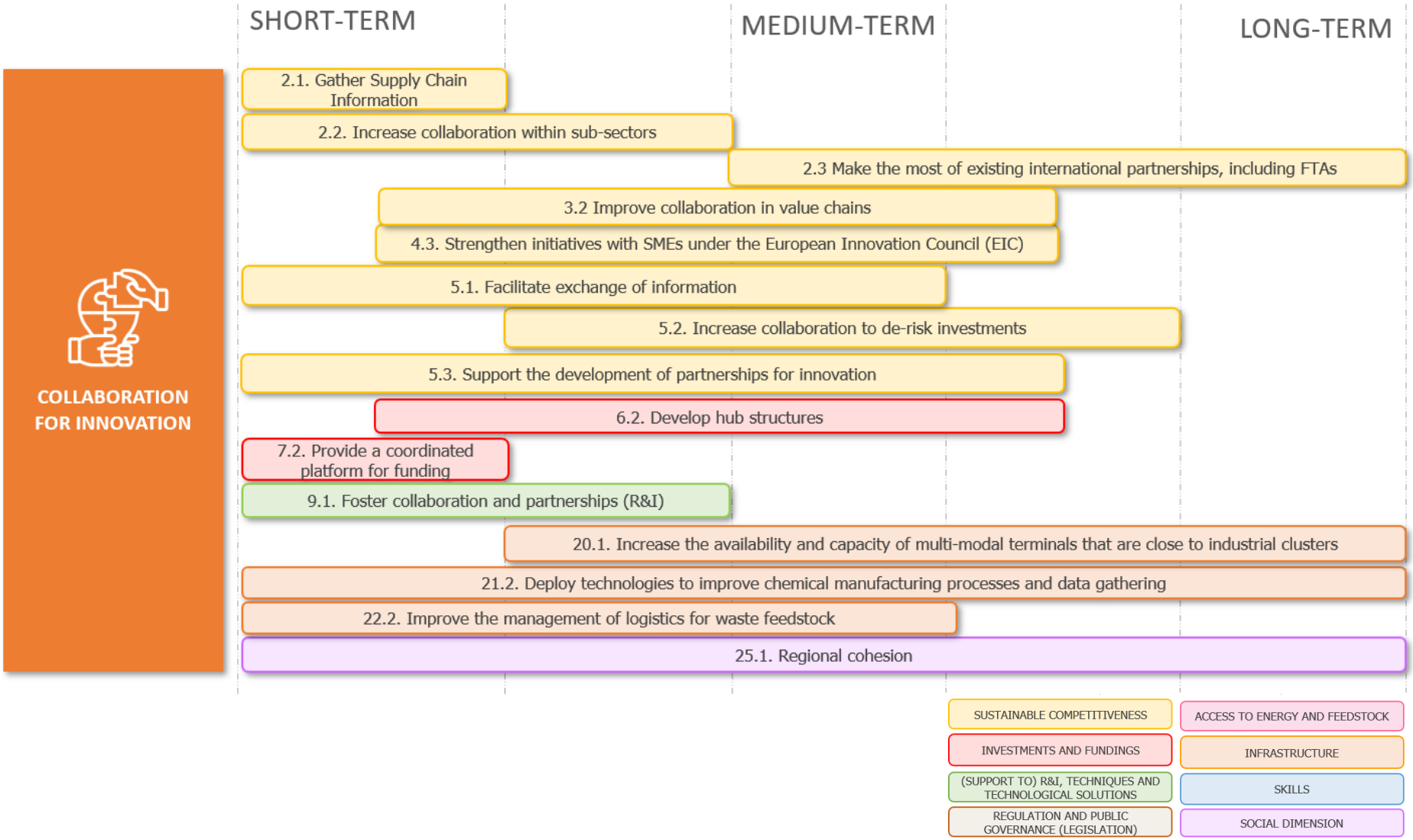
III/ ROADMAP

The Commission and stakeholders used the key topics of the eight building blocks to develop a roadmap for the EU chemical industry to achieve the twin transition and resilience of the industry. These key topics were sequenced against a timeline. The outcome is a roadmap composed of three components as set out below.

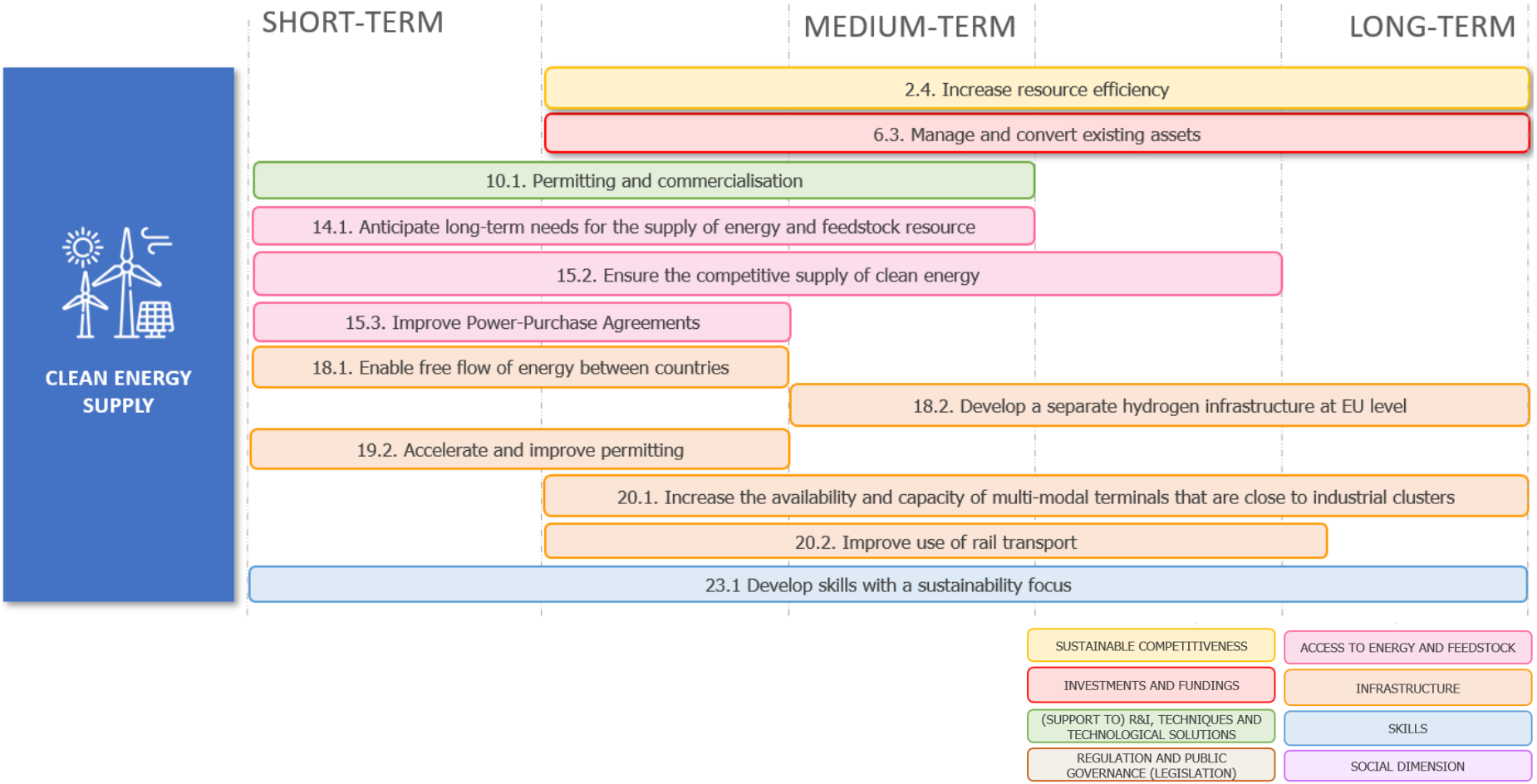
1. **An action-oriented component** grouping the topics under three cross-cutting themes: collaboration for innovation; clean-energy supply; and feedstock diversification. The choice of these themes was informed by analysis of the existing literature and discussion with stakeholders.
2. **A technology component** that provides an overview of the different topics that are related to technology as a contribution to the twin transition and resilience. The basis for this roadmap is the SET action plan, its supportive actions and EU initiatives.
3. **A regulatory component** that collects the existing legislation – including major R&I initiatives influencing developments in the chemical industry.

