RENEWABLE
CARBON
INITIATIVE
REPORT

Evaluation of Recent Reports on the Future of a Net-Zero Chemical Industry in 2050

RCI Scientific Background Report

Authors: Jörn Harrandt, Michael Carus, Christopher vom Berg (all nova-Institute)

November 2024

Renewable Carbon Initiative (RCI)
www.renewable-carbon-initiative.com

Imprint

How to cite

(Harrandt et al. 2024); Harrandt, J., Carus, M., vom Berg, C., 2024: Evaluation of Recent Reports on the Future of a Net-Zero Chemical Industry in 2050

Editor

Renewable Carbon Initiative (RCI), 2024

Authors

Jörn Harrandt, nova-Institute, Project Manager Renewable Carbon Initiative
Michael Carus, Executive Manager of RCI and Founder and CEO of nova-Institute
Christopher vom Berg, nova-Institute, Executive Manager Renewable Carbon Initiative (RCI)

V.i.S.d.P. (responsible)

Michael Carus, nova-Institut GmbH, Hürth (Germany)

Find more information at
www.renewable-carbon-initiative.com

Table of Content

List of Figures

List of Tables

Authors

Jörn Harrandt has extensive experience managing complex datasets, honing his analytical skills and attention to detail. Since January 2024, he has been part of the nova Institut team, contributing to the Renewable Carbon Initiative (RCI). His expertise bridges project management and scientific research, developing comprehensive reports that support RCI's efforts to transform chemical and material industries towards renewable carbon solutions.

Michael Carus one of the leading European experts, market researchers and policy advisers of the renewable carbon economy – including bio-based, CO2-based and recycling. At the end of 1994, he and five other scientists founded the private and independent nova-Institute for Ecology and Innovation. Ever since the beginning, Carus has been involved in the company as owner and one of the two Managing Directors. Today nova-Institute has nearly 50 scientists from a wide range of disciplines, covering markets, technologies, sustainability, communication and policy. In the year 2020, Carus founded the Renewable Carbon Initiative (RCI), which has today more than 70 members from chemicals and materials industries.

Christopher vom Berg is Executive Manager of the RCI and develops strategic concepts for transforming the chemical and material industry towards renewable carbon. He joined nova-Institute in 2017 and has worked on various projects for the Sustainability department and the Economy & Policy department. In 2020, Christopher helped founding the Renewable Carbon Initiative (RCI), where he took over increasing responsibilities over time. Today, he is mainly involved in the management, advocacy and networking of RCI, investigates policies and regulations that impact renewable carbon management, and shares and discusses its positions and opinions. He is also author and co-author of multiple background reports and position papers of the RCI.

Focus of the report

Over the last five years, more than 20 reports have been published analysing and modelling the future of the net-zero chemical industry by 2050, both globally and for Europe. The most important reports are identified, evaluated and summarised with their scope, strengths and weaknesses and main findings. More specifically, the report investigates: How are the increasing shares of renewable carbon being realised? What are the shares of the different non-fossil feedstocks and pathways in the different scenarios in 2050?

1 Procedure

The literature review in this project involved three main steps: establishing selection criteria, identifying and selecting documents, and then mapping and analysing them against a set of evaluation criteria. The first step was to establish specific criteria to determine which documents would be included in the analysis:

- **Recent**: The documents should be recent in order to reflect the latest technological advancements and innovation in manufacturing process and recycling developments. Reports shall not be published prior to 2019.
- **Net-zero ambition:** Reports were selected according to their level of ambition. Where multiple scenarios were presented, at least one scenario had to be consistent with a net-zero[1] ambition for the target year. Where no information was provided on the CO_2 emissions savings of a particular scenario, reports were only included if the feedstock shares were consistent with other net-zero reports.
- **Sufficient detail:** Publications were selected based on their level of detail. Information on growth rates, feedstock demand from biomass, CO_2 and recycling and production volumes for the chemical and plastics industries for the target year of the respective studies (either 2045 or 2050) were required for inclusion in the final selection.

Altogether, 25 were selected and mapped, out of which a total of 15 studies (with a total of 24 scenarios) fulfilled the defined criteria and were evaluated respectively. The evaluated studies can be accessed via the authors, full details are provided in the Annex.

The documents were assessed both quantitatively and qualitatively. Quantitatively in terms of growth rates, feedstock shares and production volumes, and qualitatively in terms of policy recommendations mentioned and technologies used for scale-up.

The **quantitative assessment** involved a review of the feedstock and production data provided. In particular,

[1] The OECD Report does not present a net-zero scenario. It was included in this review because of the OECD's reputation and to highlight that there is considerable variation in the extent to which new technologies and innovations in material design are predicted to change the future chemical landscape.

it was investigated a) whether shares of overall carbon demand for the different renewable carbon feedstocks and the remaining share of fossil carbon feedstock and b) growth of the investigated sector(s) were provided. Where necessary, additional calculations were made to determine the overall percentage change in production volumes by the target year (i.e. Compound Annual Growth Rate (CAGR)). In addition, where not already provided in the reports, the proportions of different feedstock sources projected for use in the target year were calculated.

The **qualitative assessment** focused on identifying the main policy recommendations outlined in the respective roadmaps. Where applicable, the scope (e.g. entire chemicals sector or plastics only), technologies and timeframes described in the roadmaps were taken into account. Data relevant to these aspects were extracted from roadmap summaries, conclusions, figures and tables. In addition, word searches were carried out to gather information on relevant terms, and mentions of each topic were recorded for each roadmap.

2 Overview of evaluated studies

Industrial Transformation 2050. Pathways to Net-Zero Emissions from EU Heavy Industry (Material Economics 2019)

The Material Economics study characterises how net-zero emissions can be achieved by 2050 from the largest sources of 'hard to reduce' emissions, including plastics. A strength of the report is that it does not look at the chemicals and plastics industries in isolation, but analyses all heavy industries together and discusses their future. The study includes three scenarios for the transition to net-zero with a reduction in fossil energy and feedstock use for the chemicals and plastics industry in 2050, unfortunately without much detail and with limited data transparency. While recycling and biomass play a large role in the 2050 net-zero scenarios, the role of CO_2-based plastics remains unclear and CCS is clearly prioritised in this report.

