
A preparedness plan for Europe: Addressing food, energy and technological security

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A preparedness plan for Europe: Addressing food, energy and technological security

The current situation in Ukraine has led to severe supply chain disruptions, contributing to a sharp increase in food and commodity prices globally and the limitation of fossil fuel imports from Russia to the EU. Moreover, to end Europe's dependence on semiconductor suppliers from Asian countries, it is necessary to take immediate action of a structural nature, involving all EU Member States and all participants in regional supply markets.

The overall aim of this study was to identify drivers of and barriers to building up open strategic autonomy at EU level, before recommending coordinated solutions and addressing supply chain resilience in four critical areas: food security, energy security, semiconductors and satellite communications. This research seeks to contribute to the European Parliament's future work by providing insights into how to protect the European agricultural sector, ensure energy security and the technological sovereignty of semiconductor production, and improve satellite communications.

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Executive summary

Justification of the relevance and topicality of the research

Being closest both geopolitically and economically to Ukraine, Europe's economy is currently distinctly vulnerable. The effects of Russia's war on Ukraine have triggered threats to Europe's energy, food, satellite communications and semiconductor supply chains. The war has led to severe supply chain disruptions, contributing to a sharp increase in food prices (corn, wheat, vegetable oil) and fossil fuels imported from Russia to the EU. Moreover, to secure Europe's independence from semiconductor suppliers from Asian countries, it is necessary to take immediate action of a structural nature, involving all EU Member States and all participants in regional supply markets. Consequently, the European Parliament's legislative activities need to be revisited and rethought. A research task with the title 'A preparedness plan for Europe: Addressing food, energy and technological security' was designed in response to the identified challenges and needs. This study explores ways to ensure food security for EU citizens and safeguard the agricultural sector. It also pinpoints possible ways to enhance the EU's energy security and ensure supply chain stability, as well as enablers and barriers to building the resilience of the semiconductor supply chain in Europe. In the area of satellite communications, the study focuses on the potential to leverage the Copernicus programme – an important EU source of Earth observation data.

Research questions and methodology

The overall aim of the study was to identify drivers and barriers to, and recommend coordinated solutions for, building up open strategic autonomy at EU level, and address supply chain resilience in four critical areas: food security, energy security, semiconductors and satellite communications. This research aims to contribute to the European Parliament's future work by providing insights into: how to protect the European agricultural sector and prepare for food shortages; how to ensure energy security; how to ensure technological sovereignty of semiconductor production; and how to improve Copernicus's capabilities in the light of supply chain disruptions.

A Delphi methodology was implemented to answer the research questions. Sixteen theses were developed for specific areas, as well as five additional cross-cutting theses demonstrating the relationship between the areas mentioned above. Four of these theses were examined within the food area: Wheat production in EU countries will be independent of Ukraine and Russia; EU countries will be the leaders in the production of sunflower oil; EU countries will invest additional financial resources in the production of NPK [nitrogen, phosphorus and potassium] fertilisers in order to become independent from Russia; There will be a reversal of the previous policy of limiting agricultural production. In the energy area, the considered theses were: The growth of renewables in the energy mix in the EU countries will be more dynamic; The role of Russia as a supplier of fossil fuels to the EU market will diminish; There will be closer integration of EU countries within European energy security; The importance of hydrogen and biomethane as energy sources will increase; There will be a transformation of the energy market in the EU towards distributed energy. Within the satellite communications area, three theses were examined: There will be rapid development of the market for free applications based on Copernicus data, which will increase the scale of stand-alone satellite data analytics by end-users; Multidimensional analysis of data provided by Copernicus will enable environmentally friendly management of supply chains by providing safe transportation, eco transportation and meteorological forecasts for transportation; In the face of socio-political crises (wars, migration, economic crises), the importance of Copernicus data analytics will increase, providing supply chain optimisation. The theses formulated in the area of the semiconductors were as follows: EU share of global cutting-edge, innovative and sustainable semiconductor production will increase from 10 to 20 %; Security of supply of semiconductors to strategic sectors of EU countries will be ensured; Building a dynamic ecosystem across the EU will strengthen Europe's capabilities to achieve its environmental goals and green transitions while improving the Union's

security (semiconductors); EU countries have sufficient resources to produce modern integrated chips.

The questionnaires comprised Delphi theses, enablers and barriers shaping the phenomena in the researched areas. The survey was addressed to experts representing one or more of the areas considered, primarily: scientists, academics, policy-makers, representatives of industry, government agencies, politicians, etc. The respondents were diverse in terms of gender, age, education, the sectors they represent and countries. The survey involved 153 experts in the first round and 117 experts in the second round.

Main conclusions

In the food area, the highest significance index was noted for decoupling wheat production in EU countries from Ukraine and Russia. The most significant factor favouring its implementation is promoting the use of advanced technologies in agriculture (such as artificial intelligence, remote sensing, geographic information software, virtual reality, drones and application programming interfaces). The strongest barrier to implementing the investigated theses is the occurrence of extreme weather conditions such as droughts, floods and other natural disasters. This is a barrier that could be treated as a wild card (high impact, low probability event) and for which the impact of political influence at EU level is not significant. The study also identified 16 factors (using STEEPED analysis) that, in the opinion of the study's authors, may favour the resilience building of food supply chains in Europe. Factors that received the highest importance scores included: the occurrence of extreme weather conditions such as droughts, floods and other natural disasters, the level of financial support to farmers, the use of advanced technologies in agriculture (such as artificial intelligence, remote sensing, geographic information software, virtual reality, drones, application programming interfaces) and conscious consumerism. The study also identified the factors with the highest uncertainty of development in the 2030 horizon. These include: the level of international migration, the level of utilisation of biogas production from agri-food waste, the occurrence of extreme weather conditions such as droughts, floods and other natural disasters, and the level of social trust in modern technologies.

In the area of energy, the highest significance index was recorded for energy cooperation within the EU, and the need for greater integration and experts' high expectations regarding the rapid development of renewables. The most important factor favouring the implementation of the theses is technological progress in the field of alternative energy sources (e.g. technologies using space-based solar power, human power, tidal power, hydrogen power, magma power, flying wind power, algae power, fusion power). The strongest barrier to implementing the theses is the reluctance of some EU Member States to cooperate on energy due to different energy goals and low stocks of energy resources in many countries of the EU. The study also identified 14 factors (using STEEPED analysis) that may favour the resilience building of energy supply chains in the EU. The most important factor affecting supply chain resilience in the EU turned out to be technological progress in the field of alternative energy sources. Factors with the highest uncertainty of development in the 2030 horizon are: the level of geopolitical stability, and the reluctance of some EU Member States to cooperate on energy due to different energy goals.

The study in the area of satellite communications focuses on the potential to leverage the Copernicus programme. The most significant factors favouring the implementation of the theses in this area are: the increase of the scope and quality of education of current and potential Copernicus end-users, the broad promotion of the Copernicus programme, and mutual and effective cooperation among key stakeholders in the Copernicus programme. The greatest barrier to implementing the theses is low competence of end-users using Copernicus data and services. The study also identified 14 factors (using STEEPED analysis) that may favour the resilience building of satellite communications supply chains in the EU. Factors that received the highest importance scores included: cooperation between key stakeholders (researchers, entrepreneurs, politicians) of

the Copernicus programme, competencies of end-users using Copernicus data and services, efficiency in the use of natural resources using modern digital technologies. The factors with the highest uncertainty of development in the 2030 horizon are: the role of civil society, the level of geopolitical stability, the quality of legislation on cybersecurity and the use of digital data and aging society.

The most significant factor favouring the implementation of the theses in the area of semiconductors are: funds for research, development and innovation, implementation of advanced semiconductors, pilot lines for prototyping, testing and experimentation, increasing the number of qualified employees, boosting dialogue with semiconductor manufacturers to prioritise production for critical sectors such as the healthcare, medical, electronics, automotive, and army sectors. The experts considered the most important barriers to be: a shortage of qualified workers and shortages of raw materials for semiconductor manufacturing, concentration of supply with respect to geographic areas and companies. The study also identified 16 factors (using STEEPED analysis) that may favour the resilience of semiconductor supply chains in Europe. Factors that received the highest importance scores included: funding of research, development and innovation, STEM investments, qualified employees in the semiconductor ecosystem. The highest uncertainty of development in the 2030 horizon received the factors: changes in environmental requirements that reduce manufacturing efficiency, fluctuation rate of demand for different types of semiconductors and conscious consumerism.

Policy options

The research carried out has led to the development of policy options that will ensure building resilience in supply chains, where resilience is understood as the ability to secure supply despite shocks and disruptions.

The experts formulated the following main proposals in the area of food: promoting local production and self-sufficiency of farms; educating end-users; science, technology, engineering, mathematics (STEM) and research and development (R&D) orientation; and creating regulations to foster resilience in food supply chains.

The policy options in the area of energy are: transformation towards energy communities / distributed energy / development of distributed energy; greater energy integration of EU countries / deepening activities for the energy union; reducing the EU's energy needs / shortening and diversifying energy supply chains in the EU / greater flexibility of the energy system in the EU.

As far as satellite communications is concerned, the experts indicated the following policy options: supporting the decisions of the EU institutions managing the Copernicus programme; and supporting end-users (non-experts) and intermediate users (experts in Copernicus data analytics and Earth observation).

In the area of semiconductors, the policy options are as follows: global partnering supporting cutting-edge semiconductor fabrication plants (mega fabs); supporting local semiconductor ecosystems and the modern semiconductor sector; STEM and R&D orientation; and increased protection of the EU market against security and safety threats.

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1. Introduction

Owing to recent events, such as the COVID-19 pandemic, Russia's war on Ukraine, natural disasters and geopolitical conflicts, the security of supply chains in four critical sectors – food, energy, semiconductors and satellite communications – is currently at risk. Taking direct action to foster the resilience of supply chains in these sectors is therefore urgently needed. The aim of the study entitled 'A preparedness plan for Europe: Addressing food, energy and technological security' was to identify the key drivers and barriers to, and recommend coordinated solutions for, building up open strategic autonomy at EU level, and address supply chain resilience in four critical areas: food security, energy security, semiconductors and satellite communications.

First, the state of the art relating to the resilience of supply chains specific to the indicated sectors was presented, which made it possible to select and adopt an appropriate research methodology.

Food systems are progressively subjected to disturbances and shocks, which are expected to increase in the foreseeable future. Most recently, the war in Ukraine and the COVID-19 pandemic have raised anxieties about the capacity to ensure the availability of food at stable rates (Rimhanen et al., 2023). In addition to the impact of the pandemic, the current Ukraine war has also resulted in severe supply chain disruptions leading to a sharp increase in food and commodity prices globally (Arora, Sarker, 2023). The events both threatened the sustainability of the food market, which has been experiencing huge transformation over recent decades (Din et al., 2022), and compromised food safety.

The recent difficult geopolitical situation has forced the promotion of food system resilience to ensure availability of and access to nutritious and safe food, despite unexpected disruptions in the operating environment (Karoliina et al., 2023).

Ukraine and Russia are two key global grain manufacturers and exporters, accounting for 12 % and 17 % of the world's wheat exports respectively. The war between Russia and Ukraine may considerably affect Ukraine's wheat production and export, as well as Russia's wheat export. This is especially true of Ukraine, which, in 2020, was the world's fifth largest exporter of wheat, with exports amounting to US\$4.61 billion in wheat according to OEC (Wheat in Ukraine, 2022), and partly lost its exporting capacities because of war restrictions, difficulties with agricultural production due to military interventions, and the price for energy resources and fertilisers. Satellite observations have shown indications of wheat production drop in Ukraine in the 2021–2022 period (Lin et al., 2023). Moreover, Russia and Ukraine represent more than half of the world's production of sunflower oil. The research results demonstrate that the war has also disrupted the supply of organic fertilisers, reducing agricultural products and contributing to the subsequent rise in the price of agricultural produce. The research indicates that the rising costs of fertilisers directly influences food production and supply (Shahini et al., 2022).

Considering the role of Russia and Ukraine in agricultural input sectors including wheat, oil, and fertilisers (especially Russia), the trade blockade caused by the conflict will give rise to price increases of between 10 % and 30 % and welfare decline of between 15 % and 25 % for most affected countries (Lin et al., 2023). As both countries are significant exporters of commodities that are vital for global food security, the resulting abrupt supply chain disruptions have created substantial uncertainty in commodity markets worldwide (Ihle et al., 2022).

The enduring conflict is anticipated to induce disruptions to agricultural production and global trade, because it can displace population and impede the free movement of people and goods, thereby blocking farmers from cultivating, harvesting and selling crops (Li et al., 2022).

The conflict's impact on non-European countries is also not negligible. Russia and Ukraine combined supply over 50 % of cereal imports in north Africa and the Middle East, while east African countries

import 72 % of their cereals from Russia and 18 % from Ukraine. If the war expands, the food crisis will be exacerbated, posing a challenge to many countries, especially those that depend on food imports, such as those in the Middle East and north Africa (MENA) region (Hassen, Bilali, 2022).

Finally, the war may jeopardise the implementation of Sustainable Development Goals (SDGs), notably SDG 1 (No poverty) and SDG 2 (Zero hunger) (Hassen, Bilali, 2022).

In light of these developments, it is therefore crucial to explore ways of ensuring food security and building resilience of supply chains for EU citizens, as well as safeguarding the agricultural sector.

Energy. The modern world economy needs more and more energy (IEA, 2021). Population growth, the high pace of economic development, and progress in the creation and use of new technologies mean that the demand for electricity is constantly growing. The EU faces many challenges in the field of energy, relating to import dependency, insufficient diversification, high and volatile energy prices, increasing global energy demand, security threats to producing and transit countries, the growing threat of climate change, decarbonisation, slow progress in energy efficiency, challenges relating to the increasing use of renewable energy sources, and the need for greater transparency of energy markets and their further integration and interconnection. To meet these challenges, the energy union strategy (COM/2015/080), published on 25 February 2015, was developed, and within it, the five dimensions of the energy union:

- Diversification of European energy sources, ensuring energy security through solidarity and cooperation between EU countries;
- Ensuring the functioning of a fully integrated internal energy market, allowing energy to flow freely within the EU through appropriate infrastructure and without technical or regulatory barriers;
- Improving energy efficiency and reducing dependence on energy imports, reducing emissions, as well as stimulating job creation and economic growth;
- Decarbonising the economy and moving to a low-carbon economy in line with the Paris Agreement;
- Promoting research into low-carbon and clean energy technologies, and prioritising research and innovation to drive the energy transition and improve competitiveness.

The EU, caring for the natural environment and striving for sustainable development, has set itself the goal of climate-neutrality by 2050, with the ambition to become the first-ever economy with net-zero greenhouse gas emissions, in line with commitments under the Paris Agreement (Clean Energy Transition Partnership, 2020).

Russia's unprovoked and unjustified military aggression against Ukraine led to the disruption of supply chains of fossil fuels imported from Russia to the EU, exposing Russia as an unreliable partner that brutally uses fossil fuels to play politics and influence importing countries. In response to the Russian aggression, the European Commission developed the REPowerEU plan, which aims to reduce Russia's share in the EU energy market (REPowerEU, 2022).

However, the consequences of the Russian aggression against Ukraine and Russia's aggressive energy policy for EU Member States are significant. Russia used to be the EU's most important energy partner. Almost 30 % of the extra-EU crude oil, 43 % of natural gas, and 54 % of solid fossil fuel (mostly coal) imports originated from Russia. It is necessary to identify actions and create policy options to meet such challenges as: the consequences of high and volatile energy prices for consumers, small and medium-sized enterprises (SMEs), and industries across all EU Member States; insufficient resources and supplies of fossil fuels; and the need to limit the role of gas in the energy transition (State of the Energy Union, 2022).

With the development of **satellite communications technology**, satellite observations have become indispensable for developing an understanding of the Earth and the phenomena occurring

on it from both the environmental (Zhao et al., 2022) and socio-economic perspectives. The study from the area of satellite communications focuses on the potential to leverage the Copernicus programme – an important EU source of Earth observation (EO) data. Copernicus provides free access to near real-time data collected by dedicated EO satellites called Sentinels and in-situ (non-space) observations. In addition, it offers a set of information services necessary for the socio-economic monitoring and management of global security and environment in a smart and sustainable way (Apicella et al., 2022). It is a programme that provides a better understanding of the impacts of climate change and improved resource management, making it a tool with great potential for many sectors (Kasmaeeyazdi et al., 2021).

Since the launch of the programme in 1998, great strides have been made in implementing many services based on accurate, timely and easily accessible information and data (Apicella et al., 2022). For example, in the field of agriculture, applications have been designed to support the development of digital and smart agriculture (Meier et al., 2020), and to facilitate crop monitoring in order to assess primary production (Wolanin et al., 2019).

The growing role of satellite imaging in various sectors is expected to have significant impact on the future of societies and economies. This market is expected to grow from US\$350 billion to US\$2.7 trillion over the next three decades. The use of data, applications and services from Copernicus in EU industries could lead to the creation of new and innovative market segments based on value-added services and resources. In addition, the spread of Copernicus across the EU can help strengthen the EU's digitisation capacity, and prepare the workforce for the ongoing digital transformation (Kasmaeeyazdi et al., 2021).

In view of the crises caused by recent geo-political tensions and events, an analysis of the Copernicus programme's services and capabilities has become an urgent necessity. The potential of satellite technology, in the face of real military-economic threats, requires additional and updated analyses. It seems necessary, for example, to identify risks for and resilience to supply chain disruptions in the area of satellite communications, and to mitigate and counter the effects of crises resulting from these disruptions in the humanitarian, agricultural, economic and other areas.

Copernicus can also enable the process of monitoring mining activities and ensuring compliance in European and foreign supply chains. The development of applications and the promotion of the use of the programme's data in selected economic sectors can contribute to the safe and sustainable supply of selected resources, as is already slowly happening in the supply of mineral resources from the raw materials sector – as in the example of the RawMatCop project (Kasmaeeyazdi et al., 2021).

On the one hand, new areas of application of Copernicus should be explored, e.g. monitoring the images of migration flows. On the other, the existing potential offered by the Copernicus programme should not be forgotten. A number of important initiatives within the Copernicus programme should be taken into account, i.e.: i) the Copernicus services, e.g. the Copernicus data space ecosystem – a service for free instant access to a wide range of data and services from the Copernicus Sentinel mission; ii) Copernicus opportunities, e.g. in the form of the Copernicus start-up programme (www.copernicus.eu); iii) Copernicus user uptake – part of the EU's strategy to raise awareness of the Copernicus programme at the European and global level (Apicella et al., 2022).

Semiconductor (chips) are central to the digital economy (regulation of the European Parliament, 2022). The shortage of semiconductors in global markets since 2020 has affected almost every sphere of life. Semiconductor supply disruptions have influenced sectors such as the automotive, energy, communications and healthcare sectors, as well as strategic sectors such as defence, security and space. In addition, emerging fake chips that endanger the security of electronic devices and systems are a serious threat. There is general agreement that the EU must strengthen its position in the semiconductor industry. A strengthening of Europe's role as a supplier of semiconductors is also needed because of the anticipated increase in the use of semiconductors

due to digitalisation. It is expected that the value of Europe's consumption – i.e. the value of semiconductors used by EU citizens and industry – will double from € 44 billion in 2020 to almost €80 billion in 2030 (Kearney Report, 2022).

According to the Digital Compass, Europe's ambition in the 2030 perspective is for the production of cutting-edge and sustainable semiconductors in Europe, including processors, to amount to at least 20 % of world production in value (2020 baseline: 10 %) (2030 Digital Compass, 2021). This means achieving manufacturing capacities below 5-nanometre nodes, aiming at 2 nanometres and 10 times more energy efficient than today.

Although the EU has lost ground in the global semiconductor market over the past 20 years, it still has strategic resources in the semiconductor supply chain. Europe's strengths in the context of rebuilding the European semiconductor ecosystem include:

- high R&D capacity, advanced-level STEM graduates (compared with US, China, Japan, South Korea);
- existing local semiconductor manufacturers (e.g. ASML, Atlas Copco, AT&S, Besi, IMEC, Zeiss);
- historically strong tradition in industries (combination of engineering and manufacturing) with high-quality infrastructure and manufacturing of factory equipment capacity;
- good examples of the efficiency of European entities in the design, manufacturing and distribution logistics of new solutions/technology (example: COVID-19 vaccines) (Kearney Report, 2022).

In taking steps to ensure the resilience of semiconductor supply chains and improve Europe's position in the global market, it is important to keep in mind that the semiconductor sector is one of the industries with high levels of investment in both R&D (22 %) and capital expenditures (26 %) (Varas et al., 2021). Europe's re-emergence in global semiconductor markets will be determined by the development of cutting-edge semiconductor technology (nodes below 10 nanometres).

2. Methodology and resources used

The overall aim of the study was to identify drivers and barriers as well as recommend coordinated solutions for building up open strategic autonomy at EU level, and address supply chain resilience in four critical areas: food security, energy security, semiconductors and satellite communications.

This research might contribute to the future work of the European Parliament by providing insights into:

- 1 How to protect the European agricultural sector and prepare for food shortages
- 2 How to ensure energy security
- 3 How to ensure technological sovereignty of semiconductors' production
- 4 How to improve Copernicus's capabilities

in light of dealing with disruptions in supply chains. Consequently, the legislative activities of the European Parliament are to be revisited and rethought.

For the implementation of the research task entitled: 'A preparedness plan for Europe: Addressing food, energy and technological security', a Delphi methodology was implemented. The Delphi method is a type of expert research, where the intuitive opinions of experts are treated as legitimate contributions to the formulation of a vision of the future of the research subject. The method is used to predict the development of long-term phenomena in a situation of uncertainty, especially when: (i) the anticipated phenomena are not suitable for the analytical techniques characteristic of forecasting, (ii) no reliable data exist on the anticipated processes, or (iii) external factors have a determining influence on the anticipated phenomena.

The following groups of experts were involved in the implementation of the study:

- the research team of Bialystok University of Technology, Poland;
- key experts involved in individual interviews (representing four key research areas);
- Delphi survey experts (153 experts in the first round and 117 experts in the second round including experts representing various stages of the supply chains in food security, energy security, semiconductors and satellite communication, academics, representatives of government agencies and politicians).

The characteristics of the research sample are presented in Table 1.

Table 1: Characteristics of the research sample

Variable	Characteristics
Gender	man – 63.25 %; woman – 35.90 %; prefer not to disclose – 0.85 %
Age	25-34 years – 18.80 %; 35-44 years – 36.75 %; 45-54 years – 29.06 %; 55-64 years – 11.11 %; 65 years or older – 4.27 %
Education	higher – Professor – 50.43 %; higher – PhD – 38.46 %; higher – BA, BEng, BSc, MA, MSc, etc. – 10.26 %; postgraduate – 0.85 %
Represented sector	scientists, researchers – 78.26 %; companies/industry – 11.59 %; farmers – 3.62 %; regional and local government / policy-makers – 2.90 %; NGOs – 1.45 %; special interest groups – 1.45 %; national policy-makers – 0.72 %
Country	Italy – 17.09 %; Romania – 12.82 %; Portugal – 1.26 %; Spain – 8.55 %; Germany – 7.69 %; Greece – 6.84 %; Poland – 5.13 %; France – 3.42 %; Netherlands – 3.42 %; Bulgaria – 2.56 %; Austria – 1.71 %; Latvia – 1.71 %; Lithuania – 1.71 %; Slovakia – 1.71 %; Slovenia – 1.71 %; Tunisia – 1.71 %; Belgium – 0.85 %; Croatia – 0.85 %; Cyprus – 0.85 %; Czechia – 0.85 %; Denmark – 0.85 %; Malta – 0.85 %; Sweden – 0.85 %; Brazil – 0.85 %; UAE – 0.85 %; Argentina – 0.85 %; Turkey – 0.85 %; Nigeria – 0.85 %; Chile – 0.85 %; Mauritius – 0.85 %

Source: Own research.