By implementing actions identified under each topic, the chemical industry will accelerate the twin transition and improve its resilience, sustainability and circularity in line with the European Green Deal.

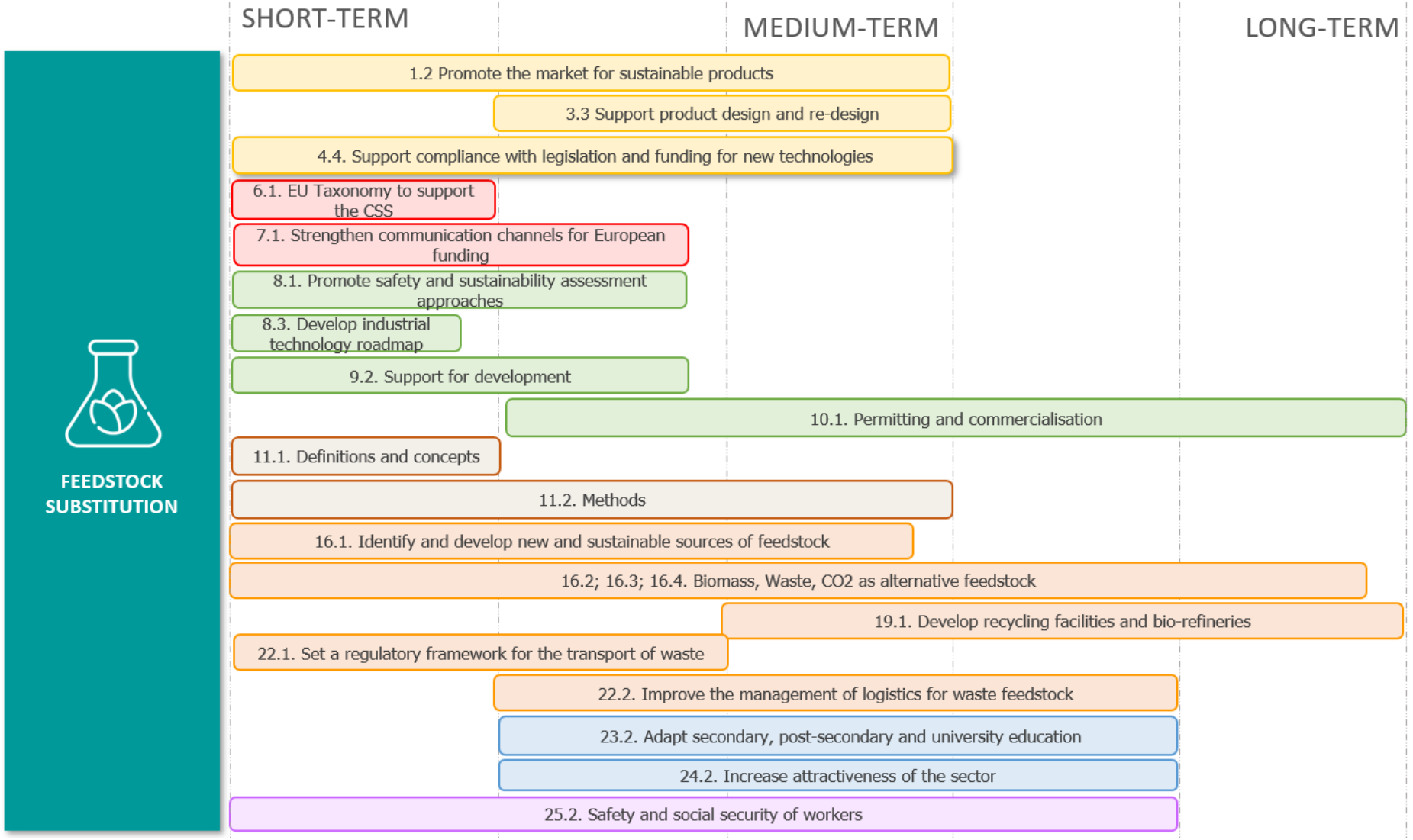
1) ACTION-ORIENTED ROADMAP



The REPowerEU plan sets out a series of measures to rapidly reduce the EU's dependence on Russian fossil fuels well before 2030 by accelerating the clean-energy transition. The REPowerEU plan is based on saving energy, producing clean energy, and diversifying the EU's energy supplies. As part of its plan to scale up the use and production of renewable energy, the Commission proposes to increase the target for the use of renewable energy to 45% of all energy used in the EU by 2030. The supply and availability of clean energy is therefore key to the chemical industry's transformation. The graph below lists actions aiming to facilitate the supply of clean energy in the EU.



Feedstock substitution is a key aspect that must be developed in order to achieve the objectives of the twin transition. The replacement of feedstock that uses a lot of fossil carbon is essential and will be driven by the deployment of current technologies and development of new ones.



2) TECHNOLOGY ROADMAP

EU Initiatives supporting Technological Transition *(SET Action Plan)*	**Actions** *(as presented in Building Blocks – Part II)*	**EU Initiatives**
A) ELECTRIFICATION	6.2. Develop hub structures 8.3. Development of an industrial technology roadmap 14. Anticipate I-t needs for the supply of energy and feedstock resource 15.1. Channel investments for clean energy 15.2. Ensure competitive supply of clean energy 15.3. Improve Power-Purchase Agreements 18.1 Enable the free flow of energy between countries 20.1. Increase availability and capacity of multi-modal terminals close to industrial clusters 20.2. Improve use of rail transport	• REPowerEU • EU Renewable Directive • TEN-E Regulation • Proposal for a directive on Energy Efficiency
B) HYDROGEN	6.2. Develop hub structures 6.3. Manage and convert existing assets 15.1. Channel investments for clean energy 15.2. Ensure the competitive supply of clean energy 18.2. Develop a separate hydrogen infrastructure at EU level	• European Clean Hydrogen Alliance • Hydrogen and decarbonised gas market package
C) BIOMASS	4.3. Strengthen initiatives with SMEs under the EIC 8.1. Promote safety and sustainability assessment approaches 9.1. Foster collaboration and partnerships 16.2. Biomass as an alternative feedstock 19.1. Develop recycling facilities and bio-refineries (and exploit synergies with the chemical industry)	• Revision of the Renewable Energy Directive • INCITE (Industrial Emissions Directive)
D) WASTE	3.2 Improve collaboration in value chains 3.3 Support product design and re-design 8.1. Promote safety and sustainability assessment approaches 11.1. Definitions and concepts 11.2. Methods 16.3. Waste as an alternative feedstock 22.1. Set a regulatory framework for the transport of waste 22.2. Improve the management of logistics for waste feedstock	• Hubs4Circularity • Waste Framework Directive • Landfill Directive
E) CCU & CCS	6.3. Manage and convert existing assets 9.2. Support for development 16.4. CO_2 as an alternative feedstock 22.2. Improve the management of logistics for waste feedstock	• Hubs4Circularity • Sustainable Carbon Cycle
F) PROCESS EFFICIENCY	3.2 Improve collaboration in value chains 3.3 Support product design and re-design 5.1. Facilitate exchange of information (new synergies) 5.3. Support the development of Partnerships for Innovation 6.3. Manage and convert existing assets 17. Process efficiency 19.1. Develop recycling facilities and bio-refineries (and exploit synergies with the chemical industry) 20.1. Increase the availability and capacity of multi-modal terminals that are close to industrial clusters 21.2. Deploy technologies to improve chemical manufacturing processes and data gathering 25.2. Safety and social security of workers	• REPowerEU • Industrial Symbiosis • Revision of the Industrial Emission Directive

