

Delphi study report: The European Chemical Industry in a 2050 perspective

*Study on the development of key areas within Economy, Geopolitics,
Society, Technology and Environment*



*Copenhagen Institute
for Futures Studies*

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Authored by

Frank-Andreas Hatzack

Jeffrey Saunders



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Executive Summary

The present report summarizes the results of the real-time Delphi study on the mid-century future of the chemical industry in Europe in the context of the world of 2050. The study was conducted by the Copenhagen Institute of Futures Studies (CIFS) on behalf of the European Chemical Industry Council (Cefic) in June 2018. Delphi participants were experts from the chemical industry (n = 195) as well as experts from other industries, academia and the public sector (n = 92). The panel was strongly engaged in the study, which is reflected in the over 1300 posted comments.

The purpose of the study was to capture the expert's views and expectations with regards to future developments in economy, geopolitics, society, technology and environment. The 90 questions posted online were developed on the basis of assumptions laid out in a preceding foresight report authored by CIFS in collaboration with Cefic. The results obtained showed that the majority of participants' responses were in alignment with the foresight report assumptions, which was the case for 67% of all questions. A more mixed picture of expert opinions was observed in 24% of all questions, whereas lacking alignment was found in only 4% of all questions. For the remaining questions the alignment criterium did not apply.

Some of the key future themes endorsed by the Delphi panel were:

- a multipolar world, facing many challenges, in which Europe's chemical industry competes successfully on the basis of technological innovation, digitization, cross-industry collaboration, increasing use of low-carbon-electricity, sustainable use of renewable feedstocks for value-added production and services
- the UN sustainable development goals, including human health & safety as well as environment and climate protection are pivotal for the industry and its business models
- the chemical industry playing a central role in Europe's evolving circular economy, with strong emphasis on molecule recirculation and transparent information flows across value chains.

Chemical experts and non-chemical experts had congruent views on the future and differed only with respect to their perception of the effects of regulation on industry competitiveness. Chemical experts tended to view regulation as a constraint whereas non-chemical experts perceived increasing regulatory requirements as a driver for innovation and competitive differentiation.

Contributors

A special vote of thanks for their contributions and input to the present Delphi study and the preceding foresight study is dedicated to the mid-century strategy taskforces (TF1, innovation; TF2, economics; and TF3, stakeholders) with names listed below in alphabetical order:

Mensink,	Marco	Cefic	Director General, Sponsor
Cayueta,	Rafael	Dow Chemical	Project Chairman
Garcia,	William	Cefic	Project Lead
Van Luijken,	Irene	Cefic	Communication Lead
Diercks,	Ann	Cefic	Sustainability Lead
Barthélémy,	Pierre	Cefic	Technology & Innovation Lead
van Sloten,	René	Cefic	Industrial Policy Lead
Northcote	Richard	Covestro	<i>In memoriam</i> , Chair TF1
Westerheide,	Peter	BASF	Chair TF2
Héry,	Bruno	LyondellBasell	Co-chair TF3
van Heiningen,	Rinske	Nouryon	Co-chair TF3
Arns,	Dorothee	Cefic	TF3
Bosman,	Bert	Sabir	TF1
Breulet,	Jacques	INEOS	TF2
Brouhns,	Alexis	Solvay	TF3
Chalot,	Véronique	Cefic	Project Executive Assistant
Chung,	Lynette	Clariant	TF3
de Warren,	Nicolas	ARKEMA	TF2
Gerhäuser,	Attila	VCI	TF1 & 3
Girotti,	Gianni	Versalis	TF3
Hadhri,	Moncef	Cefic	TF2 & 3
Hampson,	Paul	Shell	TF1
Hargrove,	Elaine	ExxonMobil	TF1
Bassett	Andrew	ExxonMobil	TF1
Höcker,	Holger	Evonik	TF2
Keruyun,	Tanguy	Total	TF1 & 2
Manders,	Ton	Cefic	TF1
McCarthy,	Adam	Albemarle	TF1
Meincke,	Henrik	VCI	TF2
Milcent,	Xavier	ExxonMobil	TF1
Pires Cabral,	Micaela	Bondalti	TF2
Robert,	Charles-Henri	Cefic	TF1
Sievering,	Christoph	Covestro	TF1
Stalmans,	Lieven	Borealis	TF1 & 3
Turner,	Jeff	DSM	TF1
van Wijk,	Dolf	Cefic	TF2
Veith,	Susanne	DowDuPont	TF1
Vermeulen,	Marc	Cefic	TF1 & 2 & 3
Vollman,	Marcello	Cefic	TF2
Weber,	Wolfgang	BASF	TF3

Introduction

The 21st century is an era of growing complexity and exponential change. A number of megatrends create an environment that is increasingly volatile, uncertain, complex, and accelerating, which makes it challenging to know what organisations should prepare for in the future. What are the key drivers, actors and dynamics that shape future developments? How can we position ourselves in the best possible way to be able to come up with solutions for both known and unknown problems as well as capture opportunities we are not even aware of today?

The present Delphi study was designed with the primary objective to test the assumptions laid out in the preceding CIFS report '*The Chemical Industry in Europe in a 2050 perspective*' which was commissioned by Cefic as part of the Mid-century Strategy (MCS) process. Testing these assumptions was achieved by developing a set of questions and statements in close collaboration with the MCS plenary group and conducting an online real-time Delphi study.

A secondary objective of the study was to gather respondent's views, opinions and expectations on the future on issues that are of relevance to players in the chemical industry in Europe.

A large and diverse crowd of over 1200 experts selected by Cefic and CIFS was invited to join the Delphi campaign. More than 23% of invitees, corresponding to 287 experts, actively engaged in the campaign by answering the questions and statements as well as entering free-text comments to support the reasoning behind their answers. The study was conducted as a real-time Delphi study. This allowed respondents to monitor reply statistics and shifting consensus, read other expert's comments and revisit and change their own responses. The option to revise answers during the campaign period is one of the strong characteristics that distinguishes the Delphi method from a traditional survey, as it allows participants to modify their perspective based on other respondent's answers and reasoning.

To capture the developments shaping the industry at large, the following five areas have been used as points of orientation for this study, while also reflecting the structure of the preceding foresight study '*The Chemical Industry in Europe in a 2050 perspective*':

1. Economy
2. Geopolitics
3. Society
4. Technology
5. Environment

Most of the questions were linked to one of the pivotal assumptions laid out in the preceding foresight report. The questions were framed in an open fashion, typically offering respondents a set of multiple options to choose one single answer from. The vast majority of the respondents were not familiar with the foresight study and were not given any additional background information as part of the Delphi campaign. Thus, respondents relied on their individual expert knowledge and their own expectations regarding the future.

Comparing the obtained Delphi results (quantitative response statistics and free-text comments) with the assumptions from the preceding foresight study, enabled a gap analysis, which revealed alignments as well as contrasts and differences with regards to views on the world of 2050 and the chemical industry within it. The present Delphi report summarizes alignments as well as contrasts and discusses possible implications as further input to the ongoing MCS process.

Based on the statistical data obtained, CIFS found a high degree of alignment between the Delphi results and the preceding foresight study describing the world in 2050 (Fig. 8, page 16). For **67%** of all

questions linked to an assumption, there were alignment between the Delphi outcome and the underlying assumption, while only 3% of the Delphi outcome revealed mis-alignment with the underlying assumption. For a sizeable group of questions (24% of the total) the Delphi outcome reflected a mixed picture and therefore requiring further discussion and interpretation.

Purpose and Methodology

Why use a Delphi method?

A Delphi study is a futures study method designed for strategic foresight, when dealing with complex areas with a high degree of uncertainty. Studying the long-term future, which is naturally shrouded with uncertainty, the Delphi method provides orientation on potential risks and opportunities based on knowledgeable experts' assessments.

Historically, the Delphi method was developed to assess long-term future developments when statistically based forecasts and projections are deemed insufficient. Based on personal assessments and perspectives of relevant subject matter experts, a Delphi study aims to explore unidentified tendencies and crucial long-term developments beyond data-driven insights¹. A Delphi survey combines different expert perspectives, but as individual opinions are shown too, potential developments that are not supported by the majority can also be taken into account. Ultimately, a Delphi study normally serves to support decision makers in politics and business in actively shaping the future.

Methodology

The present Delphi study was conducted on an externally hosted digital platform². A total of 1248 selected experts were invited to join the online Delphi study. 287 experts (23%) took actively part in the campaign which lasted from 12 June to 28 June 2018.

The digital platform allowed each participant to see the aggregated overall responses of the entire panel and to read the comments made by other experts, anonymously and in a *real-time* fashion. Participants were encouraged to revisit their answers during the survey for re-evaluation based on the shifting consensus and comments from their peers. As full anonymity was provided, the process was not influenced by the seniority, prominence or dominance of individual experts. The continuous monitoring results and exchange of viewpoint through free-text commenting created a dynamic process during which expert opinions could converge towards a consensus on a given topic.

Consensus was measured in two different ways, depending on the question type. If the question response categories followed a 4-point or 5-point Likert scale³, the consensus measure was calculated as the arithmetic mean. In case of 3-point Likert scale or non-Likert scales the consensus measure was calculated as the majority (i.e. the response with the majority of responses). Correspondingly, group stability (i.e. the strength of the consensus) was calculated differently for the different questions. For 4-point and 5-point Likert scale questions, group stability was measured as the coefficient of variance, while for 3-point Likert scale or non-Likert scale questions was measured as the percentage function (Fig. 1). The consensus threshold was set to 55% for all question. Thus, the group stability measure, whether coefficient of variance or percentage function, needed to exceed 55% in order to meet the consensus criteria.

¹ Aengenheyster et al. (2017), "Real-time Delphi in practice – A comparative analysis of existing software-based tools". *Technological Forecasting and Social Change – Volume 118, May 2017, Pages 15-27*.

² www.calibrium.com.

³ A Likert scale is used to measure respondents' level of agreement or disagreement, e.g. on a symmetric agree-disagree scale.

Figure 1: Consensus and group stability measures

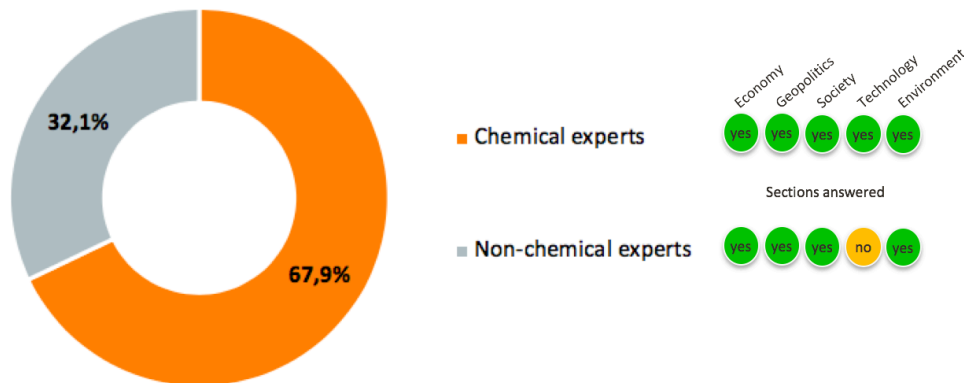
	Likert-scale (4/5-point scales)	Non Likert-scale / 3-point Likert scale
Consensus measure	Arithmetic mean	Majority
Group stability measure	Coeff. of variance $1 - (\text{std.dev.} / \text{mean})$	Percentage () function
Consensus threshold	<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> Consent => 55 % </div> <div style="text-align: center;"> Dissent < 55 % </div> </div>	<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> Consent => 55 % </div> <div style="text-align: center;"> Dissent < 55 % </div> </div>

Composition of the Delphi expert panel

One of the keys to a successful Delphi study lies in the selection of participants since the results of a Delphi depend on the knowledge and cooperation of the expert panellists. In comparison, a questionnaire survey often assumes participants to be representative of a larger population; in a Delphi study, non-representative, knowledgeable persons are needed.

The particular focus of the present Delphi study on the future of the chemical industry warranted a high inclusion of chemical experts into the campaign. Over two-thirds of the respondents (n= 195) had a subject matter expertise in the chemical industry (Fig. 2).

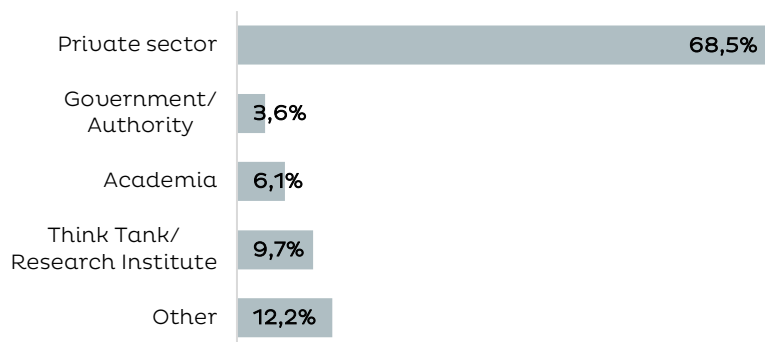
Figure 2: Expert respondents – split between chemical and non-chemical experts



It is important to note that the two different subgroups were presented with different question sets during the campaign. The entire Technology questions section which dealt almost exclusively with questions pertinent to specific technologies, processes, products and other topics in relation to the industry was presented to chemical experts only.

From a sector representation perspective, a large proportion of respondents came from the private sector, whereas the remainder consisted of persons working for - or associated with - governmental agencies/authorities, think tanks and research institutes and other organisations (Fig. 3).

Figure 3: Sectoral and organisational associations of respondents



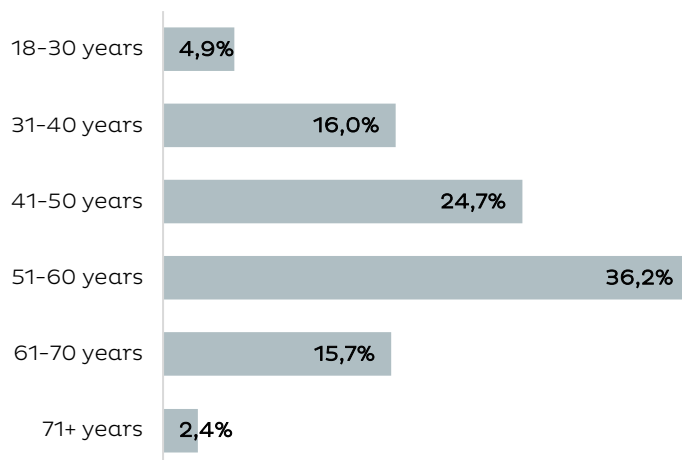
Among the subgroup of non-chemical experts, i.e. respondents with subject matter expertise outside chemistry (n= 92) experts with economic, political, social and environmental as well as technical backgrounds were represented. At the same time, more than 80% of all experts had a Masters or PhD degree. Figure 4 highlights some of the organisations that participants were associated with.

Figure 4: Examples of renowned organisations represented in the respondent crowd



The age-distribution of respondents (Fig. 5) indicated a strong representation of the age cohorts 41 – 50 years (24.7%) and 51–60 years (36.2%). On the one hand, this speaks for the seniority and experience level of the Delphi crowd, but on the other hand a stronger representation of younger age cohorts would have been desirable since many of them will actually still be in their working career in the middle of the century as the time period that concerns the present study.

Figure 5: Age cohort distribution of respondents



With regards to the regional location of the respondents, Europe was by far the strongest represented geography (Table 1). Given the scope of the study which deals with mid-century visions for the chemical industry in Europe, this distribution was to be expected and provides a solid basis. However, a somewhat stronger representation of other geographies could have added more of a global perspective which is important in relation to the geopolitical and environmental question domains. At present, a complete geographical distribution of all invitees (n = 1248) cannot be compiled due to technical reasons.

Table 1: Geographical distribution of respondents

	<i>Absolute numbers</i>	<i>Percentage</i>
Africa	1	0.3%
Asia	7	2.4%
Europe	268	93.4%
North America	9	3.1%
South America	2	0.7%
Total	287	100.0%

How to read the Delphi study results

Delphi results are organized under of the five thematic sections (Economy, Geopolitics, Society, Technology and Environment) and each section preceded by a *1-page summary* which captures the essential insights from the perspective of CIFS (Table 2). The *leading assumptions* used to derive the present Delphi questions are listed after the summaries. Each assumption bears a unique identifier, e.g. 'Tec-A'. The linkage between assumption and 'delphied' questions is indicated: e.g. 'Tec-A: Tec1-7' means that Technology assumption 'A' lead to the questions 'Tec1' to 'Tec7').

Table 2: Where to find 1-page section summaries

Economy	page 19
Geopolitics	page 44
Society	page 52
Technology	page 68
Environment	page 104

For each question, the quantitative survey responses are presented in summary graphs, supplemented with information fields containing *consensus measures*, *consensus status* and *group stability*. An additional information field indicates *alignment of panel response* with the corresponding assumption in the preceding foresight report '*The Chemical Industry in Europe in a 2050 Perspective*'. Delphi Responses could thus fall into three different categories:

1. **in alignment with assumption'** - If the respondents reached a consensus that clearly aligned with the assumption put forward in the preceding foresight study.
2. **'not in alignment with assumption'** - If the respondents reached consensus that clearly did not align with the assumption put forward in the preceding foresight study.
3. **'judgement call'** - If the distribution of responses was mixed; often consisting of one answer that was chosen by a weak majority of respondents (below 55% of all respondents).

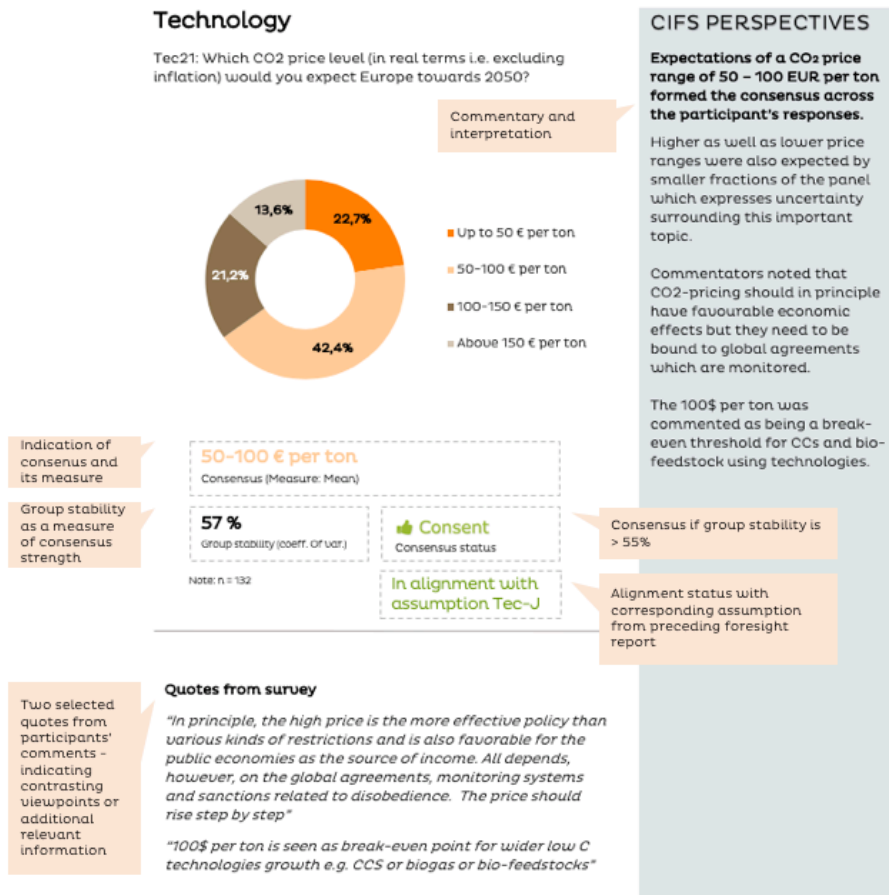
The category 'judgement call' reflected a higher degree of uncertainty among the respondent with regards to a particular future expectation. Or, put differently, an indication of the respondent crowd considering multiple alternative futures as more or less equally likely.

The text panels on the right of each results page summarise CIFS's perspectives and interpretations of findings (Fig. 6). The comments provide perspective on the Delphi results as such but also refer to the foresight report and provide input to the ongoing MCS process.

Selected free-text comments from the respondents are quoted in the bottom section of the page. The quotes were chosen with the intention to highlight certain topics of interest which are discussed under 'CIFS perspectives'. Criteria for comment selection were to exemplify opposing viewpoints or highlighting important information provided by commentators which helped to explain the overall result.

Given the large number of comments received in this Delphi (1373 in total), a comprehensive and exhaustive analysis of these data is desirable since it could reveal additional insights. Sentiment analysis and a closer look at common perceptions might be helpful in relation to the ongoing MCS project.

Figure 6: How to read the response results



Overall Results

Strong engagement

Participation in present Delphi was substantial based on a participation rate of 23%: out of 1248 invitees, 287 engaged actively which is the highest engagement rate in a Delphi conducted by CIFS (Table 3). Dependent upon research topic, target population, population size, and intended scope, the desired response rate varies. According to the survey industry, the average response rate for an external online survey lies around 10–15%.⁴ Hence, a response rate of 23% is rather high and satisfying.

The strong resonance with the invited crowd speaks to the relevance and actuality of the chosen topic. Not only did the topic of the future of the world ‘at large’ in the 2050ies inspire but also the relevance of the chemical industry as a shaping force of that future. The strong appeal of the topics is also reflected in substantial revisiting rates reflecting that a majority of participants took advantage of the Delphi’s real-time features which allows revisits and revisions of answers during the campaign period. Revisits are an important indicator that respondents saw the Delphi as more than ‘just another questionnaire’ – but to a larger extent as a dynamic forum for sharing knowledge, perspectives and opinions.

Table 3: Participation and revisit statistics

		<i>absolute numbers</i>	<i>in percent</i>
Participation	Invited experts	1248	100%
	Participating experts	287	23%
	Participating experts with chemical background	195	68%
	Participating experts with other backgrounds	92	32%
Revisits	Participants revisiting their answers more than 2 times	164	57%
	Participants revisiting their answers more than 3 times	72	25%

Active commenting

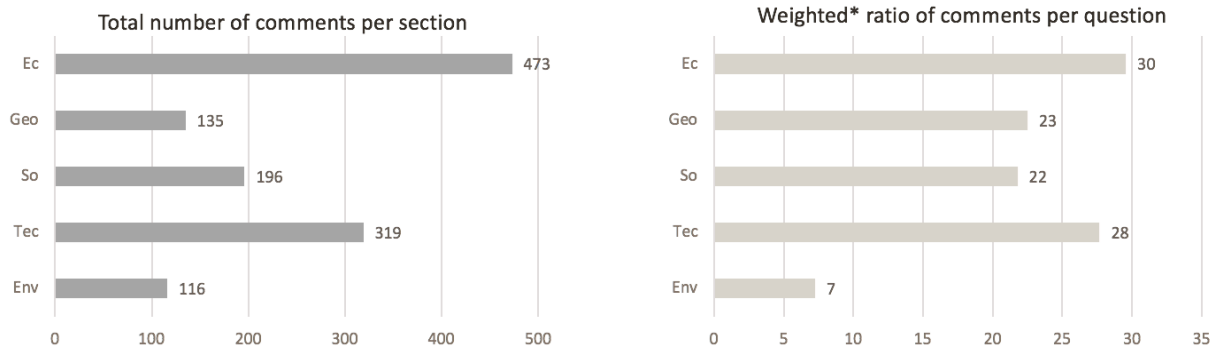
The pronounced engagement was also reflected in the significant commenting activity: Over 1300 over various lengths were entered which speaks to the importance of the Delphi for the participants (Fig. 7). It is a sign of strong interest and identification with chosen positions when respondents make a dedicated effort to argue for their chose answer. Comments were typically explanations and elaborations on the rationale of choosing a specific answer – often providing additional information and knowledge on the topic. This behaviour was consistent with one would expect from true experts in a given field. The high number and richness of comments warrants deeper analysis and data mining which could reveal more insights into participant’s knowledge and thinking. Possibly, sentiment analysis, clustering of key arguments, perspectives and prevailing opinions might serve as useful additional input to the ongoing MCS project.

In absolute terms, the Economy section was the most commented (473 comments), immediately followed by the Technology section (310 comments) which suggested a strong interest of the respondent crowd for these two topic domains. A similar tendency was observed when comparing the *weighted* ratios of comments per question across the sections, i.e. taking into account the number of respondents per section and considering that the Technology section was limited to the 195 chemical experts whereas all other sections where open to all 287 respondents. Questions about economy and technology thus triggered the strongest engagement in terms of commenting with weighted ratios of 30 and 28, respectively. While ‘Geopolitics’ and ‘Society’ were also relatively intensively commented,

⁴ <https://www.surveygizmo.com/resources/blog/survey-response-rates/>

the environmental section received markedly fewer comments per question which could suggest a survey fatigue effect.

Figure 7: Commenting statistics



*'weighted' means weighted by number of respondents per section.

An overview of the top-3 most commented questions in each section did not suggest a link between number of comments and the assumption alignment status of the results (Table 4). The numbers of comments appeared to be evenly distributed across the three result categories ('in alignment', 'not in alignment' and 'judgement call') which suggested a diversity of motivations for posting comments. Markedly increased number of comments as in the case of Soc6 (157 comments) reflected a very high proportion of single-word comments such as 'yes'. As indicated in the Detailed Results section, not all questions were open for commenting. This was the case for questions that were asked to elucidate preferences rather than taking a position.

Table 4: Top-3 commented questions in each section

Section	Question	Number of comments	Results alignment in assumptions
Economy	Ec5 How will the relocation of production closer to consumption affect trade?	56	Yes
	Ec3 Africa will escape the commodity trap and account for a significantly larger share of global GDP by 2050	51	Yes
	Ec2 India will become the second largest economy in the world by 2050	50	No
Geopolitics	Geo1 Towards 2050, do you believe that the EU continues to further integrate and strengthen itself as a political, economic and social union?	57	Judgement call
	Geo2 Towards 2050, how would the European economy be affected by moving from a global world to a multi-polar world?	29	Yes
	Geo3: Towards 2050, is it likely that European chemical producers will see more competition over access to critical resources?	22	Yes
Society	Soc6 Towards 2050, there will be shortage of STEM (Science, Technology, Engineering, Mathematics) skills in Europe	157	Judgement call
	Soc3 How will demographic changes impact demand for European chemical products? CONSUMER CHEMICALS	35	Yes
	Soc10 Some institutions opine that by 2050 > 50% of new cars sold could be at least level 4 autonomous (5 being fully autonomous). Power for autonomous cars is believed to be hybrid or fully electrical	18	Yes
Technology	Tec16 In the absence of a global market, would empowered consumers, via digital solutions, trigger a global CO2 market, e.g. by avoiding CO2 intensive products?	81	Yes
	Tec8 The chemical industry will use approximately twice as much biomass in 2050 as in 2018	55	Judgement call
	Tec1 To which degree do you expect the European chemical industry to be able to reduce its net greenhouse gas emission by 2050 in comparison to 1990s levels?	24	No
Environment	Env9 Towards 2050, Europe's chemical industry is a major contributor to the safe and sustainable use of chemicals improving the quality of human life in Europe and protecting and improving the quality of the environment?	16	Yes
	Env11 What instruments would be needed to speed up innovation to reach the necessary scale to solve these issues? (select relevant)	15	Yes
	Env14 Do you think the European chemical industry is sufficiently engaged in the societal debate on chemicals in products/wastes?	15	Yes

Strong alignment with assumptions in preceding foresight report

Perhaps the most important finding of the present Delphi was that there was a high degree of alignment between the respondent's answers and the assumptions laid out in the preceding foresight study *'The Chemical Industry in Europe in a 2050 Perspective'*. The collections of leading assumptions from the report which were used to develop the present Delphi questions are listed at the beginning of each detailed result section, right after the executive summaries.