The experts were diverse in terms of gender, age, education, sectors represented and countries.

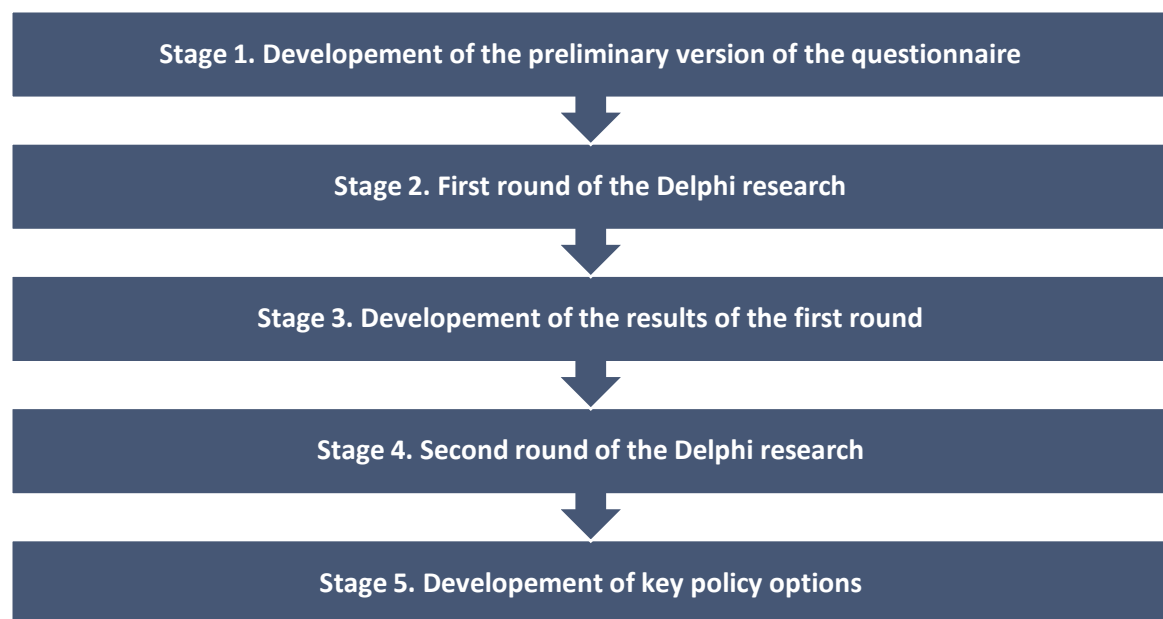
The survey involved 63.25 % men and 35.90 % women. 0.85 % of the respondents preferred not to disclose their gender. The respondents aged 35-44 and 45-54 accounted for the highest proportions, with 36.75 % and 29.06 %, respectively. Those aged 25-34 accounted for 18.80 % and those aged 65 or older – for only 4.27 %.

More than 80 % of the respondents held either a professor's degree (50.43 %) or a doctoral degree (38.46 %), with the remaining respondents holding a university degree, either at an undergraduate or master's level.

The experts participating in the survey represented thirty countries. The highest percentage of respondents in the sample were from Italy (17.09 %), Romania (12.82 %) and Portugal (10.26 %). More than 5 % of the surveyed group were experts representing Spain (8.55 %), Germany (7.69 %), Greece (6.84 %) and Poland (5.13 %).

The research methodology consisted of five stages (Figure 1).

Figure 1: The main stages of the research methodology



Source: Compiled by the authors.

The first stage of the research procedure involved individual in-depth interviews with key experts in the areas of food security, energy security, semiconductors and satellite communications, with the aim of finding out opinions on the preliminary versions of the Delphi questionnaires (comprising Delphi theses, enablers and barriers shaping the phenomena in the research areas). Preliminary versions of the Delphi questionnaires were developed by a key research team representing the Faculty of Management Engineering at the Bialystok University of Technology. Conclusions from individual interviews allowed the development of the final version of the Delphi questionnaire. **In total, sixteen theses (four in the area of semiconductors, four in the area of food, three in the area of satellite communications and five in the area of energy) were developed for specific areas and five cross-cutting theses demonstrate the relationship between areas mentioned above.** Specific enablers and barriers were prepared for each area. The impact of theses on supply chains and specific stakeholder groups was also taken into account. The questionnaire applied to the survey is included in Appendix 1.

A database of experts was developed on an ongoing basis. As of the end of December 2022, this database included about 2,000 experts, both Polish and foreign. Due to a low return rate of the questionnaires in the initial phase of the study, it was decided to significantly expand the expert database to over 20,000 records. The experts were identified on the basis of keywords relating to the topic of the research in the Web of Science database.

The intention of the authors of the study was that specific theses would be evaluated by domain experts, while the cross-cutting theses would be addressed to the entire group of experts.

In the second stage of the research procedure, the first round of Delphi thesis evaluation was carried out. The respondents were invited to participate in the study including experts representing various links in the supply chain in the areas of food security, energy security, semiconductors and satellite communications as well as academics, representatives of government agencies and politicians. It was assumed that the following principles would be priorities for their recruitment:

- recruiting experts from publicly available databases;
- using a snowballing technique – experts invited to the survey nominated further experts;
- aiming for a diversity of experts;
- the widest possible participation of representatives from different parts of the supply chain;
- socialising the process – involving a wide range of experts in the process, ensuring a sense of participation and involvement through the open nature of recruitment.

For this phase of the study, 153 experts were successfully recruited. An invitation was sent to each expert containing: a brief description of the research and the main objectives of the survey, instructions on how to complete the survey, a hyperlink to the survey and a token.

In the third stage of the research procedure, i.e. for the implementation of the second round of Delphi thesis evaluation, the experts were presented with the detailed results of the first round of the survey. Both rounds I and II of the Delphi survey were carried out using the CAWI (Computer Assisted Web Interviewing) technique. This technique allows, among other things: a) automatic (by the system supporting the survey) verification of logical correctness of the data entered; b) automatic saving of survey results on the server, which facilitates and speeds up the analysis process; c) implementation of surveys even in the case of groups of respondents dispersed over a large geographical area. The questionnaires of the second round were addressed to the same group of experts that completed the questionnaire in the first round of the survey. As in the first round of the Delphi research, the invitation to the second round was sent to each expert and contained: an appreciation for the participation in the first round of the survey, a brief description of the research and the main objectives of the survey, instructions on how to complete the survey, a hyperlink to the survey and a token. In addition, certificates of appreciation were sent to all experts participating in the survey. In the final round, 117 responses were received.

The fourth stage of the research procedure revolved around developing the results of the second round of the Delphi research. The obtained results allowed for the evaluation of between 3 and 5 Delphi theses proposed in each research area (16 theses in total) and 5 cross-cutting theses demonstrating the relationship between areas mentioned above. In order to simplify the analysis of a large volume of data collected as a result of the survey, some variables of the questionnaire were presented in the form of indicators that synthesise and organise the results of more detailed observations. In order to determine the strategic importance of particular theses, indicators of significance (I_s) were determined according to the following formula:

$$I_s = \frac{n_{VH} \cdot 100 + n_H \cdot 75 + n_A \cdot 50 + 25n_L + 0n_{VL} + 0n_{HS}}{n - n_{HS}}$$

where:

- n_{VH} the number of responses *very high*,
- n_H the number of responses *high*,
- n_A the number of responses *average*,
- n_L the number of responses *low*,
- n_{VL} the number of responses *very low*,
- n_{HS} the number of responses *hard to say*,
- n the number of all responses.

The indicator takes values from 0 to 100; the closer the value of the indicator to 100, the more strategic importance is assigned to a given thesis for the examined area (Ejdys, 2013; Nazarko, 2013; Kononiuk et al., 2021). In the same way, the indicators relating to enablers (IE) and barriers (IB) to the execution of the thesis were determined, which allowed for the identification of the most important enablers and barriers.

The fifth stage of the methodology was to develop, based on the results of the survey, policy options for creating an ecosystem in the EU that will be able to face disruption, making the supply chain more resilient.

3. Synthesis of the research work and findings: Results of the Delphi study

3.1. Food

The unprovoked Russian invasion of Ukraine has further destabilised already fragile agricultural markets. Ukraine is the EU's fourth biggest external provider of food, covering half of the EU's demand for corn, a fifth of its soft wheat demand and a quarter of its vegetable oil. The war in Ukraine dramatically changed market expectations, affecting prices in all commodities, including agri-food primary products. The global wheat market is where food security concerns are mainly concentrated. Prices in wheat futures markets have increased by 70 % since the invasion. Under the current circumstances, all trade has stopped between Ukraine and the EU because ships have difficulty leaving the Black Sea. This study will explore ways to ensure food security for the citizens of the EU and safeguard the agricultural sector in the light of these developments.

Within the food area, four theses were examined:

Thesis F_T1. Wheat production in EU countries will be independent of Ukraine and Russia

Thesis F_T2. EU countries will be leaders in the production of the sunflower oil

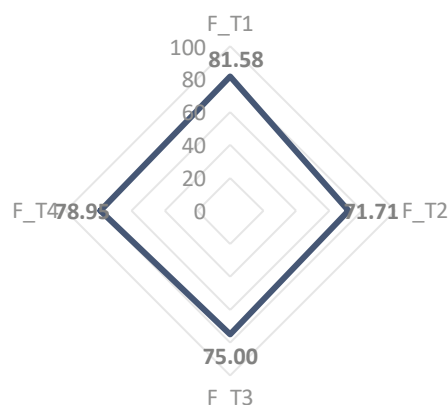
Thesis F_T3. European Union countries will invest additional financial resources in the production of NPK fertilisers in order to become independent from Russia

Thesis F_T4. There will be a reversal of the previous policy of limiting agricultural production

The selection of the theses was preceded by statistical analysis and expert discussion of Russian and Ukrainian exports in the area of grain and sunflower oil production and the importance of NPK fertilisers in food production. A paradigm shift in policy to reduce agricultural production was also considered. The analyses carried out were presented with a comparative approach. All the four theses were rated as being of high or very high importance as demonstrated by the value of significance indicators (Figure 2).

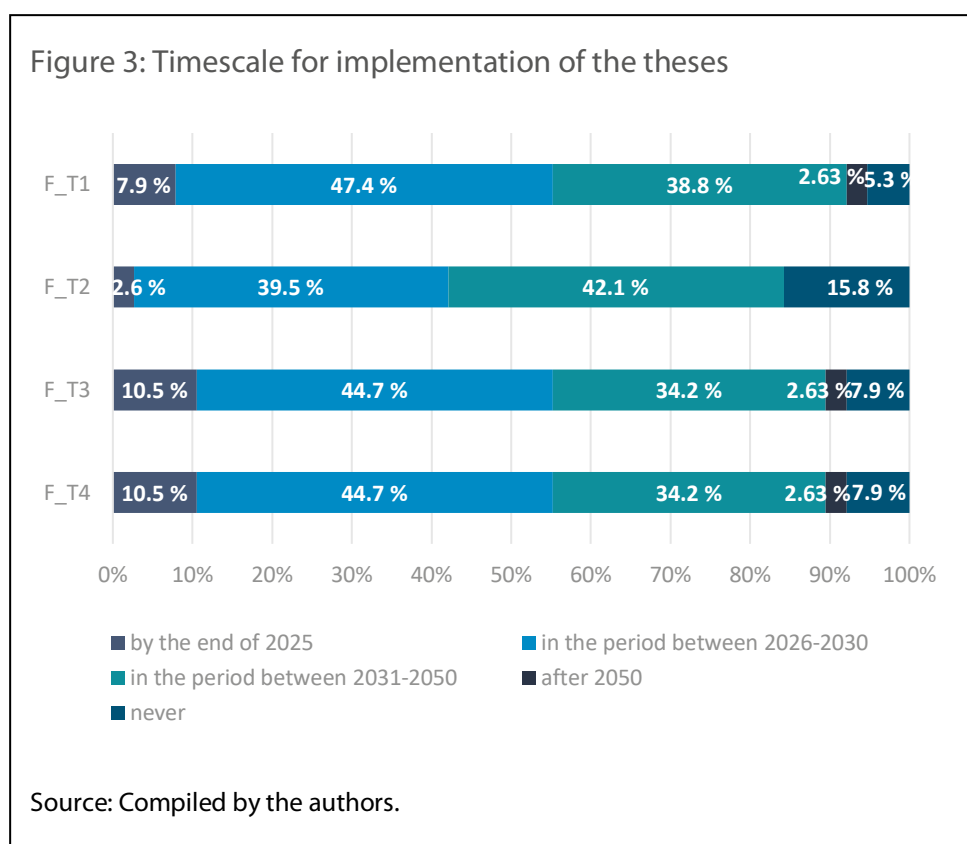
Within the analysed group of theses, the highest significance index was noted for F_T1, which may translate into a very high importance of decoupling wheat production in EU countries from Ukraine and Russia. The lowest relevance index was recorded for F_T4, which may, on the one hand, indicate that experts had the most doubts in assessing this thesis, while on the other hand, it may mean that taking action to move away from limiting agricultural production is characterised by slightly lower relevance than statements presented in the other theses.

Figure 2: Values of significance indicators for the theses in the food area



Source: Compiled by the authors.

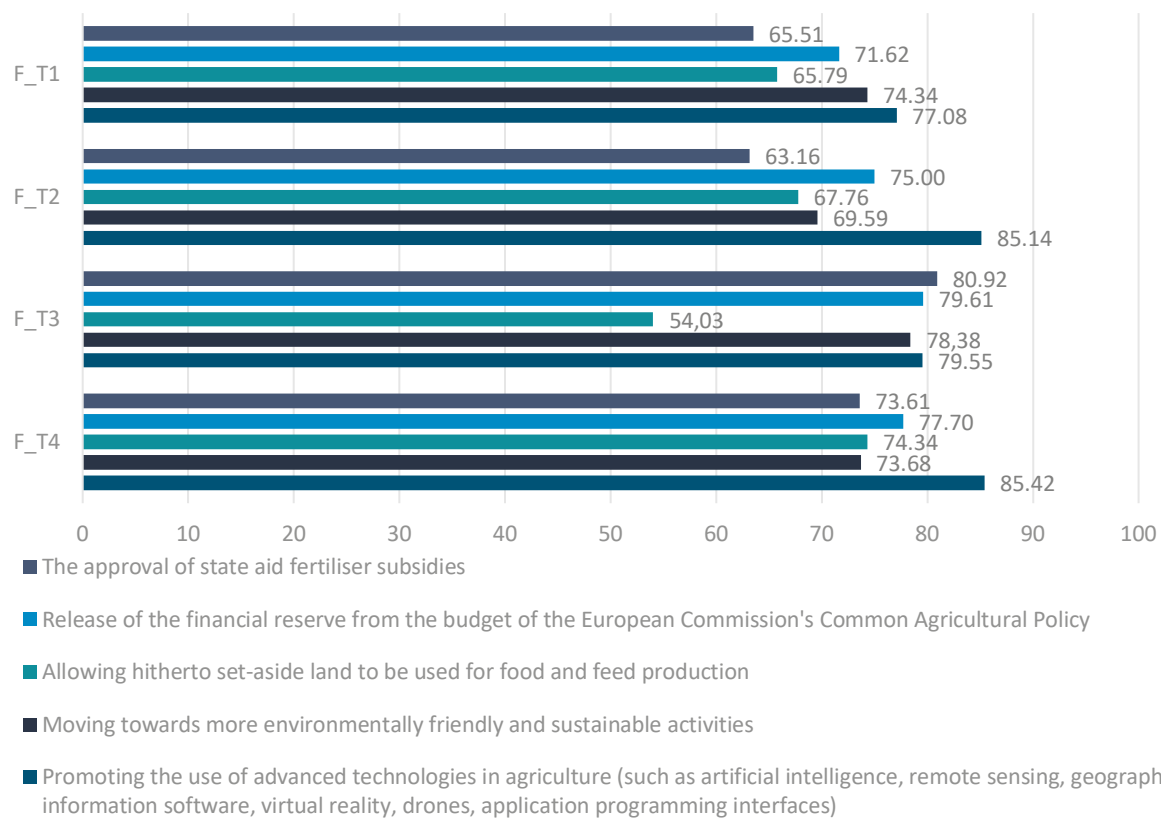
The assessment of the timescale for implementation of the theses is characterised by a similar pattern of responses (Figure 3).



In the opinion of the majority (more than 70 %) of experts, the statements included in the theses will be implemented in the period 2026-2030 or in the period 2031-2050. In the case of F_T3 and F_T4, only 10 % of experts believe that they will be implemented by the end of 2025. An even lower percentage of experts (respectively 7.9 % and 2.6 %) believe that by the end of 2025 the events described in the first and second thesis will have occurred. Analysing the data presented in Figure 3, it can also be seen that a low percentage of experts (5.3 % and 7.9 % respectively) believe that the relationships described in theses F_T1, F_T3 and F_T4 will never happen. A slightly higher percentage of responses in this respect (15.8 %) was recorded for F_T2.

Indicators were also calculated for each thesis in relation to actions that favour the implementation of the theses (Figure 4).

Figure 4: Values of indicators relating to factors favouring the implementation of the theses

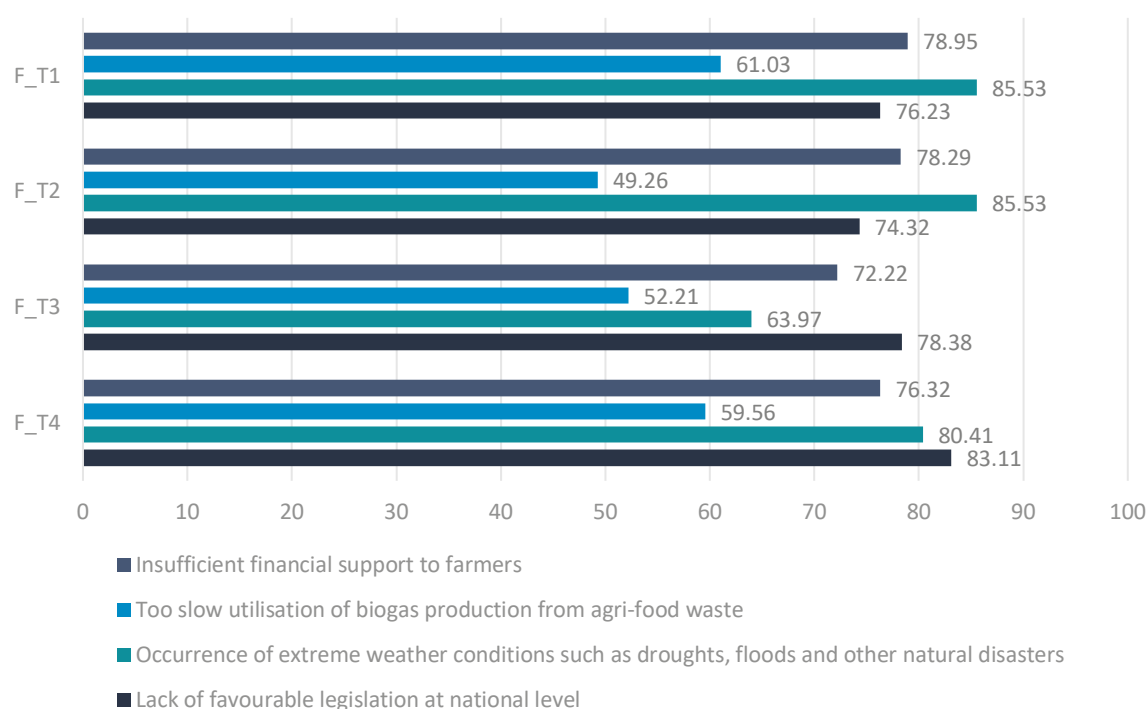


Source: Compiled by the authors.

Irrespective of the thesis (with the exception of F_T3), the most significant factor favouring the implementation of the thesis is *promoting the use of advanced technologies in agriculture (such as artificial intelligence, remote sensing, geographic information software, virtual reality, drones and application programming interfaces)*. The lowest values of the factors favouring the implementation of theses were recorded for *the approval of state aid fertiliser subsidies*, with the exception of F_T3, for which, due to the nature of the event described in the thesis, this enabling factor has the highest importance. The factor with the lowest importance for this thesis is *allowing the hitherto set-aside land to be used for food and feed production*, which may be related to the fact that it is of least relevance to the thematic scope described in the thesis.

The next step of the study presents the values of indicators of barriers to the implementation of theses (Figure 5).

Figure 5: Values of indicators of barriers to the implementation of the theses

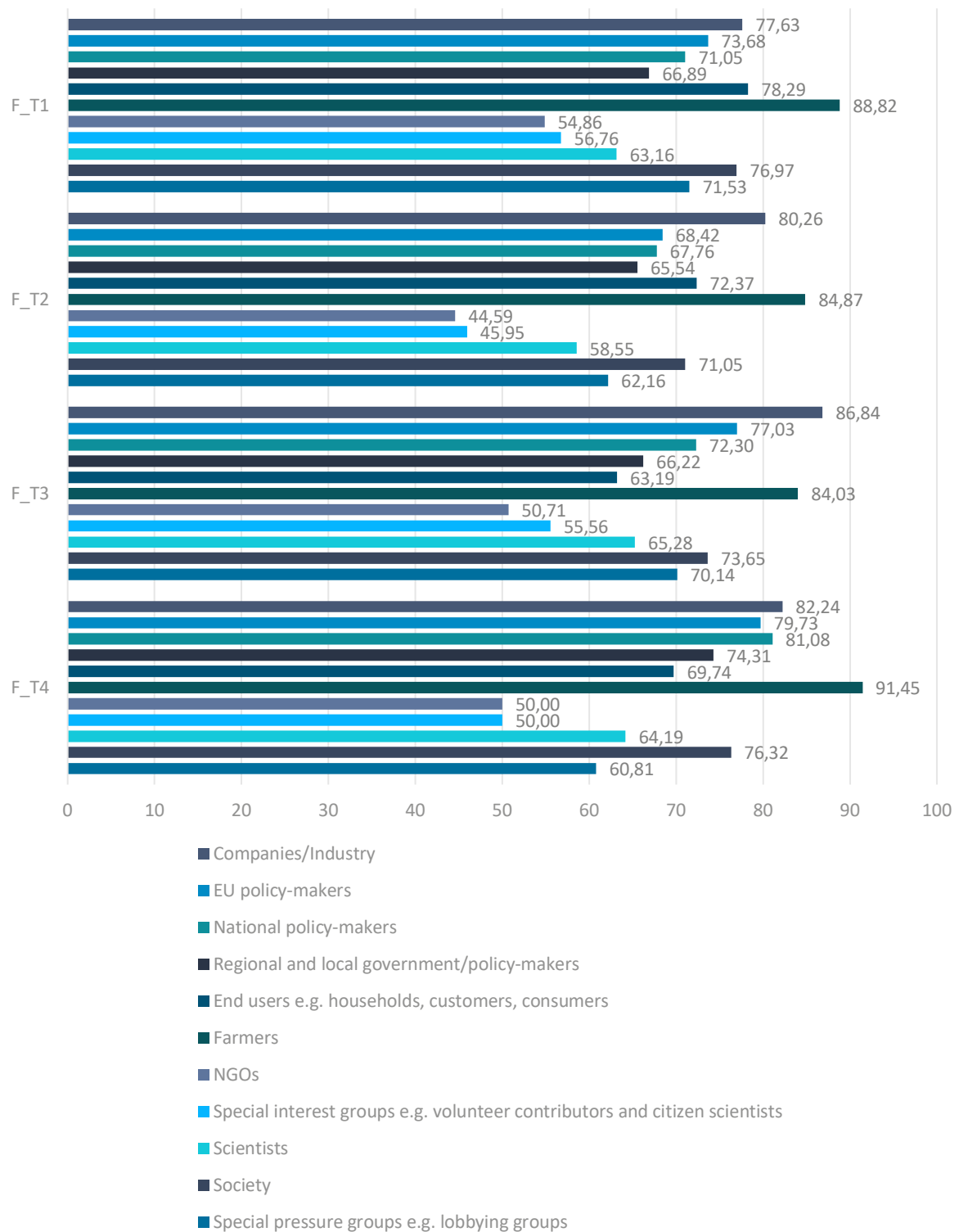


Source: Compiled by the authors.