Away from Oil. Potential and Limits of the Bioeconomy, Springer (Kircher, M., 2020) quoted from: Philp, J. 2023: Bioeconomy and Net-Zero Carbon: Lessons from Trends in Biotechnology, volume 1, issue 1

The author presents a scenario for the German chemical industry that achieves almost complete defossilisation by 2050. The feedstocks of the future will be CO_2, biomass and plastic waste, with only a very limited amount of fossil feedstocks remaining. Notably, the author clearly identifies CO_2 as the backbone of a sustainable chemical industry.

Achieving Net-Zero Greenhouse gas Emission Plastics by a Circular Carbon Economy (Meys et al. 2021)

The study reports on a series of life cycle analyses which suggest that even the current range of commercial monomers could potentially be produced and polymerised without net greenhouse gas emissions. To achieve this, a targeted combination of material and chemical recycling processes with Carbon Capture and Utilisation (CCU) and the use of biomass are considered. It is expected that the residual emissions from the incineration of non-recyclable waste will be offset by the use of biomass and the associated absorption of carbon dioxide. In addition, implemented carbon capture and utilisation allows carbon dioxide from production processes such as fermentation or biomass gasification to be reprocessed into valuable products together with renewable hydrogen from renewable energy sources.

iC2050 Project Report (Cefic 2021)

A comprehensive and detailed modelling study of 18 key chemicals, covering the main organic and inorganic building blocks, key commodity polymers and intermediates of the EU27 chemical industry. The report presents four scenarios, which are described in transparent detail, including new technologies such as PET chemical recycling via solvolysis, methanol to olefins, electrified naphtha steam crackers, methanol from CO_2 and H_2, bioethanol dehydration and many more. However, the narrow focus on specific chemicals is also a weakness, as it leaves out emerging new technologies such as electrochemistry, methanol, biotechnologies and whole sectors such as oleochemistry.

Towards Circular Carbo-Chemicals – the Metamorphosis of Petrochemicals (Lange 2021)

Lange developed two illustrative scenarios of feedstock diversification towards carbo-chemicals for the future of the chemical industry, one market-driven and one regulatory-driven, both covering the period 2000 to 2100. While CCU was not considered relevant in this report until 2050 (only later, 2100: 10%), the regulation-driven feedstock scenarios include high recycling and bio-based shares. The study is technically very detailed, but focuses only on cracker chemistry.

Global Plastics Outlook: Policy Scenarios to 2060 (OECD 2022)

The Global Plastics Outlook contains in-depth economic modelling, detailed scenarios, down to country level, polymer level and specified by application sector. The report assumes a high fossil share in 2050 and therefore paints a pessimistic picture of the future, in stark contrast to most other reports reviewed. Implementation of new technologies and changes to the system are predicted to be very low.

Planet Positive Chemicals. Pathways for the Chemical Industry to Enable a Sustainable Global Economy (Ishii et al. 2022)

The report uses detailed economic modelling to describe the future transitions of the chemical system up to 2050. There is depth, concrete figures and verifiable scenarios, as well as good graphics and policy recommendations. A major weakness of the study is the strong focus on a few major chemical pathways: Ammonia, methanol, ethanol, oleofins and aromatics. New chemical transitions in areas such as biotechnology and electrochemistry, fine chemistry, CO_2-based chemistry or even oleochemistry are not considered in detail.

ReShaping Plastics. Pathways to a Circular, Climate Neutral Plastics System in Europe (Systemiq 2022)

This report provides a comprehensive picture of how the European plastics industry can meet the challenge of carbon neutrality. The analysis focuses on the four largest consuming sectors (packaging, construction sector, non-packaging household goods, and the automotive sector), thereby considering 75% of the European plastic demand. It concludes that the four pillars of a circular economy (reduce, reuse, substitute and recycle) are of paramount importance. Whilst this report envisions that chemical recycling will become a viable option in the future, it sees only a secondary role for carbon capture and utilization.

Chemistry4Climate (VCI 2023)

The final report of the German-focused Chemistry4Climate project summarises the results of the two-year project involving some 80 partners from industry, NGOs and politics. The platform developed three exemplary scenarios for climate neutral chemistry by 2045 which all achieve full defossilisation with different shares of recycling, biomass use and CCU as feedstock.

From Fossil to Green Chemicals (Lopez et al. 2023)

This research paper examines the energy and feedstock requirements for global defossilisation of chemical production and develops scenarios that achieve net-zero emissions by 2040, 2050 and 2060 compared to business as usual by 2100. The authors have identified electricity-based methanol (e-methanol) and biomass-based methanol (bio-methanol) as the most promising green carbon feedstock and argue, that the chemical industry could become the largest e-hydrogen consumer.

RCI Renewable Carbon as a Guiding Principle for Sustainable Carbon Cycles (RCI 2023)

This report forms the basis for the concept and strategy of renewable carbon and the RCI. The authors present an exploratory scenario for 2050 with full defossilisation, in which the chemical industry's commodities are mainly produced from chemical recycling and CO_2 utilisation and, while special molecules with particularly favourable pathways are produced from biomass, e.g. fine chemicals or certain polyamides.

RCI Carbon Flows Report (RCI 2023)

This study by RCI is a compilation of fossil and renewable carbon supply and demand at a global and European level. It provides a comprehensive understanding of today's carbon flows, is consistent with the net-zero scenario in the above report on global feedstock supply for the chemical industry in 2020 and 2050, and adds a further element by including an exploratory scenario on how the heavy oil fraction can be replaced by 2050.