The overall degree of alignment was **67%** with an even higher alignment in the key sections 'Technology' (74%, see Fig. 8). The Technology section comprised the largest number of questions in the present Delphi (n= 34, corresponding to over one third of total). This section constituted a central (core) position in the foresight report because it dealt with vital aspects concerning the future vision of the industry in Europe in particular.

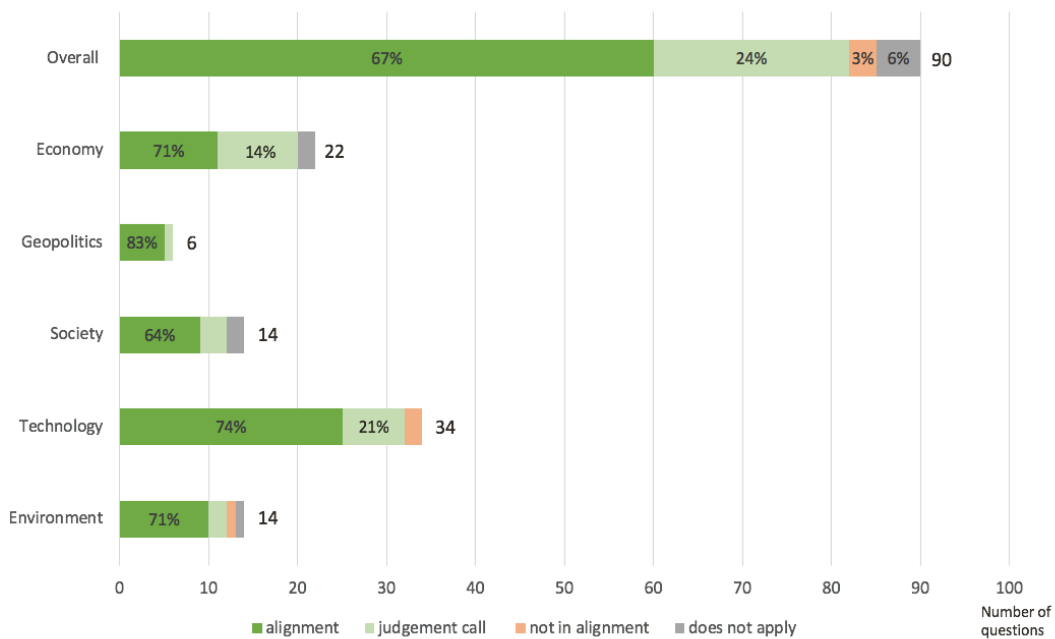
A smaller fraction of questions (24%) generated results which showed a more evenly distributed of answers. In these cases, the interpretation of the results was more of a 'judgement call' – i.e. a matter of differentiated discussion. In nearly all 'judgement call' instances there was a tendency towards

alignment with the underlying assumptions – i.e. typically a majority of answers was in alignment with the underlying assumption – but the majority was below the consensus level of 55% (of all answers given). A commentary for these cases is provided for each response result.

Given the high representation of experts from the chemical industry in the respondent crowd, one needs to be aware of a *potential confirmation bias* especially in the Technology section which was answered only by chemical industry experts. An additional expert group of ‘non-chemists’ with an equally good perspective on the chemical industry as would have been ideal. However, composing such a ‘control group’ would have required substantial additional efforts which would have been incompatible with the overall timeline of the project. However, on the other hand the high alignment observed in the Technology section can be viewed as a positive outcome because it confirmed that the industry shares a common vision with regards to its aspirations.

A small subset of questions (6%) did not relate to underlying assumptions but were asked to provide more granularity and differentiation with regards to the respondents’ perspectives on a certain topic.

Figure 8: Alignment between Delphi results and underlying assumptions from preceding foresight report



Questions with Delphi answer results not in alignment with assumptions constituted a quite small minority. Only **4** questions were answered in a fashion that reflected a consensus in pronounced contrast with the tested assumption. The questions for which this was the case are displayed in Table 5.

Table 5: Overview of Delphi-results not in alignment with assumptions

	Foresight Assumption	Report	Delphi answer results
Tec1: To which degree do you expect the European chemical industry to be able to reduce its net greenhouse gas emission by 2050 in comparison to 1990s levels?	It is expected that the European chemical industry achieves an 85% - 90% reduction		-Only 18.3% share this expectation -44% foresee a 60% - 80% reduction
Tec25: Towards 2050, which advanced technologies are likely to have a significant effect on the future of the chemical industry? NEXT GENERATION FISSION REACTORS	It is opined that next generation fission reactors are an important part of the low-carbon electricity supply to the industry		-37.4% 'Don't know' -32.3% 'Low effect'
Env5: Towards 2050, will we manage to remain at 2-degree temperature increase mark?	It is expected that global warming will not surpass the 2-degree mark		-35.9% 'Highly unlikely' -23.4% 'Unlikley'
Ec2: India will become the second largest economy in the world by 2050	India viewed as the number 2 economy globally by 2050		-55,7% 'No' -44,3% 'Yes'

With respect to the ongoing MCS project these findings should be considered in more depth. In particular with regards to the results to **'Tec1'** (greenhouse gas emissions) and **'Env5'** (global warming) further discussions seem warranted on how to deal with these aspects in the MCS document(s) being developed.

In contrast to the 4 instances of lacking alignment, the top-4 questions with the highest overall alignment are listed in Table 6. These findings reflect that the respondent crowd viewed the topics low-carbon electricity, chemical recycling and working towards a sustainable environment as being of highest importance for a successful and desirable future of the chemical industry in Europe.

Table 6: Overview of top-3 questions with highest overall alignment with assumptions

	Foresight Assumption	Report	Delphi answer results
Tec3: How significant do you assess the contribution of the following technologies for reducing greenhouse emission in the chemical industry? LOW CARBON ELECTRICITY	It is assumed that low-carbon electricity is a key technical condition to achieve emission reduction targets.		-63.0% Highly significant - 26,9% Significant - 1,9% Not significant
Tec34: Towards 2050, which advanced technologies are likely to have a significant effect on the future of the chemical industry? CHEMICAL RECYCLING	It is opined chemical recycling plays a significant role in the future of the industry		-63.0% High effect -29.9% Medium effect - 5.8% Low effect - 1.3% 'Dont' know'
Env1: On a scale from 1-5, to what extent do you believe the European chemical industry can play a leading role in the transition towards a sustainable future?	The chemical industry in Europe will play a substantial role towards an environmentally sustainable future		-51.6% '5' (very high extent) -32.3% '4' (high extent) - 13.5% '3' (medium) - 2.7% '2' (low extent) - 0% '1' (no extent)
Ec1: China will manage its economical transition by 2050	China fully transitioned by 2050		-93.7% 'Yes' -6.3% 'No'

Expert groups shared similar views

Fifty-six (56) questions of the Delphi were open for answering for both expert groups, i.e. the chemical and non-chemical experts. Comparing the response patterns between the two groups revealed only four instances (7%) of statistically significant differences (Table 7). Out of these four instances only one instance of statistically significant disagreement was found which reflects a pronounced different in perspectives (Question Ec11, Table 7). Non-chemical experts opined that the effect of the European regulatory environment will increase the competitiveness of the chemical industry while the chemical experts tended to think the opposite.

Table 7: Comparison of question results with statistically differences between the two expert groups

Question	Chemical experts' responses	Non-chemical experts' responses	Responses as expression of different views?
Ec4: The Fourth Industrial Revolution is likely to affect trade in goods and move production closer to consumption	66.9% Strongly agree/agree	48.3% Strongly agree/agree	Same view
Ec11: How will the European regulatory environment affect European companies with regards to: COMPETITIVESS	41.4% Decrease competitiveness	50.6% Increase competitiveness	Opposite view
Ec13: How will the European regulatory environment affect European companies with regards to: INVESTMENT	44.2% Create incentives...	60.2% Create incentives...	Same view
Enu9: Towards 2050, Europe's chemical industry is a major contributor to the safe and sustainable use of chemicals improving the quality of human life in Europe and protecting and improving the quality of the environment	92,3% Strongly agree/agree	84,6% Strongly agree/agree	Same view

Economy - results

Summary

- Respondents believed that China would manage their economic transition, while India and Africa will struggle (Ec-A*)
- Respondents did not align with the assumption of India as the number 2 economy as presented in the preceding foresight study (Ec-A)
- Chemical experts were more likely to believe that the Fourth Industrial Revolution will have significant impact on global supply chains than non-chemical experts (Ec-B)
- Respondents opined that primary goods trade will be growing in importance, while finished goods will be decreasing in importance (Ec-B)
- In general, chemical experts believed that chemical plants will be smaller, and many will be retrofitted for multipurpose production of smaller lot-sizes (Ec-B)
- Respondents were uncertain about the level of protectionism, e.g. tariffs and non-tariff barriers to international trade (Ec-C)
- Panelists tended to believe that technological advancements will drive cost deflation with innovation and new business models being of special importance (Ec-D)
- Respondents were uncertain as to how the regulatory environment will affect European companies in terms of competitiveness and investment (Ec-E)
- However, chemical experts were more likely to think that EU regulations would decrease the competitiveness of the industry whereas non-chemical experts thought the opposite (Ec-E)
- Panelists expected that the European chemical sector will experience net job reduction (Ec-F)
- Respondents opined that education and income distribution would be important mechanisms to address social changes in the EU (Ec-F)
- Respondents tended towards digitization as empowering consumers and limit the market power of dominant players. They debated the degree to which consumers would be empowered (Ec-G)
- Chemical experts believed that the circular economy will bring new business model perspectives and that the European chemical sector will take a leading role in the circular economy transformation (Ec-H)

*Delphi result in relation to assumption 'Ec-A', see next page

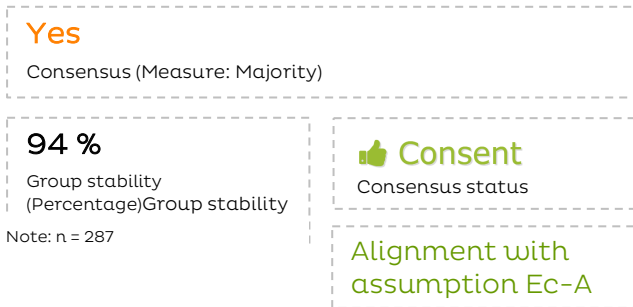
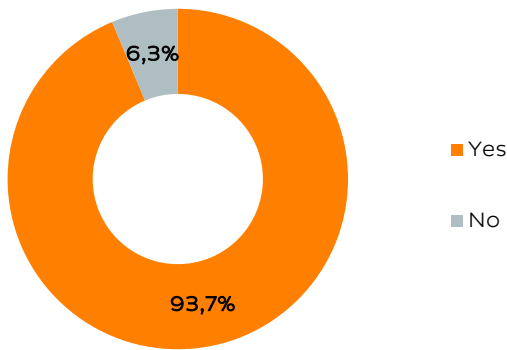
Economy – lead assumptions used for developing Delphi questions

- **Global economic balance shifts as China gains gravity and new growth stems from India and Africa.** China continues transforming from an investment and export- to an import and consumption lead economy. India's economy, contingent on a set of reforms, surpassed Japan growing at a slower pace, to be one the largest. Africa's growth potential is challenged by overreliance on natural resources and inefficient institutions. Trade regionalization is increasingly likely (Ec-A: Ec1-3*)
- **The 4th industrial revolution will affect trade in goods and move production closer to consumption.** Global trade in primary goods will increase on the expense of intermediate and final goods. For the chemical industry, this may mean an increasing importance of finished goods trade in domestic and regional markets and (possibly) a decrease in overseas exports – the likely exemptions being top-competitive, unique products that are not matched by global competition (Ec-B: Ec4-6)
- **Protectionism continues to hamper trade and subdue growth through tariffs and Non-Tariff Barriers (NTB).** NTBs are significantly trade reducing (>15% of the global trade slowdown post the crisis is attributed to NTBs) and accounted for ~80% of all implemented interventions 2008-18, a development led by high income countries. Key instruments are currency manipulation, subsidies and state aid e.g. state loans, bailouts, public procurement localization requirement (Ec-C: Ec7-8)
- **Technological advancements drive cost deflation.** Technological advancements will continue to drive cost deflation in many areas of the economy due to lower production and distribution costs, not least due to better insight in consumer needs. In Europe, this means emerging new business models and fast-moving technological universe, which are conducive of growth in small and medium sized enterprises and partnerships with multinational companies. Deflation will put pressure on producing companies as well as investors fostering further short-term focus, consolidation and cost rather than innovation focus (Ec-D: Ec9-10)
- **The regulatory environment will shape competitiveness.** In 2050, the leading companies are applying transparent platforms, focus on environment, labor conditions, etc., is primarily driven by consumer demands. Europe's strict regulatory environment has driven the Chemical industry in Europe to be first movers, gaining a competitive edge compared to other regions. However, government support for national champions elsewhere, continue to be problematic for creating a level playing field (Ec-E: Ec11-15)
- **The efficiency driven by automation could take 50-60 pct. of manually intensive jobs by 2050.** Mass redeployment will be key in solving the massive changes to the workforce. And while history shows that it is indeed possible, as when industry displaced agricultural manual labour, automation may change the rules of the employment game, especially for low-skill workers (Ec-F: Ec16-19)
- **Network economy will characterize global economy.** Individual consumers' participation in the global economy via widely-reaching platforms (i.e., digital business models) was so cost-effective and advantageous that most other considerations became secondary. The winner-takes-all economy will be increasingly based on business models driven by distributed ledger technology such as blockchain technology, which towards 2050 will deliver more efficient and transparent solutions benefitting users and to a less extent accumulate wealth within few organizations (Ec-G: Ec20-22)
- **Circular economy grows.** Circular economic models grow in prominence within industry; driven in part by innovations in digitalisation of the industry, with AI increasing industry-wide integration (Ec-H: Ec23)

*Assumption 'Ec-A', derived questions 'Ec1', 'Ec2' and 'Ec3'

Economy

Ec1: China will manage its economic transition by 2050



Quotes from survey

(50 comments)

"This is a fragile assumption, but seems to be the most probable outcome in my eyes."

"China will undoubtedly go through an economic transition, but this might be looking very different from what is expected today, especially because of the huge demographic and environmental challenges that it is already facing."

CIFS PERSPECTIVES

Respondents opined that China will manage its economic transition towards 2050

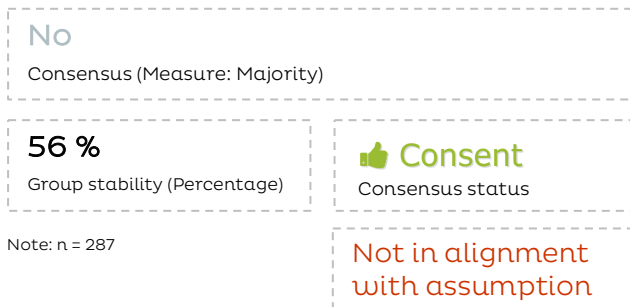
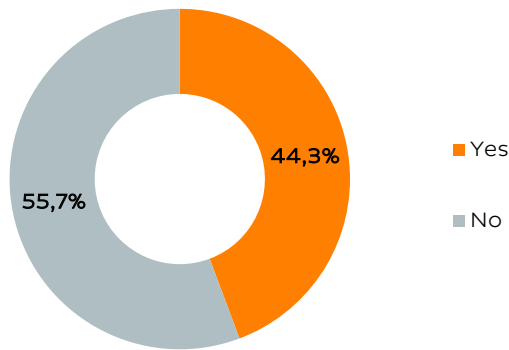
Their comments were however nuanced. Comments pointed towards the need for environmental and social transformation that would enable China to manage its transition.

Comments covered the need for strengthening middle class, improving worker rights, and environmental protection. These will need to be addressed to avoid internal clashes and revolution.

Many pointed to China's education and investment strategy, which could accelerate the transformation.

Economy

Ec2: India will become the second largest economy in the world by 2050



Quotes from survey

(54 comments)

“While India is very populous the political and physical infrastructure is not well structured to support the rate and extent of change necessary to deliver this goal.”

“Many reports indicate that India’s GDP would exceed US GDP in purchasing power parity terms by 2040. This would make India the largest economy in the world after China by 2050.”

CIFS PERSPECTIVES

Respondents disagreed with the assumption in the “Chemical Industry in Europe in a 2050 Perspective” study.

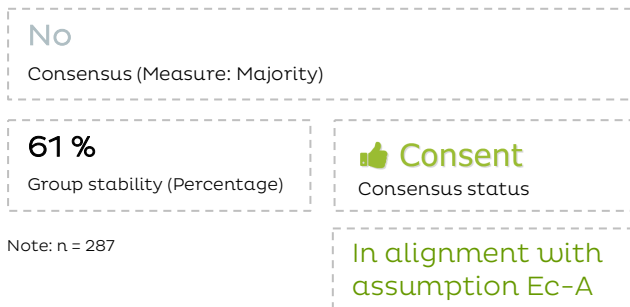
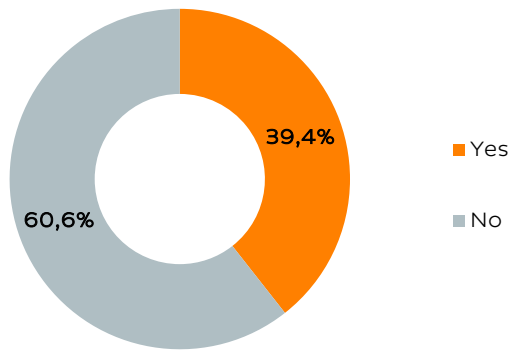
This topic generated more debate than the question, Eco1, concerning China.

Many of the comments pointed towards uncertainty and included words like “maybe”.

Comments often point towards political corruption, chaotic processes, caste systems, weak infrastructure, and pollution.

Economy

Ec3: Africa will escape the commodity trap and account for a significantly larger share of global GDP by 2050



Quotes from survey

(57 comments)

"Don't believe that Africa will escape trap in such low window period regarding current geopolitical situation. Fundamentals will be in education first to build on a better perspective for Africa region. Cohesion & unity will be the starting point to this journey. However, I think that they'll be room for GDP increase, just does not see how today, with current institutions, it can shift from growth to significant growth."

"It will have a larger share of the global GDP, but 'significantly larger' implies deep structural transformations which I don't see happening, and which need time to reach their cruising speed"

CIFS PERSPECTIVES

Even more respondents were bearish on African continent's ability to escape the "commodity trap" and account for a greater share of GDP by 2050

Respondents engaged in a strong debate over this topic.

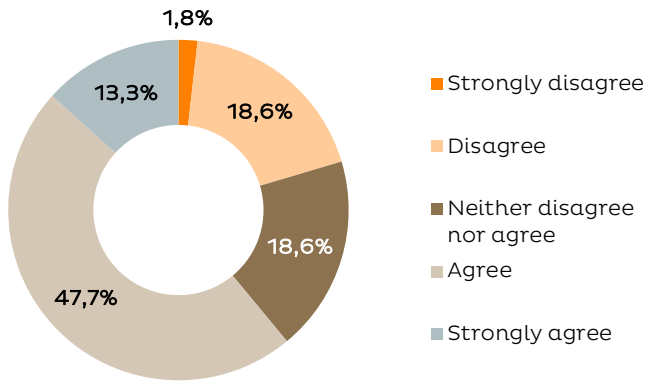
Some pointed to regional and national differences, pointing out that some regions would make the transition while others would not.

Others pointed a strong entrepreneurial culture and reverse innovation (e.g. mobile digital payments).

Several pointed to population growth, corrupt institutions, a new wave of colonialism from China and India, poor infrastructure and climate change as impacting Africa's growth potential.

Economy

Ec4: The Fourth Industrial Revolution is likely to affect trade in goods and move production closer to consumption



Agree

Consensus (Measure: Mean)

72 %

Group stability (coeff. Of var.)

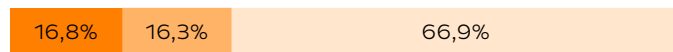
Consent

Consensus status

Note: n = 279. Statistically significant difference (95% level) between chemical experts and non-chemical experts

In alignment with assumption Ec-B

Chemical experts



Non-chemical experts



■ Strongly disagree/disagree
 ■ Neither disagree nor agree
 ■ Strongly agree/agree

Quote from survey

No comments to analyze in this section

CIFS PERSPECTIVES

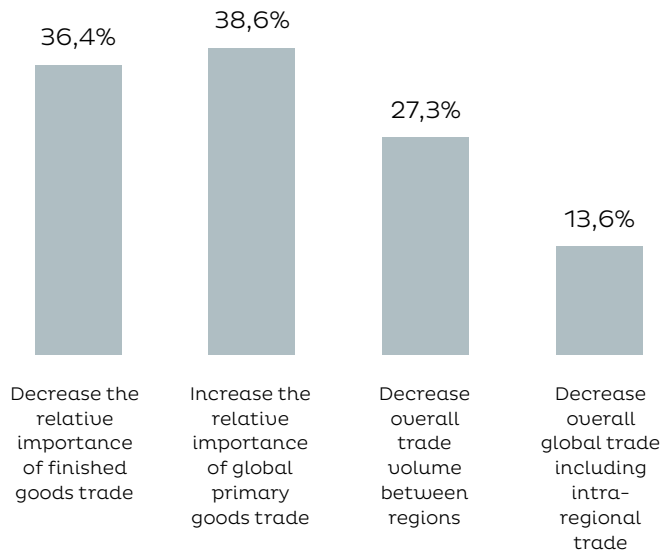
This question was the first to show significant differences among respondents.

Chemical Industry experts and non-chemical industry experts disagreed as to the degree to which the 4th IR would move production closer to consumption.

Economy

Ec5: If you agree or strongly agree to the previous statement:

How will the relocation of production closer to consumption affect trade? [Select all relevant]



Note: n = 44. This question was only posed to non-chemical experts. The total exceeds 100%, as respondents could select multiple options

In alignment with assumption Ec-B

CIFS PERSPECTIVES

Those non-chemical experts who believe in a shift in value chains due to the 4th IR believed that:

- It would shift the relative importance of global primary goods trade
- Decrease the relative importance of finished goods trade
- Decrease trade volumes between regions

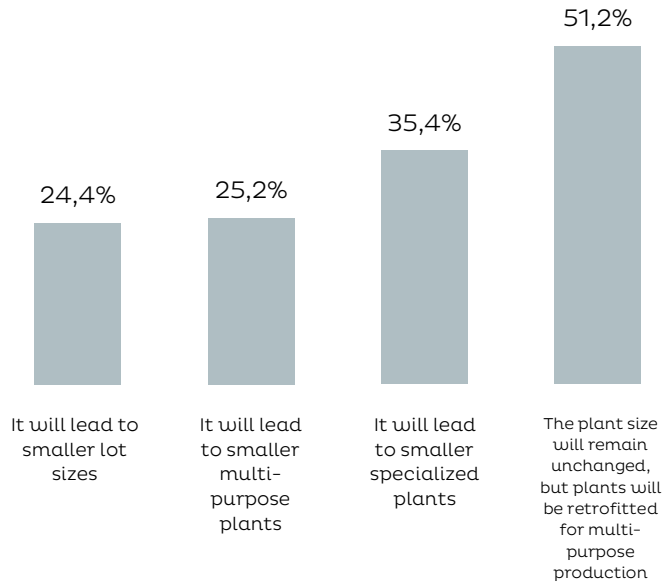
Quotes from survey

The comment option was closed for this question.

Economy

Ec6: If you agree or strongly agree to the previous statement:

How will the relocation of production closer to consumption affect the European chemical industry? [Select all relevant]



Note: n = 127. This question was only posed to chemical experts. The total exceeds 100%, as respondents could select multiple options

In alignment with assumption Ec-B

Quotes from survey

(33 comments)

"The reaction of the industry will be very product specific and lead to a broader diversity of plant types, some specialized and some multipurpose"

"The industry will increasingly be driven by considerations of resource efficiency and re-use. The logistics and costs of closing the resource loop will favour manufacturing remaining close to consumption and the locus of recycling. Energy efficiency derived from scale of operation will, relatively, be of lesser importance economically, particularly as decarbonisation of heat and power proceeds."

CIFS PERSPECTIVES

The chemical experts who believe in a shift in value chains due to the 4th IR mainly believe that it leads to retrofitted plants for multi-purpose production.

However, a significant part of the chemical experts also believe that the development can lead to smaller:

- multi-purpose plants
- smaller lot-sizes
- specialized plants

Chemical experts were much more likely to opine that the 4th IR would move production closer to consumption.

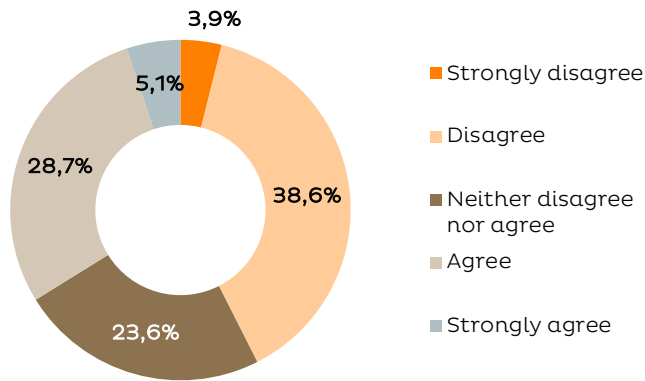
Comments debated as to where in the chemicals value chain the shift would occur.

Comments pointed that the shift would be more likely to occur in specialties over base chemicals.

Many pointed towards the role that the demand for circularity would play in this transition.

Economy

Ec7: Relative to today, international trade will be less subjected to tariffs and non-tariff barriers towards 2050



Neither disagree nor agree

Consensus (Measure: Mean)

65 %

Group stability (coeff. Of var.)

Consent

Consensus status

Judgement call
(Ec-C)

Note: n = 254

Quotes from survey

(59 comments)

"We see currently a wave of protectionism by autocratic leaders (would count president Trump in here). This is however a short-term phenomenon. By 2050 the negative economic impact of trade barriers will have taught protectionist countries a lesson however. The rise of new types of (digital) currencies will also dampen the appetite of states to manipulate their currencies."