The strongest barrier to the implementation of F_T1 and F_T2 is *the occurrence of extreme weather conditions such as droughts, floods and other natural disasters*. This is a barrier that could be treated as a wild card (high impact, low probability event) and for which the impact of political influence at the European Union level is not significant. An important barrier for which the significance index ranged from 72.22 to 78.95 in the individual theses is also *insufficient financial support to farmers*. In the case of F_T3 and F_T4, on the other hand, it can be seen that the biggest barrier is *the lack of favourable legislation at the national level*. Irrespective of the thematic scope, experts considered the barrier of lowest importance in the food area to be *the too slow utilisation of biogas production from agri-food waste*.

The study also assessed the strength of the theses' impact on stakeholders (Figure 6). Regardless of the statements presented in the theses, it can be seen that the highest values of the indicators were obtained for the impact of the theses on farmers, who are among the main stakeholders of the implemented research. High scores for theses' impact indicators were also obtained for companies and industries. In contrast, the lowest indicator values, regardless of the thesis, were obtained for NGOs and special interest groups, e.g. volunteer contributors and citizen scientists.

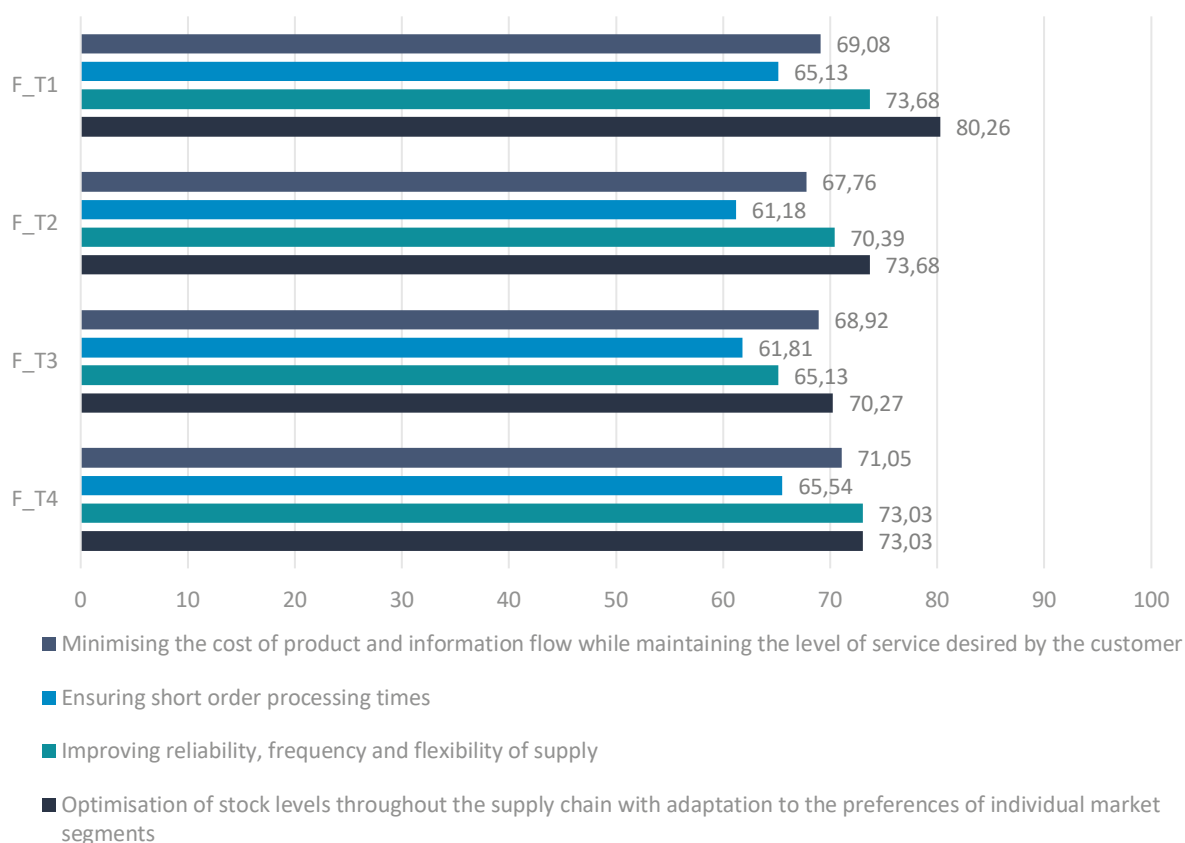
Figure 6: Values of indicators of the strength of the theses' impact on stakeholders



Source: Compiled by the authors.

The study also examined the impact of theses' statements on the functions of supply chains (Figure 7).

Figure 7: Values of indicators of the theses' impact on the functions of supply chains



Source: Compiled by the authors.

The greatest impact of the theses' statements is on the optimisation of stock levels throughout the supply chain with the adaptation to the preferences of individual market segments. The lowest impact of the statements described in the theses was noted with regard to ensuring short order processing times. Improving reliability, frequency and flexibility of supply and minimising the cost of product and information flow while maintaining the level of service desired by the customer are under the moderate sphere of influence of the theses' statements.

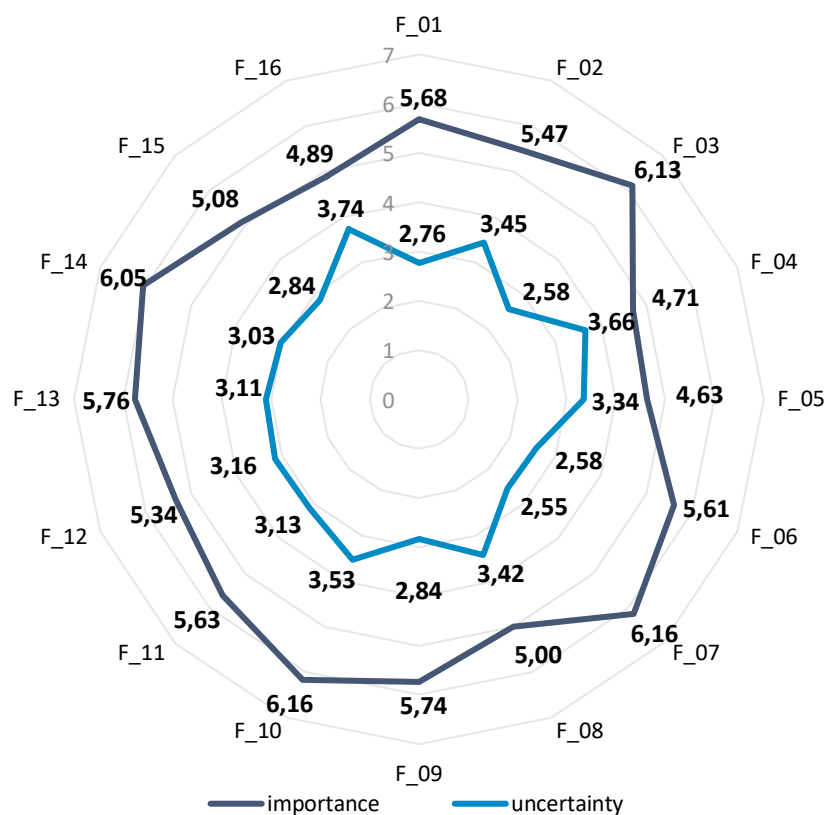
The study also identified 16 factors (using STEEPED analysis) that, in the opinion of the study's authors, may favour the resilience building of food supply chains in Europe. In the area of food, the following factors were identified:

F_01	Prevailing dietary patterns and habits
F_02	The level of social trust in modern technologies
F_03	The use of advanced technologies in agriculture (such as artificial intelligence, remote sensing, geographic information software, virtual reality, drones, application programming interfaces)
F_04	The level of utilisation of biogas production from agri-food waste
F_05	The approval of state aid fertiliser subsidies

F_06	Release of the financial reserve from the budget of the European Commission's Common Agricultural Policy
F_07	The level of financial support to farmers
F_08	The use of set-aside land for food and feed production
F_09	Moving towards more environmentally friendly and sustainable activities
F_10	The occurrence of extreme weather conditions such as droughts, floods and other natural disasters
F_11	The level of legislation at the national level
F_12	The quality of legislation on the use of digital data in agriculture
F_13	Openness to changing dietary patterns and habits
F_14	Conscious consumerism
F_15	Aging society
F_16	The level of international migration

The presented factors were then rated, according to the school of intuitive logic of scenario construction, on a seven-point scale of importance (where 1 meant the factor was of very low importance and 7 meant that the factor was of very high importance) and uncertainty (where 1 meant

Figure 8: Juxtaposition of the factors influencing building the resilience of supply chains in Europe in the area of food in terms of importance and uncertainty



Source: Compiled by the authors.

the factor had very low uncertainty, while 7 meant the factor was characterised by very high uncertainty), (Figure 8).

Generally, all of the identified factors received high average importance ratings¹. Factors that received the highest importance scores (arithmetic mean above 6) included: *the occurrence of extreme weather conditions such as droughts, floods and other natural disasters* (6.16), *the level of financial support to farmers* (6.16), *the use of advanced technologies in agriculture (such as artificial intelligence, remote sensing, geographic information software, virtual reality, drones, application programming interfaces)* (6.13) and *conscious consumerism* (6.06).

In contrast, the lowest impact on building resilience in supply chains was characterised by such factors as: *the approval of state aid fertiliser subsidies* (4.63), *the level of utilisation of biogas production from agri-food waste* (4.71) and *the level of the international migration* (an arithmetic mean of 4.89).

However, it should be noted that the differences in the average ratings of the highest and lowest rated factors are not particularly great, so one can conclude that all the factors identified in the study may have a positive impact on the resilience building of food supply chains in Europe. The study also identified factors with the highest uncertainty of development in the 2030 horizon. These include: *the level of international migration* (3.74), *the level of utilisation of biogas production from agri-food waste* (3.66), *the occurrence of extreme weather conditions such as droughts, floods and other natural disasters* (3.53) and *the level of social trust in modern technologies* (3.45).

In a situation where *the level of international migration*, *the level of utilisation of biogas production from agri-food waste* and *the level of social trust* can be politically influenced, the factor *the occurrence of extreme weather conditions such as droughts, floods and other natural disasters*, which was found to be both the most important and the most uncertain factor in the study, bears the hallmark of a wild card (high impact, low probability event) rather than a factor that can be realistically controlled as part of the policy pursued by the European Union to build supply chain resilience in Europe.

The survey questionnaire also included an open-ended question about possible actions to be taken to build resilience of food supply chains in Europe. Experts gave numerous opinions in this regard with reference to proposals such as promotion of regionalisation of food supply chains, promotion of sustainable, environmentally friendly production methods, efficient and effective promotion of the reduction of food loss and waste, improving small scale agriculture and its networks until the end consumer and fostering agroecology, permaculture, organic matter inputs and biological soil amendment, to name a few.

Detailed analyses of experts' opinions are presented in Chapter 5 with reference to policy options.

3.2. Energy

The energy market is crucial for economic development and social well-being. At the same time, it is a market that reacts strongly to any international conflicts and is susceptible to attempts at manipulation by key suppliers. EU Member States, which are highly developed, set themselves not only the security of energy supplies as a key goal in the energy market, but also the creation of a low-emission, environmentally friendly economy in line with the goals of sustainable development. Russia's invasion of Ukraine led to the disruption of the supply chains of fossil fuels imported from Russia to the EU. Most EU Member States depend on supplies of fossil fuels from third countries. In 2021, the EU imported well over half of its energy. Before the invasion of Ukraine, Russia was the most important energy partner of the EU. Almost 30 % of extra-EU crude oil, 43 % of natural gas, and 54 % of solid fossil fuel (mostly coal) imports originated from Russia. Therefore, the EU faced the challenge of replacing an unreliable partner, increasing the solidarity and integration of the EU

¹ Arithmetic means are presented in the brackets.

Member States in order to ensure the stability of supply chains and strengthen cooperation with reliable partners. This study aims to identify possible ways to enhance the EU's energy security and supply chain stability in light of these developments.

Within the energy area, five theses were examined:

Thesis E_T1. The growth of renewables in the energy mix in EU countries will be more dynamic

Thesis E_T2. The role of Russia as a supplier of fossil fuels to the EU market will diminish

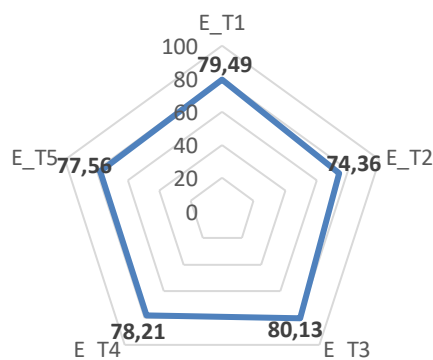
Thesis E_T3. There will be closer integration of EU countries within European Energy Security

Thesis E_T4. The importance of hydrogen and biomethane as energy sources will increase

Thesis E_T5. There will be a transformation of the energy market in the EU towards distributed energy

The selection of theses was preceded by a critical analysis of literature, data, reports and expert opinions. The key was an expert discussion of possible directions of changes in the EU energy market. The paradigm of moving away from cooperation with the largest external supplier of fossil fuels, increasing energy integration in the EU, increasing energy self-sufficiency and shortening supply chains, flexible management of the energy market and increasing the importance of energy communities were considered. The analyses are presented from a comparative perspective. All five theses were rated as being of high or very high importance as demonstrated by the value of significance indicators (Figure 9).

Figure 9: Values of significance indicators for the theses in the energy area



Source: Compiled by the authors.

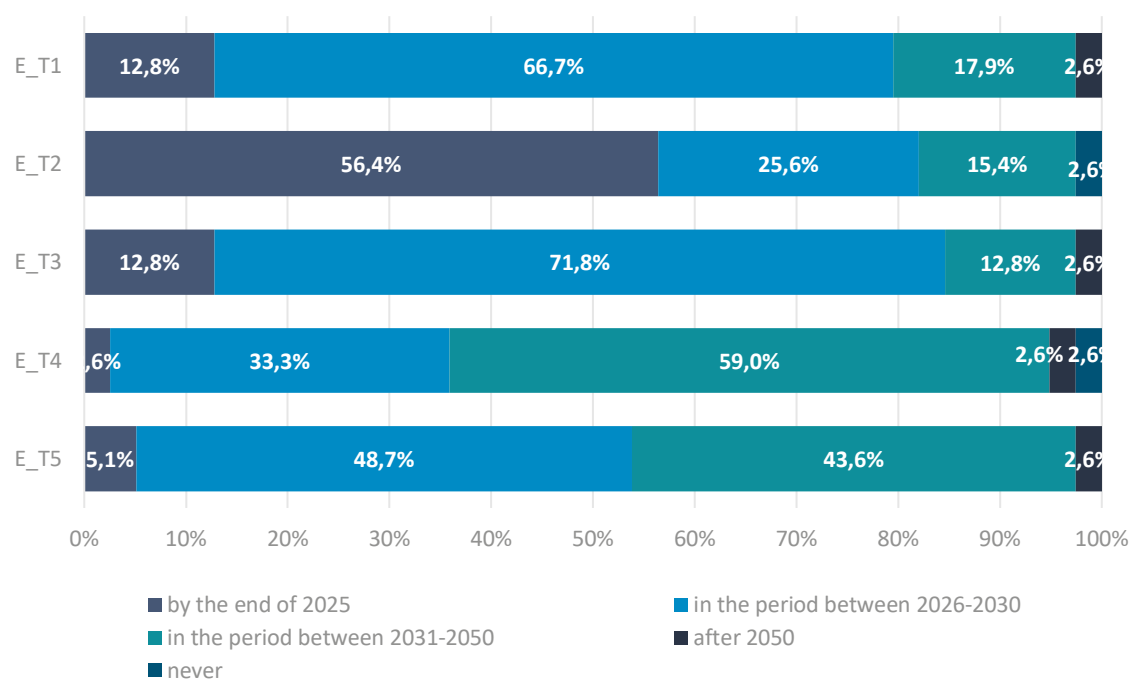
In the analysed group of theses, the highest significance index was recorded for E_T3, which shows very high importance of energy cooperation within the EU, and the need for greater integration and coordination of activities. The high ratings of E_T1, E_T4, and E_T5 indicate experts' high expectations regarding renewables' rapid development.

The lowest significance rate was recorded for E_T2, which could indicate that experts had the most doubts in assessing the possibility of replacing Russian raw materials. However, it seems more correct to infer that they perceived the process of independence from Russian resources as less important than the statements presented in the other theses. This interpretation is indicated by the

assessment of the time perspectives for the implementation of theses (Figure 10). Experts decided that E_T2 will be completed by 2025 (56.4 %) or 2030 (82.0 % in total). The period until 2030 was also indicated as the time of E_T1 and E_T3 implementation (79.5 % and 84.6 %, respectively). In the case of E_T4 and E_T5, the period until 2050 was indicated as the implementation period.

Indicators were also calculated for each thesis in relation to actions that favour the implementation

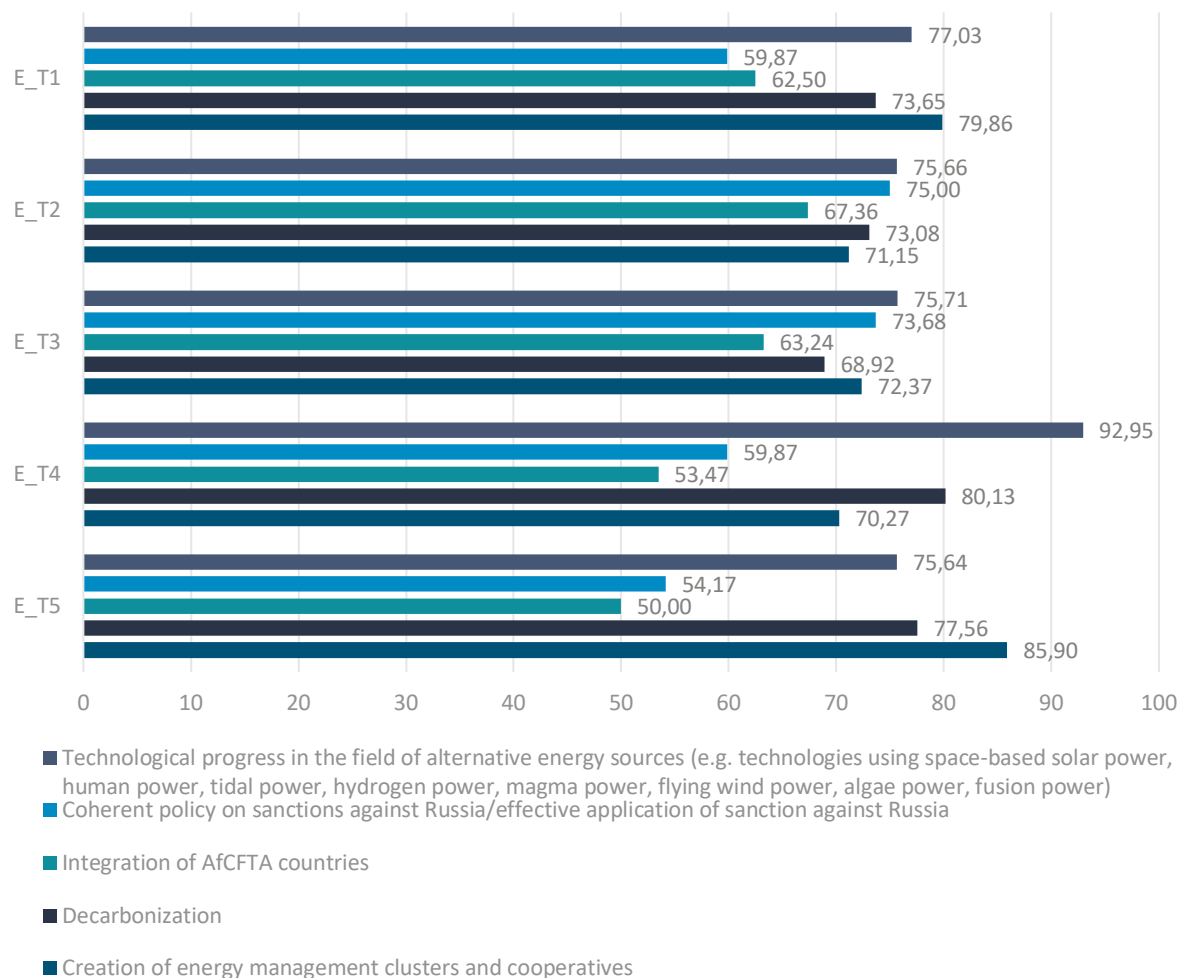
Figure 10: Timescale for implementation of the theses



Source: Compiled by the authors.

of the theses (Figure 11). In the case of E_T2, E_T3 and E_T4, the most important factor favouring the implementation of the theses is *technological progress in the field of alternative energy sources* (e.g. technologies using space-based solar power, human power, tidal power, hydrogen power, magma power, flying wind power, algae power fusion power). For E_T1 and E_T5, the most important factor is *creating energy management clusters and cooperatives*, but technological progress is also highly rated. In the case of all theses, apart from the two indicated factors, *decarbonisation* was also indicated as very favourable. The lowest values of favouring the implementation of the theses were recorded for *integration of AfCFTA countries* (E_T2, E_T3, E_T4, E_T5), which may indicate that alternatives to Russian directions of fossil fuel imports are least related to the thematic scope described in the theses.