The Plastics Transition (PlasticsEurope 2023)

The Plastics Europe Roadmap describes a vision to create a sustainable plastics system that continues to meet consumer and societal needs, while supporting the transitions of many downstream industries and remaining a strategic asset for the European economy. The roadmap consists of three pillars, including achieving a net-zero life cycle for plastics, making plastics circular by providing circular feedstocks, and promoting the sustainable use of plastics. CCU appears as a very limited feedstock for plastics.

The Contribution of CCU Towards Climate Neutrality in Europe (CO_2 Value Europe, 2024)

CVE has developed a first comprehensive quantitative assessment of the role of CCU in achieving climate neutrality in Europe, mainly for the fuels sector, but also for the chemicals sector, using complex modelling. It shows a positive outlook for the estimation of the capacity of CCU and its application in the fuels, construction and chemicals and derived materials sectors.

The Refinery of the Future (Vogt and Weckhuysen 2024)

This study argues that with sufficient long-term commitment and support, the science and technology for a completely fossil-free refinery could be developed to deliver the products needed after 2050 (less fuels, more chemicals). The authors argue that by electrifying refinery processes and switching feedstocks from fossil fuels to CO_2 and agricultural and municipal waste, carbon cycles can be attempted to be closed.

3 Key results from the evaluation

Growth until 2050

In terms of volume growth, the majority of global scenarios assumes an increase in the production of the chemical industry. The average growth rate of the global feedstock demand for the chemical or plastics industry is **2.93%** (min= 2%, max= 4%). **This indicates that growth will be somewhat lower going forward than it has been in previous decades, where CAGR was between 3 to 4%**. While most reports agree that the global demand for chemicals or plastics is expected to grow, some studies are more optimistic than others about the extent to which this growth will be offset by efficiency gains along the value chain.

This represents an increase of around **2.4 times** by 2050 compared to 2020 levels, but there are clear geographical differences. Most of the growth is expected to take place outside Europe, with feedstock volumes in Europe remaining at current levels until 2050.

This can be explained by the fact that European population is relatively stable and the circular economy continues to mature. In addition, unlike in Asia or Africa, there is no pent-up demand in Europe for plastic products such as cars, household appliances and packaging. All in all, the assumptions in the studies reveal a higher degree of uncertainty in terms of growth when it comes to the European sector, the average CAGR for Europe and Germany of the evaluated studies (combined) **is 0.4%** (min= -1%, max= 3.1%) (see Table 1).

Table 1:Overview of the Results of the Evaluation of 15 Studies and 24 Scenarios on the Net-Zero Chemical Industry 2050

Study	Year	Scope	Region	Scenario	CAGR	Biomass Share	CCU Share	Recycling Share	R-mech Share	R-chem Share	Fossil Share	CCS
Material Economics	19	P	EU	CCP	0	32.5	0	29	15	14	38.5	+
Material Economics	19	P	EU	CEP	-0.4	37	0	63	25	38	0	
Material Economics	19	P	EU	NPP	0	38	0	62	15	47	0	
Kircher, M.	20	CI	DE		3.1	20	70	5.5			3.5	
Meys et al.	21	P	W	CC	4	38.5	17.5	43.5	19	24.5	0.5	
CEFIC	21	CI, S1	EU	HE	2.2	27	5.2	7.8			60	+
CEFIC	21	CI, S1	EU	SB	2.3	35	4.8	7.2	7.1	0.1	53	+
CEFIC	21	CI, S1	EU	CC	1.25	1.0	0	11			88	+
CEFIC	21	CI, S1	EU	FC	1.25	17	10,0	19			54	+
Lange (Shell)	21	CI, S2	W	RD	2*	13	0	42	12	30	45	+
Lange (Shell)	21	CI, S2	W	MD	4*	10	0	20	15	5	70	+
OECD	22	P	W		2.6	0.5	0	12			87.5	
Ishii &Stuchtey	22	CI, S3	W	LC-NFAX	3	35	29	21.5	21.5	0	14.5	+
Systemiq	22	P, S4	EU	NZSCS	0	19	5.5	46.5			29	+
VCI, VDI	23	CI	DE	MDS	-0.5	5.5	88	6.5	6.5	0	0	
VCI, VDI	23	CI	DE	SR	-0.5	52	38	10	6	4	0	
VCI, VDI	23	CI	DE	W&PTX	-0.5	4.8	90	5.5	5.5	0	0	
Lopez et al.	23	CI, S5	W	HBM	2.8	32	62	6			0	
Lopez et al.	23	CI, S5	W	LBM	2.8	9	84	7			0	
Lopez et al.	23	(P)	W	HBM	2.8	20	49	31			0	
Lopez et al.	23	(P)	W	LBW	2.8	3	66	31			0	
nova-Institute	23	CI, S6	W		2.5	20	25	55			0	
nova-Institute	23	CI, S7	W		2.5	24.5	24	51.5			0	
PlasticsEurope	23	P	EU		0.5	17	5	43	24	19	35	+
CO_2 Value Europe	24	P, O	EU		-1	9	30.5	56.5	28	28.5	4	+
Vogt & Weckhuysen	24	CI, R			1.2	50	0	50			0	

Sope: P= plastics, CI= chemical industry, S1= 18 key chemicals (organics, inorganics, polymers), S2= (carbo-chemicals / petrochemical industry), S3= olefins & aromatics, ammonia, methanol, S4= 75% of European plastic demand (packaging, construction, non-packaging household goods, automotive sector), S5= cracker, ammonia and methanol, S6= chemicals and derived materials, S7= chemicals and derived materials incl. heavy oil fraction, O = olefins, (P)= chemicals-to-plastics (derived from Sankey diagram from feedstock for S5), R = chemicals and materials from refineries; **Region:** EU = Europe, W = World, DE= Germany; **Scenario:** Please see annex for further details; **CAGR:** Cumulative Annual Growth Rate in %; **Biomass:** Share of biomass from total feedstock in %; **CCU:** Feedstock from Carbon capture and Utilisation, share from total feedstock in %; **Recycling:** Feedstock from mechanical; and chemical recycling, share from total feedstock in %; **R-mech:** Feedstock from mechanical recycling, share from total feedstock in %; **R-chem:** Feedstock from chemical recycling, share from total feedstock in %; **Fossil:** Fossil-based feedstock, share from total feedstock in %; **CCS:** "+" indicates that emissions related to fossil share are at least partially abated via CCS

Complete defossilisation is considered in 10 of the 24 scenarios. The remaining studies with a residual share of fossil carbon feedstock tend to combine these processes with a strong implementation of CCS. It is noteworthy that the OECD report (2022) assumes that the majority of feedstock in the future chemical industry will still be fossil, with low recycling rates and negligible use of biomass feedstock, which is a clear outlier and in stark contrast to the general consensus.