"The world will not develop at the same speed to the post-fossil economy and therefore there is a need for even more trade restrictions than today. The fossil ecosystem has huge advantages: it is very cheap, well defined storage, easy logistics, large economy of scale, The post-fossil economy will be more expensive, especially in the transition period and this needs to be protected"

CIFS PERSPECTIVES

Respondents did not reach consensus on whether the global economy would develop in a more protectionist or more direction.

Comments reflect this division.

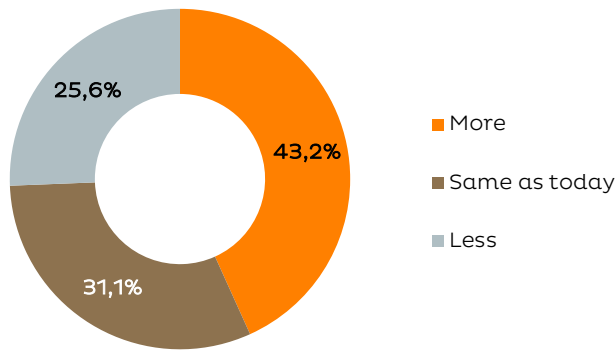
Comments ranged from the current trend towards protectionism is a momentary blip towards this is a long-term trend.

Respondents who believed in protectionism as a long-term trend opined that there will be:

- More regional barriers
- Greater focus on national interests
- Less focus on economies of scale in a post fossil fuel economy
- More protectionism to promote sustainability initiatives and promote new technologies
- More populism and nationalism

Economy

Ec8: Towards 2050, will the economic environment become more or less protectionist than it is currently



More

Consensus (Measure: Majority)

43 %

Group stability (Percentage)

Dissent

Consensus status

Note: n = 273

Judgement call
(Ec-C)

Quotes from survey

(34 comments)

"My wishful thinking is that it will become less protagonist, however this will depend on the result of national elections and trends in policy - today this looks not that optimistic"

"Contingent on how politics in coming years evolve"

CIFS PERSPECTIVES

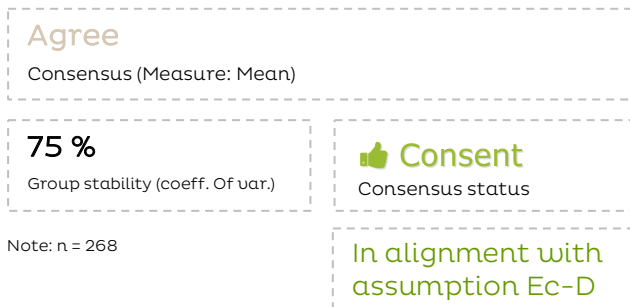
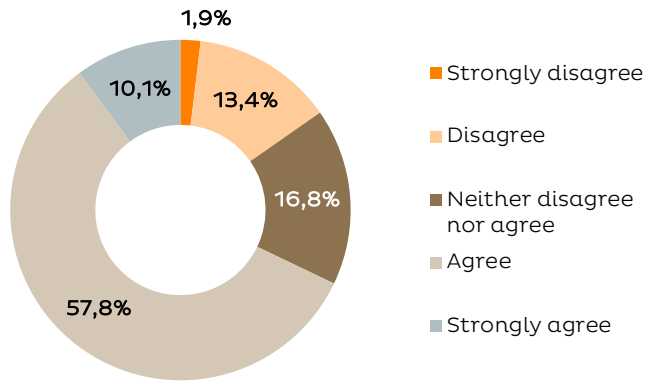
Respondents provide a mixed view as how protectionist the future economic environment could develop towards 2050.

Respondents lean towards the emergence of a more protectionist economy towards 2050.

Comments mirrored those in the previous section and many said "see my comments from above"

Economy

Ec9: Technological advancements could drive cost deflation in many areas of the economy. This will be due to lower production and distribution cost



Quotes from survey

(44 comments)

"We are already in the path for it. Looking back to e-commerce for instance is one of the revolutions which sounds the most obvious over the last 15 years. Think there is still a potential for more, but also how society is dictating customer way of consumption (Netflix vs traditional TV, e-shopping vs downtown shops, ...)"

"Technological advancements might have a cost deflation effect. However, due to environmental targets (emissions, energy transition, circular economy etc.) production routes will be more difficult and raw materials will be more expensive than today. That most probably will equalize to outweigh cost reductions by technological advancements. Distribution costs will stay around what they are today."

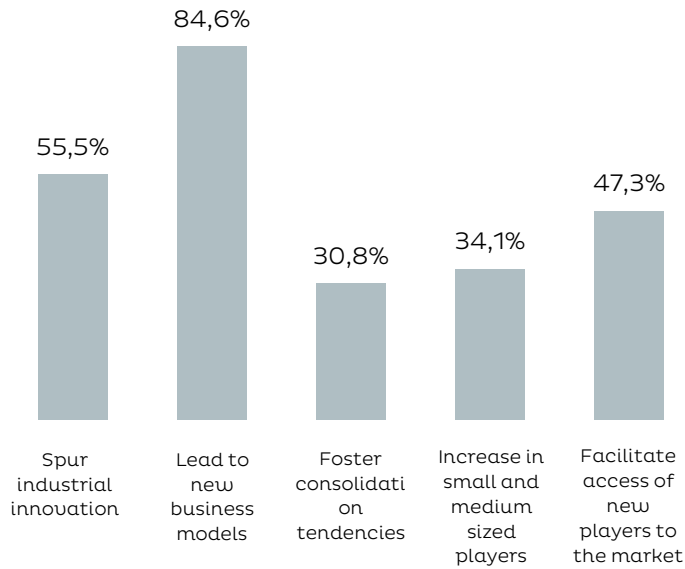
CIFS PERSPECTIVES

Respondents agree with the assumption from the backbone study and opine that technologies would drive cost deflation in many areas of the economy

Comments, however, point towards a more nuanced analysis. Some are concerned about the impacts of resource scarcity, environmental degradation, and geopolitical insecurity that could limit cost deflation effects of technology development.

Economy

Ec10: If you agree or strongly agree to the previous statement:
How will this affect the economy? [Select all relevant]



Note: n = 182. The total exceeds 100%, as respondents could select multiple options

In alignment with assumption Ec-D

CIFS PERSPECTIVES

Respondents opined that technology advancements would lead to new business models, spur industrial innovation, and facilitate access for new players to the market.

Several respondents are concerned with the broader societal implications of technological advancement, including wealth polarization and ability of new players to take on established tech giants.

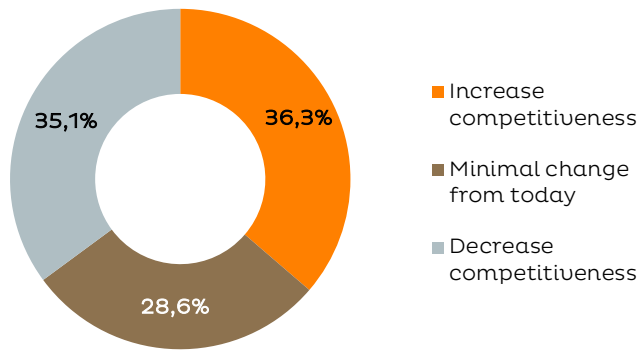
Quotes from survey

“The key question is what happens to the cost savings... are they passed on to the end consumer or do prices remain high to maximize profits? But all of the above will happen”

“Frankly more concerned with the increase in wealth inequality”

Economy

Ec11: How will the European regulatory environment affect European companies with regards to: COMPETITIVENESS



Increase competitiveness

Consensus (Measure: Majority)

36 %

Group stability (Percentage)

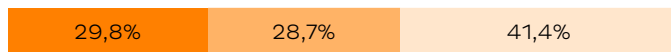
Dissent

Consensus status

Note: n = 262. Statistically significant difference (95% level) between chemical experts and non-chemical experts

Judgement call (Ec-E)

Chemical experts



Non-chemical experts



■ Increase competitiveness
 ■ Minimal change from today
 ■ Decrease competitiveness

Quotes from survey

(26 comments)

“With regard to competitiveness, it would be important to work towards global agreements / level playing field at the same time to ensure competitiveness.”

“The EU is a private sector job destruction machine - will the people allow the EU to still exist in 2050, there are already today strong popular movements against the EU in most member states”

CIFS PERSPECTIVES

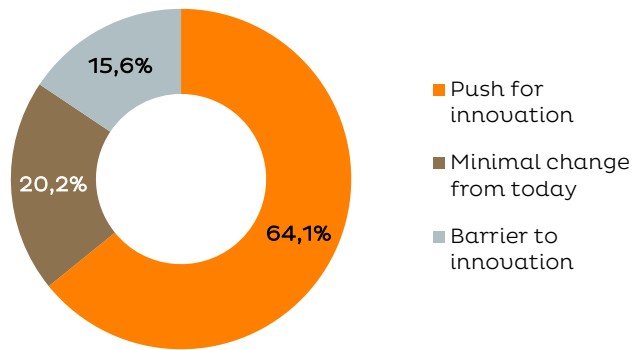
The overall view from respondents was mixed. However, when analysing differences among chemical and non-chemical experts, significant divergence was recognized.

A slight majority of non-chemical experts opined that Europe's regulatory environment would increase the chemical industry's competitiveness – while less than a third of chemical industry experts thought the same.

Comments varied from EU companies have benefited from the regulatory regime and will continue to do so to companies will seek areas of operations where they can maximize margins.

Economy

Ec12: How will the European regulatory environment affect European companies with regards to: INNOVATION



Push for innovation

Consensus (Measure: Majority)

64 %

Group stability (Percentage)

Consent

Consensus status

Note: n = 262

In alignment with assumption Ec-E

CIFS PERSPECTIVES

Both chemical and non-chemical experts believe that the EU regulatory environment will drive innovation.

This highlights the importance of innovation and the fact that innovation and regulation are viewed as interdependent.

Quotes from survey

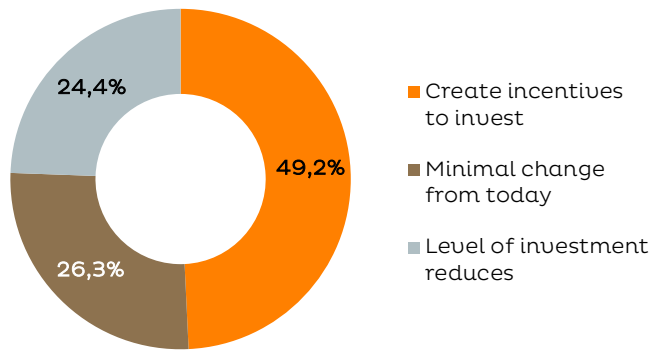
(26 comments)

“Standardization by regulation detracts from innovation and competitive advancement.”

“Comparatively stricter regulatory environments will decrease competitiveness initially, but as businesses and researchers respond by inventing ecologically benign materials, processes, and products in response, competitiveness will rise as European innovators create new markets and take the lead in established markets”

Economy

Ec13: How will the European regulatory environment affect European companies with regards to: INVESTMENT



Create incentives to invest

Consensus (Measure: Majority)

49 %

Group stability (Percentage)

Consent

Consensus status

Note: n = 262. Statistically significant difference (95% level) between chemical experts and non-chemical experts

Judgement call (Ec-E)

Chemical experts



Non-chemical experts



■ Create incentives to invest
 ■ Minimal change from today
 ■ Level of investment reduces

Quotes from survey

(26 comments)

"Innovations may take place in EU, but the actual investments will take place elsewhere in the world where there is less regulatory pressure and more incentives to invest"

CIFS PERSPECTIVES

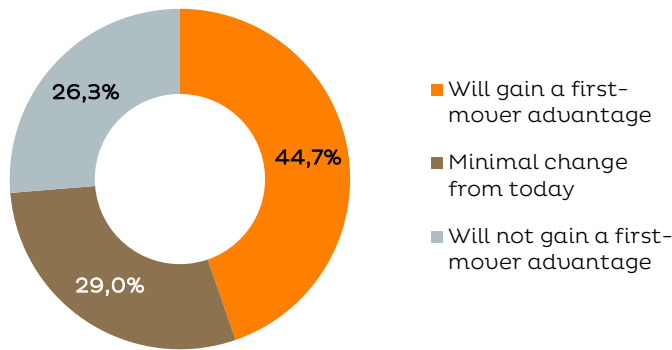
This another question where chemical and non-chemical experts differed in their opinions on how the regulatory environment will shape investments

Non-chemical experts were more likely to suggest that the EU's regulatory environment would create incentives to invest. Less than half of the chemical experts thought so.

There were few comments related to this question compared to other two regulatory questions (Ec11-13).

Economy

Ec14: How will the European regulatory environment affect European companies with regards to: FIRST-MOVER ADVANTAGE



Will gain a first-mover advantage

Consensus (Measure: Majority)

45 %

Group stability (Percentage)

Dissent

Consensus status

Note: n = 262

Judgement call
(Ec-E)

Quotes from survey

(26 comments)

“If anything, Europe tends to suffer from the first mover disadvantage”

“Assuming the tax system evolves towards one that supports sustainability (higher taxes on energy and materials, lower taxes on labour), otherwise environmental sustainability leads to a first mover disadvantage, creating a bind...”

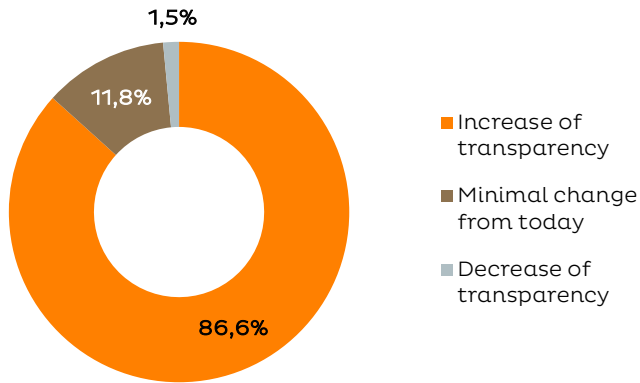
CIFS PERSPECTIVES

Chemical experts did not reach consensus as to whether the regulatory environment created a first mover advantage or not.

Analysis of the few comments that related to first mover advantage found that it was typically seen as a disadvantage unless supporting regulatory practices were in place.

Economy

Ec15: How will the European regulatory environment affect European companies with regards to: TRANSPARENCY OF CHEMICAL CONTENT



Increase of transparency

Consensus (Measure: Majority)

87 %

Group stability (Percentage)

Consent

Consensus status

Note: n = 262

In alignment with assumption Ec-E

Quotes from survey

(26 comments)

“Transparency is a delicate balance between openness to spur innovation and transparency for the sake of transparency (with its paper efforts) while the end-consumer does not really care”

“Transparency and traceability create additional costs for bureaucracy and consumers are not willing to pay for it.”

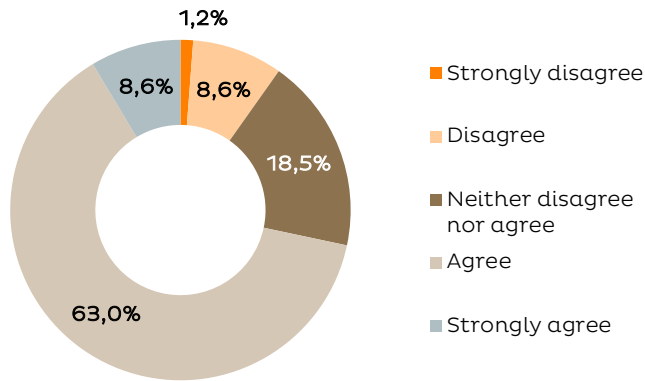
CIFS PERSPECTIVES

Respondents opined strongly that the European regulatory environment would lead to greater transparency of content.

The few comments that addressed transparency question whether consumers really care enough to cover the cost.

Economy

Ec16: Increasing levels of automation could affect 50-60 percent of jobs by 2050



Agree

Consensus (Measure: Mean)

78 %

Group stability (coeff. Of var.)

Consent

Consensus status

Note: n = 81. This question was only posed to non-chemical experts

In alignment with assumption Ec-F

CIFS PERSPECTIVES

There was a consensus in the Delphi panel regarding automation of jobs.

Most comments further elaborated that new jobs would likely be created

Many pointed towards the need for education to help workers prepare

Quotes from survey

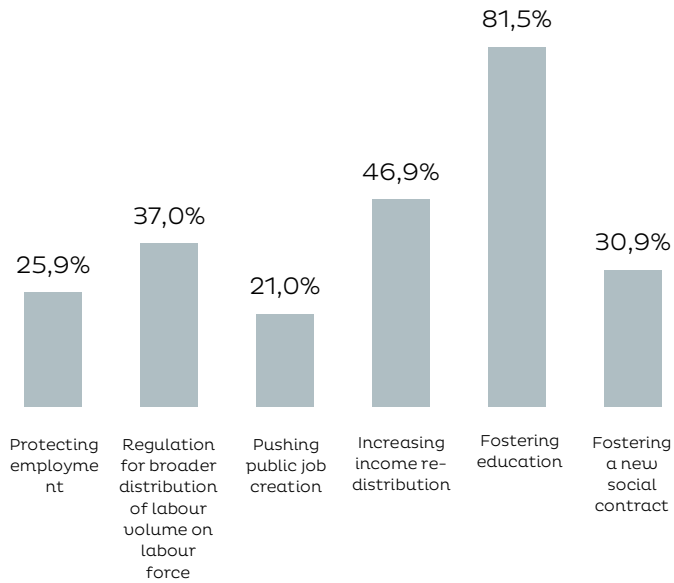
(16 comments)

"More than "traditional" automation by robots in production lines, the current fast and exponential development of AI and its applications will be a game changer also for future jobs"

"Depends what the question is asking - if existing jobs then probably yes. However as with all developments since the industrial revolution there will be a transition to different jobs"

Economy

Ec17: Which measures will the EU use to address social changes? [Select all relevant]



Note: n = 81. This question was only posed to non-chemical experts. The total exceeds 100%, as respondents

In alignment with assumption Ec-F

CIFS PERSPECTIVES

Respondents focused on the following solutions:

- Fostering education
- Increasing income redistribution
- Regulation for broader distribution of labour volume and force

Quotes from survey

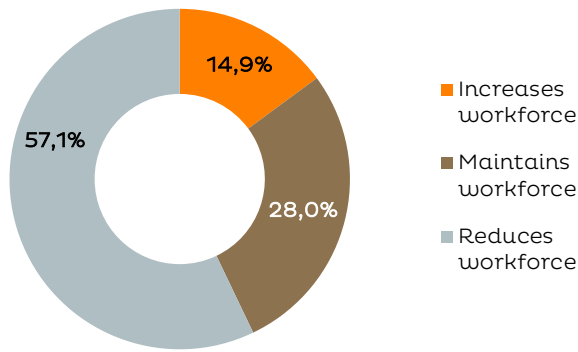
(5 comments)

"They will follow the path of least-resistance policy-making, which suggests proposing policy similar to current characteristics of European economic culture, i.e., shorter work weeks, shorter work days, longer vacations."

"It is important that mechanical slaves do not create the conditions for human misery. Jobs for life are impractical in a changing environment, but income for life and employment for life are not."

Economy

Ec18: In the digitalized world, will the European chemical industry be a smaller or bigger employer than today?



Reduces workforce

Consensus (Measure: Majority)

57 %

Group stability (Percentage)

 Consent

Consensus status

Note: n = 168. This question was only posed to chemical experts

Judgement call
(Ec-F)

Quotes from survey

No comments to analyse in this section

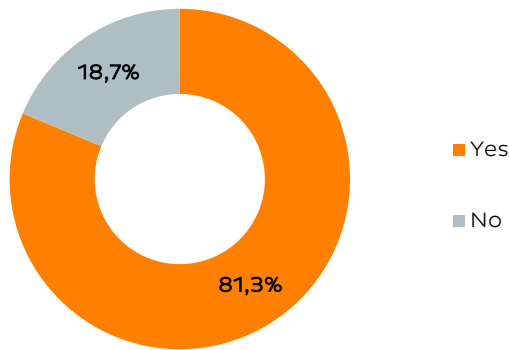
CIFS PERSPECTIVES

Chemical experts believe that there would be a net-reduction in the workforce towards 2050.

This finding points to the importance of new employment strategies, HR development and talent recruitment for a smaller workforce.

Economy

Ec19: In the digitalized world, will the job profiles within the European chemical industry be significantly different than today?



Yes

Consensus (Measure: Majority)

81 %

Group stability (Percentage)

Consent

Consensus status

Note: n = 166. This question was only posed to chemical experts

In alignment with assumption Ec-F

Quotes from survey

(31 comments)

"We are at the brink of a revolution in material science, there is a big demand for new materials that solve currently unsolvable problems. The lack of true chemical innovation in the past 20 - 30 years has made some people believe that this will be the state forever. A converted chemical industry attracts a different type of people, more innovative - this will automatically cause traction"

"IT is dominating factor in our industry. Means, less craftsmen will be needed in production, as automation will further increase. Well-skilled people, able to manage change and being creative, will be still asked to serve, but less skilled people will be not needed at the same amount as of today"

CIFS PERSPECTIVES

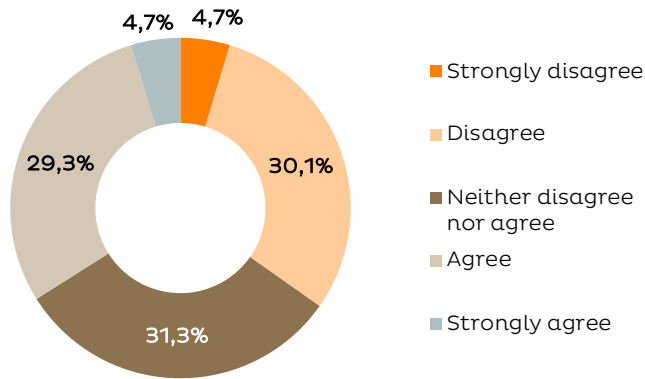
Chemical experts strongly opined that job profiles would be significantly different in 2050 compared to today

They debated as to where the job profiles would shift: up- vs. downstream, front-office vs. back-office, and vs. geography.

Many believed maintenance and other blue-collar work would be more affected.

Economy

Ec20: Towards 2050, individual consumers participation in the global economy via wide-reaching digital platforms and business models is expected to be cost-effective and advantageous. As a result, most other concerns regarding digitalization and market power of dominant corporations have become secondary



Neither disagree nor agree

Consensus (Measure: Mean)

67 %

Group stability (coeff. Of var.)

Dissent

Consensus status

Note: n = 256

Judgement call
(Ec-G)

Quotes from survey

(34 comments)

"They'll co-exist"

"The thrust to gain market power is fundamental to the capitalist system - only the means change. Digitisation is likely to become one of, or even the most, powerful means by which this will be manifest in future. That is not to say that other threats of market abuse can be dismissed as being of no consequence"

CIFS PERSPECTIVES

The respondents could not reach agreement as to whether digital platforms would play a dominant role in organising value creation and displacing organisations.

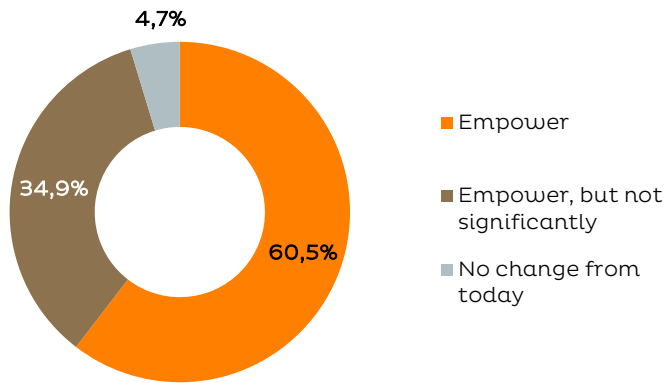
Among those who commented, comments trended towards those who thought digitisation would support the concentration of power.

This was either due to the weaknesses of distributed ledger technologies, the ability of companies to dominate key technologies, or due a disbelief in the viability of non-centralised networks.

Economy

Ec21: If you agree or strongly agree to the previous statement:

Do you believe that digitalization (e.g. distributed ledger technology) will empower consumers?



Empower

Consensus (Measure: Majority)

61 %

Group stability (Percentage)

Consent

Consensus status

Note: n = 86

In alignment with assumption Ec-G

Quotes from survey

(10 comments)

“Consumers will be empowered because they will have easier access and more transparent information with relation to the products they are buying”

“It will increase the direct relationship between producer and consumer and, to that extent, will certainly increase the absolute power of the user. However, the greater economic benefits are likely to be left in the hands of the producer”

CIFS PERSPECTIVES

Among the participants who agreed with the previous statement, respondents believed that digital platforms would empower.

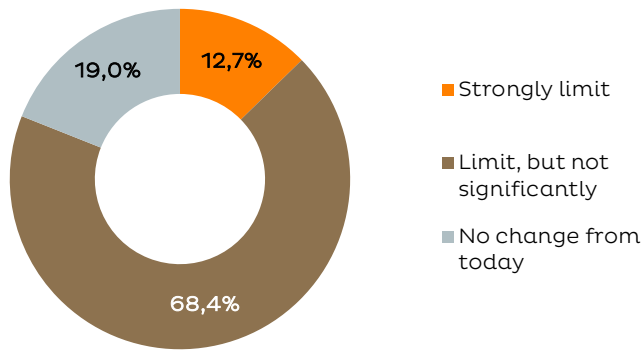
Analysis of comments centred around the differences between empowerment and benefit. While consumers could be empowered, they may not benefit from these technologies.

Some thought that it would increase the direct interaction between producers and consumers. While consumers would gain, it was opined that producers would likely gain more.

Economy

Ec22: If you agree or strongly agree to the previous statement:

Do you believe that digitalization (e.g. distributed ledger technology) will limit the market power of dominant players?



Limit, but not significantly

Consensus (Measure: Majority)

68 %

Group stability (Percentage)

Consent

Consensus status

Note: n = 79

Judgement call
(Ec-G)

Quotes from survey

(9 comments)

"If we look at GDPR, we see that bigger players will be more equipped to deal with this than smaller players. Digital economy is often winner takes all, ergo larger players will be more empowered"

"Consumers will be empowered because they will have easier access and more transparent information with relation to the products they are buying. Following the same rationale, digitalization will limit the market power of dominant players because it will facilitate the customers to have access to more product information. Therefore, the main impact in market dominance will come from innovative and improved solutions rather than due to digitalization."