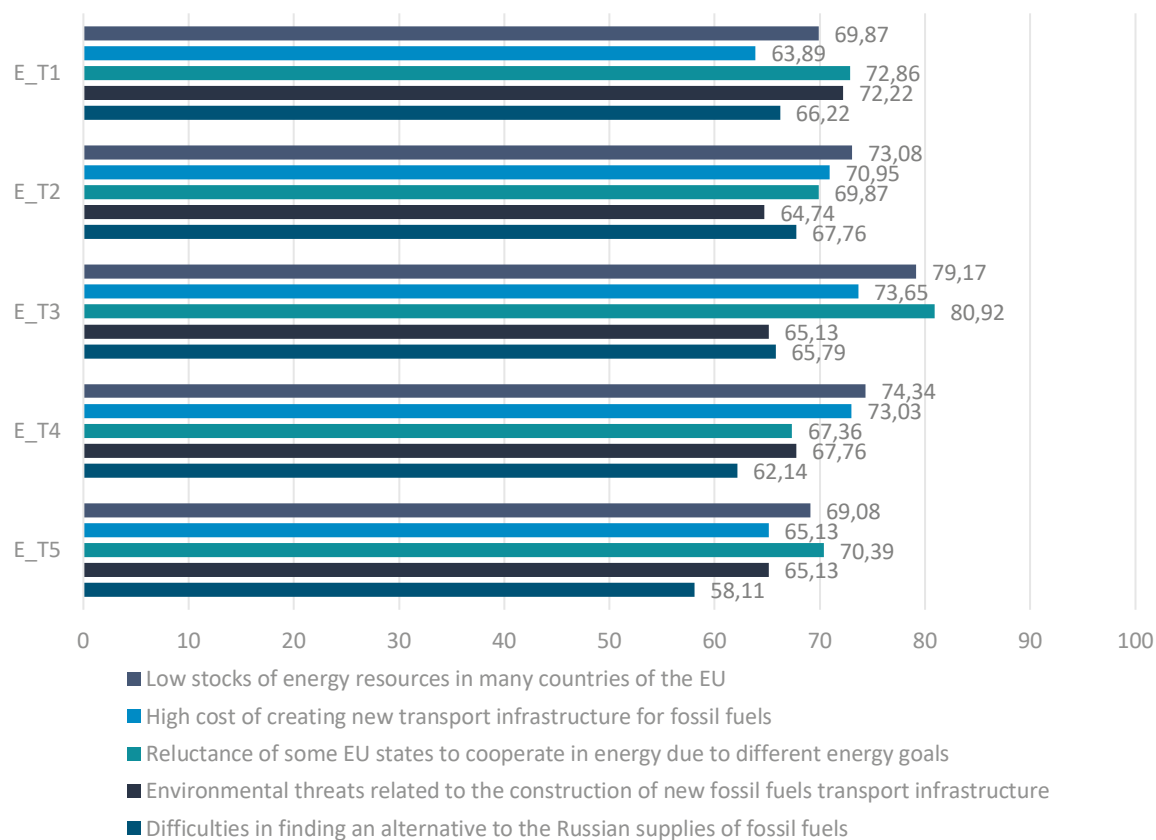
Figure 11: Values of indicators relating to factors favouring the implementation of the theses



Source: Compiled by the authors.

The study's next step presents the values of the thesis barrier indicators (Figure 12). The strongest barrier for the implementation of E_T1, E_T3 and E_T5 is the reluctance of some EU Member States to cooperate on energy due to different energy goals (72.86, 80.92 and 70.39). In turn, in the case of E_T1 and E_T3, experts indicated low stocks of energy resources in many countries of the EU as the most important barrier (73.08 and 74.34). In the case of both barriers, the effectiveness of EU policy may be crucial. The least significant barrier for E_T4 and E_T5 (62.14 and 58.11) was considered by the experts to be difficulties in finding an alternative to the Russian supplies of fossil fuels. In the case of the remaining theses, this barrier was indicated as second least important. For theses E_T2 and E_T3, environmental threats related to the construction of new fossil fuel transport infrastructure was indicated as the least significant barrier, and for E_T1 the high cost of creating new transport infrastructure for fossil fuels.

Figure 12: Values of indicators of barriers to the implementation of the theses

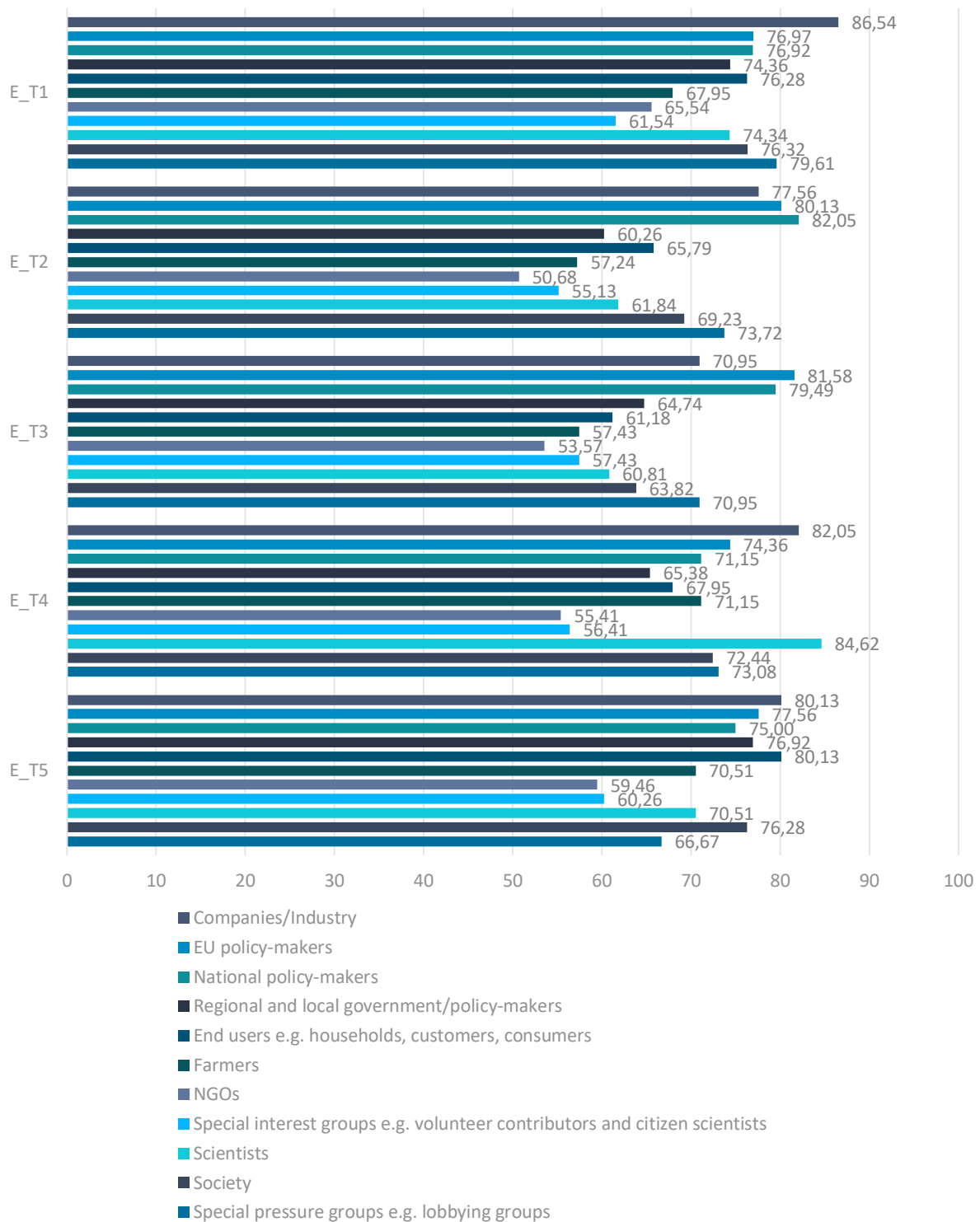


Source: Compiled by the authors.

The study also assessed the strength of the theses' impact on stakeholders (Figure 13). Regardless of the statements presented in the theses, it can be seen that the high values of the indicators, and in the case of E_T1 and E_T5 the highest values (86.54 and 80.13) were obtained for the impact of the thesis on companies/industry that are among the main stakeholders of the implemented research in the investigated area. In the case of E_T2, the experts assessed that it has the greatest impact on national policy-makers (82.05) and EU policy-makers (80.13). According to experts, E_T3 has the greatest impact on EU policy-makers (81.58) and national policy-makers (79.49), and in the case of E_T4 it has the greatest impact on scientists (84.62) ahead of entrepreneurs (82.05). In

contrast, the lowest indicator values in theses E_T2, E_T3, E_T4 and E_T5 were obtained for NGOs and in E_T1 special interest groups, e.g. volunteer contributors and citizen scientists.

Figure 13: Values of indicators of the strength of the theses' impact on stakeholders

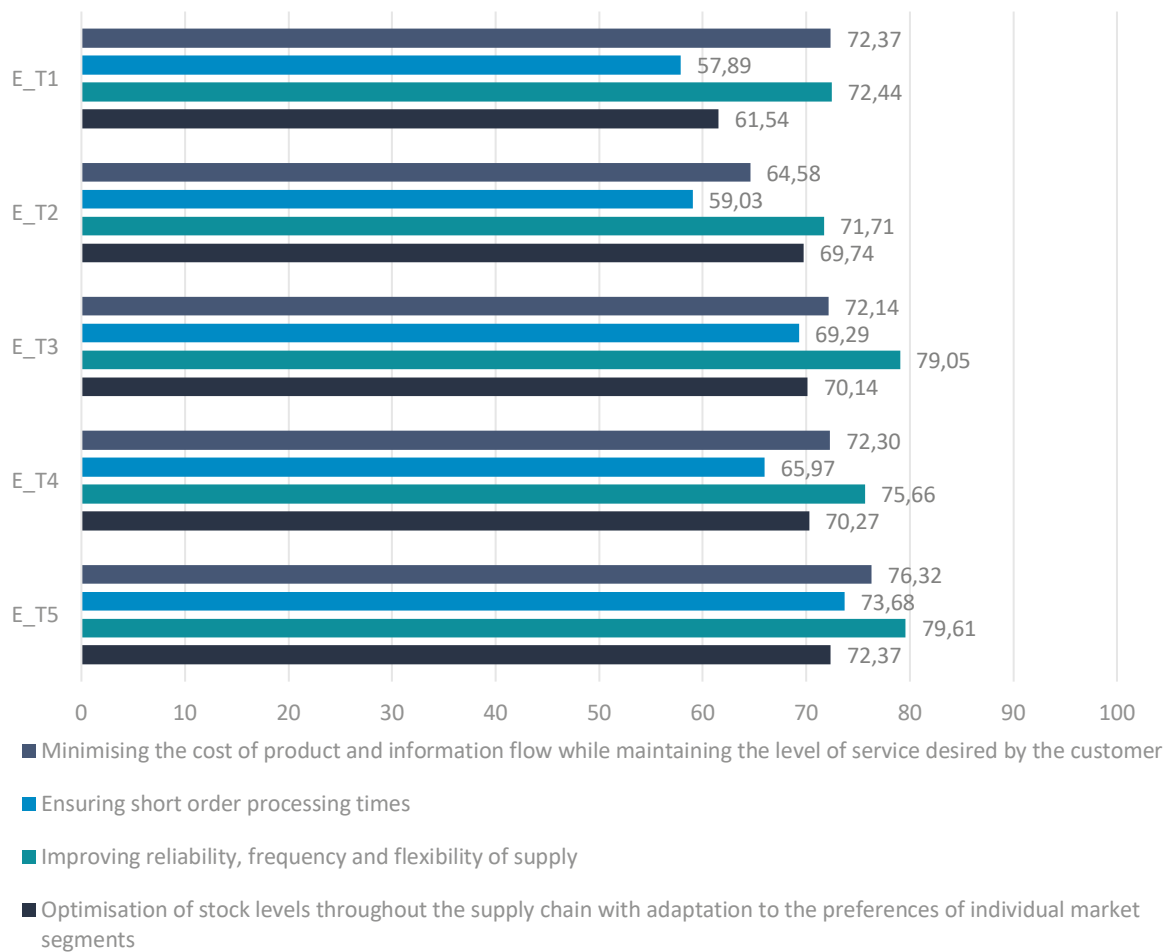


Source: Compiled by the authors.

The study also examined the impact of theses statements on the functions of supply chains (Figure 14).

The greatest impact of all thesis statements is on improving reliability, frequency, and flexibility of supply (the values of significance indicators were respectively: 74.44, 71.71, 79.05, 75.66 and 79.61). The lowest impact of the statements described in all the theses was noted with regard to ensuring short order processing times.

Figure 14: Values of indicators of the theses' impact on the functions of supply chains



Source: Compiled by the authors.

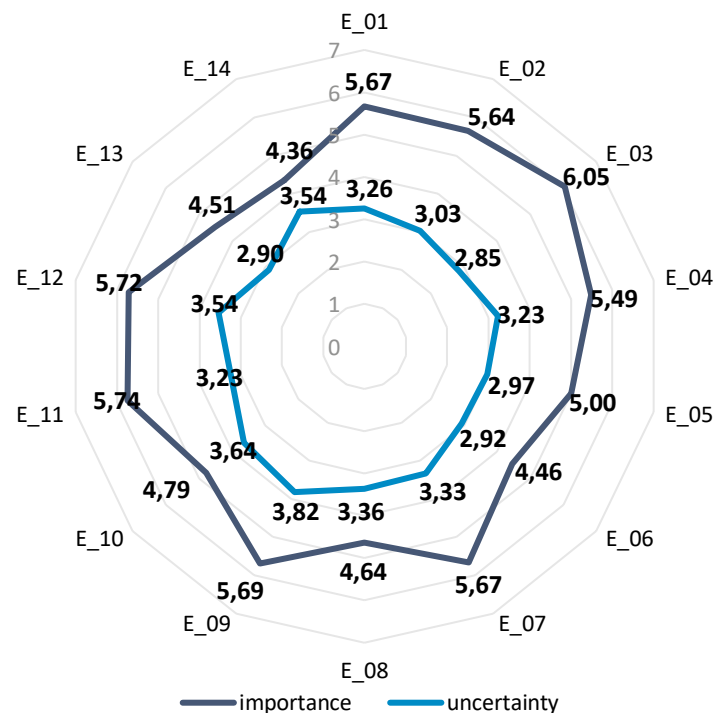
The study also identified 14 factors (using STEEPED analysis) that, in the opinion of the study's authors, may favour the resilience building of energy chains in the European Union. In the area of energy, the following factors were identified:

F_01	Quality of life and security of citizens
F_02	Energy management clusters and cooperatives
F_03	Technological progress in the field of alternative energy sources (e.g. technologies using space-based solar power, human power, tidal power, hydrogen power, magma power, flying wind power, algae power, fusion power)
F_04	Decarbonisation through the use of carbon-eliminating technologies
F_05	The level of stocks of energy resources in many countries of the EU

F_06	The cost of creating new transport infrastructure for fossil fuels
F_07	Development of the circular economy
F_08	Environmental threats related to the construction of new fossil fuels transport infrastructure
F_09	The level of geopolitical stability
F_10	Reluctance of some EU Member States to cooperate on energy due to different energy goals
F_11	Openness to technological innovations that improve the comfort of life (e.g. in terms of reducing environmental pollution)
F_12	Conscious consumerism
F_13	Aging society
F_14	Level of international migration

The presented factors were then rated, according to the school of intuitive logic of scenario construction, on a seven-point scale of importance (where 1 meant the factor was of very low importance and 7 meant that the factor was of very high importance) and uncertainty (where 1 meant the factor had very low uncertainty, while 7 meant the factor was characterised by very high uncertainty) (Figure 15).

Figure 15: Juxtaposition of the factors influencing building the resilience of supply chains in the European Union in the area of energy in terms of importance and uncertainty



Source: Compiled by the authors.

Most of the identified factors received high average importance ratings². The factor that received the highest importance score (arithmetic mean above 6) was *technological progress in the field of alternative energy sources (e.g. technologies using space-based solar power, human power, tidal power, hydrogen power, magma power, flying wind power, algae power, fusion power)* (6.05). High average importance ratings were also indicated in the case of *openness to technological innovations that improve the comfort of life (e.g. in terms of reducing environmental pollution)* (5.74), *conscious consumerism* (5.72), *level of geopolitical stability* (5.69), *quality of life and security of citizens* (5.67), *energy management clusters and cooperatives* (5.64). In contrast, the lowest impact on building resilience in supply chains was characterised by such factors as: *the level of international migration* (4.36), *the cost of creating new transport infrastructure for fossil fuels* (4.46), *aging society* (4.51) and *environmental threats related to the construction of new fossil fuel transport infrastructure* (4.64).

However, it should be noted that the differences in the average ratings of the highest and lowest rated factors are not particularly great, hence it can be concluded that all the factors identified in the study may have a positive impact on building the resilience of energy supply chains in the European Union. The study also identified the factors with the highest uncertainty of development in the 2030 horizon. These include: *the level of geopolitical stability* (3.82), *reluctance of some EU Member States to cooperate on energy due to different energy goals* (3.64), *conscious consumerism* (3.54), and *the level of international migration* (3.54).

According to the experts, the most important factor affecting supply chain resilience in the EU turned out to be technological progress in the field of alternative energy sources. At the same time, experts recognised that it was characterised by the lowest degree of uncertainty. The European Union has a large impact on shaping this factor and building the desired scenarios. The appropriate policy of the EU may also have a significant impact on the two factors indicated as those with the highest level of uncertainty, i.e.: *the reluctance of some EU Member States to cooperate on energy due to different energy goals* and *the level of international migration*.

The survey questionnaire also included an open-ended question about possible actions to be taken to build the resilience of energy supply chains in the European Union. The experts gave numerous opinions in this regard with reference to such proposals as the development of distributed energy, increasing expenditure on the search for alternative energy sources, subsidising related industries producing equipment for renewable energy, increasing the use of various forms of renewable energy/increasing research outlays in the area of various technologies using alternative energy sources.

Detailed analyses of the experts' opinions are presented in Chapter 5 with reference to policy options.

3.3. Satellite communications

The study from the area of satellite communications focuses on the potential to leverage the Copernicus programme. The analysis of the Copernicus programme could bring insights as to how to leverage its services in the face of humanitarian crises, while at the same time ensuring resilience of satellite communications – an indispensable tool for technological sovereignty. The Copernicus programme is the EU's Earth observation, which provides free access to near real-time data. It offers information services that draw on satellite observations of the Earth and in-situ (non-space) data. Copernicus data includes, among other things, basic topographic information, such as maps of the transportation network, administrative boundaries and digital terrain models, and, more recently the Copernicus programme has allowed the monitoring of migration flows. In-situ data relies, in addition to ground-based weather stations, on ocean buoys and air quality monitoring networks, as

² Arithmetic means are presented in the brackets.

well as novel data sources such as sensors and images collected by drones and on information gathered by volunteers or citizen scientists (on the basis of crowdsourcing).

Within the satellite communications area, three theses were examined:

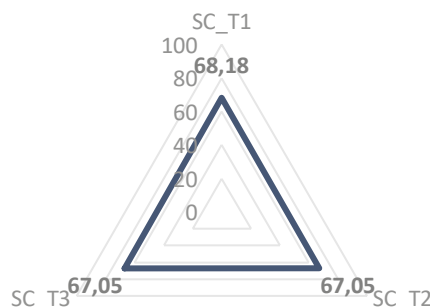
- Thesis SC_T1.** There will be rapid development of the market for free applications based on Copernicus data, which will increase the scale of stand-alone satellite data analytics by end-users
- Thesis SC_T2.** Multidimensional analysis of data provided by Copernicus will enable environmentally friendly management of supply chains by providing safe transportation, eco transportation and meteorological forecasts for transportation
- Thesis SC_T3.** In the face of socio-political crises (wars, migration, economic crises), the importance of Copernicus data analytics will increase, providing supply chain optimisation

The selection of the theses was preceded by statistical analysis, reports, article reviews, and expert discussions on the potential for enhancing the use of satellite technologies, with particular emphasis on the European Copernicus programme. The potential of satellite technology was analysed mainly in relation to the objective of levelling and counteracting the effects of crises: humanitarian, agricultural and economic, especially in the face of supply chain disruptions.

The analyses carried out were presented with a comparative approach. All the three theses were rated as being of high or very high importance, as demonstrated by the value of significance indicators (Figure 16).

In the analysed group, all three theses are characterised by a similar level of significance, with a slight advantage in favour of SC_T1, resulting, for example, from the high confidence but also the need for IT solutions that will allow Copernicus end-users to analyse satellite data themselves. Theses SC_T2 and SC_T3 scored identically highly, only slightly lower than SC_T1. This means that experts attribute moderate importance to Copernicus's multidimensional data analytics in managing supply chains in many areas.

Figure 16: Values of significance indicators for the theses in the satellite communications area



Source: Compiled by the authors.

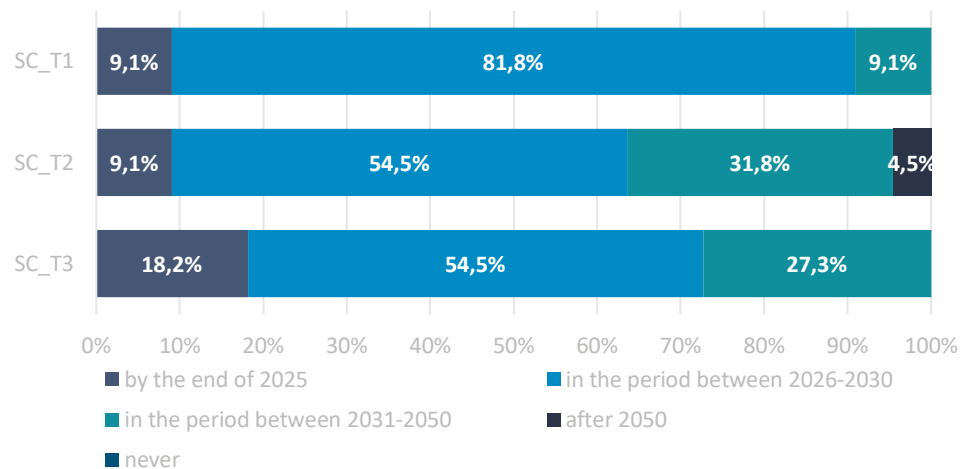
The assessment of the timescale for implementation of the theses in two cases (SC_T2 and SC_T3) is characterised by a similar pattern of responses (Figure 17).

In the opinion of the majority (more than 80 %) of experts, the statements included in SC_T1 will be implemented in the period 2026-2030. Regarding this period in the case of SC_T2 and SC_T3, over 54 % of the respondents feel the same way. In the case of SC_T2 only 4.5 % of experts believe that it will occur after 2050. This is the only thesis whose time horizon has been considered

beyond 2050. Analysing the data presented in Figure 17, it is apparent that none of the theses were considered in terms of "will never happen", which may indicate that, in the experts' opinion, each thesis has the potential to be realised, out of which priority in the period 2026-2030 should be given to the SC_T1.

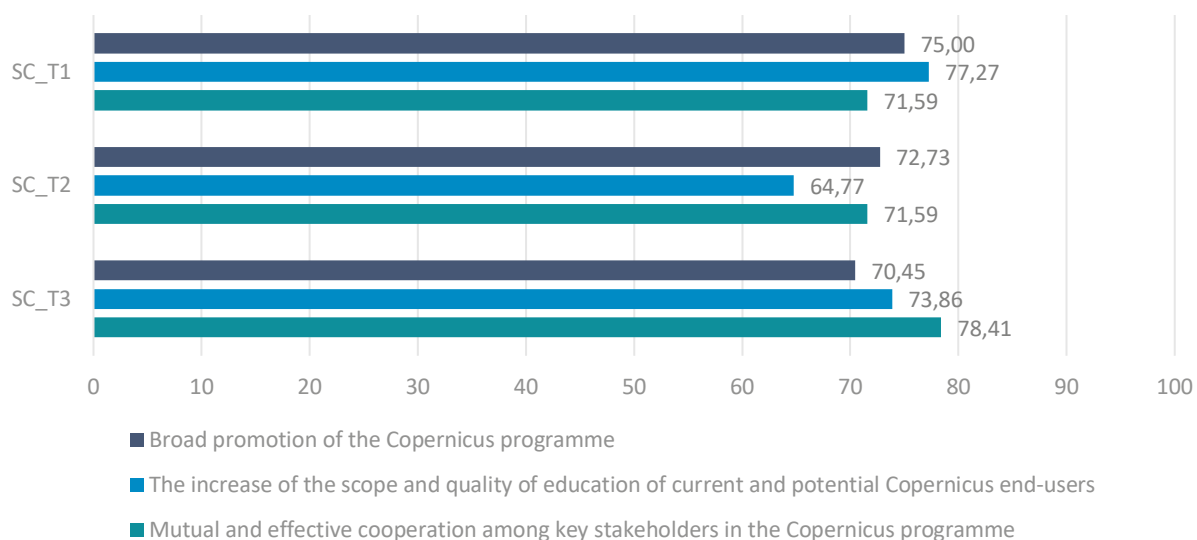
Indicators were also calculated for each thesis in relation to actions that favour the implementation of the theses (Figure 18).