The SET action plan prioritises technologies to be developed to reach the objectives of resilience and the twin transition. The table below summarises general EU initiatives and actions to support the SET action plan.

In addition, the ERA industrial technology roadmap for low-carbon technologies sketches out the key technologies and the means to transfer them to the industrial ecosystem for energy-intensive industries at EU and national level. See page 28, Table 3 - Overview of technological pathways, TRLs and application potential by sector.

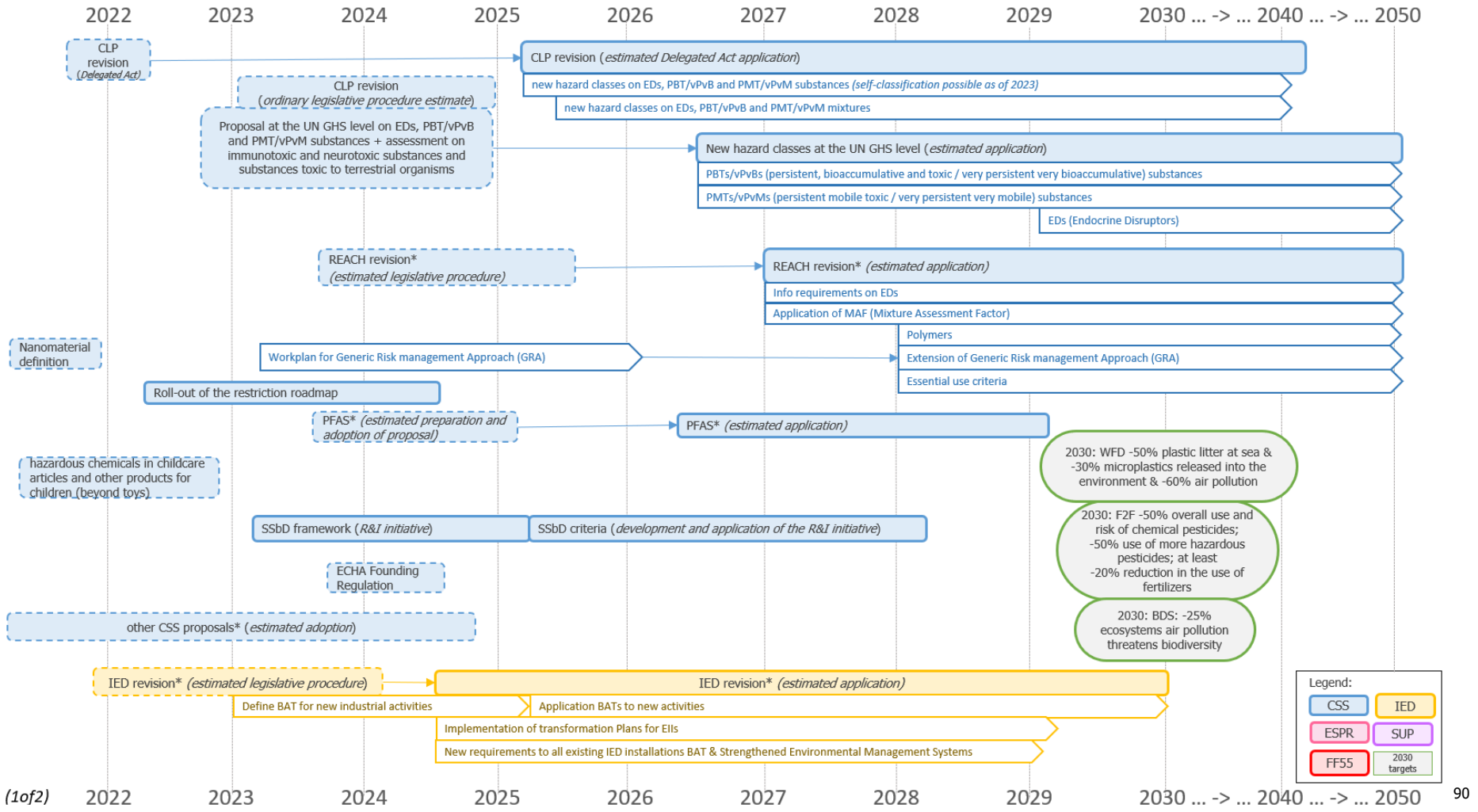
3) REGULATORY ROADMAP (INCLUDING R&I INITIATIVES)

This overview of existing legislation and major R&I initiatives relevant to the chemical industry has been developed using the best available knowledge at the time of writing. It includes the latest publicly available information and best-scenario assumptions about the ongoing legislative and non-legislative procedures, as proposed by the Commission. However, the timeline of this roadmap remains purely indicative – especially for those proposals whose content is still under development.

The overview does not include all financial opportunities supporting the implementation of the legislation (where it exists) and/or the transition of the industry. It also does not include all supportive EU documents, such as the guidance on boosting circular business models referred to in the ESPR. However, it aims to be a tool to help decision-makers and other stakeholders in the chemical industry.

In the figures below, boxes surrounded by a dashed outline indicate the timeframe for the estimated development and adoption of the proposal. Boxes with solid outlines indicate the estimated timeframe for application. However, the period in which the legislation will be valid is expected to go beyond the end of the box.

A full list of the acronyms used in the figure below is available in Annex 2, while additional information after the figure covers elements that are part of the proposals for which a detailed timeline is still not available.