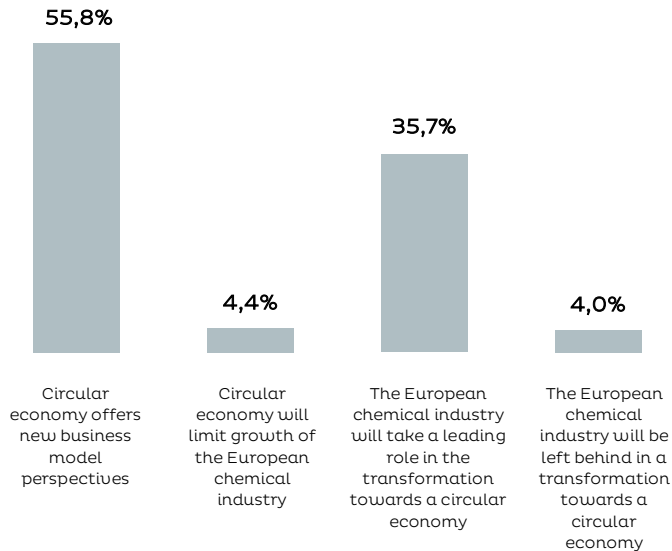
CIFS PERSPECTIVES

While the overall responses believe that the DLT would limit market power somewhat, those who commented tend to be more pessimistic.

Several thought that dominant players would have similar power or even increase from today.

Economy

Ec23: Towards 2050, how will the circular economy impact the European chemical industry?



Circular economy offers new...

Consensus (Measure: Majority)

56 %

Group stability (Percentage)

Consent

Consensus status

Note: n = 249

Judgement call
(Ec-H)

Quotes from survey

(31 comments)

"There is a great deal of chemistry necessary for the circular economy. Product life cycles are likely to shift dramatically - for example in some cases durability may be strengthened, in other cases it may be undermined."

"European chemical industry has the brain-power and the innovation capability to take the leading role. The one important piece of the puzzle that is missing to make it happen, is a legal framework that is flexible enough for innovative ideas to materialize and that acknowledges the fact that recycled and reused material is not the same as virgin"

CIFS PERSPECTIVES

Respondents selected two options as leading the leading implications of the circular economy on the chemicals industry.

The options were:

- Circular economy offers new business models / perspectives
- European chemical industry will take a leading role in the transformation towards a circular economy

Many of the comments saw circular economy as a tool for achieving a more sustainable chemical industry.

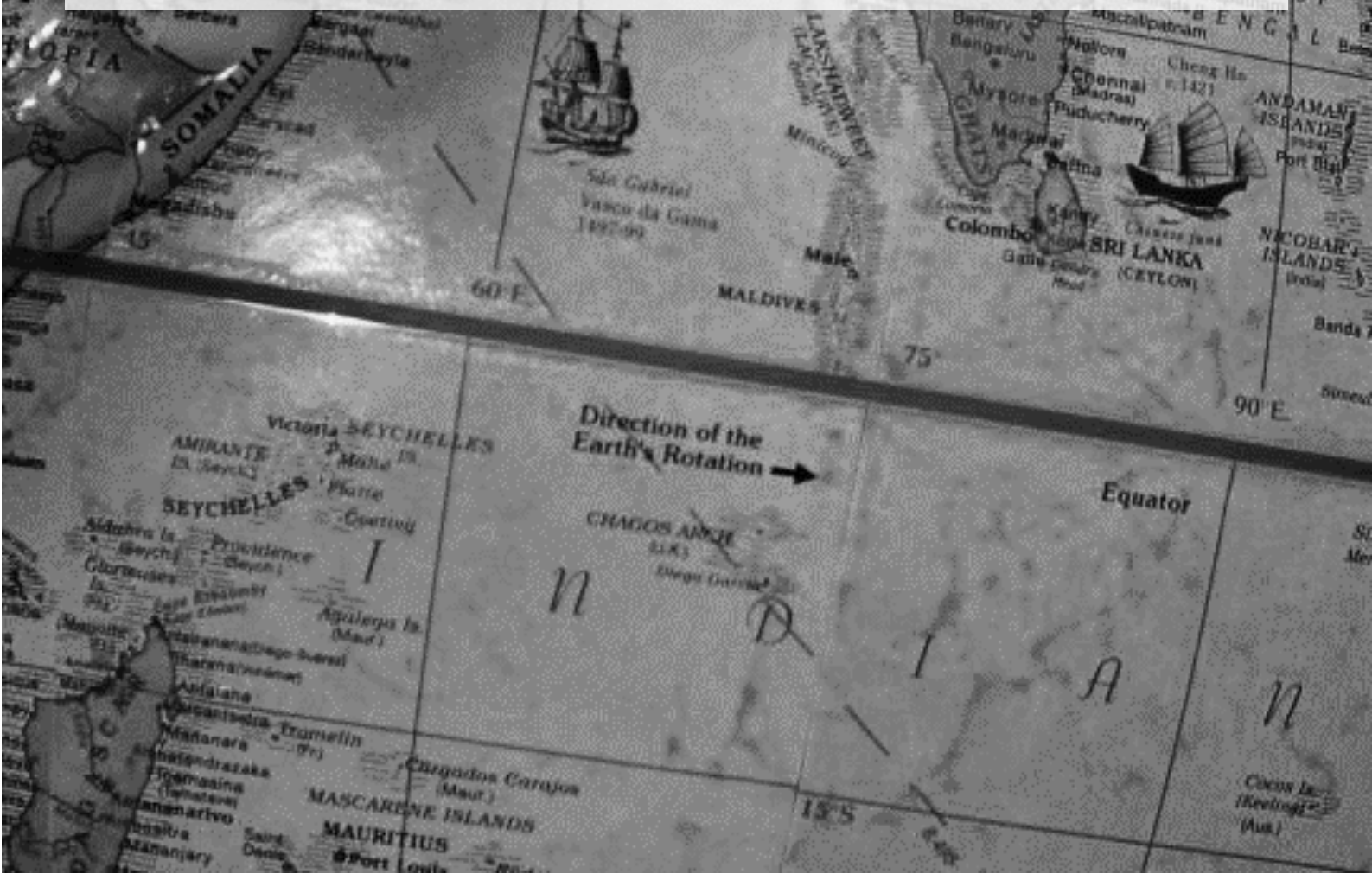
Others were more cynical and argued the concept was a buzzword based "on platitudes disconnected from reality."

Geopolitics – results

Summary

- The Delphi panel expressed uncertainty as to the European Union's further integration as a political, economic and social union (Geo-A*)
- A development towards a multipolar world was viewed as likely and as having largely negative effects on the European economy (Geo-B)
- The respondents recognized that there will be increased competition over access to critical resources for chemical producers in Europe (Geo-C)
- Relatively few participants opined believe that the decoupling between production and raw materials, combined with improved materials use and efficiency due to technological development will be sufficient to meet European sustainability goals (Geo-C)
- A combination of self-consciousness, regulations and attractive resource efficient products will drive sustainable consumption in Europe towards 2050 (Geo-D)
- According to Delphi, participants, sustainable production will mainly be driven by long-term sustainable profits and a supportive regulatory framework (Geo-D)

*Delphi result in relation to assumption 'Geo-A', see next page



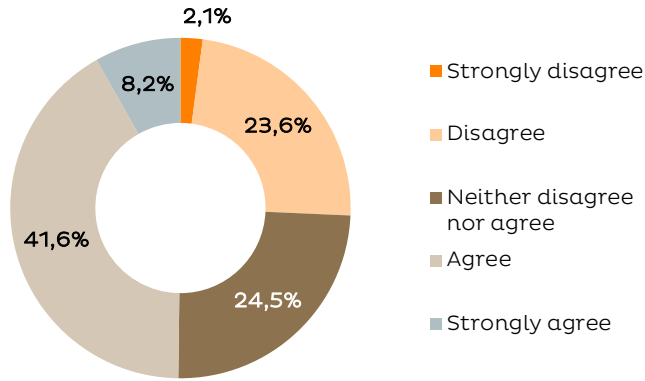
Geopolitics – lead assumptions used for developing Delphi questions

- **Geopolitics will define the business environment for the chemical industries towards 2050**, in light of greater regionalization and ongoing powershifts. The chemical industry will need a strong EU to ensure a coordinated, competitive energy policy, regulatory stability and consistency, open markets and continued access to skills/people mobility, not only ensuring a strong internal market but to also pave the way for equal access to markets and resources in Asia, Africa and the Americas (Geo-A: Geo1*)
- **Four major regional powers protect their own spheres.** China, India, the EU and US will be the four key regional powers each protecting their own spheres of influence. By 2050, no sole guarantor of the international economic and political order will exist. Regulatory frameworks and harmonization across regions will require significant effort and mutual benefits, to succeed (Geo-B: Geo2)
- **Competition over access to critical resources** (energy, materials, food, water, etc.) will raise diplomatic and geopolitical stakes for some, while increasing the leverage for others. Development of alternative material technologies and enhanced input reuse, can aid mitigating the frictions by reducing industry/consumer dependence on scarce resources (Geo-C: Geo3-4)
- **Greater focus on sustainability supports industry and consumer driven tighter regulatory standards and spurs innovation, e.g. bio-based and flexible feedstock.** The emerged geopolitical environment is conducive of technological development to be deployed for recovery and materials reuse, as well as to limit use of raw materials and bringing production systems closer to a circular economy. Such a shift would be an opportunity for the chemicals industry to establish alternative materials manufacturing and reduce their own and consumer's reliance on scarce raw materials (Geo-D: Geo5-7)

*Assumption 'Geo-A': derived question 'Geo1'

Geopolitics

Geo1: Towards 2050, do you believe that the EU continues to further integrate and strengthen itself as a political, economic and social union



Neither disagree nor agree

Consensus (Measure: Mean)

70 %

Group stability (coeff. Of var.)

Consent

Consensus status

Note: n = 233

Judgement call
(Geo-A)

Quotes from survey

(58 comments)

"After some years of centrifuge forces, there will be convergence after some generations... because EU has no other choice"

"Based on the current developments, it can go both ways (either increased integration or disintegration)"

CIFS PERSPECTIVES

Reflects ongoing uncertainty

Responses reflect broader uncertainty as to the future of the EU project in Europe as a whole.

Comments largely pragmatic

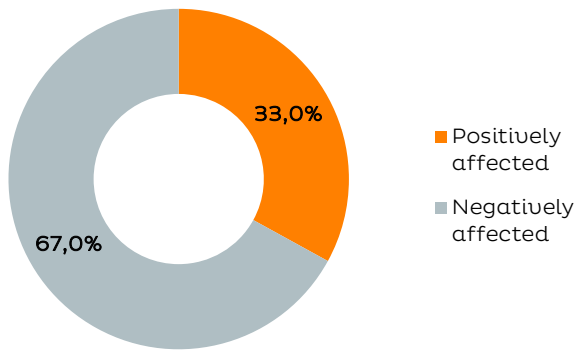
Comments were largely pragmatic in nature, noting that the EU will need to strengthen its collaboration to succeed in multi-polar world.

Many scenarios are possible

Respondents opined that many scenarios are possible, and that the EU may experience disintegration first and then integration later.

Geopolitics

Geo2: Towards 2050, how would the European economy be affected by moving from a global world to a multi-polar world?



Negatively affected

Consensus (Measure: Majority)

67 %

Group stability (Percentage)

Consent

Consensus status

Note: n = 188

In alignment with assumption Geo-B

Quotes from survey

(30 comments)

"We can be positively affected if we recognize the renewal opportunities and shape this multi-polar / segmented world."

"European countries are good exporters - with bilateral trade agreements (for which there is a lot of experience around) they should be able to profit from a less global world."

CIFS PERSPECTIVES

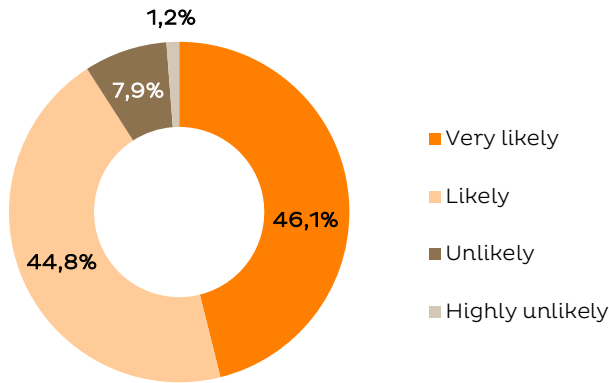
Dependent on if EU can remain together

Over two-thirds believe that the European economy will be affected negatively by the transition to a multi-polar world.

Of the 30 participants who commented, many opined that the Europe Union has been successful in creating good bilateral trade deals and could continue to do so in a multi-polar world – if it is able to maintain coherence and shape future developments.

Geopolitics

Geo3: Towards 2050, is it likely that European chemical producers will see more competition over access to critical resources?



Likely
Consensus (Measure: Mean)

58 %
Group stability (Percentage)

Consent
Consensus status

In alignment with assumption Geo-C

Note: n = 241

Quotes from survey

(22 comments)

“Raw materials scarcity, widespread resources, cost of transport etc. ...will unevenly affect producers (not only chemical by the way!) competitiveness”

“Any industry left in Europe will be almost completely run by robots/computers (lowest cost, highest quality) and has fully closed cycles; from raw material to products; and is completely based on renewable energy. This remaining industry will have a negative carbon footprint and is water usage neutral. There will competition over knowledge and talent.”

CIFS PERSPECTIVES

More competition over access to critical resources

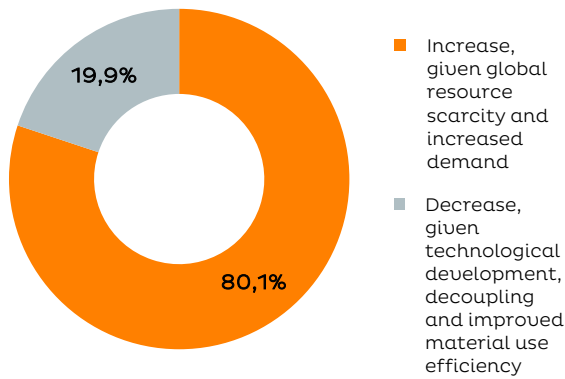
Europe will likely face more competition over access to critical resources

Is dependent upon ability to develop new manufacturing techniques

Respondents noted that this is dependent on how production, distribution and reclamation processes and technologies develop. If chemical producers continue to use similar processes to today’s, the industry will experience resource challenges. If it is able to develop automated processes and smaller scale production using circular production principles, chemical producers will avoid critical resource challenges.

Geopolitics

Geo4: Towards 2050, is it likely that competition over access to critical raw materials will:



Increase, given global resource...
Consensus (Measure: Majority)

80 %
Group stability (Percentage)

Consent
Consensus status

In alignment with assumption Geo-C

Note: n = 171. This question was only posed to chemical experts

Quotes from survey

(13 comments)

“Recycling may offset in part resource demands but global population growth and increases in life style demands will not be matched by technological change”

“Minerals needed for the electrification of life will become the bottleneck.”

CIFS PERSPECTIVES

Competition over resources will increase

The 13 comments that focused on this topic noted that competition would increase.

Where this competition would occur was debated

Chemical experts debated over where in the value chain and in which geographies and economies this competition would occur.

Geopolitics

Geo5: What would drive a shift towards investment in sustainable consumption in the EU? [Select all relevant]



Note: n = 74. This question was only posed to non-chemical experts. The total exceeds 100%, as respondents could select multiple options

In alignment with assumption Geo-D

CIFS PERSPECTIVES

Resource efficiency and regulations drive shift towards sustainable consumption

Non-chemical industry experts saw consumer awareness and regulatory compliance as key to increasing investment in sustainable consumption in Europe.

Quotes from survey

(3 comments)

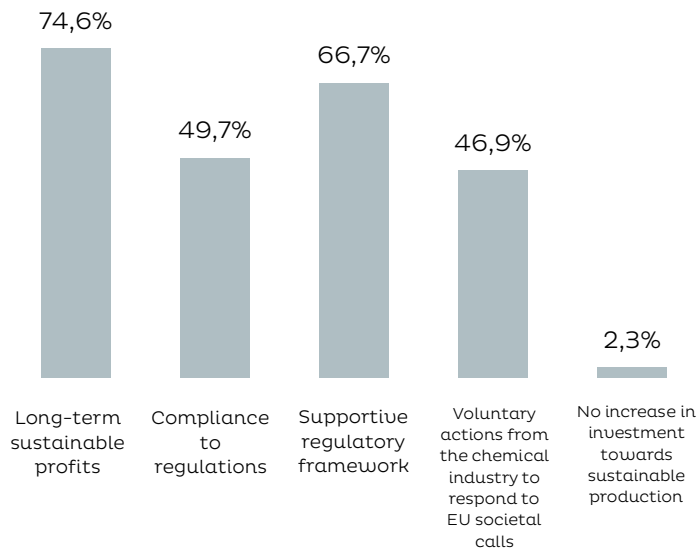
“Pressure from downstream users/end consumers”

“Educational programs need immediately to be instituted about energy of resource extraction and transport as well as efficiency and cost benefits of reuse. The adults and children need to see this clearly.”

“Due to geopolitics, core attention to resources close by and circularity”

Geopolitics

Geo6: What would drive a shift towards investment in sustainable production? [Select all relevant]



Note: n = 177. This question was only posed to chemical experts. The total exceeds 100%, as respondents could select multiple options

In alignment with assumption Geo-D

CIFS PERSPECTIVES

Shift in production drive by long-term profitability and supportive regulatory frameworks

Chemical industry experts recognize that economic viability (largely due to technological progress) will be necessary to drive the change towards more sustainable production.

Quotes from survey

(11 comments)

"This will happen provided profitability can be assured. Without viable economic drivers the rate of change towards sustainable goals will be constrained"

"For example, bio-based polyolefins did not take off due to cost disadvantage. However, if major brand owners demand bio-based plastics due to consumer's demand, the situation may change"

Society – results

Summary

- Delphi participants expected that demographic changes will impact the European chemical industry in different ways (Soc-A*). With respect to future value and volume growth (strengthened growth = 's', weakened growth = 'w')
 - Value growth:
 - (s) Pharmaceuticals
 - (s) Consumer chemicals
 - (s) Specialty chemicals
 - (w) Base chemicals
 - Volume growth:
 - (s) Pharmaceuticals
 - (?) Consumer chemicals
 - (s) Specialty chemicals
 - (w) Base chemicals
- Although respondents leaned towards a future shortage of workers with STEM competencies, there was also uncertainty surrounding this topic. Comments were split as to whether this was a long-term issue or whether market forces, technology development, and migration would solve the challenge (Soc-B)
- Respondents opined that peer-to-peer networks will radically change the way chemicals are consumed, e.g. through new business models and increased transparency regarding chemical content. They were less certain as to the implications on production. Many comments pointed to the high costs associated in production that would keep peer-to-peer solutions on the margins in production (Soc-C).
- Respondents tended towards a 'bullish' perspective on the prevalence of hybrid/electrical autonomous cars; they were 'bearish' on the extent of shared mobility solutions (Soc-D):
 - They expected that these developments will lead to increased substitution of materials. There was, however, much nuance in the comments surrounding this development concerning performance, weight, durability and recyclability.
 - Respondents' consensus view was that this shift will result in a moderate increase in revenues for the chemical industry.

*Delphi result related to assumption 'Soc-A', see next page

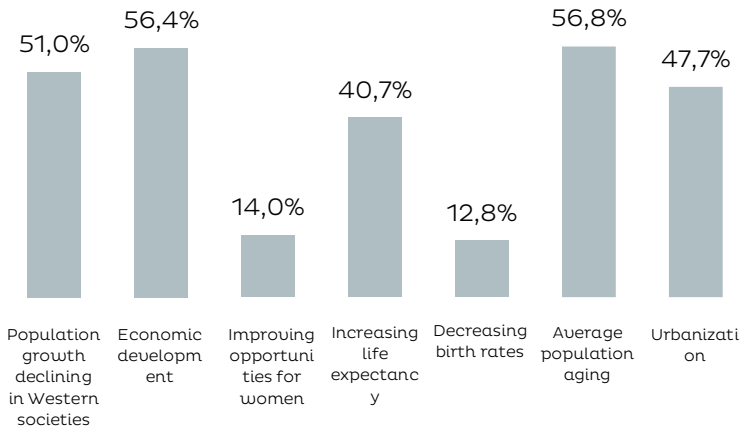
Society – lead assumptions used for developing Delphi questions

- **Demographic transition track globally.** Economic development, growing middle class, technological advancement and transfer, improving opportunities for women, all continue to transform societies, leading the demographic transition towards low birth rates and longer life expectancies. In high income markets, like Europe, the mentioned trends will contribute to holding birth rates under the replacement rate and extend longevity (Soc-A: Soc1-5*)
- **Support to STEM (Science, technology, engineering, and mathematics).** Concerns that Europe will lack an adequate supply of STEM skills will be mitigated by a strong focus on increasing the supply of STEM graduates and attracting more STEM professionals from abroad (Soc-B: Soc6)
- **Peer-to-peer networks.** Technological development has created a strong role for peer-to-peer networks permitting freedom from ownership via short-term rental models through third-party, digital platforms. Crowd-funding of new digital platforms will accelerate their formation and usage (Soc-C: 7-9)
- **Autonomous and shared vehicles have been accepted by consumers and legislators.** By 2040, >50% of new cars sold are expected to be at least level 4 autonomous (5 being fully autonomous). The implications for the chemical industry will be that increased utilization decreases volumes of cars produced and sold. The effect partly off-set by the expected increase in electrical vehicles' share in the global car fleet, which in turn increase demand for materials for the lithium-ion batteries that are vital for the electric car. Such a development creates ample room for the chemical industry to be a vital player (Soc-D: Soc10-14)

*Assumption 'Soc-A': derived questions 'Soc1' to 'Soc5'

Society

Soc1: Which of the following demographic changes would have the most significant impact on the European chemical industry? [Select three options]



Note: n = 243. The total exceeds 100%, as respondents could select multiple options

In alignment with assumption Soc-A

Quotes from survey

(8 comments)

“On a global scale I believe that urbanisation will have the greatest impact on reducing population growth. The other three ticks apply more for the European perspective only.”

“I do not agree on your vision that the middle class will grow in Europe. On the contrary, I see a pauperisation of the middle class and a greater divide between the super-rich 2% and the rest of the population”

CIFS PERSPECTIVES

Population ageing, economic development, and declining population growth

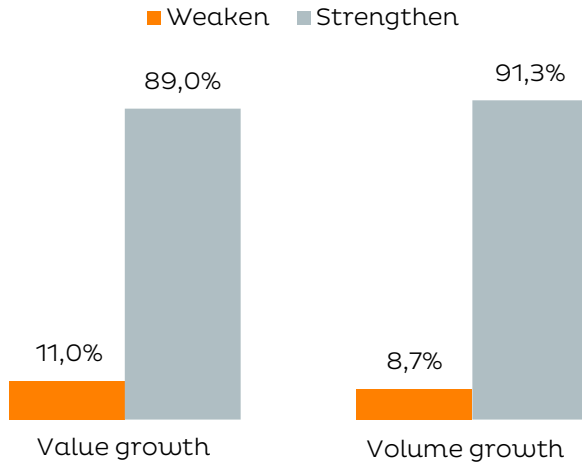
The above demographic transitions will have the largest impact on the chemical industry in Europe according to Delphi respondents.

Demographic developments outside Europe were seen as increasingly important.

Comments point towards developments in middle and low-income markets in Asia and Africa as having greater impacts on the market developments.

Society

Soc2: How will demographic changes impact demand for European chemical products? PHARMACEUTICALS



Strengthen Consensus (Measure: Majority)	Strengthen Consensus (Measure: Majority)
89 % Group stability (Percentage)	91 % Group stability (Percentage)
👍 Consent Consensus status	👍 Consent Consensus status
In alignment with assumption Soc-A	In alignment with assumption Soc-A

Note: n = 237 / 229

Quotes from survey

Comment option was closed for this question.

CIFS PERSPECTIVES

Demographic changes in Europe will lead to greater value and volume growth

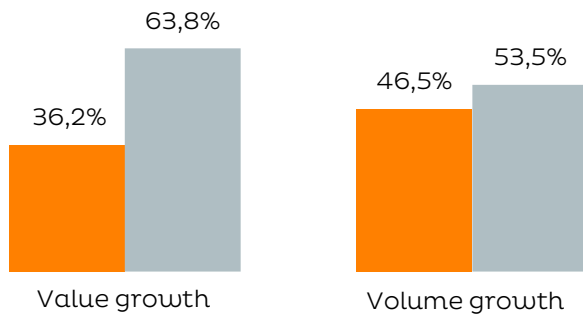
The survey points to a strong consensus on the topic, which reflects analysts' views.

There were no comments to analyse.

Society

Soc3: How will demographic changes impact demand for European chemical products? CONSUMER CHEMICALS

■ Weaken ■ Strengthen



<p>Strengthen Consensus (Measure: Majority)</p>	<p>Strengthen Consensus (Measure: Majority)</p>
<p>64 % Group stability (Percentage)</p>	<p>54 % Group stability (Percentage)</p>
<p>Consent Consensus status</p>	<p>Dissent Consensus status</p>
<p>In alignment with assumption Soc-A</p>	<p>Judgement call (Soc-A)</p>

Note: n = 232 / 226

Quotes from survey

Comment option was closed for this question.

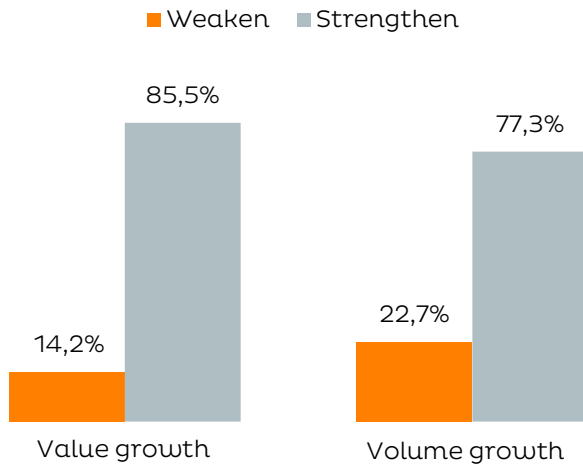
CIFS PERSPECTIVES

Consensus on value growth, but not on volume growth in Consumer Chemicals

Respondents reached a strong consensus concerning expectations for value growth, but did not reach the 55% threshold for volume growth

Society

Soc4: How will demographic changes impact demand for European chemical products? SPECIALTY CHEMICALS



Strengthen Consensus (Measure: Majority)	Strengthen Consensus (Measure: Majority)
86 % Group stability (Percentage)	77 % Group stability (Percentage)
👍 Consent Consensus status	👍 Consent Consensus status
In alignment with assumption Soc-A	In alignment with assumption Soc-A

Note: n = 233 / 220

Quotes from survey

Comment option was closed for this question.