Figure 17: Timescale for implementation of the theses



Source: Compiled by the authors.

Figure 18: Values of indicators relating to factors favouring the implementation of the theses



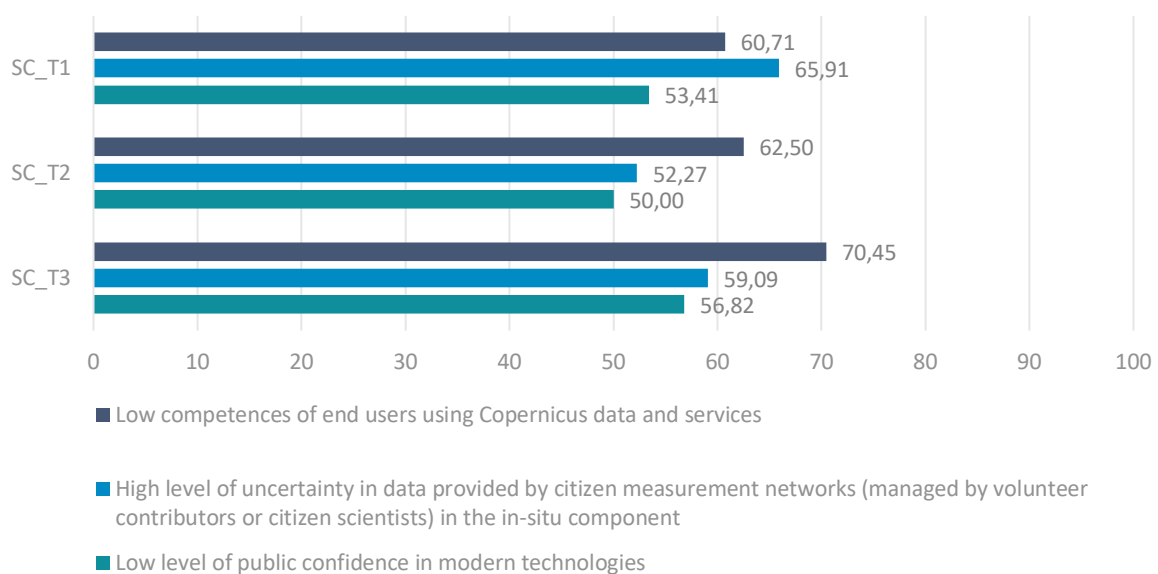
Source: Compiled by the authors.

The distribution of enablers across the different theses varied, albeit slightly. The most significant factor favouring the implementation of SC_T1 and, at the same time, the lowest values favouring

the implementation of SC_T2 was considered to be an *increase of the scope and quality of education of current and potential Copernicus end-users*. This may be due to the importance of education, including for citizens as direct Copernicus end-users of free IT applications. In the SC_T2, 2 factors were considered most important for its implementation: 1) *broad promotion of the Copernicus programme* and 2) *mutual and effective cooperation among key stakeholders in the Copernicus programme*. In the third thesis emphasising complex systemic socio-economic processes, such as crises and supply chain management, *mutual and effective cooperation among key stakeholders in the Copernicus programme* was logically considered the most significant factor favouring the implementation of the thesis. This factor was the least important in SC_T1. This is probably due to the emphasis here on the role of single, rather than complex relationships of Copernicus programme users.

The next step of the study presents the values of indicators of barriers to the implementation of the theses (Figure 19).

Figure 19: Values of indicators of barriers to the implementation of the theses



Source: Compiled by the authors.

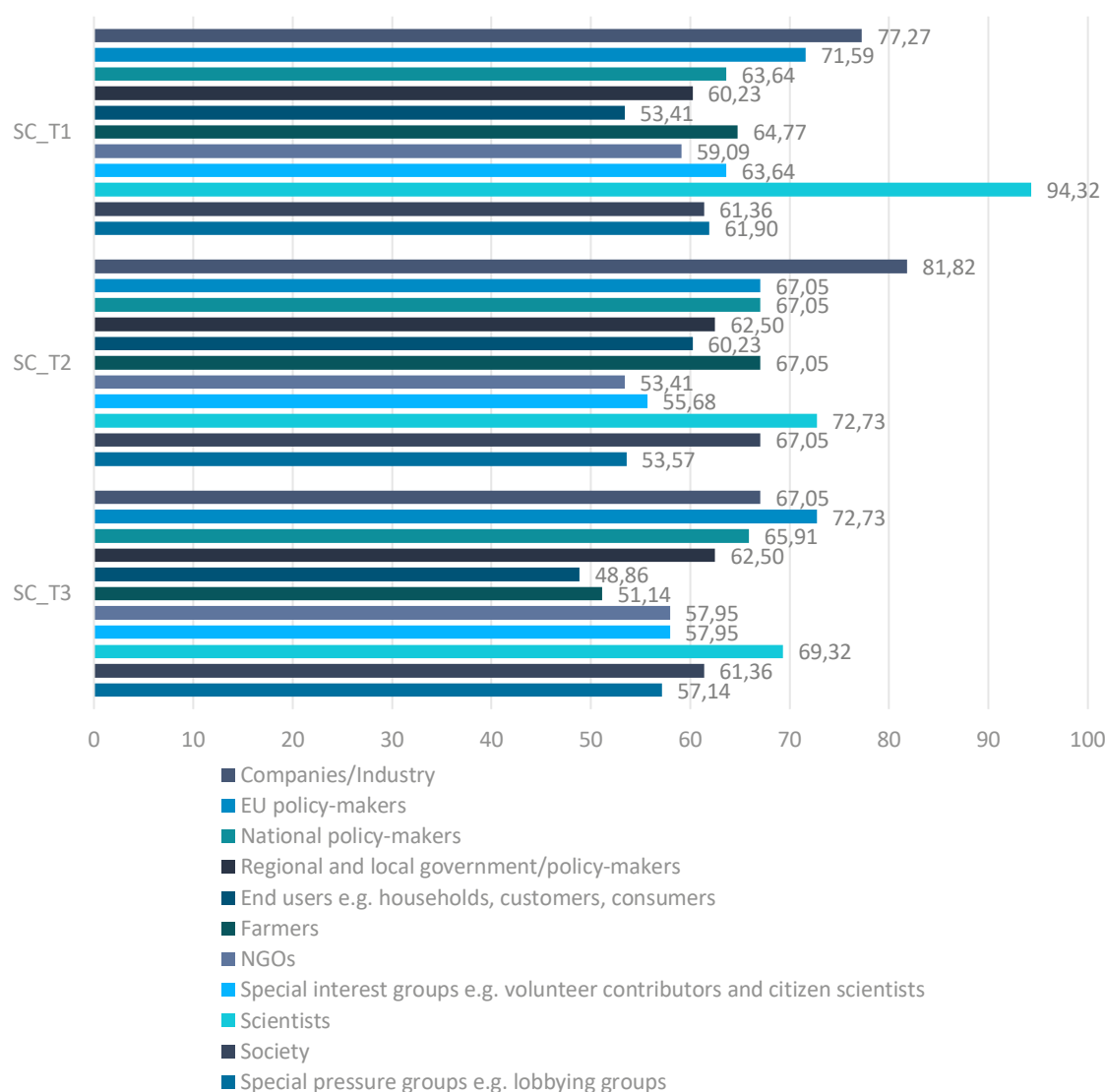
The strongest barrier to the implementation of SC_T2 and SC_T3 is *the low competences of end-users using Copernicus data and services*. This may be due to the fact that multidimensional data analysis and supply chain management in times of crises and military tensions is a necessary but difficult task. It requires complex, often interdisciplinary skills that are time-consuming and challenging to acquire.

Irrespective of the thematic scope, experts considered the barrier of lowest importance to be *the low level of public confidence in modern technologies*. This may be due to the high, often uncritical, use of various free technological solutions, especially in the ICT (information and communication technologies) field. The low importance of this barrier should be viewed in two ways. On the one hand, it raises hopes for a potentially high level of acceptance of free Copernicus application solutions. On the other hand, it poses a risk in terms of acceptance of the majority, including potentially false, of data received. *The high level of uncertainty in data provided by citizen measurement networks (managed by volunteer contributors or citizen scientists) in the in-situ component* was considered the most relevant barrier only for SC_T1. This could be explained by the

fact that an independent analysis of satellite data can only be carried out with a high level of confidence if it is based on a high level of certainty. In the absence of clear regulations for citizen measurement networks in the in-situ (non-space) component, the level of confidence will always be incomplete.

The study also assessed the strength of the theses' impact on stakeholders (Figure 20).

Figure 20: Values of indicators of the strength of the theses' impact on stakeholders



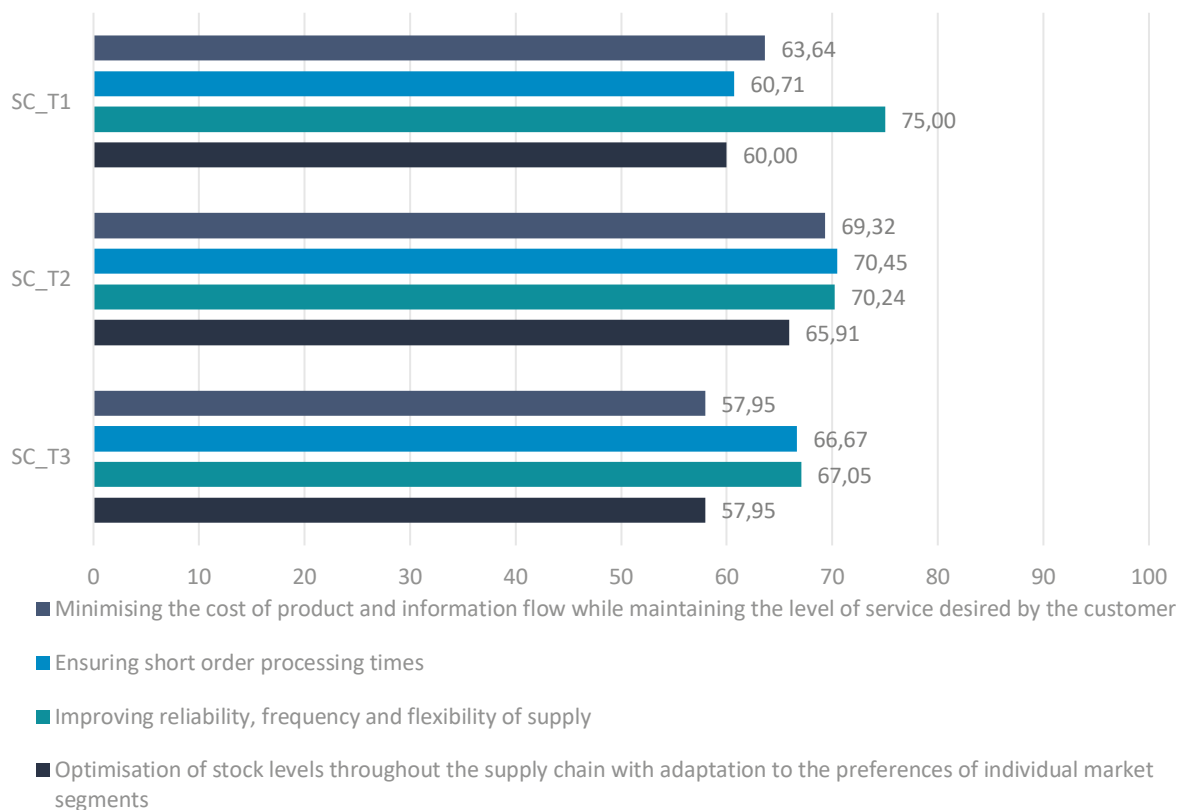
Source: Compiled by the authors.

The highest value of the indicators in SC_T1 was obtained for scientists. Scientists in SC_T2 and SC_T3 also represented high values. Such a result is derived from the complexity of the area under study, as well as the multiple possibilities for scientific analysis on the basis of the data provided by the Copernicus system. The highest value in SC_T2 was among representatives of companies/industry, which is related to the uniqueness and potential high commercial value of the data provided by the Copernicus system, especially as it is mostly free. The highest value in SC_T3 was attributed to the EU policy-makers group. Such a result is an excellent promotion of the Copernicus project, which may become a relevant tool supporting the management of various areas

of socio-economic activity in the EU. On the other hand, the lowest values of indicators, regardless of the thesis, were obtained for NGOs, special pressure groups and end-users, e.g. households, customers, consumers. The low score for the last group may be due to insufficient information activities on the benefits of using Copernicus data.

The study also examined the impact of thesis statements on the functions of supply chains (Figure 21).

Figure 21: Values of indicators of the theses' impact on the functions of supply chains



Source: Compiled by the authors.

The greatest impact of thesis statements is on improving reliability, frequency and flexibility of supply. The lowest impact of the statements described in the theses concerned optimisation of stock levels throughout the supply chain with adaptation to the preferences of individual market segments. Minimising the cost of product and information flow while maintaining the level of service desired by the customer and ensuring short order processing times are within a moderate sphere of influence of the thesis statements.

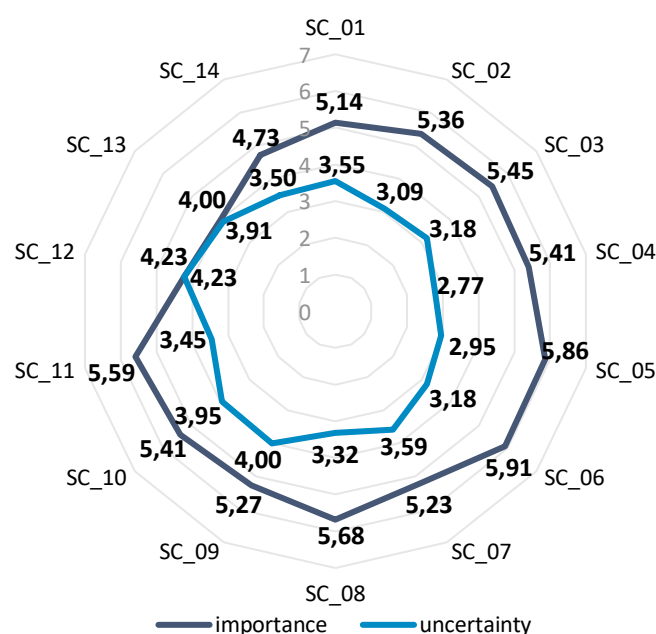
The study also identified 14 factors (using STEEPED analysis) that, in the opinion of the study's authors, may favour resilience building of satellite communication supply chains in the European Union. In the area of satellite communications, the following factors were identified:

SC_01	Quality of life and security of citizens
SC_02	Social trust in modern technologies
SC_03	Development of Artificial Intelligence
SC_04	Development of Internet of Things systems
SC_05	Competencies of end-users using Copernicus data and services

SC_06	Cooperation between key stakeholders (researchers, entrepreneurs, politicians) of the Copernicus programme
SC_07	The level of climate neutrality and biodiversity
SC_08	Efficiency in the use of natural resources using modern digital technologies, e.g. measuring and controlling, monitoring, reporting, etc.
SC_09	The level of geopolitical stability
SC_10	The quality of legislation on cybersecurity and the use of digital data
SC_11	Openness to technological innovations that improve the comfort of life (e.g. in terms of reducing environmental pollution)
SC_12	The role of civil society
SC_13	Aging society
SC_14	The level of international migration

The presented factors were later rated, according to the school of intuitive logic of scenario construction, on a seven-point scale of importance (where 1 meant the factor was of very low importance and 7 meant that the factor was of very high importance) and uncertainty (where 1 meant the factor had very low uncertainty, while 7 meant the factor was characterised by very high uncertainty), (Figure 22).

Figure 22: Juxtaposition of the factors influencing building the resilience of supply chains in the European Union in the area of satellite communications in terms of importance and uncertainty



Source: Compiled by the authors.

Generally, all of the identified factors received high average importance ratings.³ Factors that received the highest importance scores (arithmetic mean above 5.5) included: *cooperation between key stakeholders (researchers, entrepreneurs, politicians) of the Copernicus programme* (5.91), *competencies of end-users using Copernicus data and services* (5.86), *efficiency in the use of natural*

³ Arithmetic means are presented in the brackets.

resources using modern digital technologies, e.g. measuring and controlling, monitoring, reporting, etc. (5.68) and openness to technological innovations that improve the comfort of life (e.g. in terms of reducing environmental pollution) (5.59). In contrast, the lowest impact on building resilience in supply chains was characterised by such factors as: *the level of international migration* (4.73), *the role of civil society* (4.23) and *aging society* (4.00). However, it should be noted that the differences in the average ratings of the highest and lowest rated factors are not particularly great, so one can conclude that all the factors identified in the study may have a positive impact on building resilience of satellite communication supply chains in the European Union.

The study also identified the factors with the highest uncertainty of development in the 2030 horizon. These include: *the role of civil society* (4.23), *the level of geopolitical stability* (4.00), *the quality of legislation on cybersecurity and the use of digital data* (3.95) and *aging society* (3.91).

Factors with a relatively high level of uncertainty which can be realistically controlled as part of the policy of the European Union concern *the role of civil society*, *the quality of legislation on cybersecurity and the use of digital data* and *aging society*. *The level of geopolitical stability* was found to be both the most important and the most uncertain factor in the study. Due to the systemic, multidimensional and global nature of this factor, it is only partially controlled by the EU.

The survey questionnaire also included an open-ended question about the possible actions to be taken to build resilience of satellite communication supply chains in the European Union. The experts gave numerous opinions in this regard with reference to such proposals as providing secure communication services, autonomy and access to all users; better control over raw resource acquisitions and supply chains for critical technologies; ensuring that Copernicus data remain free and open; synchronising with the Copernicus programme of other relevant EU programmes like Horizon Europe, Digital Europe, etc.; creation of a robust bridge between the data provided by satellites and decision-making activities which are carried out using this data, to name a few.

Detailed analyses of the experts' opinions are presented in Chapter 5 with reference to policy options.

3.4. Semiconductors

Chips (semiconductors) are the building blocks of the digital economy, which is why the EU wants to become a global player in the semiconductor ecosystem and ensure its technological sovereignty. By pooling large-scale investments, the EU aims to double its global market share of semiconductors to 20 % by 2030 and ensure that the benefits are evenly distributed among all EU Member States. However, these ambitions are currently at risk. On the one hand, Ukraine supplies the EU with 70 % of neon gas used to produce semiconductors, while Russia is a leading exporter of this material; on the other hand, EU Member States have different capacities, needs, dependencies and infrastructures when it comes to semiconductors. The global semiconductor market is also vulnerable to wild-card events – such as the 2021 drought in Taiwan, which caused significant reductions in the supply of water needed in the silicon wafer purification process, and the COVID-19 pandemic, which reduced the production capacity of factories located in China. In order to make Europe independent of semiconductor suppliers from Asian countries and achieve the goals adopted in the European Chips Act, it is necessary to take immediate action of a structural nature, involving all EU Member States and all participants in regional supply markets.

This study explores factors favouring resilience of semiconductor supply chains in Europe and associated barriers that may slow down this process.

Within the semiconductors area, four theses were examined:

Thesis SE_T1. EU share of global cutting-edge, innovative and sustainable semiconductor production will increase from 10 to 20 %

Thesis SE_T2. Security of supply of semiconductors to strategic sectors of the EU countries will be ensured

Thesis SE_T4. Building a dynamic ecosystem across the EU will strengthen Europe's capabilities to achieve its environmental goals and green transitions while improving the Union's security (semiconductors)

Thesis SE_T4. EU countries have sufficient resources to produce modern integrated chips (made with the 7-nanometre process)

The selection of theses was preceded by analyses of reports, article reviews, statistical data and opinions of European experts (representing research, industry and policy sectors) in the area of semiconductor supply chains. The policy paradigm shift away from the global supply chain towards building regional (European) semiconductor supply chains and making supply chains more resilient has been taken into account.

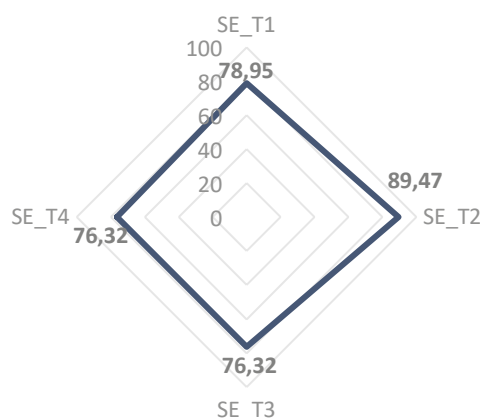
The analyses carried out were presented in the comparative approach. All four theses were rated as being of high or very high importance, as demonstrated by the values of significance indicators (Figure 23).

Within the analysed group of theses, the highest significance index was noted for SE_T2, which may translate into a very high importance of ensuring the security of supply of semiconductors to strategic sectors of EU countries.

The lowest relevance index was recorded for SE_T3 and SE_T4, which may indicate in the case of T3 that building a dynamic ecosystem across the EU while improving the Union's supply of semiconductor security is not especially relevant. The slightly lower relevance of SE_T4 may be related to the fact that experts attach more importance to the security of supply of semiconductors (in general), and the issue of their innovation and modernity plays a secondary role.

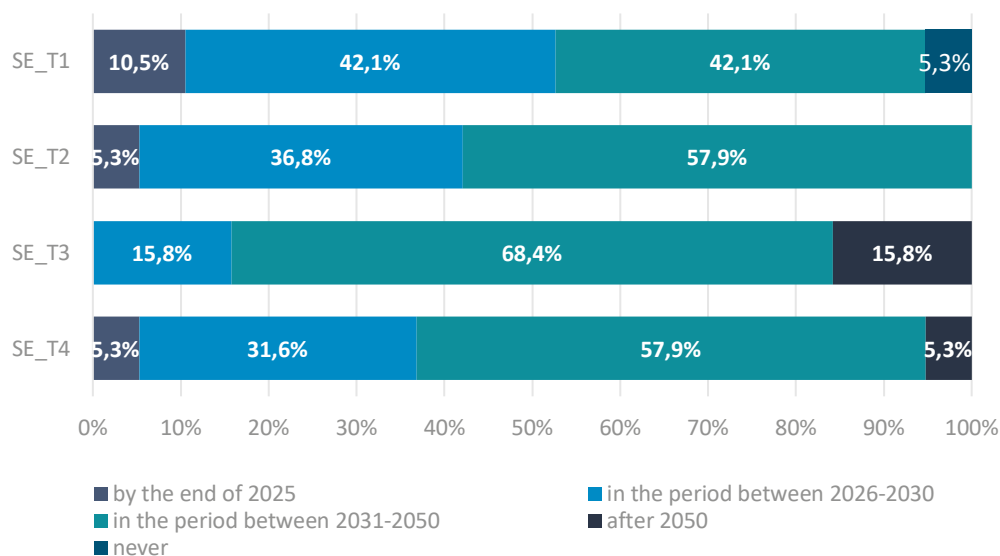
The assessment of the theses' timescale for implementation is characterised by a similar pattern of responses (Figure 24).