Renewable carbon shares and differences between the entire chemical industry and the plastics sector

In all 24 scenarios, biomass and recycling are considered as possible alternative carbon sources to replace fossil carbon. CCU is considered in 16 of the 24 scenarios.

The studies reviewed were grouped for analysis into either the plastics sector (7 reports, 10 scenarios) or the chemicals industry (CI, 9 reports and 16 scenarios), although in the latter case the scope often did not cover the full extent of the chemicals industry (see Table 1).

Biomass

In most scenarios, the share of biomass covers a significant part of the total feedstock demand, not only for **plastics (mean= 21%**, median= 19.5%, Q1= 11%; Q3= 35.9%**), but also for the chemicals** (**mean= 22%**, median= 20%, Q1= 9.8%; Q3= 32.8%). In studies where biomass is analysed in more detail, the **main sources are wood and biogenic waste and agricultural lignocellulosic** feedstocks. The share of starch, sugar and oil crops decreases in most scenarios.

CCU

The **use of CO_2** is considered in 11 reports and 16 scenarios. For the plastics scenarios, the **average share** attributed to CCU **is 17%** (median= 5.3%, Q1= 0%; Q3= 27.3%), with a considerably higher average share **of 33%** (median= 24.5%, Q1= 3.6%; Q3= 64%) for the chemical industry, which is **higher than the predicted share of biomass.** However, the reported values for CCU show substantial heterogeneity, reflected in a large interquartile range. Despite the limited robustness due to the small sample size of the total number of reports, this indicates the presence of ambiguity; some scenarios predict that CCU will become the main source of feedstock for chemicals, while others assume that CCU will not take off at all. Depending on the study, either all CO_2 sources are accepted (biogenic as well as fossil point sources and air capture) or fossil point sources are not considered.

Recycling

While the reported average share of recycling for the chemical industry is **20%** (median= 10.5%, Q1= 6.9%; Q3= 26.6%), the predicted average share for **plastics is significantly higher at 42%** (median= 43.3%, Q1= 31%; Q3= 54%). For both categories the interquartile range is quite narrow. This means that most studies **agree on the leading role of recycling for** the **plastics** sector, while the importance of recycled plastic feedstock in the wider context of the chemical industry appears to be less pronounced. Unfortunately, not all studies analyse the breakdown of recycled content between the two possible categories (chemical/mechanical) in sufficient detail. About **40% of the studies provide** explicit **shares** for **both mechanical and chemical recycling**. 50% of these studies estimated a higher share for chemical recycling than for mechanical recycling (see Table 1).

The results are visualised in the following figures, with Figure 1 shows the average shares of bio-based, CCU-based, recycled and fossil feedstocks for the chemical industry studies, while Figure 2 shows the results for the plastics industry studies.

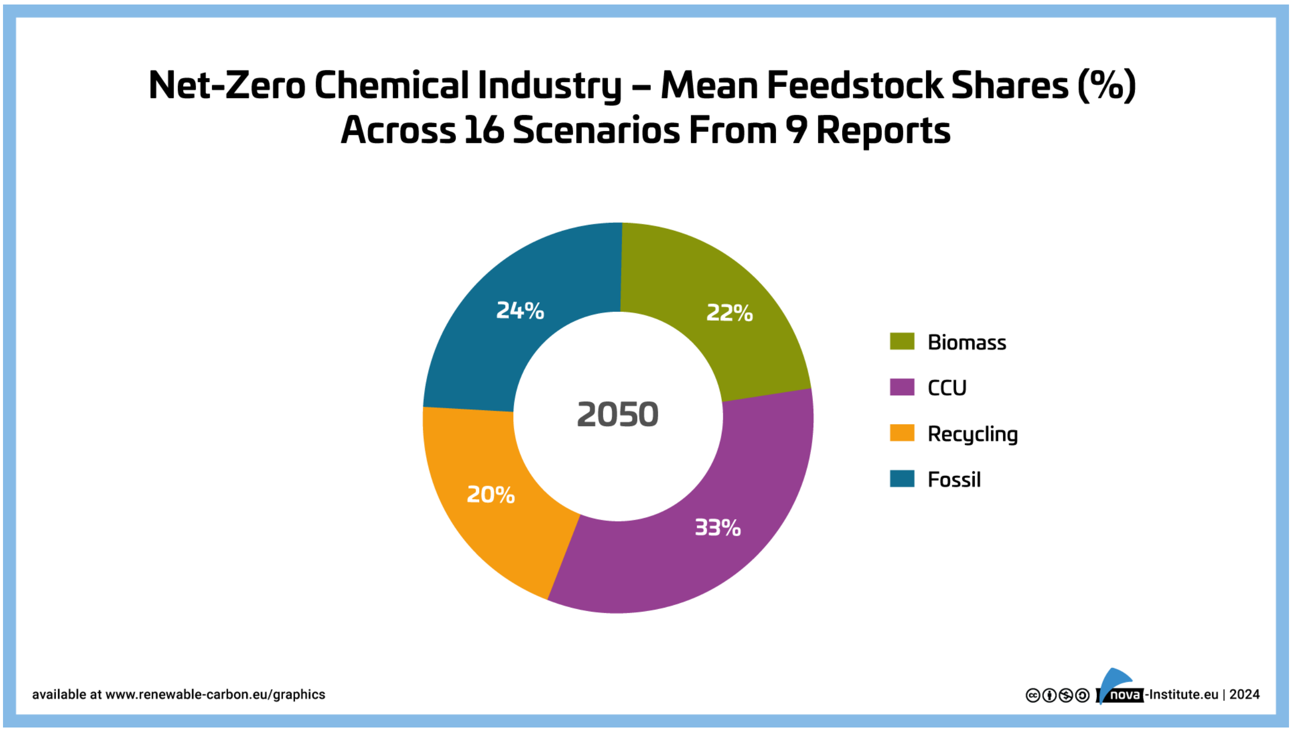

Figure 1: Mean feedstock shares derived from recent scenarios for the 2050 net-zero chemical industry.