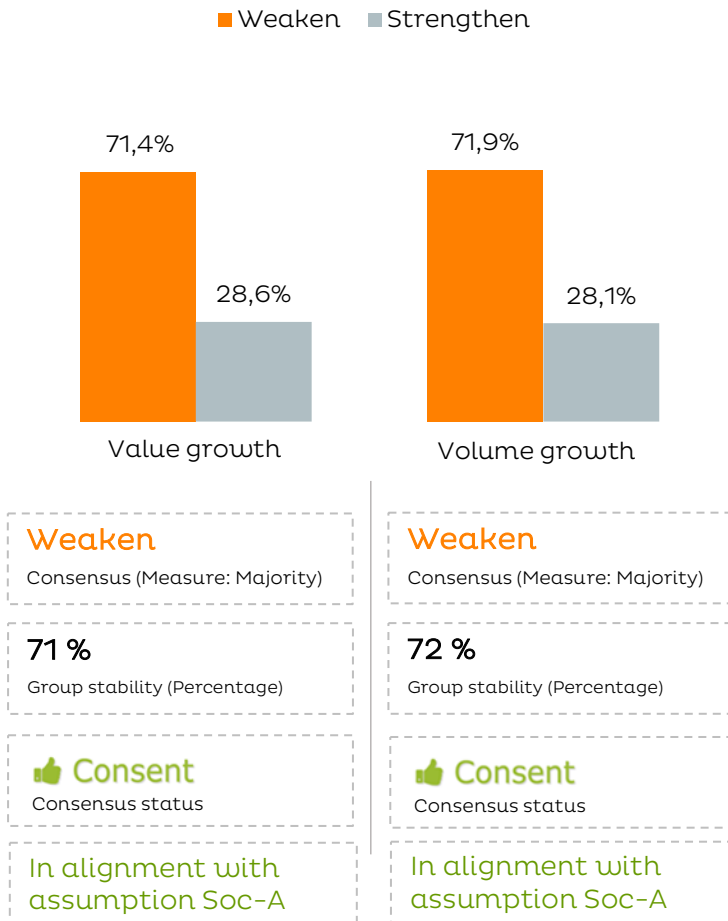
CIFS PERSPECTIVES

Delphi respondents opine both strengthened value and volume growth in Speciality Chemicals

Respondents expect strengthened growth in terms of value and volumes. They more likely to expect stronger growth in values over volume, though.

Society

Soc5: How will demographic changes impact demand for European chemical products? BASE CHEMICALS



Note: n = 231 / 221

Quotes from survey

Comment option was closed for this question.

CIFS PERSPECTIVES

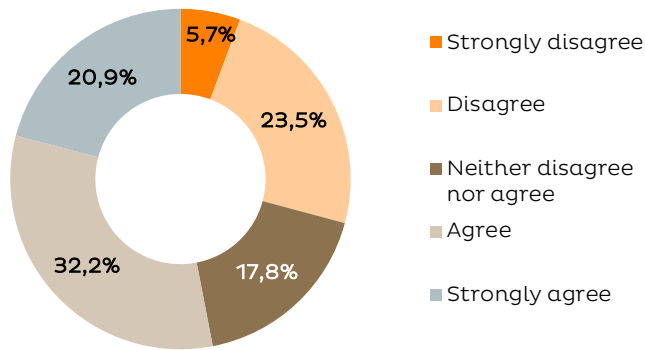
Respondents expect value and volume growth to weaken for base chemicals in European chemical product

Delphi respondents expect value and volume growth to weaken for base chemicals in European chemical products.

Society

Soc6: Towards 2050, there will be shortage of STEM (Science, Technology, Engineering, Mathematics) skills in Europe?

If you agree, can the European chemical industry attract employees with the right skills (STEM)?



Neither disagree nor agree

Consensus (Measure: Mean)

64 %

Group stability (coeff. Of var.)

Consent

Consensus status

Judgement call (Soc-B)

Note: n = 230

Quotes from survey

(157 comments)

"We will have solved this by 2050 by much better STEM education, overcoming bias-driven education of female population, integration of immigrant population into strong educational systems."

"The shortage of STEM skills in Europe is already a fact. Unless drastic measures are taken at EU level, the situation will soon become irreversible."

CIFS PERSPECTIVES

Delphi respondents divided over availability of STEM skills in Europe

While a mathematical consensus was reached in the results, Delphi respondents leaned towards agreeing, but were divided in their feedback as to this question

Comments were split between whether Europe is or is not facing a STEM skills shortage towards 2050

Comments were split 15-14 with a belief that immigration, supply-demand balancing, technology (implants) and government policy would solve the STEM shortage in Europe.

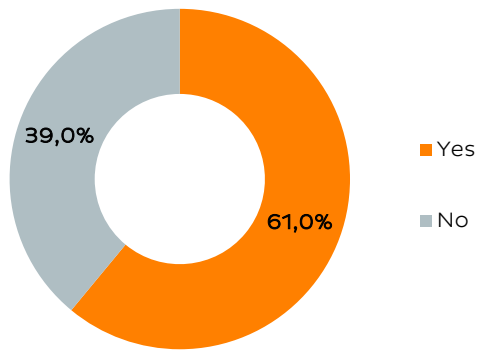
Delphi respondents did believe that the industry could be attractive to employees with STEM skill sets

Comments included "provided a proper plan is made together with ministries of economics and education (so that more people with the required future STEM skills are developed)"

"Options such as 'Green Card' / 'Immigration based on STEM capabilities' need to be explored.

Society

Soc7: Could peer-to-peer networks radically change the way chemicals are produced and consumed?



Yes

Consensus (Measure: Majority)

61 %

Group stability (Percentage)

👍 Consent

Consensus status

Note: n = 164

In alignment with assumption Soc-C

Quotes from survey

Comment option was closed for this question.

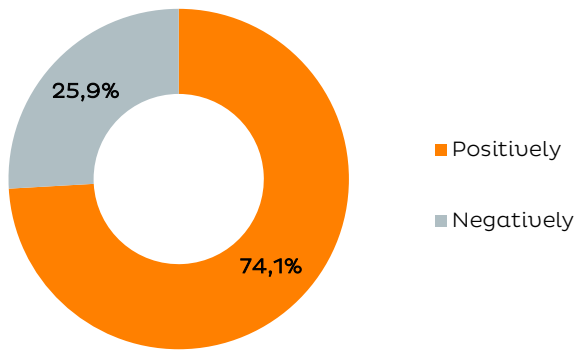
CIFS PERSPECTIVES

Respondents believe that peer-to-peer could change production and consumption of chemicals

This highlights the importance of new business models for the chemical industry to leverage the opportunities of the expected peer-to-peer network economy of the future. Compare with Soc8.

Society

Soc8: How will peer-to-peer networks impact existing business models of the European chemical industry?



Positively

Consensus (Measure: Majority)

74 %

Group stability (Percentage)

Consent

Consensus status

Note: n = 201

**In alignment with
assumption Soc-C**

Quotes from survey

Comment option was closed for this question.

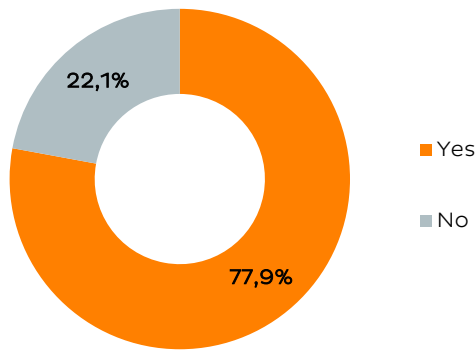
CIFS PERSPECTIVES

Respondents saw positive benefits to business models in the European chemicals industry.

The consensus around the positive effects was strong which warrants further exploration of this opportunity space. How can the industry increase its engagement through new business models going forward?

Society

Soc9: Would peer-to-peer networks foster transparency regarding chemical content in production processes?



Yes

Consensus (Measure: Majority)

78 %

Group stability (Percentage)

👍 Consent

Consensus status

Note: n = 217

In alignment with assumption Soc-C

Quotes from survey

(15 comments)

“Peer-to-peer combined with asset heavy nature of chemical plants is not an easy combination. Peer-to-peer will have a huge impact in our supply chains, not per se in the production of chemicals itself”

“Peer-to-peer will have more impact on the chemicals consumption rather than production (required high CAPEX with high commitments and entry barriers)”

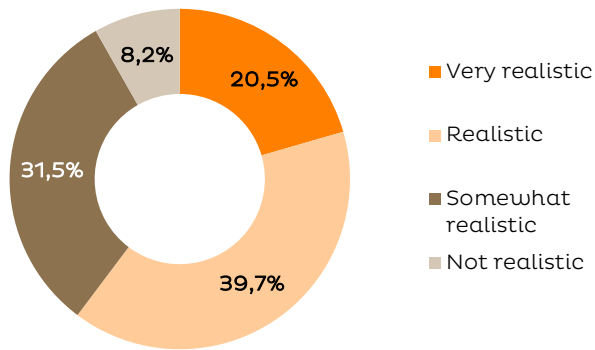
CIFS PERSPECTIVES

Respondents strongly believe that peer-to-peer networks would foster transparency.

Analysis of Delphi comments points towards a belief that the impacts would affect consumption more than production.

Society

Soc10: Some institutions opine that by 2050 > 50% of new cars sold could be at least level 4 autonomous (5 being fully autonomous). Power for autonomous cars is believed to be hybrid or fully electrical



Realistic

Consensus (Measure: Mean)

61 %

Group stability (coeff. Of var.)

Consent

Consensus status

Note: n = 73. This question was only posed to non-chemical experts

In alignment with assumption Soc-D

Quotes from survey

(5 comments)

"In Europe, it is very realistic. Worldwide is somewhat more challenging. The infrastructure needs of autonomous vehicles and of electromobility are huge and still seem underestimated."

"As long as we still have important failures in most of the easy applications/machinery around the house, how can we fully trust the autonomous cars?"

CIFS PERSPECTIVES

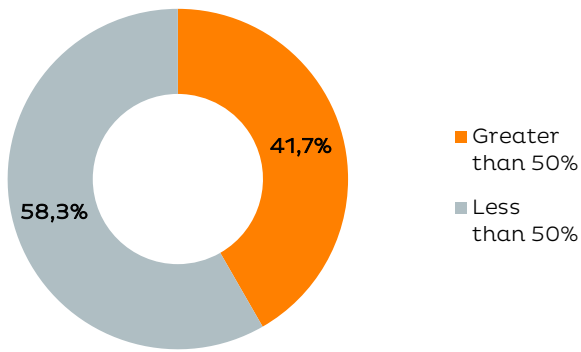
Respondents believed that it was realistic that >50% of new cars sold could be both level 4 autonomous and hybrid/electric

This belief could point towards a decline in the number of cars sold and the widespread adoption of mobility as a service solution.

This could change the demand for more greater value, more durable plastics in vehicles towards 2050.

Society

Soc11: Will the percentage of cars on the road used for car-sharing purposes be greater or less than 50% in 2050?



Less than 50%

Consensus (Measure: Majority)

58 %

Group stability (Percentage)

👍 Consent

Consensus status

Note: n = 72. This question was only posed to non-chemical experts.

In alignment with assumption Soc-D

CIFS PERSPECTIVES

The majority of respondents believe that it is possible for the number of cars using car-sharing will be greater than 50%.

However, analysis of comments points towards a belief that this will be much higher in large urban areas.

Quotes from survey

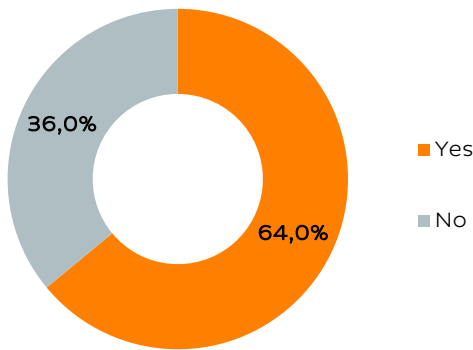
(9 comments)

"People will realize that owning a car will not be necessary anymore - provided transportation should be available when you need/want it."

"There will be of course big differences between regions. 50% will concern especially cities."

Society

Soc12: Towards 2050, do you expect that a change towards autonomous driving and shared mobility will provoke the substitution from non-chemicals (e.g. metals) towards chemicals?



Yes

Consensus (Measure: Majority)

64 %

Group stability (Percentage)



Consent

Consensus status

Note: n = 164. This question was only posed to chemical experts

In alignment with assumption Soc-D

Quotes from survey

(18 comments)

“Weight is king. If structural performance, lower weight and easier recyclability are possible then substitution will happen.”

“A ‘yes’ in brackets. For shared mobility durability and Recyclability Counts. The latter can be met with metals more easily. Durability is even. Of course, there will be an increase of e.g. light weight construction supported by chemicals.”

CIFS PERSPECTIVES

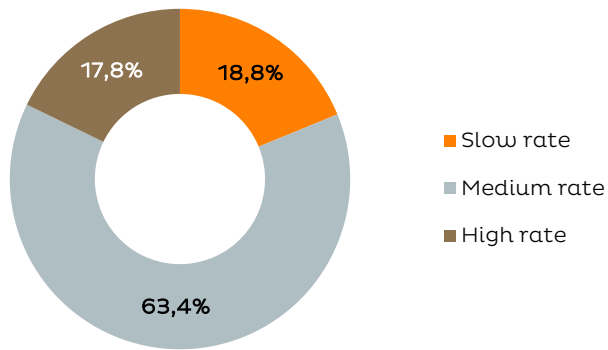
Respondents expect a substitution from metals towards chemicals

Comments points towards other factors

Comments point to a more nuanced picture. The question how manufacturers will balance plastics compare to metals in such as areas as weight, durability, recyclability, and performance towards 2050.

Society

Soc13: If you answered yes to the previous statement:
At what rate do you expect this substitution to happen?



Medium rate

Consensus (Measure: Majority)

63 %

Group stability (Percentage)

Consent

Consensus status

Note: n = 101. This question was only posed to chemical experts

In alignment with assumption Soc-D

CIFS PERSPECTIVES

Chemical experts expect a medium substitution rate

The rate was likely chosen to reflect regulation, innovation and consumer adoption lags

Quotes from survey

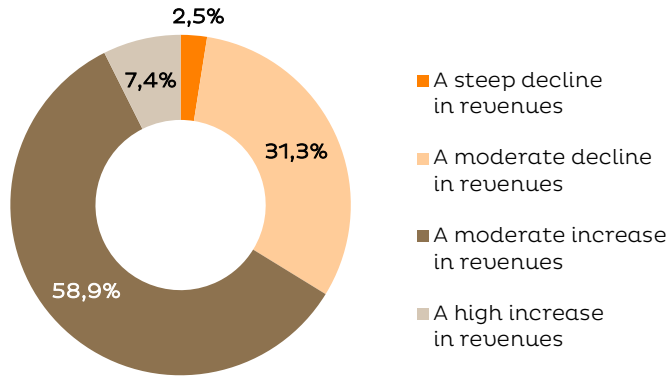
(6 comments)

"Turnover of new automotive models is five to seven years, meaning e.g. current BMW 3 stays for 5 to 7 years in the same structure, until a new model comes to market. If these sessions are not shortened in future, substitution cycles cannot advance."

"I believe that it will go in an exponential way: slow at first and then ever faster."

Society

Soc14: By 2050, how would you rate the net effect for the European chemical industry of moving from non-autonomous, combustion-based, non-shared mobility towards (semi)-autonomous electrically powered and shared mobility?



A moderate increase in revenues

Consensus (Measure: Mean)

77 %

Group stability (coeff. Of var.)

Consent

Consensus status

Note: n = 163. This question was only posed to chemical experts

In alignment with assumption Soc-D

Quotes from survey

(16 comments)

“Moderate increase in revenue but for smaller, innovation-driven chemical companies. The dinosaurs who refuse to adapt will die”

“High increase, but effect perhaps countered by reduction of cars sold. Therefore, moderate increase in revenues expected. Revenues are likely to increase in other areas.”

CIFS PERSPECTIVES

Respondents were inclined to select a moderate increase in revenues

This was due to the higher value chemicals being put into autonomous vehicles which would offset a potential decline in units sold.

Comments were made on new energy storage solutions and other technologies.

Some comments pointed towards the emergence of improved battery technology, hybrid and H2 solutions as well as increased recycling.

A few comments questioned the industry's innovative abilities.

Technology – results

Summary

- Delphi respondents expressed a consensus of the European chemical industry achieving greenhouse gas emission reductions in the range of 60-80% which is very high but below the EU target of 85-90%. This result was thus not in alignment with the assumption laid out in the preceding foresight report which reflected the EU target (Tec-A*).
- Low-carbon electricity, increased recycling, process intensity, alternative feedstocks as well as other technologies and processes were believed to be of key importance to enable greenhouse gas emission reductions in the industry going forward (Tec-A)
- Expectations on future increases of biomass feedstock use were expressed but opinions differed with regards to the volumes. A factor two increase from today's baseline appeared somewhat realistic to a majority of respondents (Tec-B)
- Uncertainty was observed as to whether the production of low-carbon electricity will be sufficient and affordable to meet the demands of the chemical sector towards 2050 (Tec-C)
- Fossil-based electricity combined with CCS was not believed to be a sustainable option by 2050 (Tec-C)
- The Delphi panel viewed CO₂/CO and H₂-based synthesis on an industrial scale as very likely in the 2050ies but was more uncertain regarding the production levels (Tec-D)
- Industrial symbiosis to supply end-of-pipe CO₂- and CO emissions as feedstocks was also seen as likely with mixed expectations around the scale of realization (Tec-E)
- Chemical experts expected value growth in specialties derived from biomass as well as conventional feedstocks, while base chemicals' value growth expectations were moderate. Uncertainty was noted around the expected overall volume growth of the industry (Tec-F)
- Developments supporting circular economy trends were expected to play an increasing role in the industry and its value chains: Recycling (Tec-G), chemical leasing and other service models (Tec-I) were expected to be widespread across the industry and its customers, with enabled powerful computing and distributed ledger (blockchain) technologies playing an enabling role (Tec-H).
- Respondents tended towards a continued increase of CO₂-price levels to a range between 50-100 EUR per ton in Europe in 2050 but substantial uncertainties were reflected in the comments (Tec-J)
- Uncertainty was noted around greenhouse gas emission reduction policies and their implementation: respondents had mixed and different perspectives regarding fragmented and regional implementation versus convergent implementation (Tec-K)
- Sustainable finance legislation to support investments into emissions reduction was seen as very important by the crowd but uncertainty was observed whether the necessary political accord could be reached across the EU (Tec-L)
- A portfolio of advanced technologies is expected to have significant impact on the future of the chemical industry. Most significant effects are expected from chemical recycling, artificial intelligence and superfast computing. The panel did not believe in or was uncertain about the future of next generation nuclear fission reactor (Tec-M)

*Delphi result in relation to assumption 'Tec-A', see next page

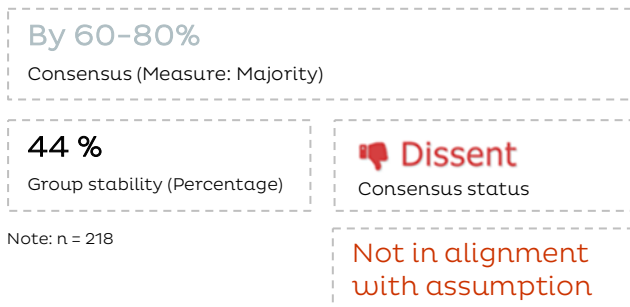
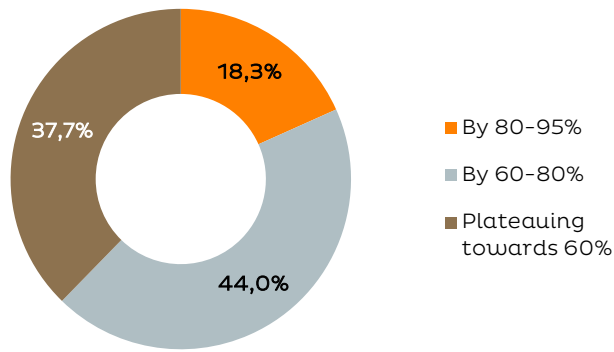
Technology – lead assumptions used for developing Delphi questions

- **The chemical industry reduces its greenhouse gas emissions by 80% – 95%** in comparison to 1990ies levels through a combination of feedstock shift towards renewables, introduction of recycling processes and switching to low-carbon electricity for processes and synthesis (Tec-A: Tec1-7*)
- **Biomass is an important raw material source for the industry and will continue to be explored as a sustainable solution. Industry will potentially use twice as much biomass as in 2018** (Tec-B: Tec8)
- **Low-carbon electricity capacities are continuously expanded and low-carbon electricity is produced in large amounts and at affordable prices.** Low-carbon electricity refers to electricity generated from renewables as well as nuclear energy. The European energy sector expands its low-carbon electricity production to a level of over 3000 TWh in Europe (as foreseen in IEA, 2-degrees scenario). Low-carbon electricity is in high demand across industries, as well as by the transportation and housing sectors (Tec-C: Tec9-10)
- **Electrified conversion of CO₂/CO and H₂-based synthesis to methanol and other chemicals can be scaled up to industrial levels in the 2050ies** (Tec-D: Tec12)
- **Industrial symbiosis enables access to end-of-pipe CO₂ and CO emissions** required for chemical synthesis in 2050. These gases are sourced from other industries such as steel making, cement production as well as power plants which are using waste, coal and natural gas (Tec-E: Tec12)
- **Production volume growth of the industry 2018-50 is comparatively low** but strong value growth is taking place in specialties which are synthesized from biomass and conventional feedstocks (Tec-F: Tec13-15)
- **Substantial amounts of chemicals are being recycled** through a combination of product reuse, mechanical recycling, chemical recycling or combustion with subsequent recovery of energy and CO₂ (Tec-G: Tec16)
- **Digital technologies such as blockchain are used widely in the industry** to manage and document transactions in the circular business models (Tec-H: Tec17-18)
- **Chemical leasing and service models are wide-spread.** Blockchain transaction volumes and speed are high due to powerful computing technology in 2050. Digital transactions supported by blockchain rely on industry standards and the presence of single digital market in the European Union (Tec-I: Tec19-20)
- **CO₂ prices in Europe continue to climb and reach a level of 50 – 100 EUR per ton in 2050.** High prices are crucial to offset the economic gap between fossil chemical routes and new low-carbon synthesis processes (Tec-J: Tec21)
- **Long-term focus on harmonized GHG emissions reduction policies.** The European Commission and the national governments keep a long-term focus on homogenous and harmonized GHG emissions reduction policies. National fragmentation with regards to emission reductions was thereby avoided (Tec-K: Tec22)
- **Sustainable finance legislation supports investments in emission reduction.** The European Union ensures sustainable finance legislation that supports investments in increased carbon productivity, recycling as well as valorization of circular economy practices (Tec-L: Tec23-24)
- **Technological developments are essential for the chemical industry's ability to grow, compete and to reduce its greenhouse emissions.** In this respect a number of technologies are expected to shape the future of the industry. Examples are: next generation nuclear fission reactors, thorium reactors, fusion reactors, superfast computing, quantum computing, 2D materials (graphene, fullerene, etc.), genome editing, artificial intelligence, additive manufacturing (Tec-M: Tec25-34)

*Assumption 'Tec-A': derived questions 'Tec1' to 'Tec7'.

Technology

Tec1: To which degree do you expect the European chemical industry to be able to reduce its net greenhouse gas emission by 2050 in comparison to 1990s levels?



Quotes from survey

(24 comments)

“The road-map of the EU is clear: 80-95%. Chemical industry as one of the key players for the transition to the post-fossil world will be allowed to lag behind, but not too much”

“This will depend on how they will be willing to do radical changes in their business models. I don't see a relevant result only by incremental changes”

CIFS PERSPECTIVES

Only 18.3% of respondents expect a greenhouse gas emission level of 80-95% which would be in line with EU Commission targets.

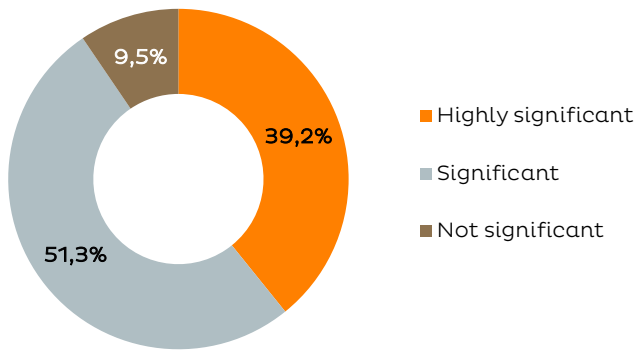
Thereby the outcome on this particular question was not alignment with the preceding foresight study where the 80-95% reduction ambition was assumed to be reached by the 2050ies.

However, it is still a positive aspect that a majority of respondents (44%) assumes a reduction level of 60-80% as achievable.

The quotes reflected contrasting opinions on the issue which suggested an intense debate on the issue in expert circles.

Technology

Tec2: How significant do you assess the contribution of the following technologies for reducing greenhouse gas emission in the chemical industry? CATALYSIS



Significant
Consensus (Measure: Majority)

51 %
Group stability (Percentage)

Dissent
Consensus status

In alignment with assumption Tec-A

Note: n = 158. This question was only posed to chemical experts

Quotes from survey

Comment option was closed for this question.

CIFS PERSPECTIVES

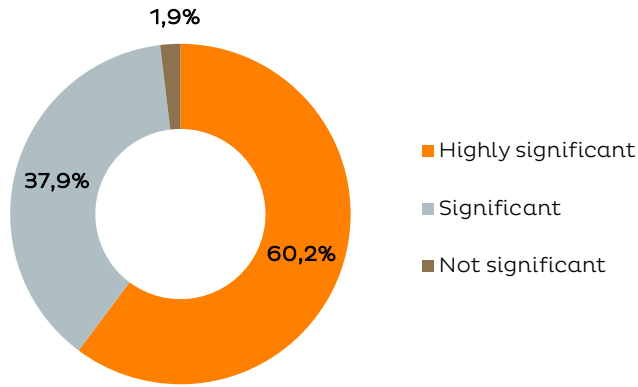
A combined majority opined that catalysis as core technology of the chemical industry will play a significant or highly significant role in achieving greenhouse gas emissions in the industry.

This finding is viewed as being in alignment with technology development assumptions despite the fact that group stability did not surpass the threshold of 55% for the option 'significant'.

A combined majority opted for 'highly significant' or 'significant'.

Technology

Tec3: How significant do you assess the contribution of the following technologies for reducing greenhouse emission in the chemical industry? LOW CARBON ELECTRICITY



Highly significant
Consensus (Measure: Majority)

60 %
Group stability (Percentage)

Dissent
Consensus status

In alignment with assumption Tec-A

Note: n = 161. This question was only posed to chemical experts

Quotes from survey

The comment option was closed for this question.