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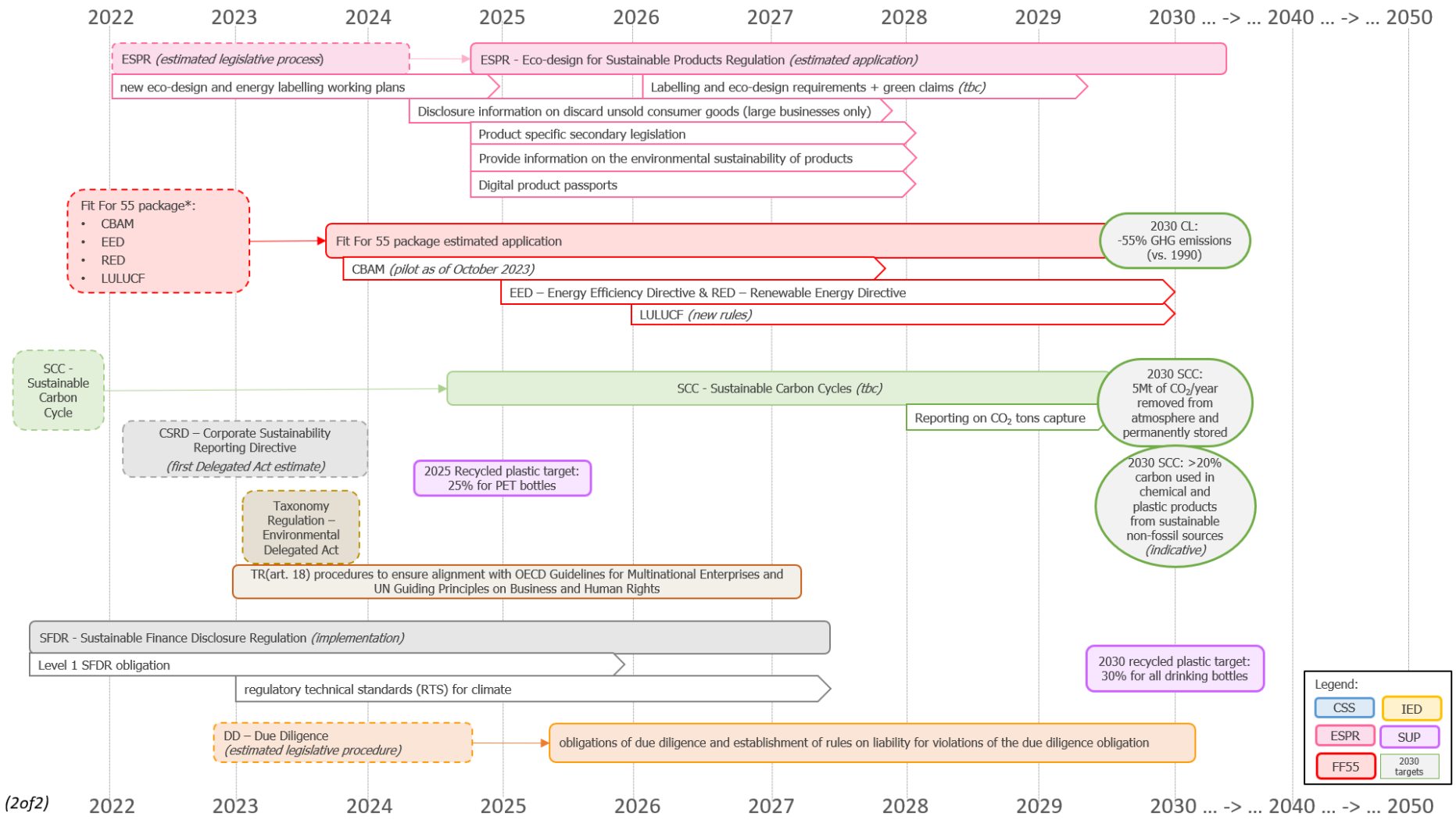
[90] Minimise the presence of substances of concern in products by introducing requirements, also as part of the SPRI, giving priority to those product categories that affect vulnerable populations as well as those product categories with the highest potential for circularity, such as textiles, packaging (including food packaging), furniture, electronics, ICT, equipment, construction and buildings.


2022
2023
2024
2025
2026
2027
2028
2029
2030 … -> … 2040 … -> … 2050
ESPR (estimated legislative process)
ESPR - Eco-design for Sustainable Products Regulation (estimated application)
new eco-design and energy labelling working plans
Labelling and eco-design requirements + green claims (tbc)
Disclosure information on discard unsold consumer goods (large businesses only)
Product specific secondary legislation
Provide information on the environmental sustainability of products
Digital product passports
Fit For 55 package*:
• CBAM
• EED
• RED
• LULUCF
Fit For 55 package estimated application
2030 CL: -55% GHG emissions (vs. 1990)
CBAM (pilot as of October 2023)
EED – Energy Efficiency Directive & RED – Renewable Energy Directive
LULUCF (new rules)
SCC - Sustainable Carbon Cycle
SCC - Sustainable Carbon Cycles (tbc)
2030 SCC: 5Mt of CO2/year removed from atmosphere and permanently stored
Reporting on CO2 tons capture
CSRD – Corporate Sustainability Reporting Directive
(first Delegated Act estimate)
2025 Recycled plastic target: 25% for PET bottles
2030 SCC: >20% carbon used in chemical and plastic products from sustainable non-fossil sources (indicative)
Taxonomy Regulation – Environmental Delegated Act
TR(art. 18) procedures to ensure alignment with OECD Guidelines for Multinational Enterprises and UN Guiding Principles on Business and Human Rights
SFDR - Sustainable Finance Disclosure Regulation (implementation)
Level 1 SFDR obligation
regulatory technical standards (RTS) for climate
2030 recycled plastic target: 30% for all drinking bottles
DD – Due Diligence
(estimated legislative procedure)
obligations of due diligence and establishment of rules on liability for violations of the due diligence obligation
Legend:
CSS
IED
ESPR
SUP
FF55
2030 targets
(2of2)
2022
2023
2024
2025
2026
2027
2028
2029
2030 … -> … 2040 … -> … 2050

*PFAS – *additional elements* COM(2020) 667 final:

- Restriction under REACH for all non-essential uses including in consumer products.
- Add PFAS where possible as a group in the review of annexes of the Environmental-Quality Standards Directive and Groundwater Directive.
- Proposal to address the emissions of PFAS from the waste stage including through the revision of the Sewage Sludge Directive.
- Address the presence of PFAS in food by introducing limits in the Food Contaminants Commission Regulation.
- Address PFAS concerns at a global scale via proposals under the Stockholm Convention and the Basel Convention.

*REACH revision – *additional elements* COM(2020) 667 final:

- Authorisation and restriction processes + requirements for registration.
- Amend Article 68(2) to include professional users.
- Introduce MAFS in Annex I.
- 'One substance, one assessment' process.
- Draft a restrictions roadmap of CMRs, EDs, PBT/vPvBs, immunetoxicants, neurotoxicants, substances toxic to specific organs and respiratory sensitisers.
- Amend REACH Article 57 to add EDs, PMT and vPvM substances to the list of substances of very high concern.

*Other proposals (according to Annex CSS):

- 2021: EU Strategic Framework on Health and Safety at work - Occupational safety and health in a changing world of work.
- 2022: EU repository of human and environmental health-based limit values.
- 2023: Creation of an open platform on chemical-safety data and tools for accessing relevant academic data.
- 2023: General proposal to: (i) remove legislative obstacles to the re-use of data; (ii) streamline data flows across legislation; and (iii) extend the open-data and transparency principles from the EU food-safety sector to other pieces of chemical legislation.
- 2023: Proposals to allow EU and national authorities to commission testing and monitoring of substances as part of the regulatory framework.