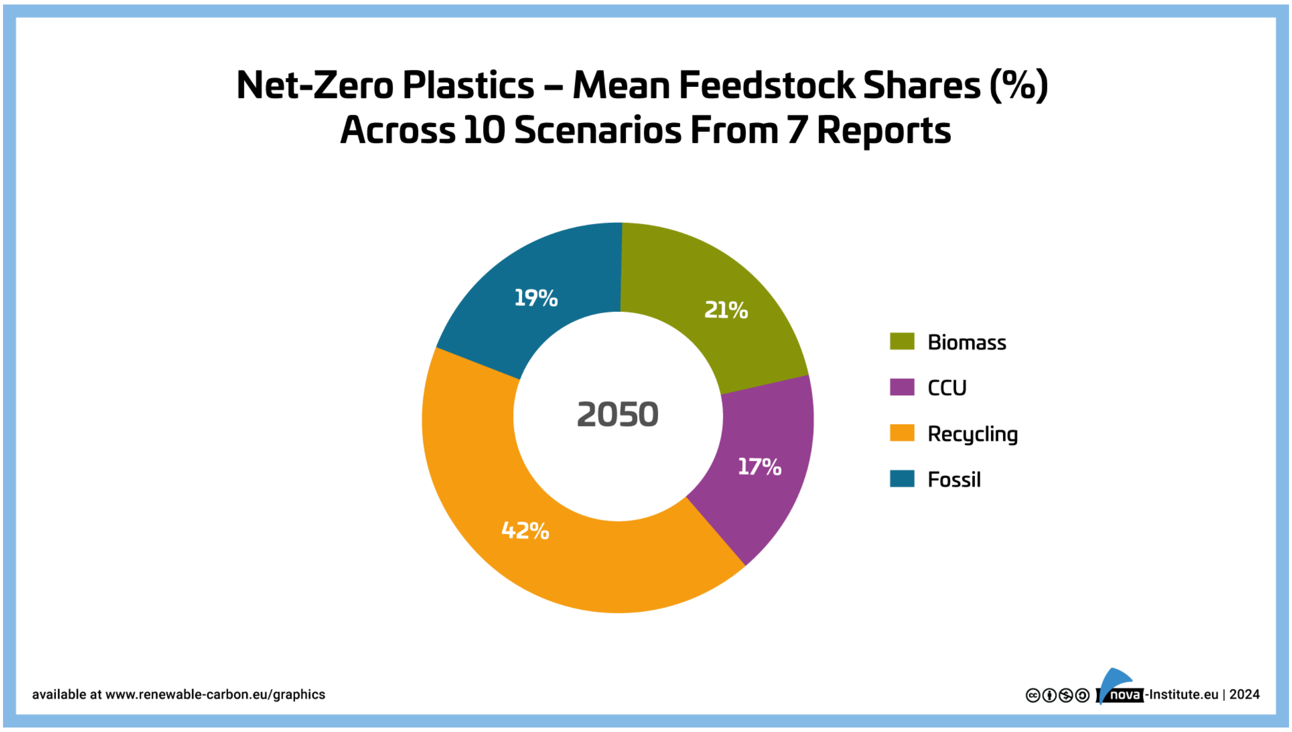

Figure 2: Mean feedstock shares derived from recent scenarios for the 2050 net-zero plastics sector.

Figure 3 (for the chemical industry studies) and Figure 4 (for the plastics industry studies) show in more detail on the dispersion of the shares between the different studies. Both show box plots for the bio-based share, the CCU-based share, the recycled share (separated into mechanical and chemical recycling where possible) and the remaining fossil share. The individual points in a box plot indicate the share of a particular study, while the box visualises the middle 50% of the data. The line in the box plot shows the median.