CIFS PERSPECTIVES

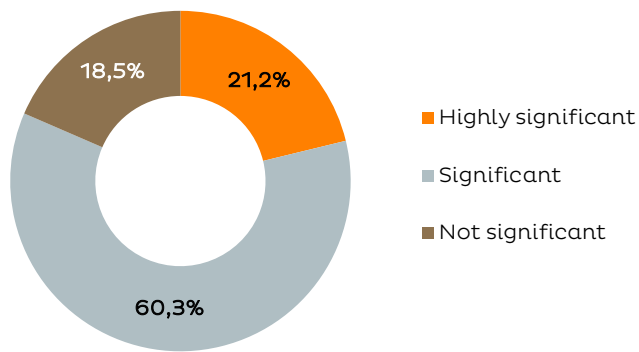
Among the technological enablement factors which are considered as being required for emission reductions low-carbon electricity is viewed as the most important one.

More than 98% of all respondents believe that low-carbon electricity is of significant or even highly significant importance

This outcome is hence in alignment the foresight report assumption.

Technology

Tec4: How significant do you assess the contribution of the following technologies for reducing greenhouse emission in the chemical industry? PROCESS INTENSIFICATION



Significant

Consensus (Measure: Majority)

60 %

Group stability (Percentage)

 Dissent

Consensus status

Note: n = 151. This question was only posed to chemical experts

In alignment with assumption Tec-A

CIFS PERSPECTIVES

Process intensification is another technology condition which was viewed as necessary to enable further emission reductions by the industry

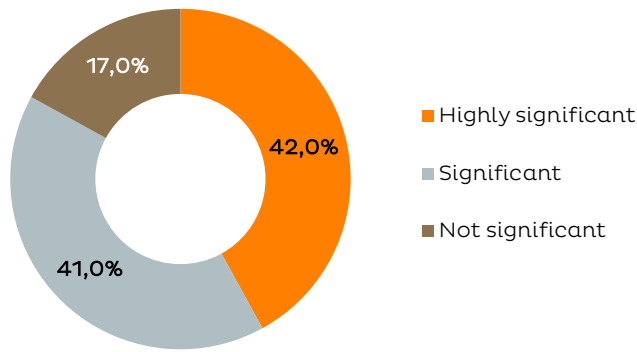
However, the overall agreement is somewhat lower than as compared to 'catalysis' and 'low-carbon electricity' (preceding questions Tec2 and Tec3).

Quotes from survey

The comment option was closed for this question.

Technology

Tec5: How significant do you assess the contribution of the following technologies for reducing greenhouse emission in the chemical industry? SWITCH TO ALTERNATIVE FEEDSTOCK



Highly significant

Consensus (Measure: Majority)

42 %

Group stability (Percentage)

Dissent

Consensus status

Note: n = 159. This question was only posed to chemical experts

In alignment with assumption Tec-A

Quotes from survey

The comment option was closed for this question.

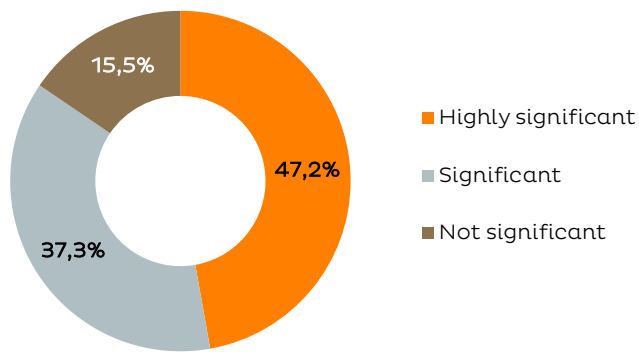
CIFS PERSPECTIVES

Feedstock switch is viewed on par with process intensification (Tec4) with respect to its significance for emission reductions on a mid-century perspective.

Follow-on questions on biomass feedstock (Tec8) and CO₂/CO and H₂-based feedstocks (Tec11) revealed more details on the respondent's perspectives in relation to the topic of feedstock switch.

Technology

Tec6: How significant do you assess the contribution of the following technologies for reducing greenhouse emission in the chemical industry? INCREASED RECYCLING, DURABILITY, RESOURCE EFFICIENCY



Highly significant

Consensus (Measure: Majority)

47 %

Group stability (Percentage)

Dissent

Consensus status

Note: n = 161. This question was only posed to chemical experts

In alignment with assumption Tec-A

Quotes from survey

The comment option was closed for this question.

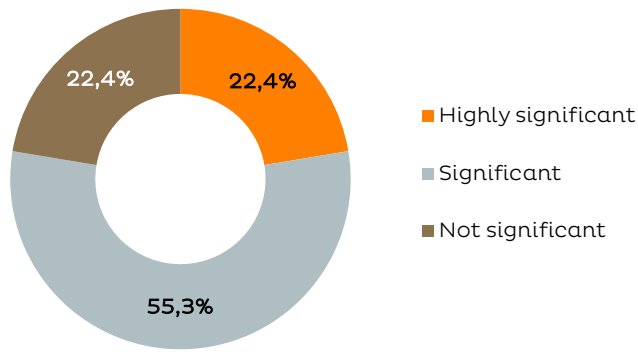
CIFS PERSPECTIVES

Increased recycling, durability and resource efficiency are collectively considered as very important to enable further emission reductions.

The respondent statistics are comparable to the preceding technology questions (Tec3-5) – indicating a high degree of agreement on the potential benefits of these technologies.

Technology

Tec7: How significant do you assess the contribution of the following technologies for reducing greenhouse emission in the chemical industry? ARTIFICIAL INTELLIGENCE AND DIGITISATION



Significant
Consensus (Measure: Majority)

55 %
Group stability (Percentage)

Consent
Consensus status

In alignment with assumption Tec-A

Note: n = 161. This question was only posed to chemical experts

Quotes from survey

The comment option was closed for this question.

CIFS PERSPECTIVES

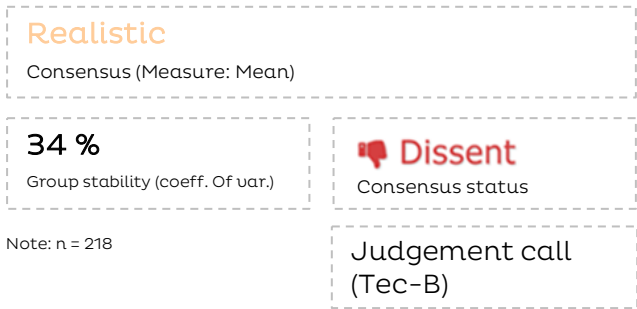
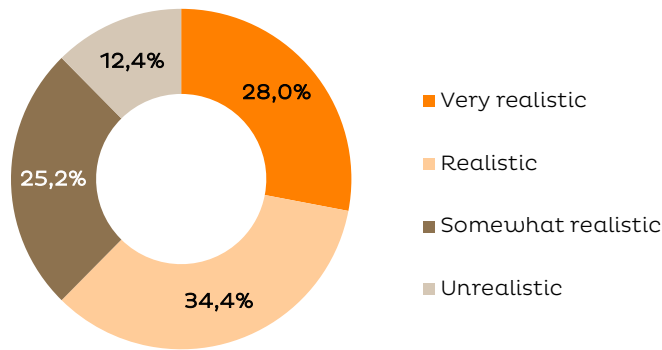
Artificial intelligence and digitisation are believed to be of significance to leverage further emission reductions in the industry.

However, the respondents' agreement is somewhat weaker in comparison to the preceding results on the questions concerning process intensification (Tec4), recycling... (Tec5) and feedstock switch (Tec6).

This could suggest that the respondents are either less familiar with AI and digital technologies or that they cannot easily see how these technologies (alone and in combination) should lead to increased emission reductions.

Technology

Tec8: The chemical industry will use approximately twice as much biomass in 2050 as in 2018



Quotes from survey

(21 comments)

“Will depend on political support and targets for biomass/renewables in the Circular Economy”

“The conversion to biomass-based feedstocks is limited by availability and pricing versus fossil based materials. If these two limits can be overcome then there will be increasing use of biomass.”

CIFS PERSPECTIVES

The responding chemical experts expressed positive expectations on the future volumes of biomass used by the industry.

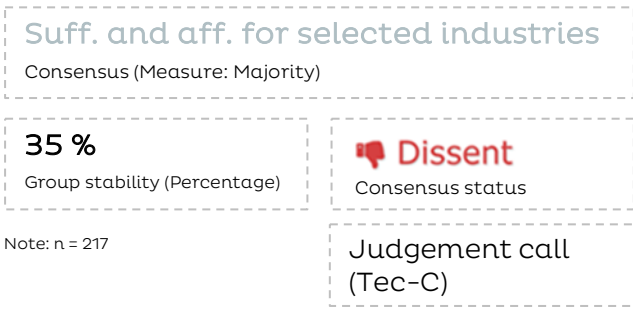
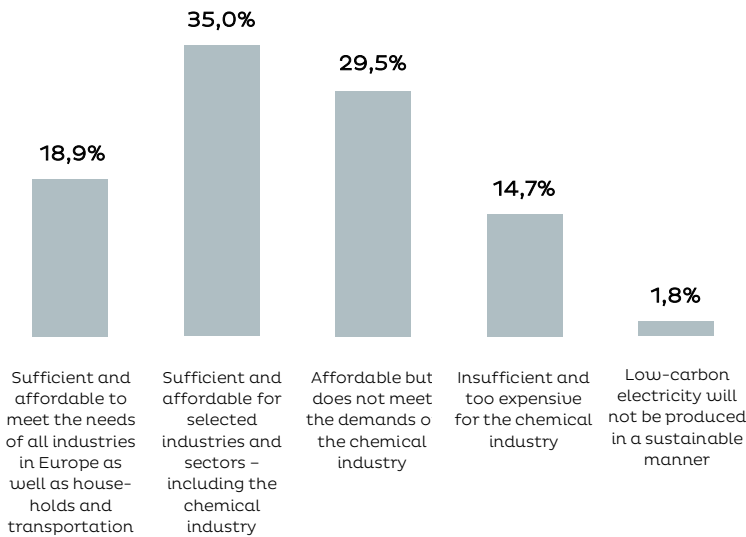
Although a consent (>55% majority) was not achieved in a single multiple-choice option there still was a clear majority of 62.4% of respondents who expected a doubling of biomass use as ‘realistic’ or ‘very realistic’.

The observed optimism strongly outweighed the sceptics.

The comments pointed to the ramifications and conditions that were seen as critical for a marked increase of biomass use by the industry – e.g. availability, pricing and political support

Technology

Tec9: Towards 2050, low-carbon electricity will be produced in a sustainable manner that is:



Quotes from survey

(9 comments)

“We are currently in a transition phase. Currently we want to adapt low-carbon electricity to the need of the industry, but it will more and more lead to the adaption of the industry to the availability of low-carbon electricity”

“Renewable electricity is affordable in EU, but not competitive enough compared with other regions, particularly ME and NA. Most chemical products are globally traded products, except ammonia. Unless EU implements boarder adjustment to complement higher energy price for renewable energy, cost competitive chemicals from ME and NA will flood the EU market.”

CIFS PERSPECTIVES

As the preceding results on question Tec3 already indicated, low-carbon electricity was viewed as a key technological enabler for emission reductions.

The present question explores the topic of expected supply situation which takes not only the chemical industry but also other industries and sectors into account

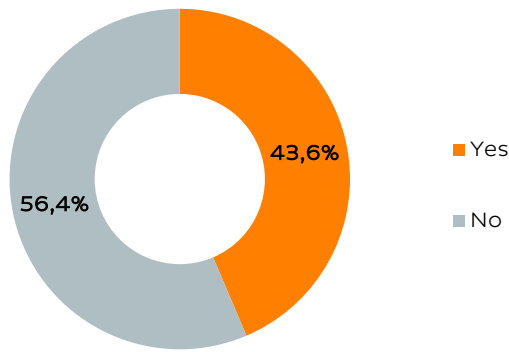
The results pointed to a mixed picture: In an optimistic perspective a majority of experts expected sufficient and affordable future supplies for the chemical industry (35%) and a smaller fraction even for all Europe (18.9%). On the more pessimistic side, a sizeable proportion expected supply limitations and/or too high prices.

The important conclusion on these results seems to be that optimistic viewpoints are collectively outweighing the more pessimistic ones.

Quoted comments indicated the significant importance of low carbon electricity for the industry – they pointed out that it is not only about availability but also about prices and global competitiveness

Technology

Tec10: Do you think that fossil-based electricity combined with carbon capture and storage is a likely sustainable option by 2050?



No
Consensus (Measure: Majority)

56 %
Group stability (Percentage)

Consent
Consensus status

In alignment with assumption Tec-C

Note: n = 188

Quotes from survey

"I'd rather think carbon capture and utilisation, because for the time being due to public opinion issues, no carbon capture and storage has been completed"

"Yes, provided the current prohibitive cost of CCS comes down"

CIFS PERSPECTIVES

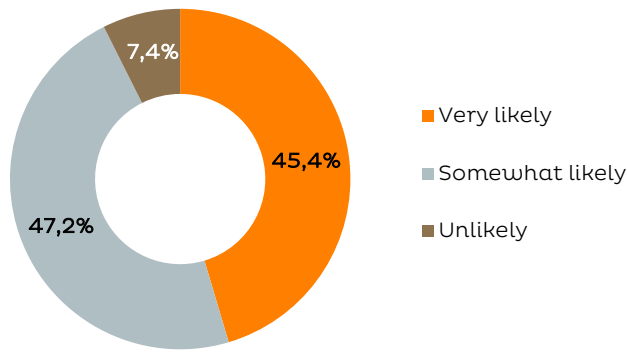
The results indicated a consensus that fossil-based electricity in combination with carbon capture and storage (CCS) does not appear to be a sustainable option in 2050

Comments suggested that carbon capture and utilization (CCU) was preferable over CCS high capital expenditure requirements.

The outcome is in alignment with the assumption(s) of the foresight report which pivot around low-carbon electricity and a lesser significance of fossil fuels in the future

Technology

Tec11: Towards 2050, can CO₂/CO and H₂-based synthesis of e.g. methanol be scaled to industrial levels?



Somewhat likely
Consensus (Measure: Majority)

47 %
Group stability (Percentage)

Dissent
Consensus status

In alignment with assumption Tec-D

Note: n = 163. This question was only posed to chemical experts

Quotes from survey

“For any synthesis or transformation you need energy. The question is about the right technology/energy source to obtain a net reduction of CO₂. If you have an abundant (CO₂-free) energy, everything is possible”

“The scaling itself should be possible. The big question will be at what cost”

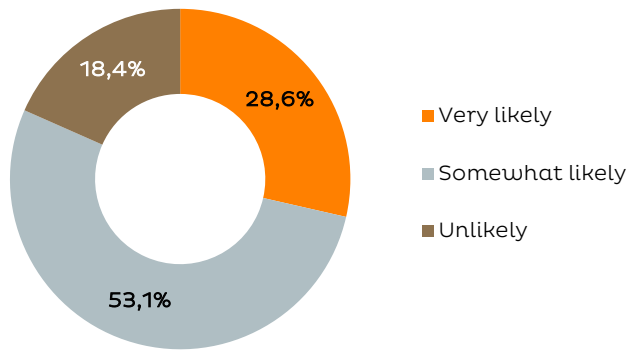
CIFS PERSPECTIVES

The panel opined that industrial scaling to CO₂, CO and H₂ as alternatives feedstocks is likely on a 30 years perspective.

Given the fact that syngas / H₂-based synthesis technologies are still under development and only piloted to a smaller extent the respondents' view expresses optimism.

Technology

Tec12: Towards 2050, will industrial symbiosis be implemented on a large scale to provide sufficient end-of-pipe CO₂ and CO for chemical synthesis?



Somewhat likely

Consensus (Measure: Majority)

53 %

Group stability (Percentage)

 Dissent

Consensus status

Note: n = 147. This question was only posed to chemical experts

In alignment with assumption Tec-E

Quotes from survey

“The symbiosis will not just be for CO₂/CO but a few giant corporations will own these sectors all together. Chemicals, steel, cement, glass, etc. ... will all melt into an overall 'materials' sector industry with micro scale plants at work-sites”

“Very unlikely in EU as the production will move east where this new technology will get utilized. The EU is high cost and over-regulated”

CIFS PERSPECTIVES

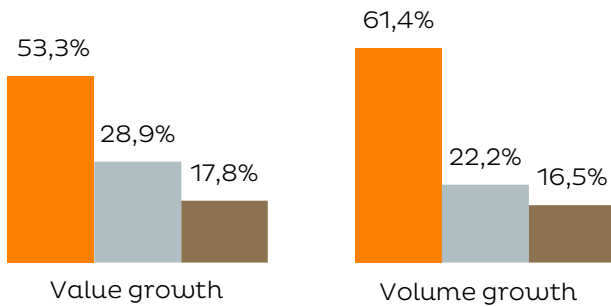
A combined majority of panellists view industrial symbiosis as likely but they are uncertain about its scale since a lot depends on the co-location of emitting and consuming industries.

Comments pointed to the competitive viability of industrial symbiosis the EU. They also pointed out opportunities for symbiosis between smaller plants which are part of large industrial conglomerates as the result of large-scale consolidation across the manufacturing sector

Technology

Tec13: Compared to today, what are your long-term expectations for growth in specialties and base chemicals towards 2050 in Europe? BASE CHEMICALS

■ Lower ■ Same ■ Higher



<p>Lower</p> <p>Consensus (Measure: Majority)</p>	<p>Lower</p> <p>Consensus (Measure: Majority)</p>
<p>53 %</p> <p>Group stability (Percentage)</p>	<p>61 %</p> <p>Group stability (Percentage)</p>
<p>Disent</p> <p>Consensus status</p>	<p>Consent</p> <p>Consensus status</p>
<p>Judgement call (Tec-F)</p>	<p>In alignment with assumption Tec-F</p>

Note: n = 152 / 158. These questions were only posed to chemical experts

Quotes from survey

“Volume growth will become a more and more irrelevant parameter. decoupling value from volumes need to reach the next level to allow a profitable future for the industry.”

“Volume will be put under pressure by the shift towards a more circular economy”

CIFS PERSPECTIVES

According to the panellists' responses base chemicals are expected to see lower growth in terms of volume and value.

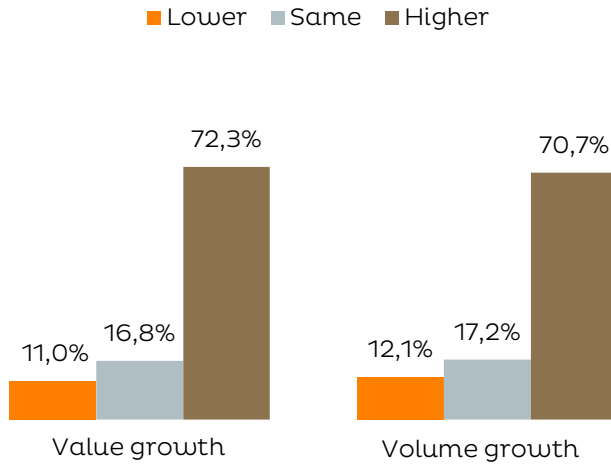
Volume growth is expected to be stronger affected than value growth which could reflect an expectation of manageable price erosion.

Comments indicated that growth will be decoupled from volume and that circular economy trends could lead to lower volume demands.

CIFS views the outcome as in alignment with assumptions with 'value growth' closely missing the 55% consensus threshold.

Technology

Tec14: Compared to today, what are your long-term expectations for growth in specialties and base chemicals towards 2050 in Europe? SPECIALTY CHEMICALS



<p>Higher Consensus (Measure: Majority)</p>	<p>Higher Consensus (Measure: Majority)</p>
<p>72 % Group stability (Percentage)</p>	<p>71 % Group stability (Percentage)</p>
<p>👍 Consent Consensus status</p>	<p>👍 Consent Consensus status</p>
<p>In alignment with assumption Tec-F</p>	<p>In alignment with assumption Tec-F</p>

Note: n = 155 / 157. These questions were only posed to chemical experts

Quotes from survey

“The trend will be to a greater specialization in the products and their value chain.”

“More innovation and specialties. More flexible plant set ups and business models”

CIFS PERSPECTIVES

Specialties chemicals business is expected to increase both in term of volume and value.

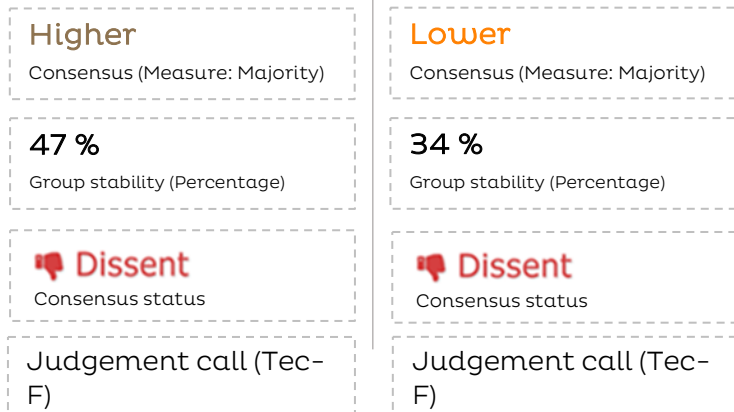
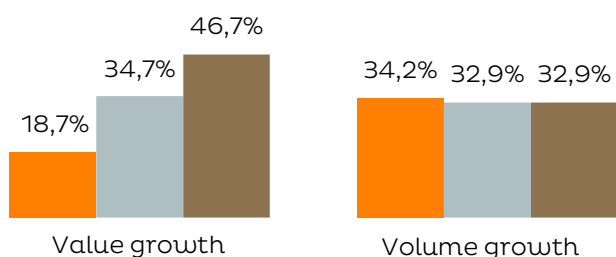
Long-term growth expectations for value and volume are very similar which is in accordance with assumptions and reflects a 'bullish' perspective.

As the comments indicate, the industry's ability to stay innovative and competitive with regards to specialties is seen as important.

Technology

Tec15: Compared to today, what are your long-term expectations for growth in specialties and base chemicals towards 2050 in Europe? OVERALL

■ Lower ■ Same ■ Higher



Note: n = 150 / 152. These questions were only posed to chemical experts

Quotes from survey

"To enable reuse and recycling we need to limit the amount of specialty chemicals and work as much as possible with base chemicals, single material solution. The growth will come from recycling and therefore overall I see lower volume production from traditional plants."

"Specialties will grow faster us base chemicals, but the overall European product market will become more sophisticated and use more chemicals. With the exception of plastics which will reduce due to recycling"

CIFS PERSPECTIVES

Value growth is expected but volume growth expectations are mixed

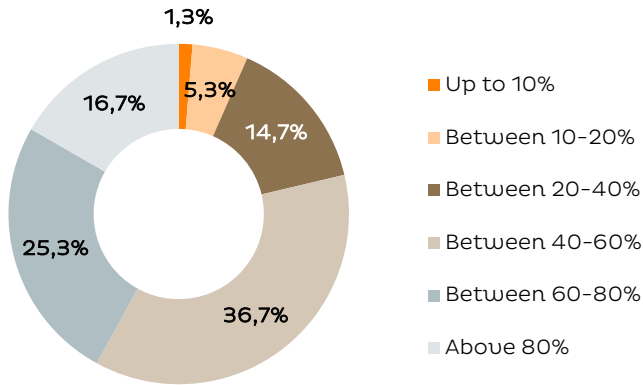
The Delphi panellists tended to believe in higher value growth in the future whereas expectations around volume growth where evenly spread.

Comments indicated that value comes from specialties but their recyclability was questioned. Expectations pointed towards recycling and circular economy having an impact chemical demands, and reduction of volume demands was mentioned in the comments as a likely development.

The majority of 47.6% was pronounced but still under the consensus threshold of 55%. Therefore, the crowds' verdict tended to agree with the assumptions but was still viewed as a judgement call by CIFS.

Technology

Tec16: What is the total amount out of total volumes of petrochemicals (including plastics) that you expect to be subject to recycling in one form or the other by 2050?



Between 40-60%
Consensus (Measure: Mean)

73 %
Group stability (coeff. Of var.)

Dissent
Consensus status

In alignment with assumption Tec-G

Note: n = 150. This question was only posed to chemical experts

Quotes from survey

“Under increasing retailers and societal pressure, the industry will design fully recyclable base packaging. The issue will then be the collection of say bottles etc. That is a societal issue”

“I suspect that all plastic waste will be eliminated and recycled in one form or another. However, the “downgrading” of materials will continue (e.g. PET bottles into fibers)”

CIFS PERSPECTIVES

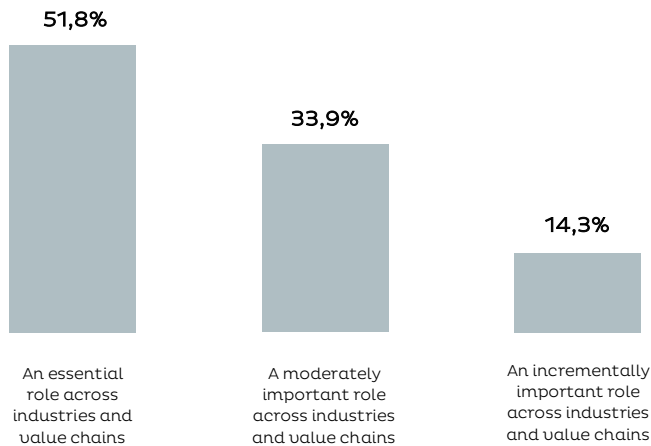
A majority of the Delphi crowd saw expected substantial levels of petrochemicals recycling but they differed markedly in their view of the potential implications

A combined majority viewed petrochemical recycling levels of at least 40% as realistic for the 2050ies with societal pressure being stated as a main driver in the comments.

However, respondents also expressed concerns around the necessary innovation efforts which have to take place with regards to both chemicals.

Technology

Tec17: In the circular economy of 2050, digital technologies such as blockchain play:



An essential role...
Consensus (Measure: Majority)

52 %
Group stability (Percentage)

Dissent
Consensus status

In alignment with assumption Tec-H

Note: n = 56. This question was only posed to non-chemical experts

Quotes from survey

"An essential, but rather invisible role - as in non-circular economies. It is not the primary driver of a circular economy"

"...not an expert on blockchain, but we have seen in the past promising technologies being overtaken by other more pervasive technologies. So not sure blockchain will exist as it is in 2050 when AI is becoming part of our daily lives"

CIFS PERSPECTIVES

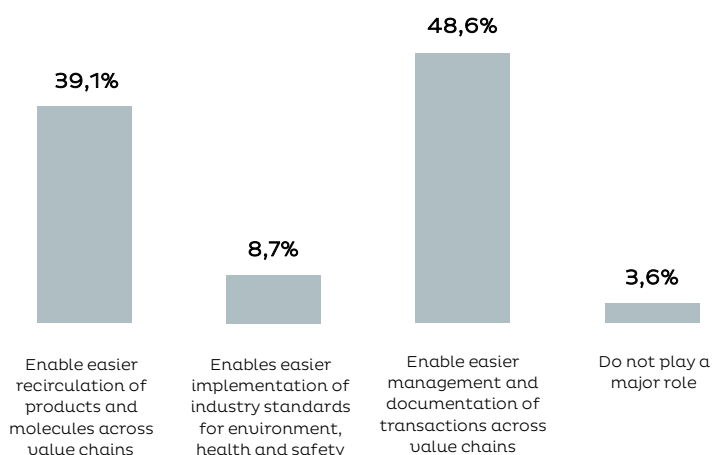
A pronounced majority of respondents saw blockchain as playing an essential (or moderate) role across value chains.