Figure 23: Values of significance indicators for the theses in the semiconductors area



Source: Compiled by the authors.

Figure 24: Timescale for implementation of the theses

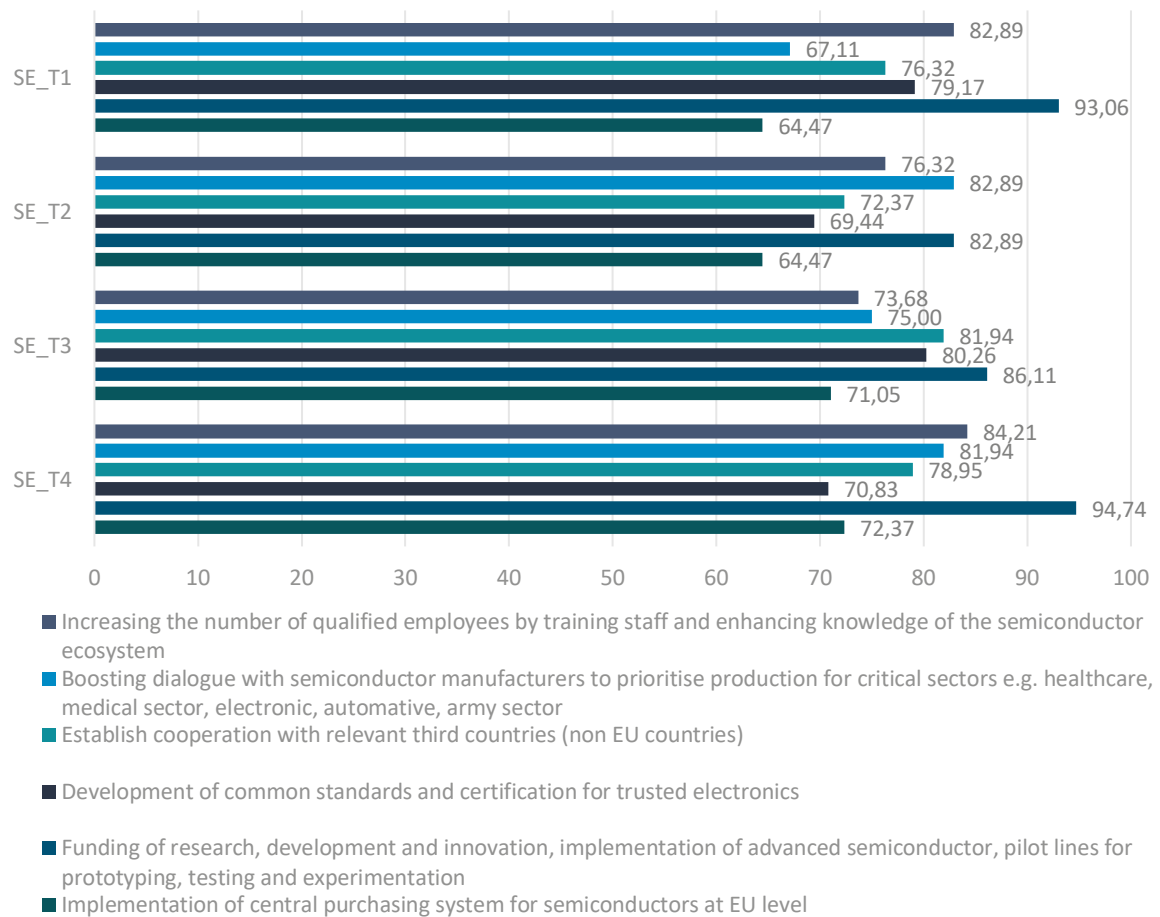


Source: Compiled by the authors.

In the opinion of more than 42 % of the experts, the thesis SE_T1 will be implemented in the period 2026-2030 or 2031-2050. Compared to other theses, the experts are more optimistic about the chance that the EU share of the global semiconductor market will increase from 10 to 20 % in the period 2026-2030. Only 10.5 % of the experts believe that SE_T1 will be implemented by the end of 2025. At the same time, 5.3 % believe that the hypothesis will never be implemented. More than 57 % of the experts believe that the security of supply of semiconductors to strategic sectors (SE_T2) will be ensured in the longer term – in the period 2031-2050. Furthermore, according to the experts, ensuring that EU countries will have sufficient resources to produce modern integrated chips (SE_T4) requires more time.

Indicators were also calculated for each thesis in relation to actions that favour the implementation of the theses (Figure 25).

Figure 25: Values of indicators relating to factors favouring implementation of the theses

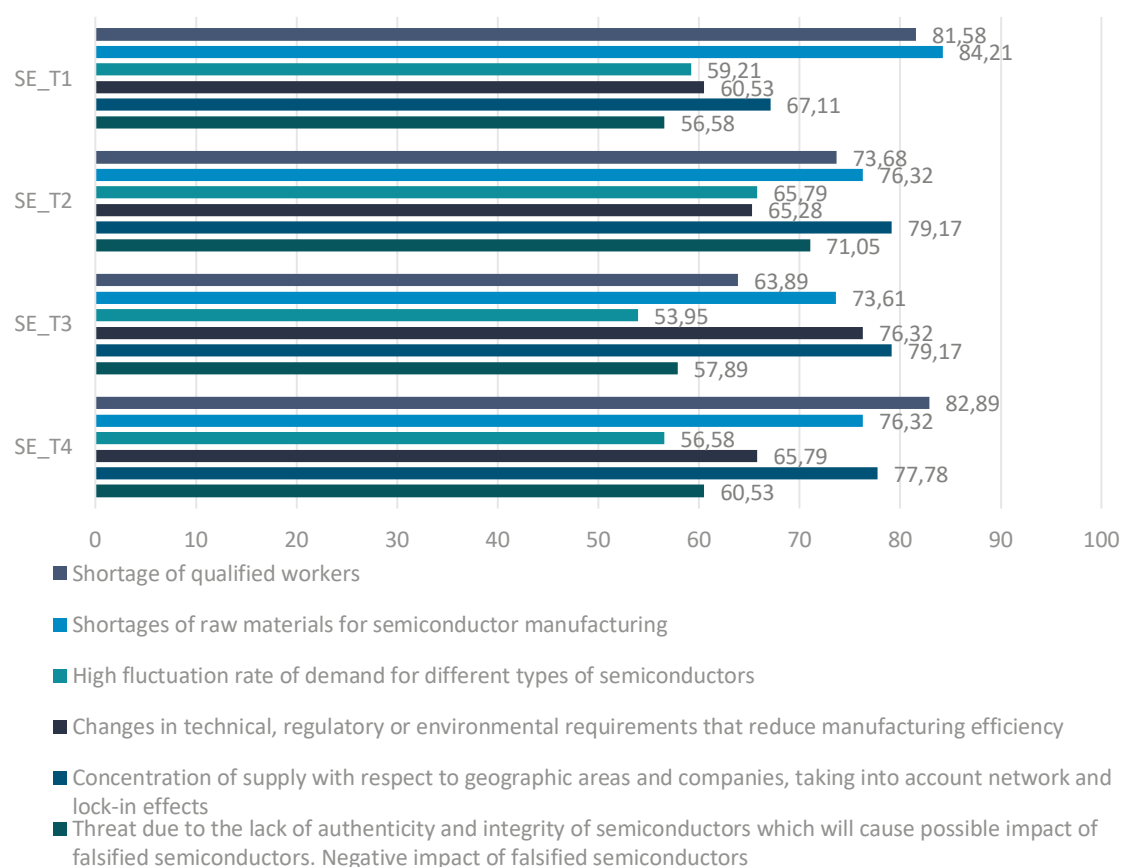


Source: Compiled by the authors.

The most significant factor favouring implementation of the theses is *funding of research, development and innovation, implementation of advanced semiconductors, pilot lines for prototyping, testing and experimentation*. The lowest values favouring the implementation of the theses were recorded for *the implementation of a central purchasing system for semiconductors at the EU level*. The low estimation of this factor may be due, on the one hand, to the fact that the experts are concerned about interfering with free market principles or, possibly, to a lack of faith in the feasibility of such a solution. In the opinion of the experts, the realisation of SE_T1 and SE_T4 can also be accelerated by *increasing the number of qualified employees by the training staff and enhancing knowledge of the semiconductor ecosystem*. An important determinant of security of supply of semiconductors to strategic sectors (SE_T2) is *boosting dialogue with semiconductor manufacturers to prioritise production for critical sectors, e.g. the healthcare, medical, electronic, automotive, army sector*.

The next step of the study presents the values of thesis barrier indicators (Figure 26). The assessment of the relevance of the analysed barriers relating to the degree of implementation of the theses varied within each thesis.

Figure 26: Values of indicators of barriers to the implementation of the theses



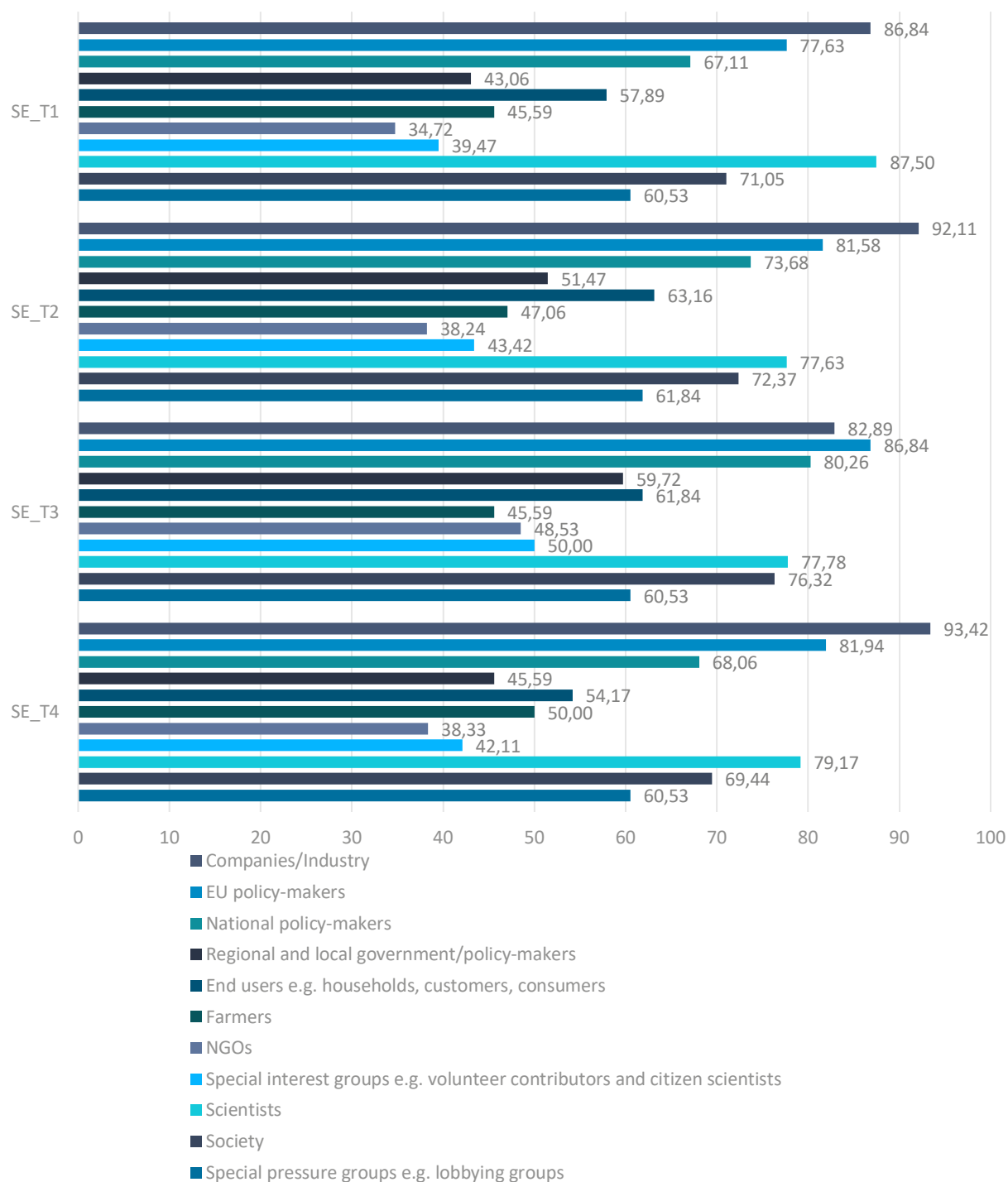
Source: Compiled by the authors.

Regarding SE_T1, the experts considered the most important barriers to be: *shortages of qualified workers* and *shortages of raw materials for semiconductor manufacturing*. In the case of thesis SE_T2, the factors indicated above also play an important role as barriers, but an additional important barrier is *the concentration of supply with respect to geographic areas and companies*. The degree of realisation of SE_T4, which reflects EU ability to produce modern integrated chips will mainly depend on eliminating the barrier of *the shortage of qualified workers*.

The study also assessed the strength of the theses' impact on stakeholders (Figure 27). The highest values of the indicators were obtained for the impact of the theses on company/industry sectors (SE_T1, SE_T2, SE_T4). In the case of thesis SE_T3, reflecting Europe's capabilities to achieve its environmental goals and green transitions while improving the Union's semiconductor security, the experts' opinions confirmed that this thesis will affect three groups of stakeholders: EU policy-makers, national policy-makers and company/industry sectors. The implementation of European Green Deal goals requires a number of legal and administrative actions involving policy makers and

a transformation in the approach to business. All the theses will have a significant impact on scientists both in terms of targeting research topics and sharing research funding.

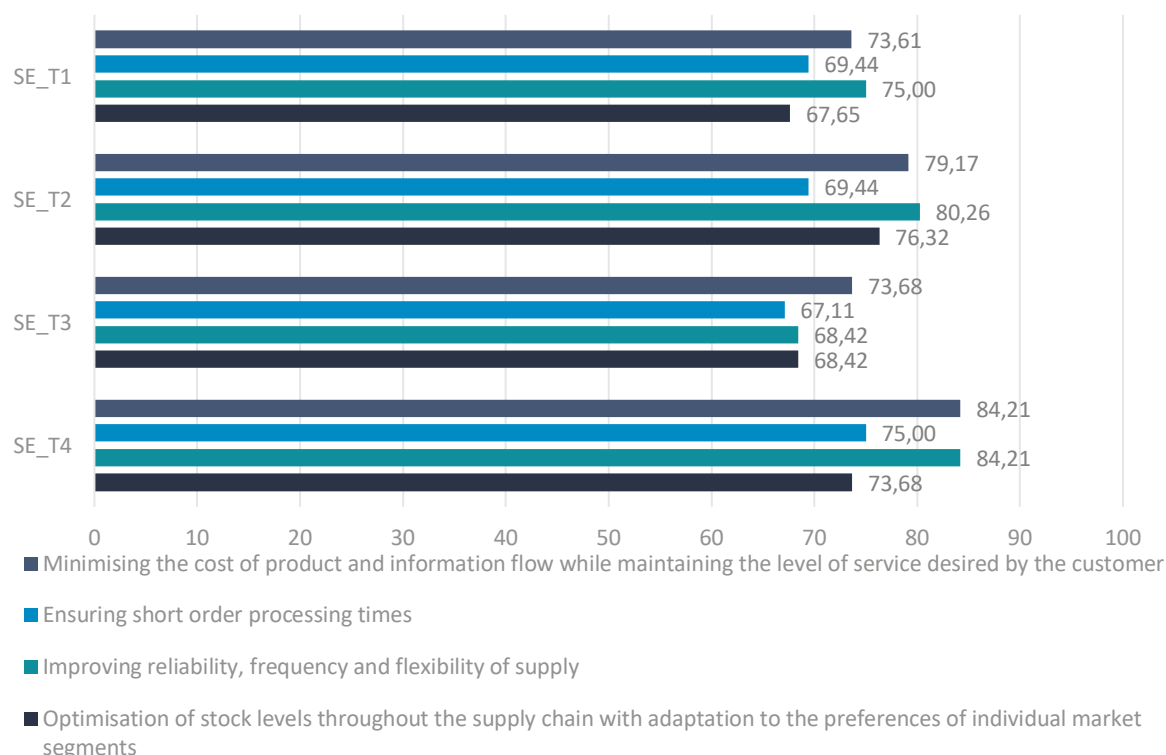
Figure 27: Values of indicators of the strength of the theses' impact on stakeholders



Source: Compiled by the authors.

The study also examined the impact of the theses' statements on the functions of supply chains (Figure 28).

Figure 28: Values of indicators of the theses' impact on the functions of supply chains



Source: Compiled by the authors.

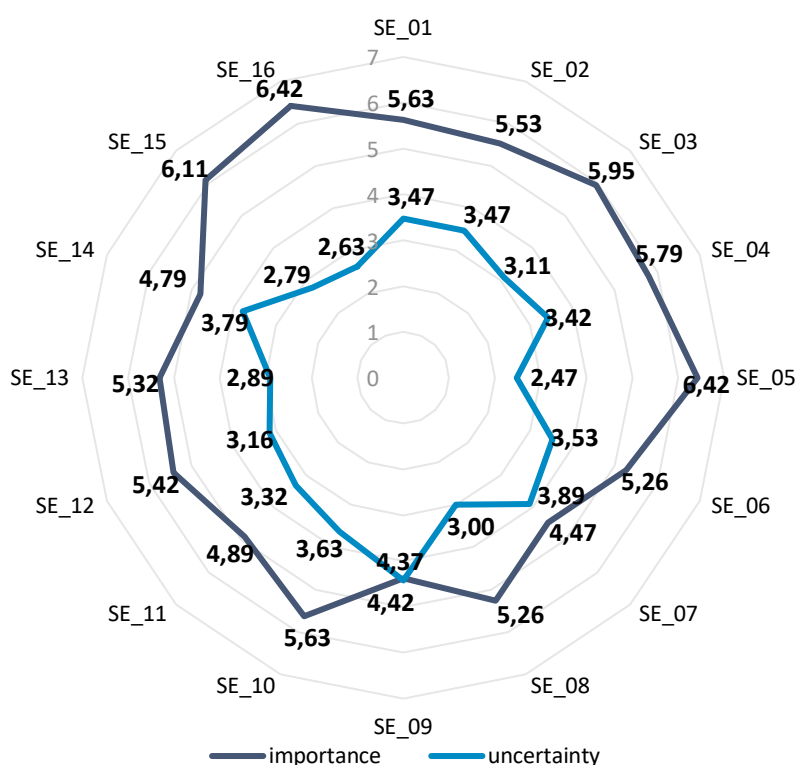
The greatest impact of the theses' statements is on minimising the cost of product and information flow while maintaining the level of service desired by the customer and improving reliability, frequency and flexibility of supply. The lowest impact of the statements described in the theses was noted with short order processing times and optimisation of stock levels throughout the supply chain with adaptations to the preferences of individual market segments.

The study also identified 16 factors (using STEEPED analysis) that, in the opinion of the study's authors, may favour resilience building of the semiconductor supply chain in Europe. The following factors were identified:

SE_01	Dialogue with semiconductor manufacturers to prioritise production for critical sectors
SE_02	Demand for leading-edge chips driven by Artificial Intelligence, autonomous driving and 5G/6G
SE_03	Dialogue between semiconductor manufacturers and policy makers
SE_04	Shortages of raw materials for semiconductor manufacturing
SE_05	Funding of research, development and innovation, implementation of advanced semiconductors (such as pilot lines for prototyping, testing and experimentation)
SE_06	Central purchasing system for semiconductors at the EU level
SE_07	Fluctuation rate of demand for different types of semiconductors
SE_08	Concentration of supply with respect to geographic areas and companies, taking into account network and lock-in effects
SE_09	Changes in environmental requirements that reduce manufacturing efficiency
SE_10	Development of energy-efficient semiconductors
SE_11	Development of common standards and certification for trusted electronics
SE_12	Cooperation with relevant third countries (non-EU countries)
SE_13	Authenticity and integrity of semiconductors
SE_14	Conscious consumerism
SE_15	Qualified employees in the semiconductor ecosystem
SE_16	STEM (Science, Technology, Engineering, Mathematics) talent investments

The presented factors were later rated, according to the school of intuitive logic of scenario construction, on a seven-point scale of importance (where 1 meant the factor was of very low importance and 7 meant that the factor was of very high importance) and uncertainty (where 1 meant the factor had very low uncertainty, while 7 meant the factor was characterised by very high uncertainty), (Figure 29).

Figure 29: Juxtaposition of the factors influencing building the resilience of the supply chains in Europe in the area of semiconductors in terms of importance and uncertainty



Source: Compiled by the authors.

Factors that received the highest importance scores (arithmetic mean above 6) included: *funding of research, development and innovation* (6.42), *STEM (Science, Technology, Engineering, Mathematics) talent investments* (6.42), *qualified employees in the semiconductor ecosystem* (6.11). In contrast, the lowest impact on building resilience in semiconductor supply chains was characterised by such factors as: *changes in environmental requirements that reduce manufacturing efficiency* (4.37), *fluctuation rate of demand for different types of semiconductors* (4.47) and *conscious consumerism* (4.79).

The study also identified the factors with the highest uncertainty of development in the 2030 horizon. These include: *changes in environmental requirements that reduce manufacturing efficiency* (4.42), *fluctuation rate of demand for different types of semiconductors* (3.89) and *conscious consumerism* (3.79).

The factor with a relatively high level of uncertainty connected with *changes in environmental requirements that reduce manufacturing efficiency* can be realistically controlled as part of the policy of the European Union. Two other factors remain outside the EU's control.

The survey questionnaire also included an open-ended question about possible actions to be taken to build resilience of semiconductor supply chains in Europe. The experts gave numerous opinions in this regard with reference to such proposals as: bringing back semiconductor manufacturing capabilities to Europe by creating the European semiconductor manufacturing centre; developing a circular economy for semiconductors (between the U.S. and Europe) by extending the lifetime of devices and semiconductors as an important element in circular economy; boosting European semiconductor research and development by implementing rules at the level of the ICS (Industrial Control System) production and security process; implementation of import restrictions on all products that use ICS which do not purchase according to safety rules and good production practices.

Detailed analyses of the experts' opinions are presented in Chapter 5 with reference to policy options.

3.5. Analysis of cross-cutting theses

For the purpose of the research, five cross-cutting theses were formulated in relation to the following areas: food, energy, satellite communications and semiconductors. These five cross-cutting theses were defined to indicate the relationship between the specified areas. They were addressed to the entire group of experts.

Thesis CC_T1. The EU economy will become circular and the global value chain will be shifted closer to the sites of consumption. As a result, European Union supply chains (food, energy, satellite technologies, and semiconductors) will become shorter and lose their international importance

Thesis CC_T2. Poverty in the EU will be a marginal phenomenon

Thesis CC_T3. Fully self-sufficient European Union supply chains (food, energy, satellite communications and semiconductors) will generate substantial incremental costs and lead to dramatic increases in EU product prices

Thesis CC_T4. The Copernicus programme will be used in the EU to designate agricultural land suitable for growing crops

Thesis CC_T5. The Copernicus programme will be used in the EU to monitor and assess the potential of alternative (renewable) energy sources, which will enable independence from external energy resource supplies

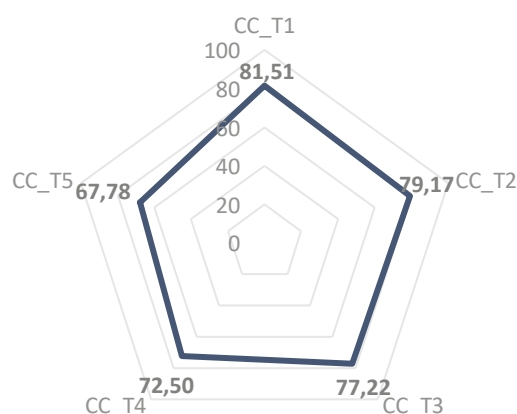
The selection of the theses was preceded by statistical analysis and expert discussion. The analyses carried out were presented with a comparative approach. All five theses were rated as being of high or very high importance, as demonstrated by the value of significance indicators (Figure 30).