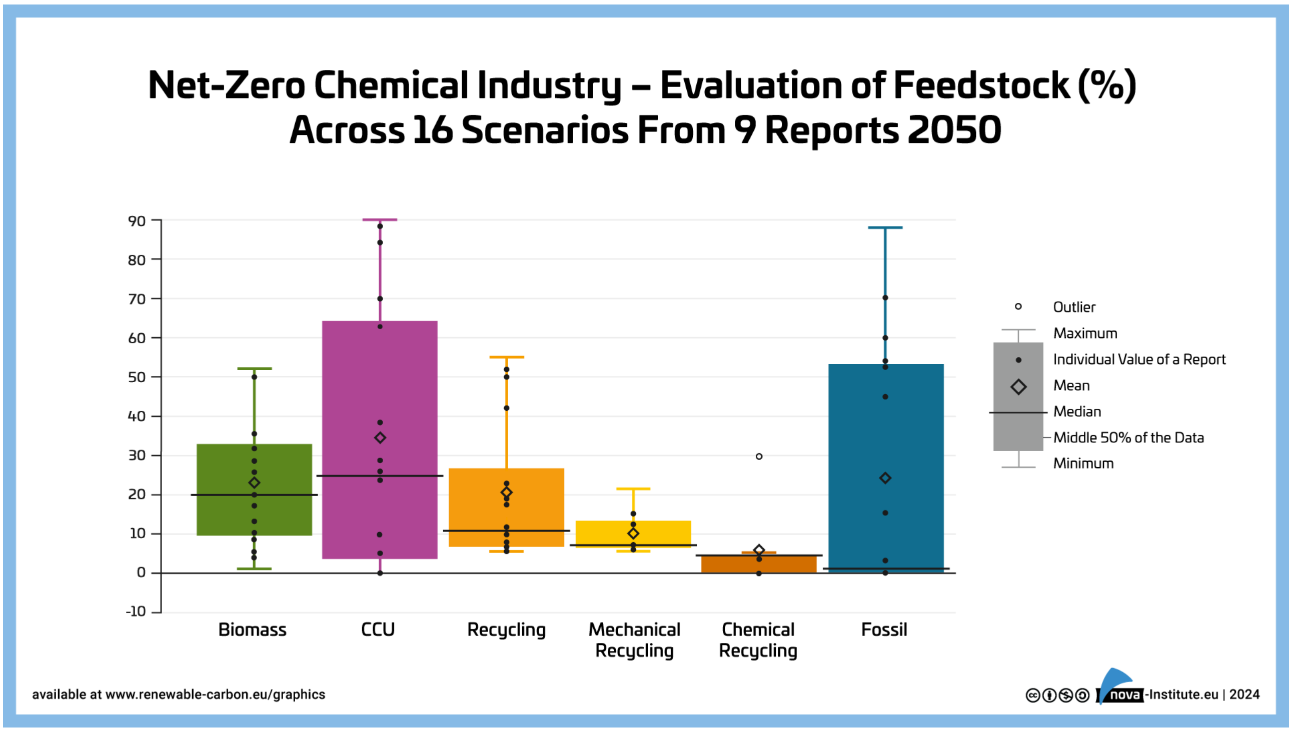

Figure 3: Carbon feedstock shares across 9 recent reports with scenarios on the future of the chemical industry.

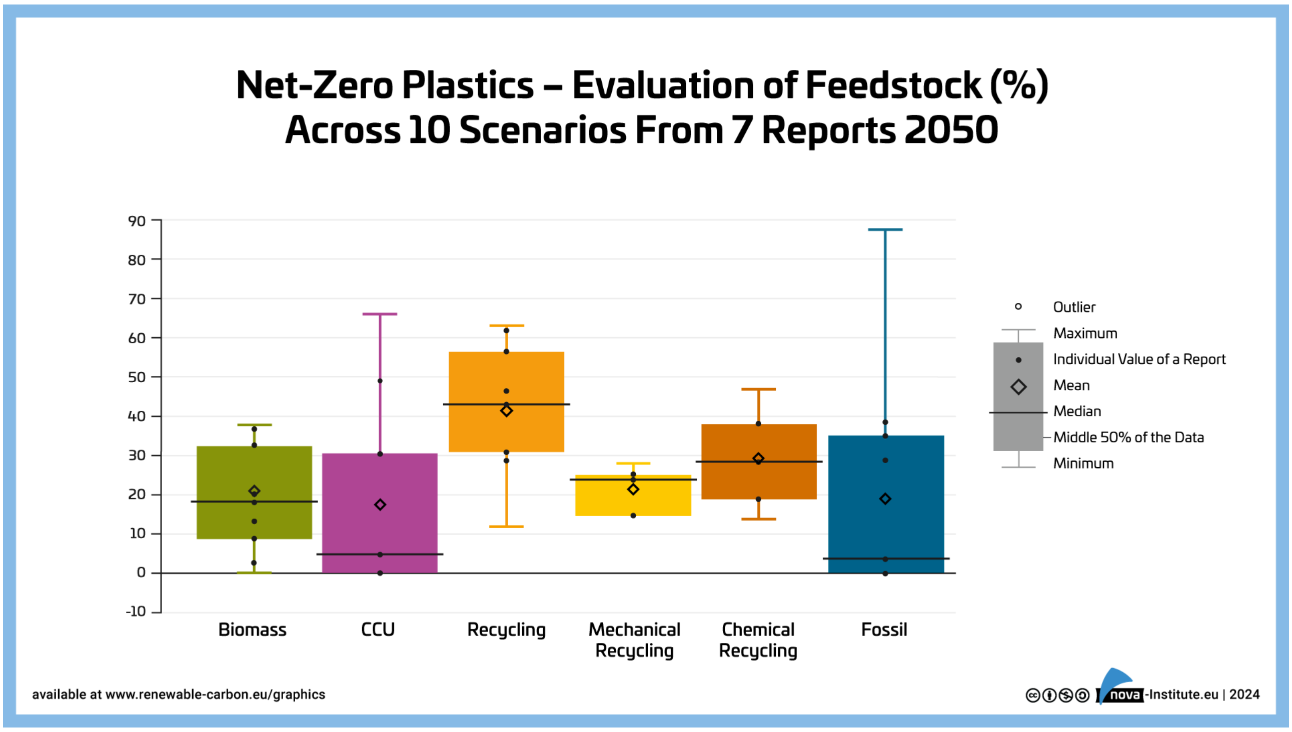

Figure 4: Carbon feedstock shares across 7 recent reports with scenarios on the future of the plastics industry.

In summary, despite the differences in modelling, assumptions and scope, the results of the studies are not very far apart and tend to be in general agreement. **The vast majority of reports predict a dramatic reduction in the share of fossil feedstock compared to today, and have identified biomass, CCU and recycling as the future backbone of the chemical industry's feedstock base**. Notably, recycled feedstock is projected to become the main source of carbon for plastics production (see Figures 1 and 2). Due to the current low TLR, there seems to be some ambiguity about the role that chemical recycling will play. However, the results clearly show that maximising carbon recovery and cycling through recycling can only be achieved through inclusion of chemical recycling.

Policy instruments found in the reports and studies

Many of the reports reviewed provide at least some policy recommendations on how to address the challenges associated with such a large-scale industrial transformation. High-level recommendations tend to focus on investment and economic support, the establishment of robust regulatory frameworks, and the promotion of renewable energy and infrastructure development.