However, comments reflected the degree of visibility of blockchain, and questioning whether blockchain as such is a primary driver or more an enabling element of the circular economy developments

Likewise, uncertainty was expressed with regards to blockchain pervasiveness, especially in comparison with expected spread of artificial intelligence (AI).

Technology

Tec18: Towards 2050, in the circular economy processes that involve the European chemical industry, digital technologies such as blockchain play an important role because they:



Enable easier management...

Consensus (Measure: Majority)

49 %

Group stability (Percentage)

 Dissent

Consensus status

Note: n = 138. This question was only posed to chemical experts

Judgement call
(Tec-H)

Quotes from survey

"Blockchain can have a high impact in the supply chain (logistics) side of the business and potentially in some applications within the companies (e.g. tracking feedstock in their production lines), but it will probably be very hard to track molecules across the value chain."

"I do not support the wording of this question: digital technologies will play a huge role; blockchain maybe not. It could be obsolete in 2050 already and might have never found an economic use case for problems in the chemical industry."

CIFS PERSPECTIVES

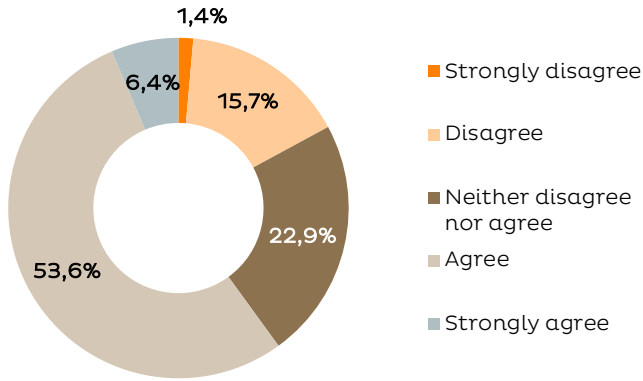
Blockchain was viewed as an enabling digital technology with regards to recirculation of products and molecules as well as facilitated transaction documentation management.

Uncertainty was expressed in the comments about the expected penetration of blockchain across the all aspects of the value chain.

Furthermore, commentators questioned whether blockchain will have been replaced but other digital technologies in the 2050ies – which was similar to the comments in preceding question Tec17.

Technology

Tec19: Towards 2050, chemical leasing and service models are going to be widespread across the industry and its customers



Agree
Consensus (Measure: Mean)

75 %
Group stability (coeff. Of var.)

Consent
Consensus status

In alignment with assumption Tec-1

Note: n = 140. This question was only posed to chemical experts

Quotes from survey

“Leasing models will be limited to applications where the delivered product remains physically present”

“Chemical leasing will grow, but not become ‘widespread’”

CIFS PERSPECTIVES

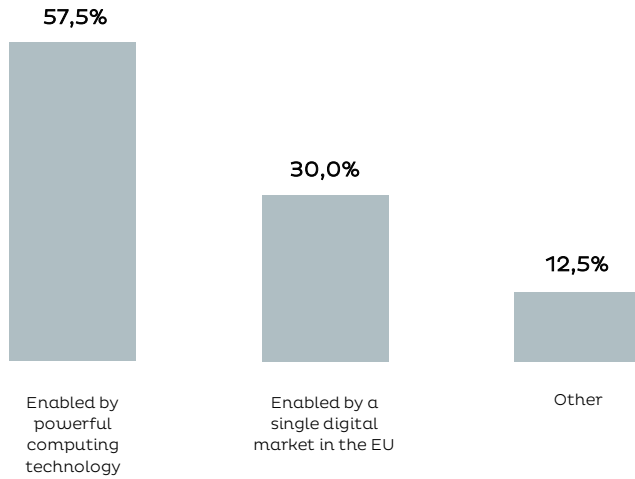
The panellist's majority expected spreading of chemical leasing and service models – but uncertainties were expressed towards the scale.

Commentators expected growth but were doubtful whether this growth can be expected to be ‘widespread’. They noted that limitations such as physical presence of the products do apply.

Technology

Tec20: If you agree or strongly the following statement:

What do you see as the main enabler?



Enabled by powerful computing tech
Consensus (Measure: Majority)

58 %
Group stability (Percentage)

Consent
Consensus status

In alignment with assumption Tec-1

Note: n = 80. This question was only posed to chemical experts

Quotes from survey

"...Change of mindset allowing new business models. technology is already there but not used enough as the old models are still working well"

"...legal framework. That is the only way to decouple resource usage and economic growth and it is the only way to manage the climate goals"

CIFS PERSPECTIVES

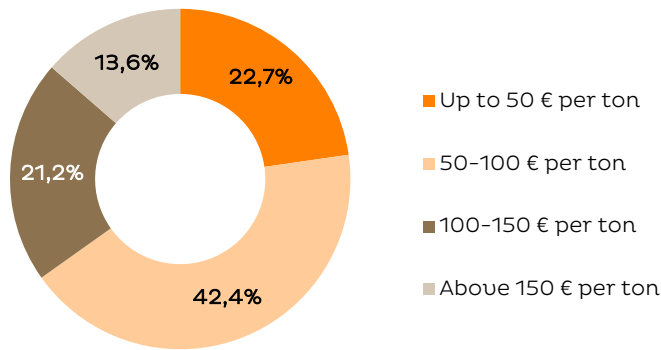
Powerful computer technology is seen as an enabler of recycling and service models in the industry.

Consensus on the pivotal importance of underlying computer power in relation to recycling and service models was observed across the respondents.

Commentators pointed out that it is not only about enabling computer power but also about necessary mind shifts and legal framework changes.

Technology

Tec21: Which CO₂ price level (in real terms i.e. excluding inflation) would you expect Europe towards 2050?



50-100 € per ton

Consensus (Measure: Mean)

57 %

Group stability (coeff. Of var.)

👍 Consent

Consensus status

Note: n = 132

In alignment with
assumption Tec-J

Quotes from survey

"In principle, the high price is the more effective policy than various kinds of restrictions and is also favorable for the public economies as the source of income. All depends, however, on the global agreements, monitoring systems and sanctions related to disobedience. The price should rise step by step"

"100\$ per ton is seen as break-even point for wider low C technologies growth e.g. CCS or biogas or bio-feedstocks"

CIFS PERSPECTIVES

Expectations of a CO₂ price range of 50 – 100 EUR per ton formed the consensus across the participant's responses.

Higher as well as lower price ranges were also expected by smaller fractions of the panel which expresses uncertainty surrounding this important topic.

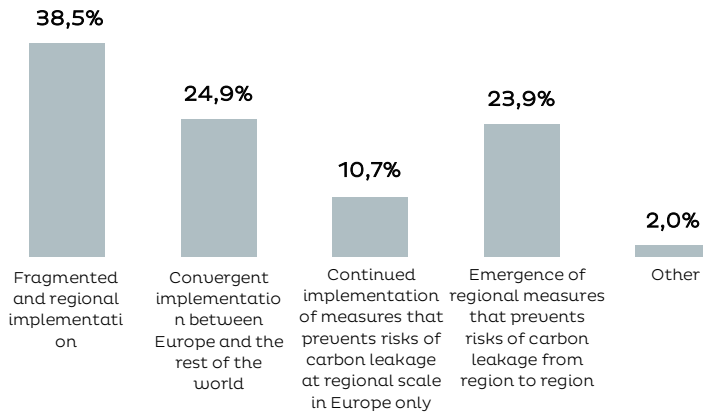
Commentators noted that CO₂-pricing should in principle have favourable economic effects but they need to be bound to global agreements which are monitored.

The 100\$ per ton was commented as being a break-even threshold for CCs and bio-feedstock using technologies.

Technology

Tec22: Towards 2050, what kind of greenhouse gas emissions reduction policy will be implemented?

In the absence of a global market, would empowered consumers, via digital solutions, trigger a global CO2 market, e.g. by avoiding CO2 intensive products?



Fragmented and regional...
Consensus (Measure: Majority)

39 %
Group stability (Percentage)

Dissent
Consensus status

Judgement call (Tec-K)

Note: n = 205

Quotes from survey

"A convergent implementation between Europe and the rest of the world would be the desirable direction to go, but it is unlikely to reach it by 2050 unless big players such as the US decide to jump in"

"Unless many countries will suffer under climate change, I don't see a way for a global harmonized system"

CIFS PERSPECTIVES

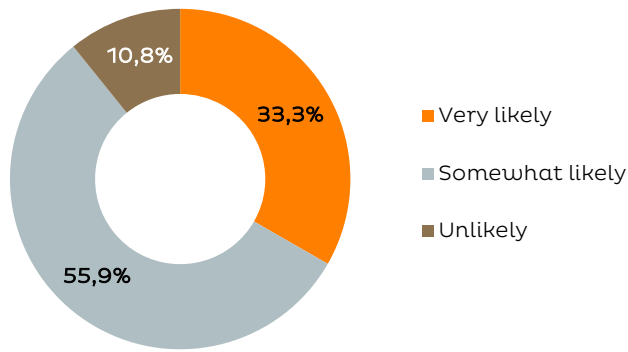
Respondents tended to view fragmented and regional implementation as a likely scenario but multiple other possibilities were considered too.

Comments reflected substantial uncertainty around the issue: the importance of accord between major global players such as the USA and Europe were noted.

Climate change was mentioned as an accelerating factor which could promote harmonized policy development.

Technology

Tec23: Towards 2050, will the EU ensure sustainable finance legislation that supports investments in increased carbon productivity, emission reductions as well as valorization of circular economy practices?



Somewhat likely

Consensus (Measure: Majority)

56 %

Group stability (Percentage)

👍 Consent

Consensus status

Note: n = 204

In alignment with assumption Tec-L

Quotes from survey

"We have to be successful on sustainable financing (as it also stimulates innovation, job growth etc. next to climate change mitigation), but much will depend on our ability to opt for and invest in common interest solutions and approaches"

"EU fiscal measures require unanimity. Very unlikely to have that."

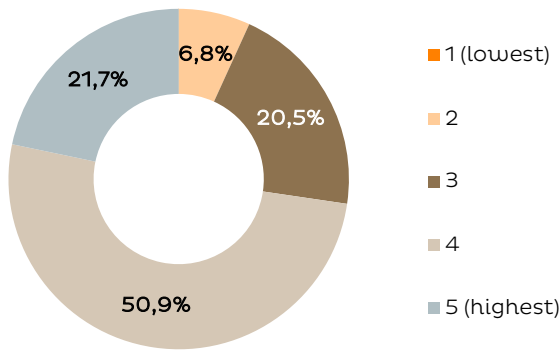
CIFS PERSPECTIVES

Consensus was noted around the topic of sustainable finance regulation to support such investments.

Comments underlined the importance of such an accord across the EU as well as the benefits to be gained in regards to innovation and economy. However, substantial uncertainties whether this accord could be reached.

Technology

Tec24: On a scale from 1-5, to what extent do you believe the European chemical industry is capable of meeting increasing expectations on environmental, social and government criteria?



4
Consensus (Measure: Mean)

78 %
Group stability (coeff. Of var.)

Consent
Consensus status

In alignment with assumption Tec-L

Note: n = 161. This question was only posed to chemical experts

Quotes from survey

“The capability for sure is there. The question is if we will have a framework where this is possible”

“Was always / is a leading industry.”

CIFS PERSPECTIVES

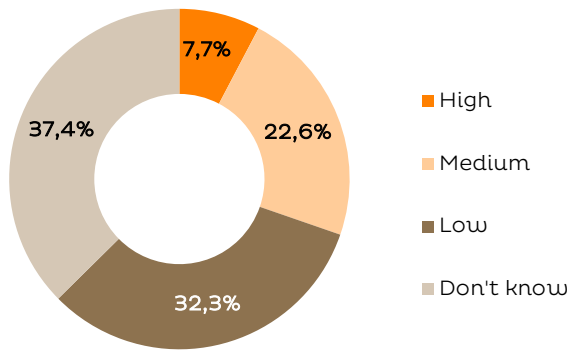
A strong consensus was observed on the topic of the industry’s capability to meet increasing expectations with regards to the environment, society and governmental regulations

The comments expressed confidence in the chemical industry’s capabilities which are grounded in a historic track-record on meet such criteria and the leading role that the industry takes in this regard.

However, commentators also expressed the necessity of a solid framework to enable the industry to play this leading role.

Technology

Tec25: Towards 2050, which advanced technologies are likely to have a significant effect on the future of the chemical industry? NEXT GENERATION FISSION REACTORS



Don't know
Consensus (Measure: Majority)

37 %
Group stability (Percentage)

Dissent
Consensus status

Not In alignment with assumption

Note: n = 155. This question was only posed to chemical experts

Quotes from survey

Commenting option was disabled for this question.

CIFS PERSPECTIVES

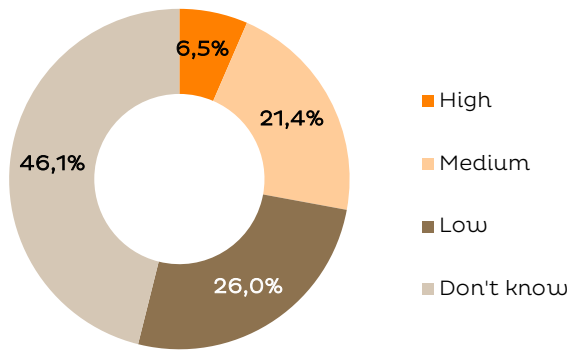
The Delphi expert crowd did not recognize a pronounced likelihood of next generation fission reactors having a significant effect for the chemical industry.

This finding was not in alignment with assumptions laid out in the preceding foresight report in which nuclear energy in the form of modernized fission technology plays a substantial role in meeting low-carbon electricity demands.

A sizeable proportion of participants also expressed that they (simply) did not know whether such a role of nuclear technology could be expected. Such voting is interpreted as a substantial level of uncertainty around the topic.

Technology

Tec26: Towards 2050, which advanced technologies are likely to have a significant effect on the future of the chemical industry? THORIUM REACTORS



Don't know
Consensus (Measure: Majority)

46 %
Group stability (Percentage)

Dissent
Consensus status

In alignment with assumption Tec-M

Note: n = 154. This question was only posed to chemical experts

Quotes from survey

Commenting option was disabled for this question.

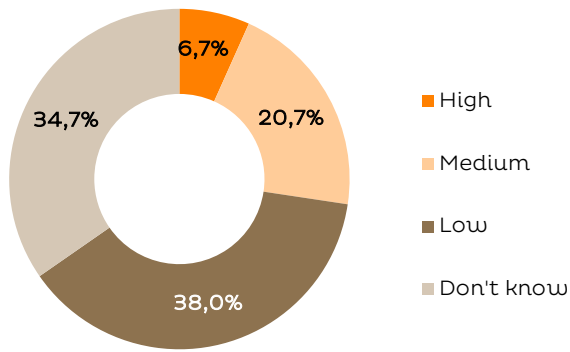
CIFS PERSPECTIVES

The experts expressed strong uncertainty and low likelihood with regards to Thorium reactor technology in the 2050ies

This outcome was in alignment with the assumptions – and even if Thorium technology has a very low technology readiness level today the question was worth asking because of the high demands of low-carbon electricity expected in the middle of the century.

Technology

Tec27: Towards 2050, which advanced technologies are likely to have a significant effect on the future of the chemical industry? FUSION REACTORS



Low
Consensus (Measure: Majority)

38 %
Group stability (Percentage)

Dissent
Consensus status

In alignment with assumption Tec-M

Note: n = 150. This question was only posed to chemical experts

Quotes from survey

Commenting option was disabled for this question.

CIFS PERSPECTIVES

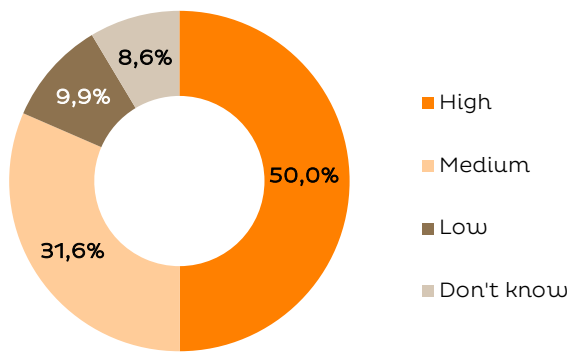
Fusion reactors were not seen as very likely energy source in the 2050ies by the expert panel.

Successful introduction of fusion technologies is expected to solve fundamental challenges around energy supply and emission reduction.

The panel's scepticism was in alignment with the assumptions laid out in the preceding report – despite the substantial investments being made in fusion research and development.

Technology

Tec28: Towards 2050, which advanced technologies are likely to have a significant effect on the future of the chemical industry? SUPERFAST COMPUTING



High

Consensus (Measure: Majority)

50 %

Group stability (Percentage)

 Dissent

Consensus status

Note: n = 152. This question was only posed to chemical experts

In alignment with assumption Tec-M

CIFS PERSPECTIVES

Superfast computing as an advanced technology was viewed as pivotal for the future of the industry.

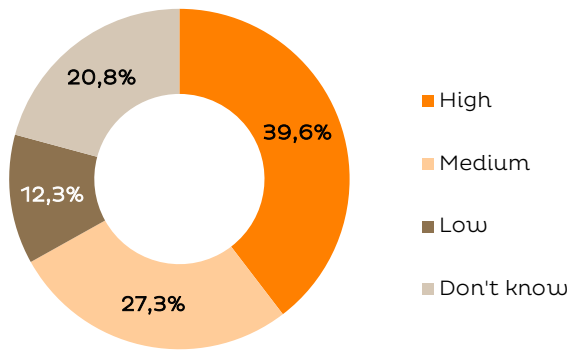
The obtained response distribution reflected an implicit expectation that very few technological advancements in the industry and its value chains can be achieved without superfast computing.

Quotes from survey

Commenting option was disabled for this question.

Technology

Tec29: Towards 2050, which advanced technologies are likely to have a significant effect on the future of the chemical industry? QUANTUM COMPUTING



High

Consensus (Measure: Majority)

40 %

Group stability (Percentage)

Dissent

Consensus status

Note: n = 154. This question was only posed to chemical experts

In alignment with assumption Tec-M

Quotes from survey

Commenting option was disabled for this question.

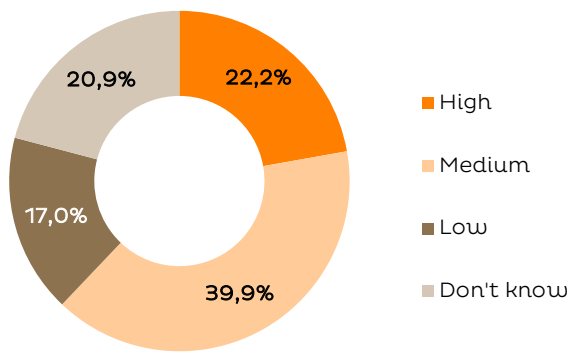
CIFS PERSPECTIVES

Quantum computing was considered as very likely in having a significant effect on the industry.

The obtained distribution of answers pointed towards positive expectations around this technology. This outcome is to be seen in conjunction with preceding results on question Tec28 (re. superfast computing). Quantum computing is most likely seen as the enabling technology for superfast computing in the 2050ies.

Technology

Tec30: Towards 2050, which advanced technologies are likely to have a significant effect on the future of the chemical industry? 2D MATERIALS (graphene, fullerene etc.)



Medium

Consensus (Measure: Majority)

40 %

Group stability (Percentage)

 Dissent

Consensus status

Note: n = 153. This question was only posed to chemical experts

Judgement call
(Tec-M)

CIFS PERSPECTIVES

Advanced 2D materials are believed to be reality with a significant effect on the industry by a weak majority of respondents

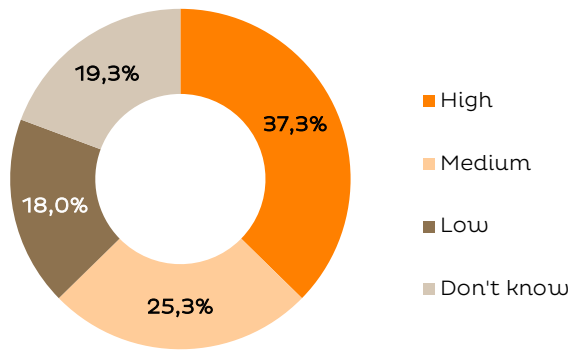
However, substantial proportions of the panel also expressed uncertainties with regards to the topic. Taken together, the outcome on the questions represents a judgement call.

Quotes from survey

Commenting option was disabled for this question.

Technology

Tec31: Towards 2050, which advanced technologies are likely to have a significant effect on the future of the chemical industry? GENOME EDITING



High

Consensus (Measure: Majority)

37 %

Group stability (Percentage)

Dissent

Consensus status

Note: n = 150. This question was only posed to chemical experts

Judgement call (Tec-M)

CIFS PERSPECTIVES

Panellists opined that **genome editing is likely to have a significant effect on the industry but positive responses stayed under the consensus level.**

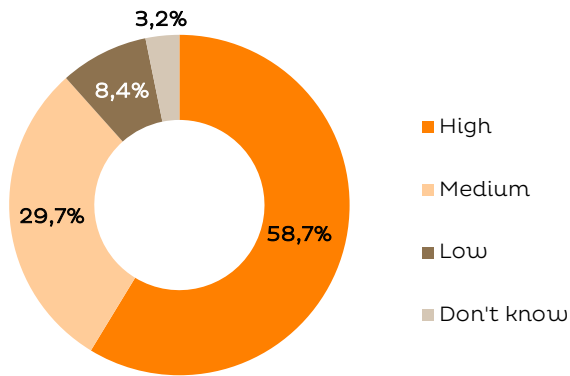
The outcome might indicate that respondents recognized the potential of genetic editing as such but were unsure to which extent it might impact the future of the industry. Impacts are most likely where biotechnology plays a role as the underlying production technology.

Quotes from survey

Commenting option was disabled for this question.

Technology

Tec32: Towards 2050, which advanced technologies are likely to have a significant effect on the future of the chemical industry? ARTIFICIAL INTELLIGENCE



High

Consensus (Measure: Majority)

59 %

Group stability (Percentage)

Consent

Consensus status

Note: n = 155. This question was only posed to chemical experts

In alignment with assumption Tec-M

CIFS PERSPECTIVES

Clear consensus was observed around the significance of artificial intelligence for the future of the industry

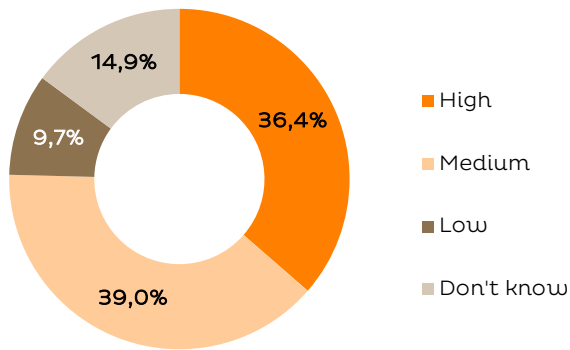
The expression of consensus seems very strong given the relatively limited spread of AI in the industry as of today.

Quotes from survey

Commenting option was disabled for this question.

Technology

Tec33: Towards 2050, which advanced technologies are likely to have a significant effect on the future of the chemical industry? ADDITIVE MANUFACTURING



Medium

Consensus (Measure: Majority)

39 %

Group stability (Percentage)

 Dissent

Consensus status

Note: n = 154. This question was only posed to chemical experts

Judgement call
(Tec-M)

Quotes from survey

Commenting option was disabled for this question.

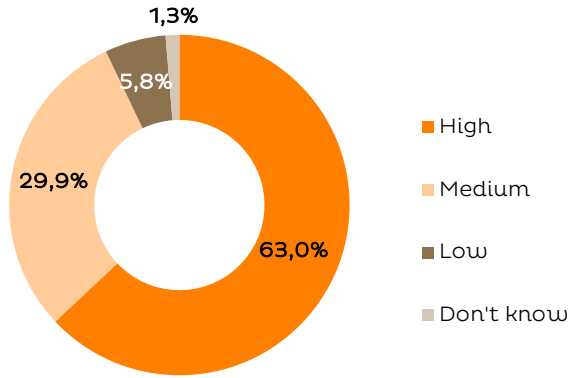
CIFS PERSPECTIVES

Additive manufacturing as an advanced technology was perceived as significant by a combined majority of the panel

Similar to preceding questions on advanced technologies the present outcome expresses overall positive expectations on the panellists' side.

Technology

Tec34: Towards 2050, which advanced technologies are likely to have a significant effect on the future of the chemical industry? CHEMICAL RECYCLING



High
Consensus (Measure: Majority)

63 %
Group stability (Percentage)

Consent
Consensus status

In alignment with assumption Tec-M

Note: n = 154. This question was only posed to chemical experts

Quotes from survey

Commenting option was disabled for this question.

CIFS PERSPECTIVES

Chemical recycling as an advanced technology of the future received a pronounced positive response by the crowd.

The outcome is consistent with preceding respondent answers on expectations around recycling and circular economy (e.g. Tec6, Tec16).