*IED revision – *additional elements* COM(2022) 156 final:

- Permits – reviewing and updating permits, depending on the status of the receiving environment, and/or planning measures to comply with environmental-quality standards, objectives, plans and programmes under water legislation.
- More detailed reporting of pollutants at installation level.
- Indirect release of polluting substances – clarifying the rules that apply to the indirect release of polluting substances into water through urban wastewater treatment plants.
- Fostering innovation will help address persistent chemical substances and substances newly identified as being of concern, including PFAS, microplastics and pharmaceuticals.
- BREFs – 'exchange of information' process under the IED to draw up and review best-available-technique reference documents (BREFs). These BREFs should take account of the identification of substances of concern under EU water legislation. In particular, these include 'watch lists' of substances for groundwater and surface water, and substances identified as possibly posing a significant risk to or via the aquatic environment at EU level.
- Setting additional and updated criteria to support the EU Taxonomy on sustainable investments.
- List of pollutants replaced by Annex II on pollutants of E-PRTR Regulation (as amended).
- Strengthened provisions on sanctions + specified minimum content of penalties.
- Extension to large-scale battery production (manufacture of lithium-ion batteries with a production capacity of 3.5 GWh or more per year) and mining.

*Fit For 55 package – *additional elements* COM(2021) 550 final:

- **CBAM** broadening of the scope to include organic chemicals, plastics, hydrogen, ammonia and indirect emissions.
- **EED** – Energy Efficiency Directive: Annual energy-savings obligations for MSs of more than 0.8% (2021-2023) & annual energy savings obligations for MSs of more than 1.5% (2024-2030).
- **RED** – Revision of the Renewable Energy Directive to increase the binding EU minimum share of renewable energy sources in final energy consumption to 40% by 2030, in effect doubling the share of renewable energy sources in the energy mix over the course of a single decade (2021-2030). The proposal would also set a comprehensive framework for the deployment of renewable energy sources across all sectors of the economy, with a particular focus on sectors where progress has been slow (transport, buildings and industry). The

binding EU headline target of 40% would be supported by a series of higher EU and national targets for these different sectors, and the promotion of hydrogen consumption in transport and industry.

- **Energy taxation**: main changes include the following points:
  - fuels will start being taxed according to their energy content and environmental performance rather than their volume, helping businesses and consumers alike to make cleaner, more climate-friendly choices;
  - according to this ranking, conventional fossil fuels, such as gas oil and petrol will be taxed at the highest rate and electricity at the lowest rate;
  - products are categorised for taxation purposes in a simplified way to ensure that fuels most harmful to the environment are taxed the most;
  - exemptions for certain products and home heating will be phased out (thus, fossil fuels can no longer be taxed below minimum rates);
  - fossil fuels used as fuel for intra-EU air transport, maritime transport and fishing should no longer be fully exempt from energy taxation in EU.
- **ESR** – Effort Sharing Regulation.
- **LULUCF** proposal for: (1) moving away from the 'no-debit' rule (where GHG emissions cannot exceed GHG removals within the sector) from 2026; (2) increasing the carbon-sink potential to deliver GHG removals in the current decade; (3) strengthening Member States' obligation to submit integrated mitigation plans for the land sector; (4) improving monitoring requirements using digital technologies supported by the European Environment Agency and the Copernicus programme; (5) alignment with other key biodiversity and bioenergy policy initiatives; (6) expanding the scope of the regulation to cover the whole land sector from 2031 by including non-CO_2 emissions from the agriculture sector; and (7) setting a value on mitigation actions by introducing a carbon-removal certification scheme and the possibility to trade in certificates.
- **SCF** – Social Climate Fund.

IV/ NEXT STEPS

The co-creation process with stakeholders has shown how relevant it is to work together to support the twin transition. However, the cooperation must not stop when the transition pathway is published. It should continue with a co-implementation process involving all interested stakeholders, accompanied by structures and participatory processes to bring forward the agreed actions and monitor progress on the industry's transition.

The co-implementation process will start by the publication of the transition pathway and by disseminating this pathway to all relevant stakeholders. Then, the Commission services could organise a first co-implementation meeting. The aim of this meeting would be the discussion of – and agreement on – the approach to follow for such co-implementation.

The co-implementation process will consider policy coordination necessary across EU Member States. Indeed, the support of the EU Member States for the transition is crucial, to guide and provide support at regional and local levels and to implement regulatory changes in a coordinated and harmonised manner.

The specific approach will be discussed and agreed with stakeholders participating in the co-implementation once the final version of the transition pathway for the chemical industry is published. Stakeholders should consider the following points:

- Organising an annual plenary meeting for a stocktaking exercise on the co-implementation of the transition pathway. During this meeting, participants will also identify topics and actions to tackle in the coming months. They may wish also to agree on a prioritisation for carrying out specific actions before others and announce pledges. This meeting would be also an opportunity to prepare yearly conclusions on the implementation progress of the transition pathway for the chemical industry.
- Adopting an annual progress report to be shared and discussed with the Competitiveness Council and all relevant EU and national institutional stakeholders.
- If necessary, creating specific task forces dedicated to topics of high priority that require additional discussion. Actions set out for these topics in the transition pathway will then be allocated to these task forces to follow and guide. These task forces would self-organise their work, and with the support of Commission services, they would prepare each year a summary of the progress made on the actions which would be presented at the annual meeting.
- Distributing an annual survey for stakeholders who have made specific commitments to help implement transition-pathway actions and objectives. Such commitments will be as quantifiable as possible, with an appropriate engagement level by different actors. These commitments will also mention an indicative timeframe for implementation. The updated status of commitments would be published online to inform and encourage other stakeholders.
- This Pathway may be updated to take account of new developments and the evolution of EU legislation.

ANNEXES

Annex 1 - Overview of Green Deal objectives impacting the chemical industry

This Annex collects the objectives for the green and digital transition, as well as for resilience of the chemicals sector, based on existing EU documents; including strategies, actions plan, etc.

Green objectives	Source[91]
Climate neutrality by 2050	
No net emission of greenhouse gas emissions in EU by 2050	GD
Net reduction of GHG emissions by at least 55% (By 2030 vs. 1990 level)	CL1
5Mt of CO_2 to be annually removed from the atmosphere and permanently stored through frontrunner projects by 2030	SCC1
Energy	
EU gross final consumption of energy to be at least 45% from renewable energy sources (2030) {*binding target*}	RED II
At least 32.5% improvement in energy efficiency by 2030 (2007 projects for 2030)	EED1
Reducing primary (39%) and final (36%) energy consumption by 2030	EED2
Annual energy savings obligations by MSs: 2021-2023: >0.8% and 2024-2030: >1.5%	EED3
Environment and Health	
Improving water quality by reducing waste, plastic litter at sea (by 50%) and microplastics released into the environment (by 30%) (2030)	ZPAP1
Reduction in air pollution (60%, 2030)	ZPAP2
Reducing the EU ecosystems where air pollution threatens biodiversity (25%)	ZPAP3/BD
Reducing the overall use and risk of chemical pesticides (50%) and the use of more hazardous pesticides (50%) by 2030 and at least 20% reduction in the use of fertilizers (2030)	F2F
Circularity	
Increasing municipal waste recycling: >55% by weight by 2025 >60% by weight by 2035	WFD
Restrict landfilling of waste recyclable or suitable for energy recovery (2030)	LD
Content recycling target (2025): 25% for PET bottles 30% for all drinking bottles	SUPD
75% target for recycling of packaging waste (2030)	PPWD

[91] See Annex 2 for the full list of abbreviations.