Technology Processes highlighted in the reports and studies

The analysis of the key processes required for a sustainable chemical industry showed that there is no single solution. The general consensus can be narrowed down to three basic pillars: establishing a renewable feedstock base, substituting conventional processes with new processes or process chains, and changing the heat supply.

New source of feedstock carbon. Enhance circularity of carbon by transitioning away from fossil-based feedstocks to renewable carbon sources, including biomass, industrial by-products, waste CO_2 and recycled plastics.

The share of alternative carbon feedstocks is expected to increase gradually. While a large proportion of the 2050 scenarios assume a complete defossilisation of the chemical industry by 2050, some reports still assume a significant fossil share (often mitigated by CCS). In the future, the increased use of biomass (biotechnology, gasification to syngas), the use of plastic waste (chemical recycling), and CCU (e.g. via syngas and Fischer-Tropsch (naphtha), electrochemistry or the methanol route) will form the new feedstock and process base for basic chemicals. In this context, the most discussed sustainable feedstocks for the global chemical industry are alternative naphtha and methanol, e-methanol and biomass-based methanol (bio-methanol), which can be used either directly or as a feedstock for olefins and aromatics via the methanol-to-olefins (MTO) and methanol-to-aromatics (MTA) processes.

New processes or process chains. Significant reductions in CO_2 emissions can be achieved by improving existing processes and developing new ones. While there is still significant room for improvement in the context of mechanical recycling (i.e. collection, sorting), several reports have identified chemical recycling of end-of-life plastics as the key tool to increase carbon circularity. This includes depolymerisation, pyrolysis and gasification, but also physical recycling such as dissolution.

Change of processes energy

Although outside the scope of this report, it is worth noting that in addition to feedstock substitution and the scale-up of new processes, the electrification of manufacturing has often been identified as an important measure to support industrial transformation and CO_2 emission reduction. While some process equipment, such as pumps, compressors and low-temperature boilers, are relatively easy to convert, other tasks are more challenging. For example, the development of large-scale electrically heated steam cracking furnaces.

4 Annex

References	Link
Material Economics (2019). Industrial Transformation 2050 - Pathways to Net-Zero Emssions from EU Heavy Industry.	https://www.climate-kic.org/wp-content/uploads/2019/04/Material-Economics-Industrial-Transformation-2050.pdf
Scenario 1 "CARBON CAPTURE Pathway" → CCP	
Scenario 2 "CIRCULAR ECONOMY Pathway" → CEP	
Scenario 3 "NEW PROCESSES Pathway" → NPP	
Kircher, M. (2020). Away from Oil. Potential and Limits of the Bioeconomy, Springer cited in Philp, J. (2022). Bioeconomy and net-zero carbon: lessons from Trends in Biotechnology, volume 1, issue 1. Trends in Biotechnology. 41.	DOI: 10.1016/j.tibtech.2022.09.016
Meys, R., Kätelhön, A., Bachmann, M., Winter, B., Zibunas, C., Suh, S., Bardow, A. (2021). Achieving net-zero greenhouse gas emission plastics by a circular carbon economy. Science (New York, N.Y.). 374. 71-76.	DOI: 10.1126/science.abg9853
CEFIC (2021). iC2050 PROJECT REPORT Shining a light on the EU27 chemical sector's journey toward climate neutrality	
Scenario 1 "High electrification" → HE	
Scenario 2 "Sustainable biomass" → SB	
Scenario 3 "CO2 capture" → CC	
Scenario 4 "Fostering Circularity" → FC	
Lange, J.-P. (2021). Towards circular carbo-chemicals – the metamorphosis of petrochemicals. Energy & Environmental Science.	DOI: 10.1039/d1ee00532d
Scenario 1 "market-driven" → MD	
Scenario 2 „regulation-driven" → RD	
OECD (2022). Global Plastics Outlook: Policy Scenarios to 2060, OECD Publishing, Paris.	DOI: 10.1787/aa1edf33-en
Ishii, N. & Stuchtey, M. (2022). Planet Positive Chemicals, Pathways for the chemical industry to enable a sustainable global economy.	https://www.systemiq.earth/wp-content/uploads/2022/09/Main-report-v1.20-2.pdf
Scenario "Low Circularity, No Fossil production capacity installed After 2030" → LC-NFAX	
SYSTEMIQ (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe.	https://plasticseurope.org/wp-content/uploads/2022/04/SYSTEMIQ-ReShapingPlastics-April2022.pdf

Scenario"Net-Zero System Change Scenario" → NZSCS	
VCI, VDI (2023). Wie die Transformation der Chemie gelingen kann.	https://www.vci.de/vci/downloads-vci/publikation/broschueren-und-faltblaetter/final-c4c-broschure-langfassung-es.pdf
Szenario 1 „Maximale Direktnutzung von Strom“ → MDS	
Scenario 2 „Fokus auf Wasserstoff und PtX“ → W&PTX	
Szenario 3 „Fokus auf Sekundärrohstoffe“ → SR	
Lopez, G., Keiner, D., Fasihi, M., Koiranen, T. (2023). From fossil to green chemicals: Sustainable pathways and new carbon feedstocks for the global chemical industry.	DOI: 10.1039/D3EE00478C.
Scenario 1 "NZE 2050 High Biomass 2050" → HBM	
Scenario 2 "NZE 2050 Low Biomass 2050". →> LBM	
vom Berg, C. & Carus, M. et al. (2023). Renewable Carbon as a Guiding Principle for Sustainable Carbon Cycles. Editor: Renewable Carbon Initiative (ed.), Hürth 2023.	DOI: 10.52548/QUHG1295
Kähler, F., Porc, O., Carus, M. (2023) RCI Carbon Flows Report: Compilation of supply and demand of fossil and renewable carbon on a global and European level. Editor: Renewable Carbon Initiative, May 2023.	DOI: 10.52548/KCTT1279
Plastics Europe (2023). The Plastics Transition Our industry's roadmap for plastics in Europe to be circular and have net-zero emissions by 2050.	https://plasticseurope.org/wp-content/uploads/2023/10/PlasticsEurope_Report_24.10.pdf
Sapart, C., Perimenis, A., Bernier, T. (2024). The Contribution of Carbon Capture & Utilisation Towards Climate Neutrality in Europe (Scenario Development and Modelling Exercise). CO2 Value Europe.	https://co2value.eu/wp-content/uploads/2024/01/FINAL-LAYOUT_CVEs-EU-Roadmap-for-CCU-by-2050.pdf
Vogt, E. & Weckhuysen, B. (2024). The refinery of the future. Nature. 629. 295-306.	DOI: 10.1038/s41586-024-07322-2