Environment – results

Summary

- Respondents were in strong consensus around the European chemical industry to be *capable* in playing a leading role in the transition towards a sustainable future. However, uncertainty was observed regarding the industry's actual level of *sustainability success* by 2050 (Envu-A*)
- Participants expressed beliefs that the industry's sustainability agenda will result into an overall competitive advantage (Envu-A)
- With regards to global warming expectations respondents were not in line with the assumption of the preceding foresight report. Their consensus was that global warming will surpass the 2-degree temperature mark in the coming decades (Envu-B)
- The respondent panel expected significant impacts on Europe resulting from climate change caused migration (Envu-C)
- Europe's chemical sector was expected to be a significant contributor to the safe and sustainable use of chemicals across value chains towards 2050 – with chemical experts slightly more optimistic compared to non-chemical experts (Envu-D)
- A majority of respondents tended to agree with the expectation of full internalization of externalities as reflected in market prices of goods in 2050 (Envu-D)
- Experts opined that Innovation efforts in the industry need to increase in order to reach sustainability ambitions – as well as a positive investment climate is required (Envu-D)
- The European chemical industry needs to ramp up stakeholder engagement in relation to the societal debate on chemicals in products and wastes (Envu-E)

*Delphi response in relation to assumption 'Envu-A', see next page

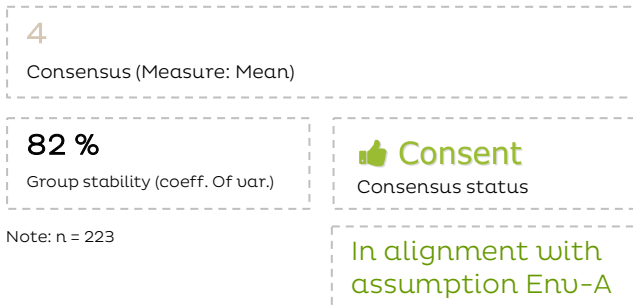
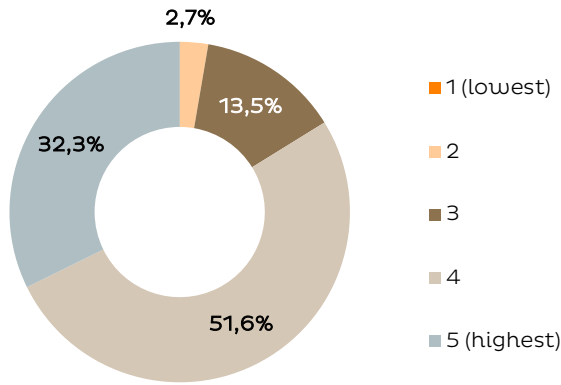
Environment – lead assumptions used for developing Delphi questions

- **EU remains front-runner for sustainability.** The EU maintains its position as a front-runner for environmental sustainability, emissions/pollution reduction, renewable energy and recycling technologies (Env-A: Env1-4*)
- **Global warming remains within the 2-degree temperature increase mark.** Global savings on emissions from renewable technologies, to a limited extent nuclear power, and increased efficiency are all conducive of our ability to keep the temperature increase within the 2-degree target (Env-B: Env5-6)
- **Social unrest fueled by climate change and environmental challenges.** Environmental degradation as a result of climate change, pollution and inadequate land management, exacerbated by basic resource scarcity will fuel social tension and unrest, potentially leading to increased migration pressure on Europe (Env-C: Env7)
- **Environmental impact fears stay high on the agenda and the debate continues.** European initiatives to reduce pollutants will intensify over coming decades, including focus on reducing plastic waste. Similarly, the debate over environmental impact of chemical products persist; presenting a changing and challenging regulatory framework for the chemical industry to operate within' "are they the problem or the solution" (Env-D: Env8-11)
- **Pollution and waste are still a concern.** Environmental pollution, especially through plastic waste, will challenge freshwater, maritime and terrestrial ecosystems alike. It will require significant effort from the public and private sectors, to not only limit incremental waste, but to also address the amounts already accumulated (Env-E: Env12-14)

*Assumption 'Env-A: derived questions 'Env1' to 'Env4'

Environment

Env1: On a scale from 1-5, to what extent do you believe the European chemical industry *can play* a leading role in the transition towards a sustainable future?



Quotes from survey

"It is a joint effort of all industries, but the chemical industry with its thinking with a long-term perspective will be willing to work on transitional developments."

"Chemical industry can play a role, question is if industry is willing to"

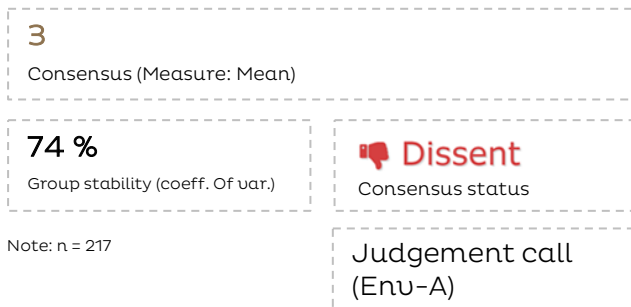
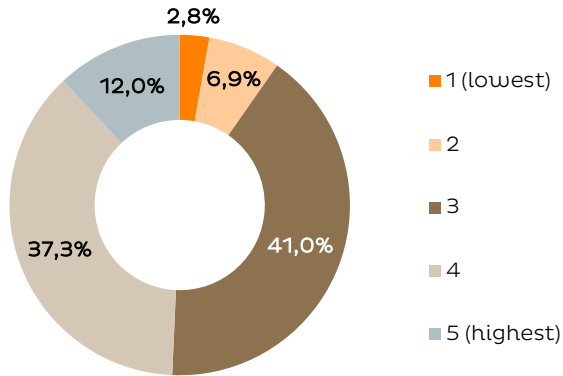
CIFS PERSPECTIVES

Strong support by the respondents on the vision of the chemical industry playing a lead role in the transition into a sustainable future was obtained from the experts.

Commentators underlined the necessity of this transition happening. They expressed beliefs in the industry's capability while individual commentators also questioned the willingness (i.e. the industry's commitment) to do so.

Environment

Env2: On a scale from 1-5, to what extent do you believe the European chemical industry *have succeeded* in playing a leading role in this transition by 2050?



Quotes from survey

“Will the industry manager to really make the change and move? Several individual companies will have a leading role...”

“China, India and USA could be the TOP CHAMPIONS”

CIFS PERSPECTIVES

A majority of participants saw the industry succeeding on a 205ies perspective with regards to lead sustainable change.

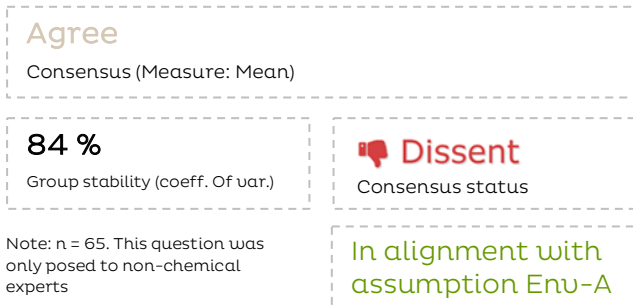
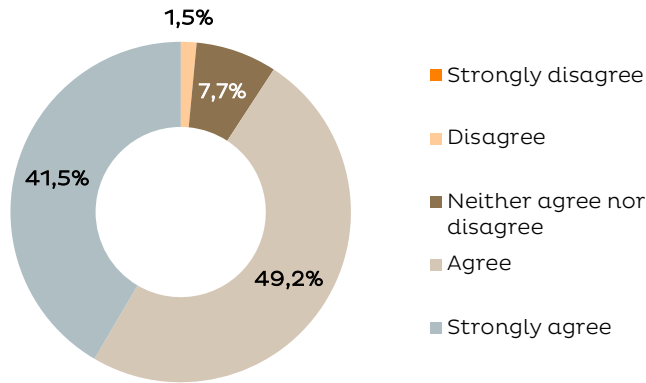
The endorsement of this statement did however not reach the same level about the preceding question (Env1) about the industry’s capability to lead in this transition.

Viewed in combination, the responses to Env1 and Env2 suggested strong trust in the industry’s capability paired with some uncertainty whether the industry will actually succeed with its ambitious mission.

Commentators pointed to the accord necessary across the companies making up the industry and to the fact that (competing) world regions will make their bid too.

Environment

Env3: Towards 2050, European industries with a strong sustainability agenda will enjoy a competitive advantage



Quotes from survey

“The real advantage is and will remain the competitiveness”

“In 2050 those kinds of firms will probably be especially profitable, but the problem is that the firms have to manage also years between the present and 2050”

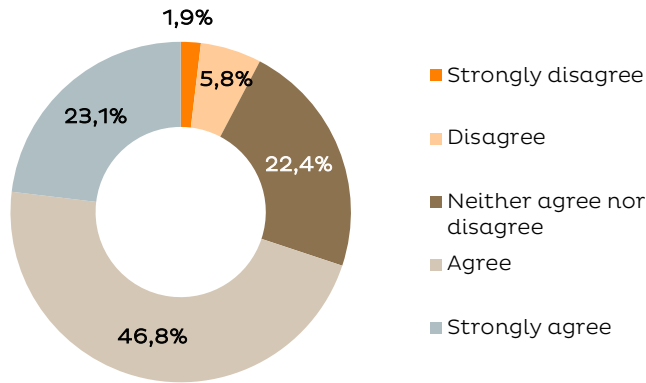
CIFS PERSPECTIVES

A strong majority of respondents (strongly) agree that the sustainability agenda will translate into competitive advantage(s) for European industries.

Comments reflected on the necessity of balancing investments into sustainability with economics and competitiveness in global markets over the coming decades.

Environment

Env4: Towards 2050, Europe's chemical industry with a strong sustainability agenda will enjoy a competitive advantage



Quotes from survey

"...because it should help to stay innovative and to reduce costs even if in other regions like China and US the framework might be less demanding."

"Sustainability will be a "must have" and doesn't generate a competitive advantage since everybody in business will have it."

CIFS PERSPECTIVES

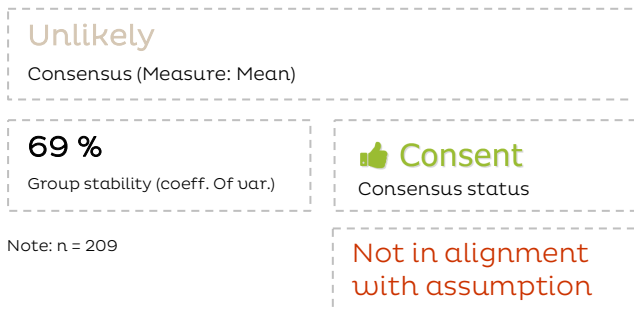
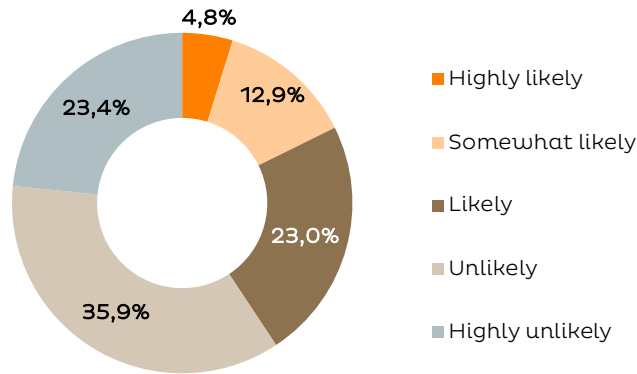
The panels expectation was that the sustainability agenda of Europe's chemical industry will translate into competitive advantage

The outcome is in alignment with assumptions as well as the results from the preceding question (Tec3) which was asking about European industries in general.

The comments suggested that the connection between innovation and sustainability was of importance to the respondents as was the question regarding different (not aligned) sustainability compliance requirements in other economic regions (e.g. China and the USA).

Environment

Env5: Towards 2050, will we manage to remain at 2-degree temperature increase mark?



Quotes from survey

“Present policies are insufficient and will miss the mark by a large margin; implementation of more effective policies will take time (if taken at all).”

“But, this is a global issue...Europe cannot solve this alone... Depends on large emerging economies.”

CIFS PERSPECTIVES

A majority of respondents opined that global warming is unlikely or even highly unlikely to remain at the 2-degrees mark.

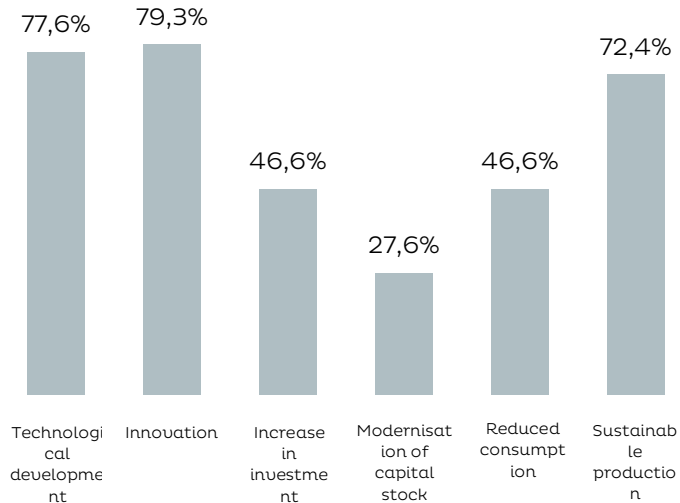
This outcome is not in alignment with the assumptions laid out in the preceding foresight study which was in line with moderate increase in the range of two degrees.

Comments expressed expectations of more intense warming. They also reflected upon the necessity of cooperation and alignment across the established and emerging economies.

Environment

Env6: If you chose likely or highly likely to the previous question:

How will we achieve this? [Select all relevant]



Note: n = 51. The total exceeds 100%, as respondents could select multiple options

Judgement call
(Env-B)

Quotes from survey

“Remaining well below 2 degrees above pre-industrial temperatures requires a very profound, systemic change in the way the economy works, and thus requires a high degree of political and social consensus, at local, regional and national levels, as well as transnationally (e.g. EU level) and globally. All the options above will need to be pursued, and there will be disruption, and winners and losers in this process, so the management of the transition will require great political skills, including a different mind-set and approach to politics itself”

“The broad scale restoration of estuaries and shallow tropical seas is a highly efficient way of investing in carbon sequestration which is all positive with few leakages, or negative side-effects”

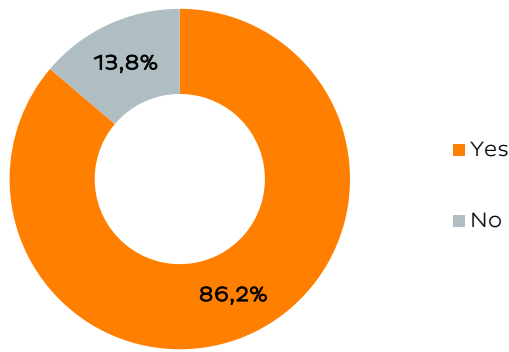
CIFS PERSPECTIVES

Innovation and technological development together with sustainable production were seen as the main conditions to keep global warming at/below two degrees.

Commentators pointed out the massive scale of change required to slow down global warming. They alluded to the necessity of joint efforts in virtually all areas of human activity (i.e. economics, politics, society as well as environmental restoration to enable carbon sequestration).

Environment

Env7: Do you perceive that climate change caused migration will have significant impact on Europe towards 2050?



Yes

Consensus (Measure: Majority)

86 %

Group stability (Percentage)

Consent

Consensus status

Note: n = 203

In alignment with
assumption Env-C

Quotes from survey

“Climate change caused migration will have a significant impact first on the South of Europe which have been affected most from the current geopolitically caused migration. This situation can lead to social tensions and regional instability affecting EU as a whole”

“Issue is too complex to relate it to Climate Change.”

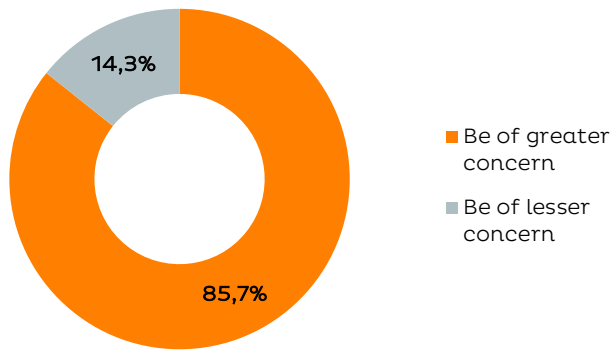
CIFS PERSPECTIVES

A marked consensus was noted on the expectations of climate change induced migration having significant impacts on Europe

Some of the comments posted on this topic elaborated on how these impacts may play out in terms of geography and sequence, whereas others expressed the view that migration as a phenomenon is too complex to link it to climate change (alone).

Environment

Env8: Towards 2050, environmental and safety concerns with regards to chemicals in comparison to other sustainability challenges will:



Be of greater concern
Consensus (Measure: Majority)

86 %
Group stability (Percentage)

Consent
Consensus status

In alignment with assumption Env-D

Note: n = 56. This question was only posed to non-chemical experts

Quotes from survey

“They will be of greater concern than sustainability challenges that are not linked to human health...”

“Heavy metals, organo-compounds which disrupt the ecosystems will be of greater concern”

CIFS PERSPECTIVES

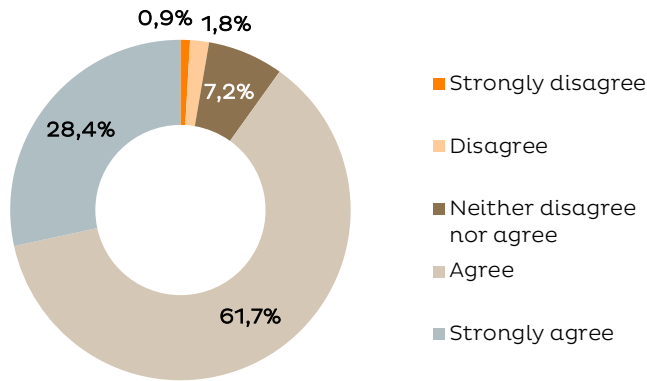
The panel was in strong agreement that safety and environmental issues will be of even greater concern thirty years from now than they are today

The consensus strength and group stability on the issue reflected broad alignment of expectations within the crowd.

Commentators provided additional details on the type of concerns expected.

Environment

Env9: Towards 2050, Europe’s chemical industry is a major contributor to the safe and sustainable use of chemicals improving the quality of human life in Europe and protecting and improving the quality of the environment



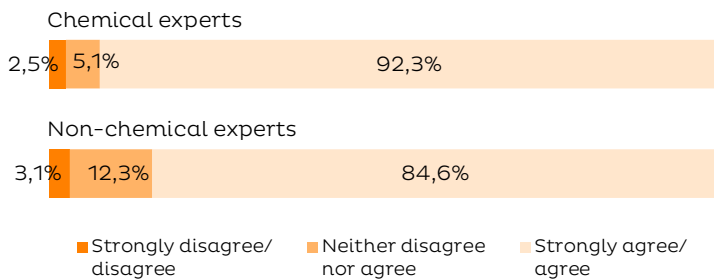
Agree
Consensus (Measure: Mean)

83 %
Group stability (coeff. Of var.)

Consent
Consensus status

In alignment with assumption Env-

Note: n = 222. Statistically significant difference (95% level) between chemical experts and non-chemical experts



Quotes from survey

“I hope it will be - but it will depend on its actions now and in coming years as to whether that is the case. Too soon to say, therefore”

“Who else should do that?”

CIFS PERSPECTIVES

A broad consensus was observed around the chemical industry’s major contributing role to improved quality of human life an environment in Europe

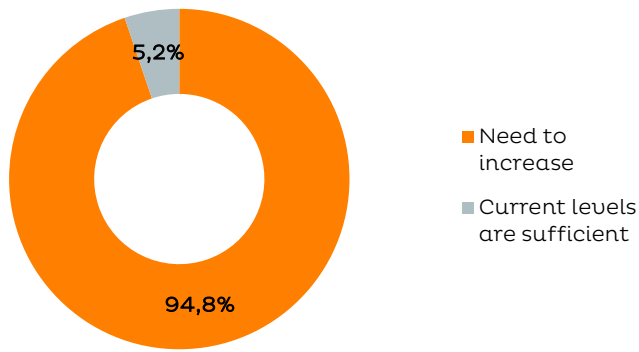
The response to this question were clear-cut: expressing a very positive and consistent view on the industry’s pivotal role in relation to environmental targets.

The statistical differences noted (bar graph) between chemical and non-chemical experts indicated aligned perspectives between the group with the chemical experts expressing a higher level of agreement though.

Comments expressed positive agreement but also indicated the requirement of firm commitment to these future goals in the present – as well as continuous efforts in the years to come.

Environment

Env10: Is the current technology of the European chemical industry sufficient or do innovation efforts need to be increased to overcome key environmental challenges (climate change, pollution, waste)



Need to increase
Consensus (Measure: Majority)

95 %
Group stability (Percentage)

Consent
Consensus status

In alignment with assumption Env-D

Note: n = 154. This question was only posed to chemical experts

Quotes from survey

"it is not a question of invention, but on money spending (capex)."

"Directed innovation efforts towards environmental safety will be needed"

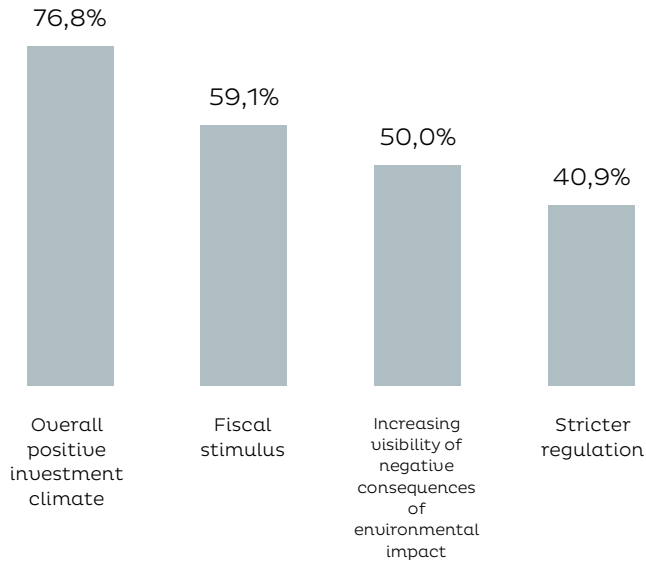
CIFS PERSPECTIVES

The crowd agreed strongly with the necessity to step up innovation efforts to overcome environmental challenges

Commentators provided further differentiation by stating that the lacking bit is not so much on the inventiveness part but on the willingness for capital expenditure (and risk taking) on innovative concepts.

Environment

Env11: What instruments would be needed to speed up innovation to reach the necessary scale to solve these issues?
[Select all relevant]



Note: n = 164. This question was only posed to chemical experts. The total exceeds 100%, as respondents could select multiple

In alignment with assumption Env-D

Quotes from survey

"Increase visibility of positive consequences of investing in solutions for environmental challenges."

"Specific Funds should be dedicated to these topics. Please consider the new ETS Fund"

CIFS PERSPECTIVES

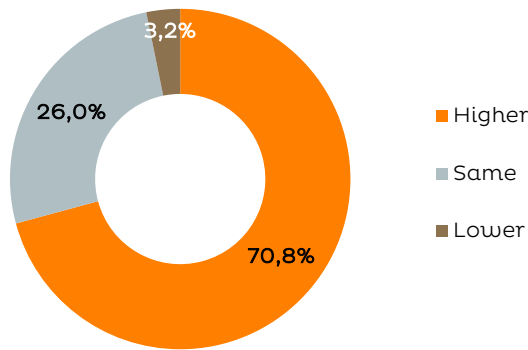
A majority of respondents chose a positive investment climate and fiscal stimuli as necessary preconditions to accelerate innovation

The comments offered shed light on the necessity of specific funds to be created, and to boost visibility of positive consequences and benefits from investing into solutions for environmental challenges.

Through their voting the panel expressed preference towards incentives and stimuli rather than increased regulation or stepping up communication on negative consequences.

Environment

Env12: Towards 2050, do you expect there will be the same level of protection in terms of chemical safety globally?



Higher

Consensus (Measure: Majority)

71 %

Group stability (Percentage)

Consent

Consensus status

Note: n = 154. This question was only posed to chemical experts

In alignment with assumption Env-E

Quotes from survey

“New TSCA and Reach will be copied by other states - means chemical safety goes up.”

“Are we talking about chemical safety or environment??? Chemicals are safe but progress needs to be made on the environmental front.”

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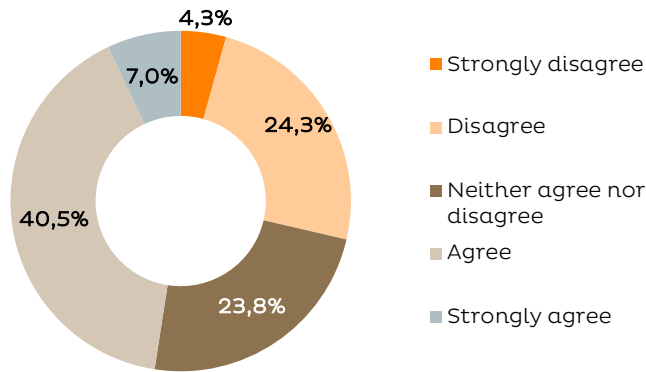
In the eyes of the expert crowd, levels of protection in terms of chemical safety are likely to increase globally.

This expectation is in alignment with assumptions and comments posted indicated that European best-practices will spread to other countries/regions.

Other comments pointed to the necessity to increase environmental safety, while chemical safety issues were seen as solved and therefore of lesser importance.

Environment

Env13: Towards 2050, the market prices of goods and services properly reflect all costs and benefits of external factors, all externalities have been internalized



Neither agree nor disagree

Consensus (Measure: Mean)

68 %

Group stability (coeff. Of var.)

👍 Consent

Consensus status

Note: n = 185

In alignment with assumption Env-E

Quotes from survey

"The Asian markets and the US don't care for such "European" crazy things like externalities."

"Many external factors have no "real" and undisputed price tag. Qualitative conditions do not easily translate into monetary terms."

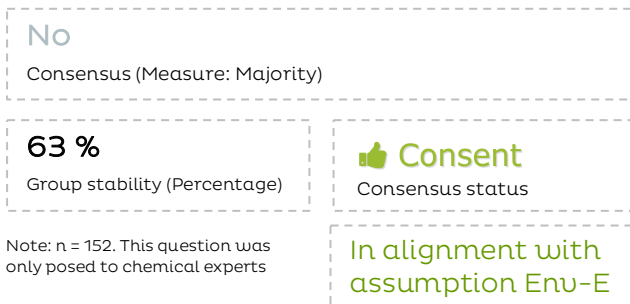
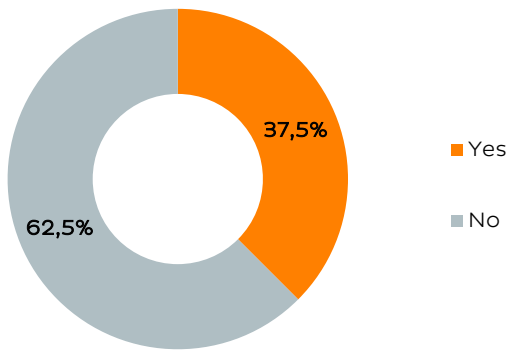
CIFS PERSPECTIVES

The experts expressed a consensus in believing that externalities will be fully internalized in market prices by 2050.

Comments posted reflected on the issue of competitiveness in global markets which must be secured in the long-run - as well as the challenge of adequately pricing of externalities as such.

Environment

Env14: Do you think the European chemical industry is sufficiently engaged in the societal debate on chemicals in products/wastes?



Quotes from survey

"We're more and more engaged but still in defense-mode (and also perceived by the public (NGOs) as being in that mode)."

"Discussion is lead very superficially and the issues that the chemical industry has in a global economy (free-riding problem of the not-complying competitor) are a taboo."


CIFS PERSPECTIVES

A substantial majority opined that the industry should engage even more in the societal debate around chemicals in products/wastes

This result was in alignment with assumptions and reflected a clear expectation that a stepped-up engagement is in the industry's interest.

Commentators advocated an even more proactive and less defensive role in the industry's ways of engaging – in particular relative to the NGO's.

Other comments pointed out that engagement in societal debates cannot be limited to a European context but must look broader – i.e. consider global competitors' environmental compliance (or lack thereof).



PHONE +45 3311 7176
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