Reduce transport-related greenhouse gas emissions by 90% by 2050	GD

Green objectives: Industry Level	Rf
Climate[92]	
At least 20% of carbon used in the chemical and plastic products to be from sustainable non-fossil sources by 2030 (indicative)	SCC2
Reporting every ton of CO_2 captured, transported, used and stored and accounting it by fossil, biogenic or atmospheric origin (2028)	SCC3
Environment and Health	
Stepping up innovation for the green transition of the chemical industry and its value chains.	CSS(G1)
Making the EU chemicals policy evolve and establish safe and sustainable chemicals as an EU global benchmark, securing international competitiveness.	CSS(G2)
Most harmful substances banned for consumer products unless they are essential for society.	CSS(G3)

Digital objectives	Rf
Development of digital tools and instruments towards safer and sustainable chemicals	CSS(D)
Digitalisation of chemical production (e.g. through internet of things, big data, artificial intelligence, smart sensors and robotics exploitation, digital product passports, data sharing across supply chains, etc.) bulding upon the actions, initiatives and mearures for the digitalization of bussiness set in Digital Decade Policy Programme.	SCC(D1)
Paperless chemicals transport based on data sharing across the supply chain, and multimodal optimisation of transportation capacity.	SCC(D2)
Exploitation of digital tools for faster action on enforcements and optimal use of resources, including of market surveillance authorities, and foster digital innovations for advanced tools, methods and models, and data analysis capacities to also move away from animal testing.	SCC(D3)

Resilience objectives	Rf
Strengthening EU's open strategic autonomy by notably promoting the EU's resilience of supply and sustainability of critical chemicals	CSS(R)
Substitution of alternative feedstock, integration of renewable energies and increase in energy efficiency (reduce EU energy consumption) in order to avoid dependencies from Russian gas to be fastened as announced in REPowerEU	REP(R)

[92] This list does not include indications from impact assessments and are Commission's working documents. For example, the IA SWD(2020) 176 final mentions "Industry to reduce GHG emissions between 20.3% & 25.15 by 2030 (vs 2015 level)".

Annex 2 - Overview of initiatives impacting the chemical industry

Non-exhaustive list of initiatives that include green and digital objectives for the chemical industry, as identified by stakeholders:

Annex 1 source	Full reference	URL
BDS	EU Biodiversity Strategy for 2030	https://europa.eu/!vw76Rn
CL1	European Climate Law	https://europa.eu/!b9jcXm
CL2	SWD(2020) 176 final - Impact Assessment accompanying document for COM/2020/562 final.	https://europa.eu/!gC43Cr
CSS	Chemicals Strategy for Sustainability Towards a Toxic-Free Environment	https://europa.eu/!Vt94Yr
EED II	Proposal for a Directive on energy efficiency (recast) – COM(2021) 558 final	https://europa.eu/!w4jVHV
F2F	Farm to Fork Strategy	https://europa.eu/!rt73kQ
GD	The European Green Deal	https://europa.eu/!DG37Qm
GT[93]	EU taxonomy for sustainable activities	https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en
IS II	A New Industrial Strategy for Europe	https://europa.eu/!ghHBCV
LD	Landfill Directive	https://europa.eu/!F88pXB
PPWD	Packaging and Packaging Waste Directive	https://europa.eu/!qYCFN7
RED III	Renewable Energy Directive (recast) – COM(2021) 557 final	https://europa.eu/!TBQJtY
REP	REPowerEU	https://europa.eu/!WDnDg6
SCC	Sustainable Carbon Cycle	https://europa.eu/!9xCx8D
SUPD	Single-Use Plastics directive	https://europa.eu/!RD46Uw
WFD	Waste Framework Directive	https://europa.eu/!TW93TN
ZPAP	Pathway to a Healthy Planet for All EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'	https://europa.eu/!wRCWv9

Additional policy initiatives impacting chemical industry's twin transition:

- The Eco-design for Sustainable Products Regulation
- Revision of REACH

[93] In the case of the EU Green Taxonomy, it is not an objective but rather a system to classify which parts of the economy may be marketed as sustainable investments.

- Revision of CLP - Classification, Labelling and Packaging
- Implementation of EU ETS - Phase 4
- Definition of sectorial targets for GHG emissions reduction by 2030 and by 2050 (vs. 1990 levels)
- Bioeconomy Strategy and Bioeconomy Action Plan
- Circular Economy and Action Plan
- EU Methane Strategy
- Corporate Sustainability reporting Directive
- Initiative on substantiating green claims

Additional policy initiatives that will have an impact on the industry resilience:

- European Critical Raw Materials Act
- Corporate Sustainability Due Diligence
- EU Advanced Materials manifesto and the critical raw material strategy
- Review of EU strategic dependencies and capacities
- EU's Trade strategy
- IED – Industrial Emissions Directive's revision
- Revision of the Environmental Crime Directive.

Annex 3 – Summary of the topics under each building block

Building Blocks	Topics
Sustainable Competitiveness	**Topic 1:** International Competitiveness **Topic 2:** Reduction of unsustainable dependencies and supply chains vulnerabilities **Topic 3:** Safety and Sustainability **Topic 4:** Innovation and growth of SMEs **Topic 5:** New synergies
Investments and Funding	**Topic 6:** Fund for Green Investments **Topic 7**: Access to Funding
R&I, Techniques and Technological Solutions	**Topic 8:** Better conceptualisation of new techniques and technical solutions (TRL 1 to 5) **Topic 9:** Developing new techniques and technological solutions (TRL 6 to 7) **Topic 10:** Deployment of new techniques and technological solutions (TRL 8 to 9)
Regulation and Public Governance (legislation)	**Topic 11:** More effective and predictable legislation **Topic 12:** Vertically and horizontally coherent legislation **Topic 13**: Effective and efficient enforcement
Access to energy and feedstock	**Topic 14**: Anticipate long-term needs for Energy and Resource Supply **Topic 15**: Economically viable purchase of clean energy **Topic 16**: Feedstock Substitution **Topic 17**: Process and resource efficiency
Infrastructure	**Topic 18**: Large-scale electricity and hydrogen infrastructure **Topic 19**: Development of new sustainable production facilities **Topic 20**: Sustainable transport of raw materials and chemical products **Topic 21**: Deployment of digital technologies **Topic 22**: Circularity: recycling and reuse infrastructure
Skills	**Topic 23**: Education (reskilling/upskilling the workforce) **Topic 24**: Sufficient supply of jobs at technical level
Social Dimension	**Topic 25**: Impact on workforce and consumers **Topic 26**: Improve gender diversity and equality in the sector

Annex 4 – Additional actions on legislation suggested by stakeholders

Stakeholders suggested additional actions to those included in the chapter "regulation and public governance (legislation)" as potential contributors to the transition of the chemical industry towards green and digital objectives, as well as its resilience. These proposals are not part of the final roadmap of the EU chemicals transition pathway because it only includes actions and measures deriving from existing legislation.