Within the analysed group of theses, the highest significance index was noted for CC_T1, (the value of the indicator is 81.51), which may translate into very high importance of the EU's pursuit of a circular economy and moving the global supply chain closer to sites of consumption.

This in turn can contribute to shortening European Union supply chains in the areas of: food, energy, satellite communications and semiconductors. A high significance index was also noted for CC_T2 (the value of the indicator is 79.17). Therefore, according to the experts, it is very important to strive to minimise poverty in the EU. In turn, the lowest significance index, with a value of 67.78, was noted for CC_T5. On the one hand, it may indicate that the experts had the greatest doubts in assessing this thesis. On the other hand, it may mean that taking actions aimed at using the Copernicus programme in the EU to monitor and assess the potential of alternative (renewable) energy sources is characterised by a slightly lower significance than the statements presented in the other theses.

The assessment of the theses' timescale for implementation is characterised by a different pattern of responses (Figure 31). In the opinion of the vast majority of experts (over 80 %), the statements contained in theses CC_T1, CC_T3, CC_T4 and CC_T5 will be implemented in the period 2026-2030 or in the period 2031-2050. Only 25 % of the experts claim that the statement described in thesis CC_T2 will be implemented in the period 2026-2030 or in the period 2031-2050, whereas over 16 % of the experts assume that thesis CC_T4 will be implemented by 2025. An even smaller percentage of the experts (6.7 %) believe that the CC_T3 thesis will be implemented before 2025. Fewer than 5 % of the experts state that the events described in theses CC_T1 and CC_T5 will occur by the end of 2025. According to all the experts participating in the study, thesis CC_T2 will not be implemented by 2025. Analysing the data presented in Figure 31, it is apparent that none of the experts stated that thesis CC_T4 will never be implemented. All the experts believe that the events described in thesis CC_T4 (the Copernicus programme will be used in the EU to designate agricultural land suitable for growing crops) will be realised by 2050 at the latest. Additionally, a small percentage of the experts (fewer than 7 %) believe that the relationships described in thesis CC_T1, CC_T3 and CC_T5 will never happen. More than half of the experts do not believe in the realisation of thesis CC_T2, more than 58 % of the experts believe that the relationships described in this thesis will never happen. According to more than half of the experts, it is impossible for poverty in the EU to be a marginal phenomenon.

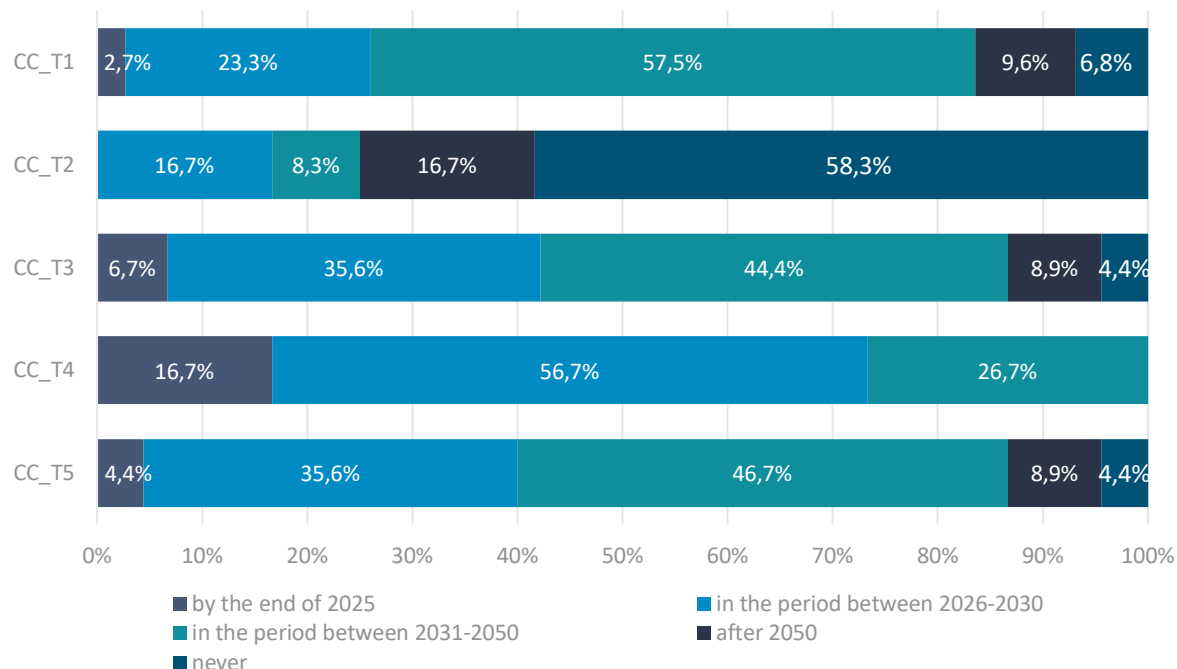
Figure 30: Values of significance indicators for the cross-cutting theses



Source: Compiled by the authors.

Indicators were also calculated for each thesis in relation to actions that favour the implementation of the theses (Figure 32).

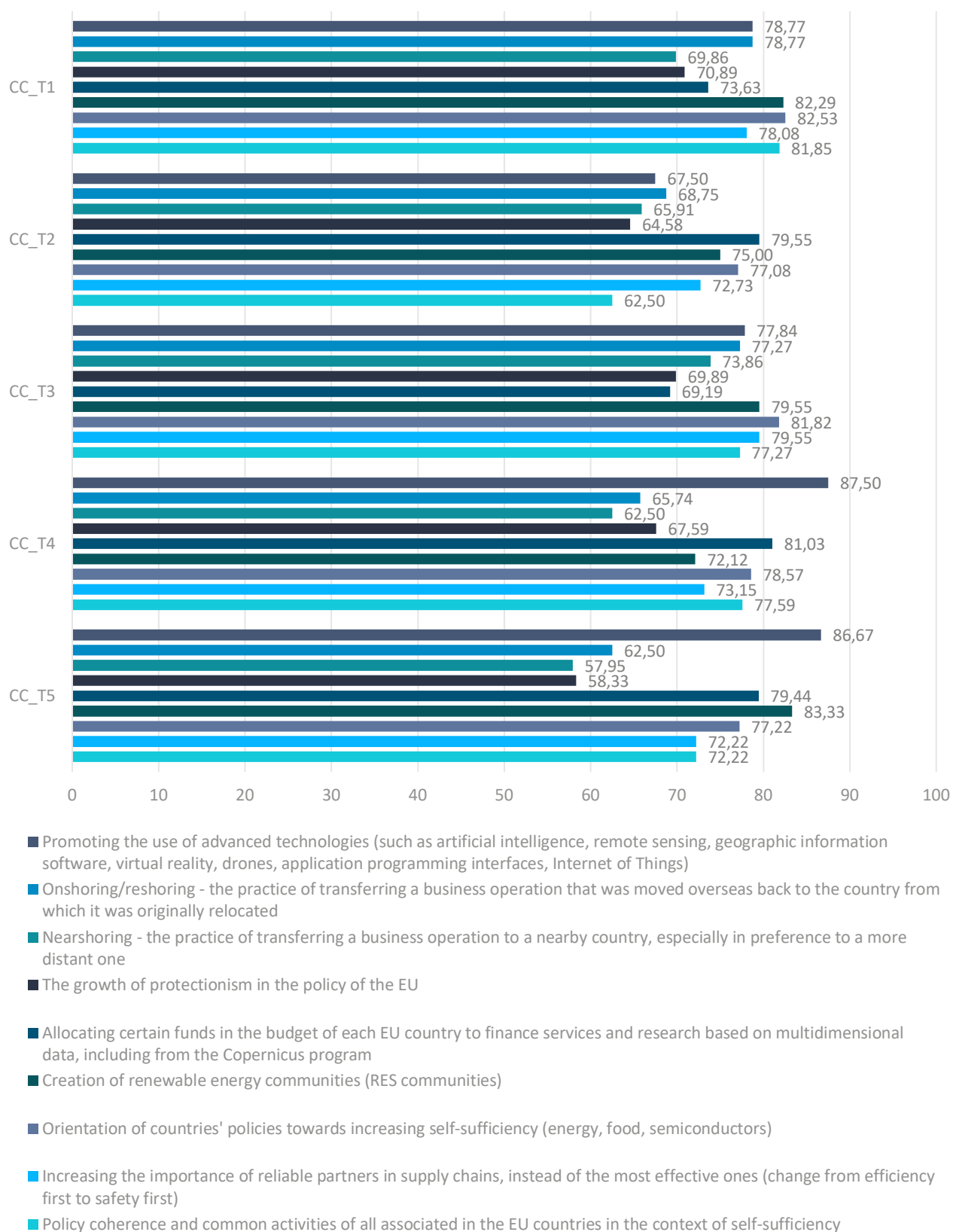
Figure 31: Timescale for implementation of the theses



Source: Compiled by the authors.

Analysing Figure 32, it can be seen that the most important factor conducive to the implementation of CC_T4 and CC_T5 is *promoting the use of advanced technologies (such as artificial intelligence, remote sensing, geographic information software, virtual reality, drones, application programming interfaces, Internet of Things)*. The significance index of this factor in CC_T4 and CC_T5 was respectively: 87.5 and 86.67. However, in the case of CC_T1 and CC_T3, according to the experts, the most important is *the orientation of countries' policies towards increasing self-sufficiency (energy, food, semiconductors)*. The most significant factor favouring the implementation of the theses is *allocating certain funds in the budget of each EU country to finance services and research based on multidimensional data, including from the Copernicus programme*. However, the factor related to *allocating certain funds in the budget of each EU country to finance services and research based on multidimensional data, including from the Copernicus programme*, has the lowest relevance concerning CC_T3 realisation (the significance index was 69.19). The lowest values conducive to the implementation of CC_T1, CC_T4 and CC_T5 were noted for the factor: *nearshoring — the practice of transferring a business operation to a nearby country, especially in preference to a more distant one*. The factor with the lowest importance for CC_T2 is: *policy coherence and common activities of all associated with the EU countries in the context of self-sufficiency* (the value of the indicator was 62.50).

Figure 32: Values of indicators relating to factors favouring the implementation of the theses

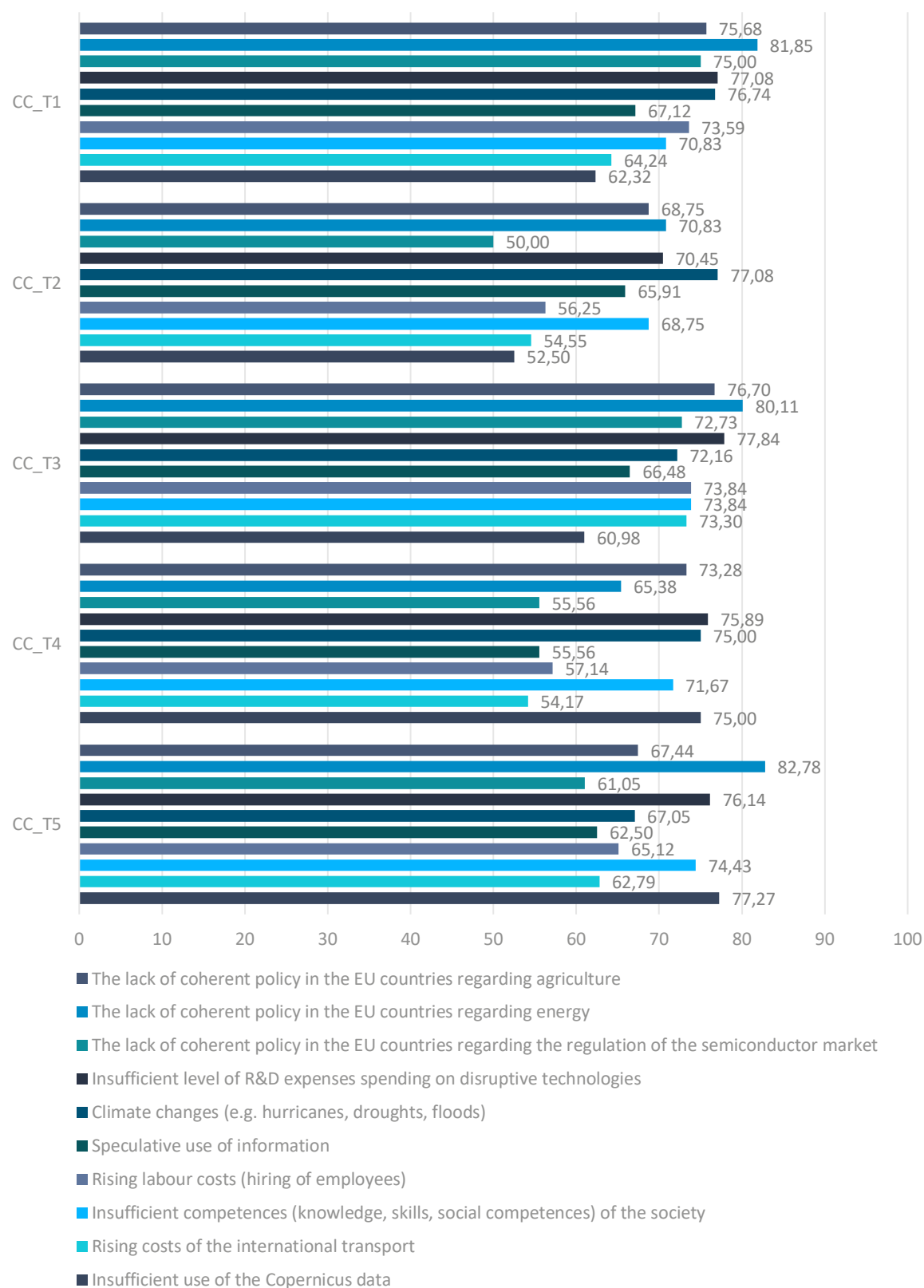


Source: Compiled by the authors.

Analysing the data presented in Figure 33, it can be seen that the strongest barrier to the implementation of CC_T1, CC_T3 and CC_T5 is *the lack of coherent policy in EU countries regarding energy*. The significance indicator of this factor in individual theses was, respectively: 81.85, 80.11 i 82.78. In turn, in the case of thesis CC_T2, according to the experts, the most important barrier is: *climate changes (e.g. hurricanes, droughts, floods)*, where the value of the indicator was 77.08. *An insufficient level of R&D expenses spending on disruptive technologies* is the strongest barrier to the implementation of CC_T4. The significance indicator of this barrier in the case of CC_T4 is 75.89. According to the experts, the least significant barrier to the implementation of CC_T2 and CC_T5 is: *the lack of coherent policy in EU countries regarding the regulation of the semiconductor market*. The significance index of this barrier is 50.00 and 61.05, respectively. In turn, the implementation of CC_T1 and CC_T3 is least affected by the factor: *insufficient use of the Copernicus data*. The least significant barrier to the implementation of CC_T4 is: *rising costs of the international transport*. The significance indicator of this barrier was 54.17.

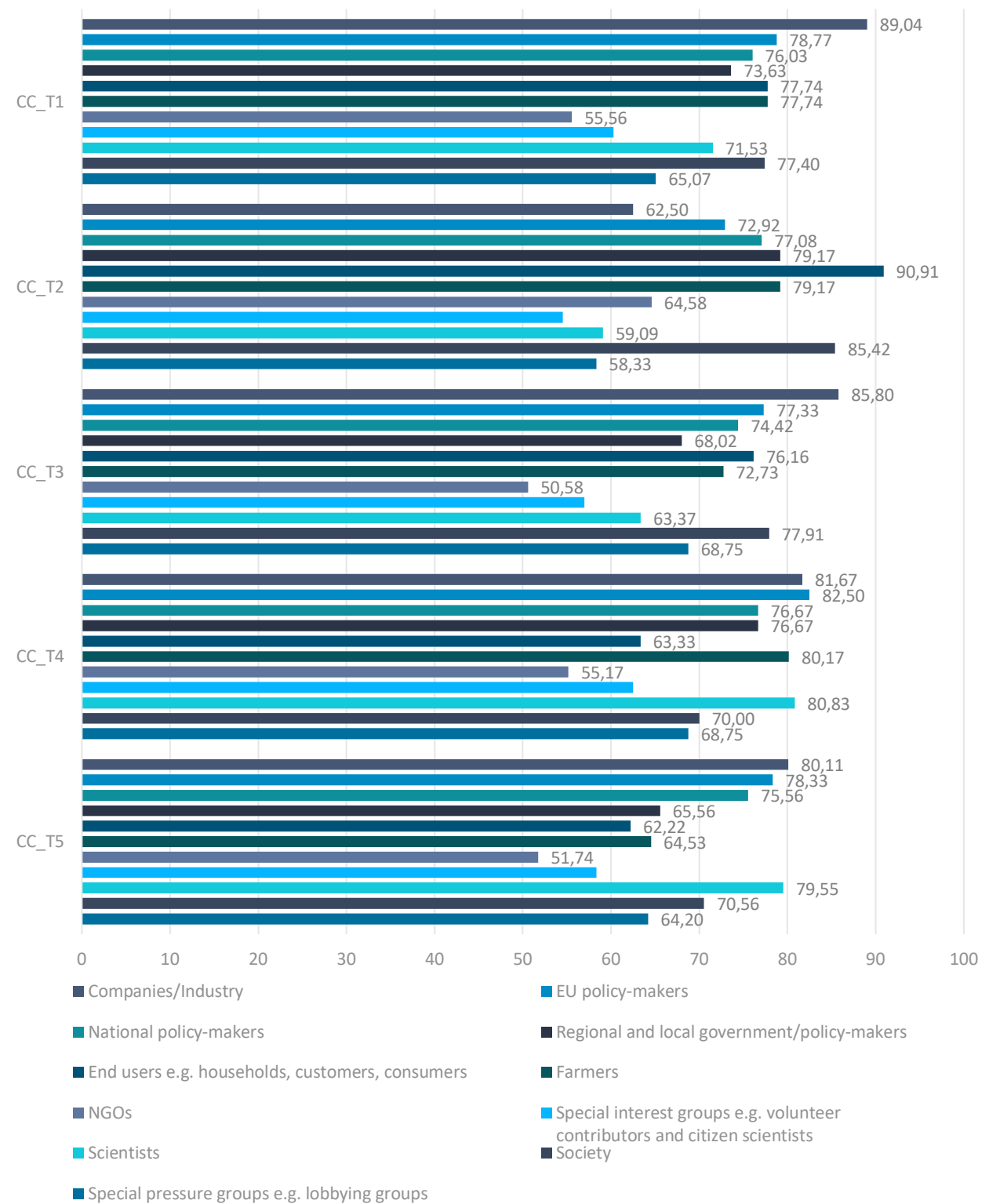
The study also assessed the strength of the theses' impact on stakeholders (Figure 34). Analysing Figure 34, it can be seen that CC_T1, CC_T3 and CC_T5 have the highest value of the impact indicators on companies/industry. The indicator values were respectively: 89.04, 85.50 and 80.11. The highest values of the indicators were obtained for the impact of the thesis on end-users, e.g. households, customers, consumers (the value of the indicator was 90.91), and CC_T4 on EU policy-makers (the value of the indicator was 82.50). Low values of impact indicators were obtained for NGOs in the case of CC_T1, CC_T3, CC_T4 and CC_T5 implementation. In turn, the implementation of CC_T2 has the lowest impact on special interest groups, e.g. volunteer contributors and citizen scientists, where the value of the indicator was 54.55.

Figure 33: Values of indicators of barriers to the implementation of the theses



Source: Compiled by the authors.

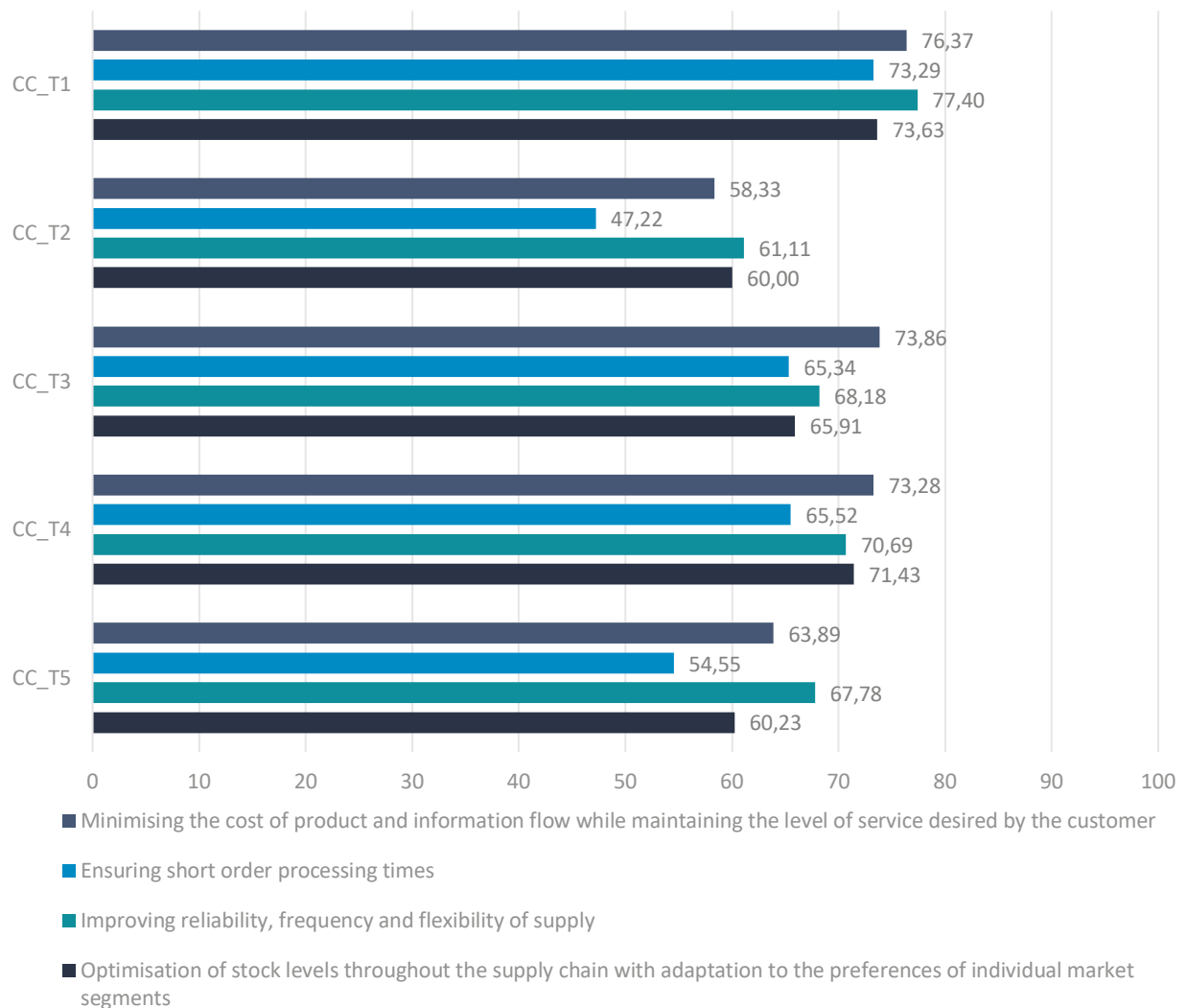
Figure 34: Values of indicators of the strength of the theses' impact on stakeholders



Source: Compiled by the authors.