RENEWABLE CARBON INITIATIVE

Bio-based CO2-based Recycling

Circular Economy

Shape the Future of the Chemical and Material Industry

WHY JOIN RCI?

RCI is an organisation for all companies working in and on renewable chemicals and materials – plastics, composites, fibres and other products can be produced either from biomass, CCU or recycling. RCI members profit from a unique network of pioneers in the sustainable chemical industry, creating a common voice for the renewable carbon economy.

To officially represent the RCI in Brussels, the RCI is registered in the EU's transparency register under the number 683033243622-34.

LinkedIn:
www.linkedin.com/showcase/renewable-carbon-initiative
#RenewableCarbon

Executive Managers:
Christopher vom Berg & Michael Carus

Contact: Verena Roberts
verena.roberts@nova-institut.de

JOIN NOW

Become a part of the Renewable Carbon Initiative (RCI) and shape the future of the chemical and material industry
www.renewable-carbon-initiative.com

Find all current RCI members at:
www. renewable-carbon-initiative.com/members

MEMBERS OF THE INITIATIVE

LARGE SUPPLIERS

ADM, Alfa Laval, Arkema, BASF*, Beckers, Borealis, Braskem, Cerdia, Clariant, Cosun Beet Company*, Covation Bio, Covestro*, CropEnergies, Dow, Fortum, Givaudan*, Peter Greven, H&R, IFF*, Kemira, Kuraray, Lenzing*, Lubrizol, Mane, Mercer, Neste*, PCC SE, SCGC, SHV Energy*, Stahl*, Stepan, Südzucker Group, Sulzer, Syensqo, Symrise, TÜV Austria, Uniper, UPM Biofore*, Verbio, Wacker

SME

AllocNow, Avantium, Fibenol, FKuR, Futerro, LanzaTech*, nova, SCS Global Services

BRANDS

Beiersdorf, Continental, Henkel*, IKEA, LEGO, Michelin, On, P&G, Reckitt, Vaude

START-UPS

Aduro Clean Technologies, Amynova Polymers, BioBTX, Chaincraft, Clariter, Colipi, dab, Dioxycle, Econic, Avoco, Greenlyte Carbon Technologies, Modern Meadow, TripleW

RESEARCH INSTITUTES

Danish Technological Institute, IKT Kunststofftechnik Stuttgart, ITA RWTH Aachen University, Leibniz-Institut für Verbundwerkstoffe, NORCE

* Board Member

PARTNERS

C.A.R.M.E.N., Chemie Cluster Bayern, Circular Rubber Platform, CO2 Value Europe, ECBF, ecp-news, EIHA, ePURE, Global CO2 Initiative University of Michigan, GO!PHA, IBB Netzwerk GmbH, Renewable Carbon Plastics Magazine, Textile Exchange, WWF

RCI Scientific Background Reports

- **Evaluation of Recent Reports on the Future of a Net-Zero Chemical Industry in 2050**
  November 2024
- **Non-level Playing Field for Renewable Materials vs. Fossil in Life Cycle Assessments**
  January 2024
- **Case Studies Based on Peer-reviewed Life-Cycle Assessments – Carbon Footprints of Different Renewable Carbon-based Chemicals and Materials**
  November 2023
- **RCI Carbon Flows Report – Compilation of Supply and Demand of Fossil and Renewable Carbon on a Global and European Level**
  October 2023
- **Renewable Carbon as a Guiding Principle for Sustainable Carbon Cycles**
  September 2023
- **Making a Case for Carbon Capture and Utilisation (CCU)**
  July 2023
- **The Use of Food and Feed Crops for Bio-Based Materials and the Related Effects on Food Security**
  June 2023
- **CO2 Reduction Potential of the Chemical Industry Through CCU**
  May 2022

RCI Position Papers

- **Swift Implementation of EU Biotech and Biomanufacturing Initiative is Key to Strengthen EU Competitiveness and Accelerate defossilisation**
  September 2024
- **Towards an Ambitious Industrial Carbon Management for the EU**
  July 2024
- **Chemical and Physical Recycling**
  May 2024
- **How to Enable the Transition From Fossil to Renewable Carbon in the Chemical and Material Sector**
  November 2023
- **Comprehensive Carbon Management**
  October 2023
- **Commission Proposal for a Green Claims Directive (GCD)**
  September 2023
- **RCI's Manifesto for the next European Commission (2024-2029)**
  August 2023
- **Commission Proposal for a Packaging and Packaging Waste Regulation**
  May 2023
- **Communication on Sustainable Carbon Cycles**
  April 2023
- **Letter to the Commission on the Definition of Natural Polymers in the Reach Microplastics Restriction**
  February 2023
- **RCI's Position on Mass Balance and Free Attribution**
  October 2022
- **RCI's Position on the Draft EU Policy Framework on Bio-Based, Biodegradable and Compostable Plastics**
  October 2022

More Publications of RCI and Information
renewable-carbon-initiative.com/media/library

RENEWABLE CARBON INITIATIVE

Bio-based CO_2-based Recycling

RCI members are a diverse group of companies addressing the challenges of the transition to renewable carbon with different approaches. The opinions expressed in these publications may not reflect the exact individual policies and views of all RCI members.