To make the EU legislation more effective and predictable, stakeholders propose:

- To deepen the climate component of the transition pathway by developing a sectoral roadmap to meet the climate neutrality objective of the chemicals sector; in line with the European Climate Law (art.10);
- To develop and to implement – with the support of Member States - a plan of work proposed by Commission services for staged implementation of the GRA (Generic Risk Assessment) under REACH revision, differentiating substances, consumer mixtures and articles, and distinguishing professional uses according to exposure patterns;
- To develop OECD testing schemes and testing methods for the safety assessment of polymers in cooperation with the authorities (linked to the REACH revision);
- To create new regulations to require an increasing proportion of materials to be reused, recycled or from renewable materials and to be designed for circularity (binding goals, not just for packaging; adoption of a "mass-balance" methodology in support of recycling[94];
- Consider the use of predictive toxicology, such as QSAR by the OECD, to fill the gaps in (eco)toxicity data needed for the assessment of chemicals hazard;
- Inclusion in the Better Regulation of a balance between requests for data and costs for the industry in collecting and reporting the requested data;
- Do not hamper the use of digital technologies by the chemical industry under the ongoing legislative initiatives on digital. For example, in the definition of "high risk AI – Artificial Intelligence" consider the potential negative impact on including some of the chemical industry appliances.

To improve the coherence of legislation vertically and/or horizontally, stakeholders proposed:

- Establishing a coordination mechanism within the Commission services to agree and synchronise – to the extent possible – legislation on chemicals. For example, revision of the Waste Framework Directive to happen before Packaging and Packaging Waste Directive review[95]. This would avoid an "all in once" implementation of the legislation. A link between PACT and such mechanism should also be explored;

[94] This may include verification and certification protocols for mass balance systems, clear definitions of recycled content and chemical-recycling technologies and a harmonized EU implementation of the Basel Convention.

[95] A stakeholder suggests also improving the interplay between OSH legislation and other chemicals legislation and strengthen their enforcement to promote the safer use of chemicals as well as the use of safer and more sustainable chemicals to support a harmonised enforcement in Member States.

- To align chemicals, waste and product legislation[96] on key definitions such as "recycling";
- Harmonisation of rules on the end-of-waste criteria in the revision of the EU Waste Framework Directive;
- Revision of Block Exemption Regulations and of antitrust rules to facilitate value chain cooperation for the development and implementation of techniques and technical solutions largely contributing to the twin transition. This could include using "regulatory sandboxes"[97].

Finally, to ameliorate the enforcement and implementation of existing legislation, stakeholders proposed:

- Explore the use of digital tools to support market surveillance and customs authorities, as well as to improve the compliance of products containing chemicals sold online to European consumers;
- Include in bilateral and multilateral trade agreements a cooperation on enforcement of chemicals legislation and on capacity building necessary for enforcement;
- Proposal for carbon leakage protection for export and across the entire value chain;
- Support the deployment of synergies to exploit between industry and health authorities, occupation and epidemiological databases as a basis for future regulatory action;
- Consider reattribution of technical and scientific work on chemicals performed under the relevant pieces of legislation to European agencies, including work of SCHEER and SCCS[98] as also proposed in the Commission's Chemicals Strategy for Sustainability;
- Foresee a "warning" mechanism providing an advice service to SMEs before sanctioning the company in case of non-compliance with EU legislation due to regulatory overburden;
- Propose a new partnership mechanism to support development of high-quality REACH registration dossiers and support SMEs for safety assessment;
- Provide incentives to the downstream users and customers, help the uptake of new technological solutions via Green Public Procurement[99] or eco-modulated EPR fees[100], among others.

[96] This includes, among others, Eco-design for Sustainable Products Regulation, Waste Framework Directive, Waste Shipment Regulation and Packaging and Packaging Waste Directive.

[97] European Commission, TOOL #21. Research & Innovation, Better Regulation Toolbox; European Commission 6783/20 (COM (2020)103); Council conclusions 13026/20 Annex.

[98] A stakeholder suggests allowing EU and national authorities to commission testing and monitoring of substances. Another strengthening and formalize the role of the ECHA Enforcement Forum.

[99] GPP is a voluntary instrument, it has a key role to play in the EU's efforts to become a more resource-efficient economy. It can help stimulate a critical mass of demand for more sustainable goods and services which otherwise would be difficult to get onto the market. GPP is therefore a strong stimulus for eco-innovation.

[100] OECD, 2021. Modulated fees for extended producer responsibility schemes (EPR) https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/WKP(2021)16&docLanguage=En

Annex 5 – Additional actions on R&I suggested by stakeholders

In addition to product (re-)design, main R&I priorities to decrease GHG emissions, increase resource efficiency and circularity as well as safety in the chemical industry include:

- The integration of climate-neutral energy through direct and indirect electrification (e.g. electrification of heat); steam generation or upgrade; electrification of chemical processes in particular through electrochemical processes; or alternative energy forms like plasma and photons
- The use of alternative carbon feedstock (see the energy and feedstock building block)
- The production of hydrogen with a reduced carbon footprint for existing and expected higher future use, either as chemical feedstock, or in the future, as an energy carrier
- Process efficiency, including process intensification and advanced separation technologies
- Carbon capture and storage.

Such priorities require new process technologies and their combination will be essential to reach the 2050 EU climate-neutrality objective. Advanced tools supporting decision-making from the design phase to production, supported by digital technologies as well as advanced materials, will also be key enabling priorities for the chemical sector.

Stakeholders suggested a series of initiatives to further strengthen the role of R&I in the twin transition and economic resilience of the EU chemical industry. These actions include:

- A dedicated Horizon Europe Innovation Programme on the CSS (focus on SSbD for most impacted value chains), a joint public-private programme supporting projects with higher TRL to avoid "valley of death";
- Development of different project assessment's criteria for higher TRLs (from TRL7 upwards) in European funding;
- Involve industry closely to ensure transfer of knowledge into innovation;
- Support faster co-creation of new digital technologies and related collaborations as well as early adopters of digital technologies through appropriate risk sharing and funding measures for the chemical industry;
- Propose a framework on how to exchange data at EU level (incl. IPRs implications across EU technology platforms and activities) via innovation platforms;
- Simplified and coordinated access to EU and national research programmes (especially for SMEs);
- Further strengthen the agility and effectiveness of the EU project funding process;
- Develop methodologies for chemical risk assessment that consider the whole life cycle of substances, materials and products;
- Develop effective Risk-Sharing Instruments with appropriate evaluation at all TRLs including for demonstration plant and first-of-its-kind (FOAK) plant;

Annex 6 – Glossary

Carbon Border Adjustment Mechanism (CBAM)

Carbon Border Adjustment Mechanism (CBAM) is a system designed in compliance with World Trade Organization (WTO) rules and other international obligations of the EU. EU importers will buy carbon certificates corresponding to the carbon price that would have been paid, had the goods been produced under the EU's carbon pricing rules. Conversely, once a non-EU producer can show that they have already paid a price for the carbon used in the production of the imported goods in a third country, the corresponding cost can be fully deducted for the EU importer. The CBAM will help reduce the risk of carbon leakage by encouraging producers in non-EU countries to green their production processes.

Carbon Capture and Storage

Carbon Capture and Storage (CCS) technologies aim to capture as much as 85% - 90% of CO_2 emissions from power plants and heavy industry before transporting it by pipeline or ship and storing it permanently and safely at least 800 metres below the earth's surface.

Carbon Capture and Utilisation

Carbon capture and utilisation technologies may mitigate climate change by removing CO_2 from the atmosphere and converting it into other materials such as fuels, chemicals and plastics.

Circular economy

A circular economy aims to maintain the value of products, materials and resources for as long as possible by returning them into the product cycle at the end of their use, while minimising the generation of waste.

Circular Economy Action Plan

It's one of the main building blocks of the European Green Deal, Europe's new agenda for sustainable growth. The EU's transition to a circular economy will reduce pressure on natural resources and will create sustainable growth and jobs. It is also a prerequisite to achieve the EU's 2050 climate neutrality target and to halt biodiversity loss.

Cohesion Fund

The Cohesion Fund provides support to Member States with a gross national income (GNI) per capita below 90% EU-27 average to strengthen the economic, social and territorial cohesion of the EU. It supports investments in the field of environment and trans-European networks in the area if transport infrastructure.

Digital Innovation Hubs

European Digital Innovation Hubs (EDIHs) are one-stop shops supporting companies to respond to digital challenges and become more competitive. More information is available at the webpage https://digital-strategy.ec.europa.eu/en/activities/edihs

Energy and Industry Geography Lab (EIGL)

The Energy and Industry Geography Lab is a tool for geographical data related to energy, industry and infrastructure. The tool makes it possible to find and filter energy-related data, and create and share maps displaying this data. It enables analyses and assessments that support Europe's transition to climate neutrality.

Energy-intensive industries

Energy-intensive industries (EIIs), embedded in many strategic value chains, make up more than half of the energy consumption of the EU industry. EIIs produce goods and materials that enable reduction of emissions in other sectors of the economy, including transport, construction and power generation.

ERA industrial technology roadmap

Industrial technology roadmap under the new European research area (ERA) provides an evidence base on the state of play of low-carbon technologies in energy-intensive industries in the EU and available support instruments, and points to possible research and innovation action in view of accelerating development and uptake of these technologies. These possible ways forward build on contributions from industry, other research and innovation stakeholders, Member States, and relevant European partnerships. This roadmap will feed into the transition pathway for the energy-intensive industries ecosystem under the EU industrial strategy and supports the work to accelerate the green and digital transitions under the ERA policy agenda.

EU Chemicals Strategy for Sustainability

The EU's chemicals strategy aims to better protect citizens and the environment and boost innovation for safe and sustainable chemicals. Its main actions are banning the most harmful chemicals in consumer products - allowing their use only where essential, boosting the investment and innovative capacity for production and use of chemicals that are safe and sustainable by design.

Euroclusters

Clusters are groups of firms, related economic actors, and institutions located near each other and with sufficient scale to develop specialised expertise, services, resources, suppliers and skills. Together, SMEs can be more innovative, create more jobs, and

register more international trademarks and patents than alone. There are over 1500 clusters located in more than 200 EU-27 regions. Clusters account for almost 25% of total EU employment.

European Digital Innovation Hubs (EDIHs)

They help companies dynamically respond to the digital challenges and become more competitive. By providing access to technical expertise and experimentation as well as the possibility to 'test before invest', EDIHs help companies improve business/production processes, products, or services using digital technologies. They also provide innovation services, such as financing advice, training, and skills development that are needed for a successful digital transformation. Environmental issues are also considered, regarding energy consumption and low carbon emissions.

European Green Deal

The European Green Deal will transform the EU into a modern, resource-efficient and competitive economy in order to overcome challenges as climate change and environmental degradation that are an existential threat to Europe and the world.

Green Public Procurement (GPP)

Green Public Procurement (GPP) is defined in the Communication "Public procurement for a better environment" (COM (2008) 400 final) as "a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured." GPP is a voluntary instrument, which means that Member States and public authorities can determine the extent to which they implement it.

Horizon Europe Research & Innovation Programme

Horizon Europe is the EU's key funding programme for research and innovation with a budget of €95.5 billion from 2021 to 2027. It tackles climate change, helps to achieve the UN's Sustainable Development Goals and boosts the EU's competitiveness and growth. The programme facilitates collaboration and strengthens the impact of research and innovation in developing, supporting and implementing EU policies while tackling global challenges. It supports creating and better dispersing of excellent knowledge and technologies. It creates jobs, fully engages the EU's talent pool, boosts economic growth, promotes industrial competitiveness and optimises investment impact within a strengthened European Research Area. Legal entities from the EU and associated countries can participate.

Hubs4Circularity

The Hubs 4 Circularity (H4C) are key instruments to advance the research and innovation agenda of European industries towards the Green Deal's objectives. H4Cs have a strong technological focus and industrial dimension, but their implementation leverages elements well beyond research and innovation. Specific implementation (including funding) strategies will have to be co -designed, ensuring the participation of all stakeholders; industry, Small and medium-sized enterprises (SMEs), research and technology organizations (RTOs), local authorities, educational institutions and civil society.

Industrial symbiosis

Industrial symbiosis is the process by which wastes or by-products of an industry or industrial process become the raw materials for another. Application of this concept allows materials to be used in a more sustainable way and contributes to the creation of a circular economy.

Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change is the United Nations body for assessing climate change science. It produces regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation. These reports inform governments in the development of climate policy as well as guiding the UN's international climate change negotiation.

Just Transition Fund (JTF)

The Just Transition Fund is a new instrument with an overall budget of €17.5 billion, of which €7.5 billion are coming from the Multiannual Financial Framework (MFF) and €10 billion from the NextGenerationEU. The JTF is a key element of the European Green Deal and the first pillar of the Just Transition Mechanism (JTM). It aims to alleviate the social and economic costs resulting from the transition towards a climate-neutral economy, through a wide range of activities directed mainly at diversifying the economic activity and helping people adapt in a changing labour market.

Just Transition Mechanism (JTM)

The Just Transition Mechanism (JTM) is a key tool to ensure that the transition towards a climate-neutral economy happens in a fair way, leaving no one behind. It provides targeted support to help mobilise around €55 billion over the period 2021-2027 in the most affected regions, to alleviate the socio-economic impact of the transition.

Open Innovation Test Beds

It is a set of entities, established in at least three Member States or Associated Countries, providing common access to physical facilities, capabilities and services required for the development, testing and upscaling of nanotechnology and advanced materials in industrial environments. Its objective is to bring nanotechnologies and advanced materials within the reach of companies and users advancing from validation in a laboratory to prototypes in industrial environments.

Private-Public Partnerships

Long term contractual arrangements between the government and a private partner whereby the latter delivers and funds public services using a capital asset, sharing the associated risks. This broad definition shows that PPPs can be designed to achieve a wide array of objectives in various sectors, such as transport, social housing and healthcare, and can be structured under different approaches.

QSAR

The JRC QSAR Model Database is a historical archive providing information on the validity of Quantitative Structure-Activity Relationship (QSAR) models that were submitted to JRC's EU Reference Laboratory for Alternatives to Animal Testing (EURL ECVAM).

Safe and sustainable-by-design

A process to accelerate widespread market uptake of new and alternative chemical products and technologies that deliver greater consumer confidence in their safety, environmental and societal benefits and advance the transition towards a circular economy and climate-neutral society.

Social Life Cycle Assessment

Social Life Cycle Assessment (S-LCA) is is a method that can be used to assess the social and sociological aspects of products, their actual and potential positive as well as negative impacts along the life cycle. This looks at the extraction and processing of raw materials, manufacturing, distribution, use, reuse, maintenance, recycling and final disposal.

Sustainable Products Initiative (SPI)

It aims to make products placed on the EU market more sustainable. Consumers, the environment and the climate will benefit from products that are more durable, reusable, repairable, recyclable, and energy efficient.

Trans-European Networks for Energy

The Trans-European Networks for Energy (TEN-E) is a policy that is focused on linking the energy infrastructure of EU countries. As part of the policy, nine priority corridors and three priority thematic areas have been identified.

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