The study also examined the impact of the thesis statements on the functions of supply chains (Figure 35).

Figure 35: Values of indicators of the theses' impact on the functions of supply chains



Source: Compiled by the authors.

Analysing Figure 35, it can be seen that, according to the experts, the highest value of the impact of the statements described in CC_T1, CC_T3 and CC_T4 was noted with regard to minimising the cost of product and information flow while maintaining the level of service desired by the customer (the values of the significance indicators were respectively: 76.3, 73.86 and 73.28). The statements described in CC_T2 and CC_T5 have the greatest impact on improving reliability, frequency and flexibility of supply (the values of the significance indicators were, respectively: 61.11 and 67.78). In contrast, the statements described in all the theses have the lowest impact on ensuring short order processing times.

4. Conclusions

The conclusions presented in this section refer to the main findings and results obtained in the Delphi study in the four areas: food, energy, semiconductors and satellite communications. Detailed policy options to support resilience building in supply chains are presented in Chapter 5.

In the area of **food**, four theses were examined. The highest significance index was noted for F_T1 (*Wheat production in EU countries will be independent of Ukraine and Russia*), which may translate into a very high importance of decoupling wheat production in EU countries from Ukraine and Russia.

In the opinion of most (more than 70 %) of the experts, the statements included in the theses will be implemented in the 2026-2030 period or in the 2031-2050 period.

Irrespective of the theses (with the exception of F_T3 (*EU countries will invest additional financial resources in the production of NPK fertilisers in order to become independent from Russia*), the most significant factor favouring the implementation of the theses in the area of food is *promoting the use of advanced technologies in agriculture (such as artificial intelligence, remote sensing, geographic information software, virtual reality, drones and application programming interfaces)*. The lowest values favouring the implementation of the theses were recorded for *the approval of state aid fertiliser subsidies*, with the exception of F_T3, for which, due to the nature of the event described in the thesis, this enabling factor has the highest importance.

The strongest barrier to the implementation of F_T1 and F_T2 (*EU countries will be leaders in the production of the sunflower oil*) is *the occurrence of extreme weather conditions, such as droughts, floods and other natural disasters*. This is a barrier that could be treated as a wild card (high impact, low probability event) and for which the impact of political influence at the EU level is not great. A further important barrier for which the significance index ranged from 72.22 to 78.95 in the individual theses is *insufficient financial support to farmers*. In the case of F_T3 and F_T4 (*There will be a reversal of the previous policy of limiting agricultural production*), the greatest barrier is *the lack of favourable legislation at the national level*. Irrespective of the thematic scope, experts considered the barrier of lowest importance in the food area to be *the too slow utilisation of biogas production from agri-food waste*.

The study also assessed the strength of the impact the theses have on stakeholders. The highest values of the indicators were obtained for the impact of the theses on farmers, who are among the main beneficiaries of the research implemented in the area of food. High scores for the theses' impact indicators were also obtained for companies and industries. In contrast, the lowest indicator values, regardless of the thesis, were obtained for NGOs and special interest groups, e.g. volunteer contributors and citizen scientists.

The study also examined the impact of the thesis statements on the functions of supply chains. The greatest impact of thesis statements is on the optimisation of stock levels throughout the supply chain with the adaptation to the preferences of individual market segments. The lowest impact of the statements described in the theses was noted with regard to ensuring short order processing times.

Furthermore, 16 factors were identified (using the STEEPED analysis) that may favour resilience building of food supply chains in Europe. By and large, all of the factors identified received high average importance ratings. Factors that received the highest importance scores included: *the occurrence of extreme weather conditions, such as droughts, floods and other natural disasters; the level of financial support to farmers; the use of advanced technologies in agriculture (such as artificial intelligence, remote sensing, geographic information software, virtual reality, drones, application programming interfaces) and conscious consumerism*.

By contrast, the lowest impact on building resilience in supply chains was characterised by such factors as *the approval of state aid fertiliser subsidies, the level of utilisation of biogas production from agri-food waste and the level of international migration*.

The study also identified the factors with the highest uncertainty of development in the 2030 horizon. These include: *the level of international migration, the level of utilisation of biogas production from agri-food waste, the occurrence of extreme weather conditions, such as droughts, floods and other natural disasters and the level of social trust in modern technologies*.

In the area of **energy**, five theses were examined. The highest significance index was noted for E_T3 (*There will be closer integration of EU countries within European energy security*), which points to high importance of energy cooperation within the EU, and the need for greater integration and coordination of activities. The high ratings of E_T1 (*The growth of renewables in the energy mix in EU countries will be more dynamic*), E_T4 (*The importance of hydrogen and biomethane as energy sources will increase*), and E_T5 (*There will be a transformation of the energy market in the EU towards distributed energy*) indicate the experts' high expectations regarding the rapid development of renewables. The lowest significance rate was recorded for E_T2 (*The role of Russia as a supplier of fossil fuels to the EU market will diminish*), which could indicate that experts perceived the process of independence from Russian resources as less important than the statements described in other theses. This interpretation is confirmed by the assessment of the timescale for the implementation of theses. The experts estimated that E_T2 will be completed by 2025 (56.41 %) or 2030 (82.05 % in total). The period until 2030 was also indicated as the time of E_T1 and E_T3 implementation. For E_T2, E_T3 and E_T4, the most important factor favouring the implementation of the theses is *technological progress in the field of alternative energy sources (e.g. technologies using space-based solar power, human power, tidal power, hydrogen power, magma power, flying wind power, algae power fusion power)*. For E_T1 and E_T5, the most important factor is *creating energy management clusters and cooperatives*, although *technological progress* is also highly rated. The lowest values of favouring the implementation of theses were recorded for *integration of AfCFTA countries*, which may indicate that alternatives to Russian directions of fossil fuel imports are least relevant to the thematic scope described in the theses. The strongest barrier to the implementation of E_T1, E_T3, and E_T5 is *the reluctance of some EU Member States to cooperate on energy due to different energy goals*. In turn, in the case of E_T1 and E_T3, the experts indicated *low stocks of energy resources in many countries of the EU* as the most important barrier. The least significant barriers indicated by the experts were: *difficulties in finding an alternative to the Russian supplies of fossil fuels* (E_T4 and E_T5); *environmental threats related to the construction of new fossil fuels transport infrastructure* (E_T2 and E_T3); and *the high cost of creating new transport infrastructure for fossil fuels* (E_T1).

The study also assessed the strength of the theses' impact on stakeholders. Regardless of the statements presented in the theses, the high values of the indicators, and in the case of E_T1 and E_T5, the highest values were obtained for the impact of the theses on companies/industry. For E_T2 and E_T3, experts assessed that they would have the greatest impact on national policy-makers and EU policy-makers. In contrast, the lowest indicator values in theses were obtained for NGOs and special interest groups, e.g. volunteer contributors and citizen scientists.

The greatest impact of all the thesis statements, in the area of the functioning of supply chains, is on improving reliability, frequency, and flexibility of supply. The lowest impact of the statements described in all theses was noted with regard to ensuring short order processing times.

Moreover, the study identified 14 factors, highly rated by the experts, that may favour resilience building of energy chains in the EU, namely: *quality of life and security of citizens; energy management clusters and cooperatives, technological progress in the field of alternative energy sources (e.g. technologies using space-based solar power, human power, tidal power, hydrogen power, magma power, flying wind power, algae power, fusion power), decarbonisation through the use of carbon-eliminating technologies, the level of stocks of energy resources in many countries of the EU, the cost of*

creating new transport infrastructure for fossil fuels, development of the circular economy, environmental threats related to the construction of new fossil fuel transport infrastructure, the level of geopolitical instability, reluctance of some EU Member States to cooperate on energy due to different energy goals, openness to technological innovations that improve the comfort of life (e.g. in terms of reducing environmental pollution), conscious consumerism, aging society, the level of international migration. The factor that received the highest importance scores was *technological progress*. The lowest impact on building resilience in supply chains was characterised by *the level of international migration*, and *the cost of creating new transport infrastructure for fossil fuels*. Factors with the highest uncertainty of development in the 2030 horizon are *the level of geopolitical instability*, and *the reluctance of some EU Member States to cooperate on energy due to different energy goals*.

In the area of **satellite communications**, three theses were examined. In the experts' opinion, all three theses were characterised by a similar level of significance, with a slight advantage in favour of SC_T1 (*There will be rapid development of the market for free applications based on Copernicus data, which will increase the scale of stand-alone satellite data analytics by end-users*). According to the experts, in the long term, satellite communication supply chains should become an ecosystem that includes all value-added activities, in the form of, for example, self-analysis and data visualisation through free and easy-to-use apps. Most experts (more than 80 %) believe this will be possible in the 2026-2030 period.

The distribution of enabling factors across the theses varied, albeit slightly. *Increasing the scope and quality of education of current and potential Copernicus end-users* was considered the most important enabling factor for SC_T1 (*There will be rapid development of the market for free applications based on Copernicus data, which will increase the scale of stand-alone satellite data analytics by end-users*). In SC_T3 (*In the face of socio-political crises (wars, migration, economic crises), the importance of Copernicus data analytics will increase, providing supply chain optimisation*) *mutual and effective collaboration between key stakeholders of the Copernicus programme* was considered the most important driver for the thesis. This factor, in addition to *the broad promotion of the Copernicus programme*, was also identified as the most important factor in SC_T2 (*Multidimensional analysis of data provided by Copernicus will enable environmentally friendly management of supply chains by providing safe transportation, eco transportation and meteorological forecasts for transportation*).

Irrespective of the thematic scope of theses, the experts considered the barrier of the lowest importance to be *the low level of public confidence in modern technologies*. The strongest barrier for the implementation of SC_T2 and SC_T3 is *the low competences of end-users using Copernicus data and services*. *The high level of uncertainty in data provided by citizen measurement networks (managed by volunteer contributors or citizen scientists) in the in-situ (non-space) component* was considered the most relevant barrier for SC_T1.

The study also assessed the strength of the theses' impact on stakeholders. The highest value of the indicators was obtained in all theses for scientists. The highest value in SC_T2 was observed for representatives of companies/industry, which is related to the uniqueness and potentially high commercial value of the data provided by the Copernicus system, especially as it is mostly free. The highest value in SC_T3 was attributed to the EU policy-makers group. The lowest values of indicators, regardless of the thesis, were obtained for NGOs, special pressure groups and end-users, e.g. households, customers, consumers. The low score for the last group may be due to insufficient information activities on the benefits of using Copernicus data.

Moreover, the study examined the impact of thesis statements on the functions of supply chains. The greatest impact of thesis statements is on improving reliability, frequency and flexibility of supply. The lowest impact of the statements described in the theses was noted with regard to optimisation of stock levels throughout the supply chain with adaptation to the preferences of individual market segments.

Furthermore, the study identified 14 factors (using the STEEPED analysis) that, in the experts' opinion, may favour the resilience building of satellite communication supply chains in the EU. Generally, all the factors identified in the study may have a positive impact on building resilience of satellite communication supply chains in the EU. Factors that received the highest importance scores included: *cooperation between key stakeholders of the Copernicus programme, competencies of end-users using Copernicus data and services, efficiency in the use of natural resources using modern digital technologies, e.g. measuring and controlling, monitoring, reporting, etc. and openness to technological innovations that improve the comfort of life*. The study also identified the factors with the highest uncertainty of development in the 2030 horizon. These include: *the role of civil society, the quality of legislation on cybersecurity, the use of digital data and aging society and the level of geopolitical stability*. The last of these factors was found to be both the most important and the most uncertain factor in the study.

The **semiconductor** global market, and any turbulence in semiconductor supply chains, has an unquestionable impact on almost every area of human activity. The events of the past three years – relating to the COVID-19 pandemic, the Russia–Ukraine war, natural disasters, geopolitical conflicts – have exacerbated the destabilisation and disruption of semiconductor supply chains. Almost all industries, such as the automotive, electronics, IT, medical, and military industries, and society as a whole, have felt the effects. Delphi's survey of experts has identified factors that will reduce the disruption of supply chains, on the one hand, and ensure the improvement of its resilience, on the other.

In the experts' opinion, the key issue is to ensure the security of supply of semiconductors to strategic sectors of EU countries. More than 57 % of the experts believe that *the security of supply of semiconductors to strategic sectors* (SE_T2) will be ensured in the longer term – in the 2031-2050 period. The experts are more optimistic about the chance that *the EU share of the global semiconductor market will increase from 10 to 20 %* (SE_T1) in the 2026-2030 period.

The relationships studied – with the use of the Delphi method – and reflected in the theses concerned: possibilities of the *EU to increase its share of the global semiconductor supplier market from 10 to 20 %* (SE_T1), ensuring *security of supply of semiconductors to strategic sectors of EU countries* (SE_T2), *building a dynamic ecosystem across the EU will strengthen Europe's capabilities to achieve its environmental goals and green transitions while improving the Union's security (semiconductors)* (SE_T3) and *EU sufficient resources to produce modern integrated chips (made with the 7-nanometre process)* (SE_T4). The most significant factor favouring the implementation of the theses indicated by the experts was: *funding of research, development and innovation, implementation of advanced semiconductors, pilot lines for prototyping, testing and experimentation*. In the experts' opinion, the realisation of SE_T1 and SE_T4 can also be accelerated by *training staff and enhancing knowledge of the semiconductor ecosystem, thereby increasing the number of qualified employees*.

Regarding the verified theses, the experts considered the most significant barrier constraining the implementation of the theses to be a *shortage of qualified workers and shortages of raw materials for semiconductor manufacturing*.

The realisation of the analysed theses, in the context of the supply chain functions, will have the greatest impact on: i) minimising the cost of product and information flow while maintaining the level of service desired by the customer, and ii) improving reliability, frequency and flexibility of supply.

Factors susceptible of favouring the resilience of semiconductor supply chains in Europe that received the highest importance scores included: *funding of research, development and innovation, STEM (science, technology, engineering, mathematics) talent investments, qualified employees in the semiconductor ecosystem*. By contrast, the lowest impact on building resilience in semiconductor supply chains was characterised by such factors as: *changes in environmental requirements that*

reduce manufacturing efficiency, fluctuating rates of demand for different types of semiconductors and conscious consumerism.

Five cross-cutting theses were formulated to indicate the relationship between the research areas under consideration (food, energy, satellite communications and semiconductors).

The highest significance index was noted for CC_T1 (*The EU economy will become circular and the global value chain will be shifted closer to sites of consumption. As a result, European Union supply chains (food, energy, satellite technologies, and semiconductors) will become shorter and lose their international importance*). This may translate into a very high importance of the EU's move towards a circular economy and a shift of the global supply chain closer to sites of consumption. *The orientation of countries' policies towards increasing self-sufficiency (energy, food, semiconductors) is the most significant factor favouring the implementation of this thesis*. In contrast, the lowest values favouring implementation, according to the experts, is *nearshoring – the practice of transferring a business operation to a nearby country, especially in preference to a more distant one*. In the opinion of the experts, the strongest barrier to the implementation of this thesis is *the lack of coherent policy in EU countries regarding energy*.

According to the experts, thesis CC_T2 (*Poverty in the EU will be a marginal phenomenon*) is also significant. The significance index of this thesis is less than 2.4 % lower than that of thesis CC_T1. The most significant factor favouring the implementation of this thesis is *allocating certain funds in the budget of each EU country to finance services and research based on multidimensional data, including from the Copernicus programme*. The strongest barrier to implementing this thesis is *climate changes (e.g. hurricanes, droughts, floods)*.

More than 80 % of the experts believe that the statements contained in most of the theses (with the exception of thesis CC_T2: *Poverty in the EU will be a marginal phenomenon*) will be implemented in the 2026-2030 period or the 2031-2050 period. According to more than 58 % of the experts, it is impossible for poverty in the EU to be a marginal phenomenon.

The implementation of most of these theses (with the exception of CC_T2) has the highest impact on companies/industry and the lowest impact on NGOs. In the case of CC_T2, the experts assessed that it has the greatest impact on end-users, e.g. households, customers, consumers. In contrast, the lowest indicator values in this thesis were obtained for special interest groups, e.g. volunteer contributors and citizen scientists.

The greatest impact of theses CC_T1, CC_T3 and CC_T4 in the area of the functions of supply chains is on minimising the cost of production and information flow while maintaining the level of service desired by the customer. In contrast, improving reliability, frequency and flexibility of supply was reported to have the greatest impact of the CC_T2 and CC_T5 theses.

The lowest impact of the statements described in all the theses was noted with regard to ensuring *short order processing times*.

5. Policy options and their assessment

5.1. Food

The research carried out has led to the development of policy options that will promote open strategic autonomy at EU level, and build resilience in food supply chains, where resilience is understood as the ability to secure food supply despite shocks and disruptions. The policy options in the area of food revolve around four main spheres, namely: promoting local production, educating end-users, STEM and R&D orientation and creating regulations to foster resilience in food supply chains.

For each policy option, possible actions, the main benefits and costs in terms of social, economic, environmental, knowledge and regulatory effects have been proposed, as follows:

Policy option 1. Promoting local production and self-sufficiency of farms

- promoting local/regional production and consumption;
- improving food market infrastructure and access for farmers/consumers to regional/local market; creating short supply chains – farm to table;
- increasing the energy self-sufficiency of farms by increasing biogas production;
- supporting small farmers – financially, with technology, with knowledge – to implement sustainable agriculture;
- improving small scale agriculture and its networks until the end consumer (the more entities there are the more there are buffers against shocks. This ties back to theories about (bio)diversity. (Bio)diversity is one major factor in securing the resilience of (eco)systems);
- creating dense networks of food suppliers, searching for balance between over-connectivity and overly efficient connectivity (which has less buffer capacity);
- lowering environmental constraints to production;
- the applications of the principles of the collaborative economy in agriculture, (communities should be organised in such a way that they become independent by creating their own supply chains);
- promoting agriculture in and around cities (peri-urban) along with encouragement of change in how agriculture is perceived in these areas;
- promoting the cultivation of different crops and varieties within the same year.

Table 2: Policy option 1. Promoting local production and self-sufficiency of farms

Criterion	Description
Social impact	Benefits: highlighting the importance and role of farmers in the local employment structure; promoting entrepreneurial attitudes among farmers Costs: exclusion of less entrepreneurial farmers
Economic effects	Benefits: shorter supply chains; smaller risk of external factors (wild cards) affecting supply chains Costs: risk of increased food prices; high costs of active promotion of the use of the locally sourced food
Environmental impact	Benefits: greater likelihood of cultivating previously unexploited land Costs: risks associated with the different vegetation cycles of plants
Knowledge effects	Benefits: increasing public awareness of buying from local suppliers; enhancing the knowledge and role of farmers in the application of modern technologies in agriculture

	Costs: costs of promotional campaigns; the need to develop funds for the purchase of modern technologies
Regulatory effects	Benefits: harmonisation of regulations governing the operation of self-sustaining farms and production patterns in the European Union Costs: need to change organisational structures in municipalities; delegation of persons in charge of handling applications for support dedicated to farmers; costs of creating the policy space to let the grassroots projects thrive and develop bottom-up responses to sustainable consumption

Policy option 2. Educating end-users

- the efficient and effective promotion of the reduction of food loss and waste;
- the promotion of responsible food consumption;
- developing dedicated educational programmes diversified by education on food waste aimed at younger generations;
- promoting the adoption of a sustainable dietary pattern, in which the nutrients are present in the necessary quantities and avoiding overconsumption, especially that of proteins of animal origin;
- educational marketing for importance of food waste;
- promoting the consumption of local products;
- promoting the cultivation of different crops and varieties within the same year;
- promoting food donations.

Table 3: Policy option 2. Educating end-users

Criterion	Description
Social impact	Benefits: greater awareness among the public of the importance and role of local food and sustainable consumption; adoption of a sustainable dietary pattern in which nutrients are present in the necessary quantities and by these means avoiding overconsumption, especially that of proteins of animal origin; sustainable lifestyle, a decrease in the prevalence of chronic (also metabolic) diseases linked to overconsumption Costs: less diversity of foodstuffs consumed
Economic effects	Benefits: more sensible purchasing choices; greater demand for sustainable products Costs: lower food demand; reduced consumption resulting in an increase in food prices; an increase in costs of nutrition education in schools
Environmental impact	Benefits: decrease in the amount of waste, increase in energy savings; decrease in greenhouse gas emissions that contribute to global climate change, sustainable consumption Costs: the impact of climate on plant production cycles
Knowledge effects	Benefits: increased knowledge of prosperous and healthy life Costs: risk of social exclusion of less educated end-users
Regulatory effects	Benefits: unification of sustainable consumption regulations Costs: costs of creating the policy space to let the grassroots projects thrive and develop bottom-up responses to sustainable consumptions

Policy option 3. STEM and R&D orientation

- expanding research and collaborative activities between science and farmers to achieve sustainable food supply chains;
- promoting the use of advanced technologies in agriculture (such as artificial intelligence, remote sensing, geographic information software, virtual reality, drones and application programming interfaces);
- promoting the use of sustainable and ecological production technologies;
- fostering a systemic thinking (e.g. the study of food supply chains and of their resilience should be undertaken within socio-ecological systems in which they are integrated); the identification of critical dependencies and an increasing understanding of complex interactions and feedback;
- development of new technologies, such as: agroponics and hydroponics;
- fostering agro-ecology, permaculture, organic matter inputs and biological soil amendments;
- promoting precision agriculture to save water and reduce fertiliser use.

Table 4: Policy option 3. STEM and R&D orientation

Criterion	Description
Social impact	<p>Benefits: more resilient, productive and sustainable agriculture and food systems that better meet consumer needs</p> <p>Costs: costs of educating farmers in the application of advanced technologies in agriculture</p>
Economic effects	<p>Benefits: higher supply of highly qualified farmers on the labour market; increase in the demand for the supplies and equipment that enable on-farm decarbonisation; enhanced production of food and livestock; farmers' increased awareness of the possibilities of using modern technologies in agriculture</p> <p>Costs: costs of lost sales during the period of farmers' education; the risk of human labour being replaced by technology; which may result in a decline in agricultural employment</p>
Environmental impact	<p>Benefits: an increase in the use of sustainable and ecological production technologies, the application of precision agriculture to save water and reduce fertiliser use; plant-based and lower-emission protein production for alternative food products</p> <p>Costs: reduction of biodiversity of soil microbes by ultimately taking away their function of recycling nutrients</p>
Knowledge effects	<p>Benefits: expanding research and collaborative activities between science and farmers in the area of advanced technologies to achieve sustainable food chains</p> <p>Costs: limited access to advanced technology</p>
Regulatory effects	<p>Benefits: a growing role of digital technologies in the automation of administrative processes for agriculture and the development of expanded government services, e.g. in relation to extension or advisory services; enabling new ways for governments to monitor and ensure compliance with standards and to provide faster and more efficient border procedures that are essential for perishable products</p> <p>Costs: costs of launching procedures to obtain funding for advanced technologies in agriculture</p>

Policy option 4. Creating regulations to foster resilience in food supply chains

- creating a Common European policy, as well as Member State policies fostering resilience in food supply chains to be integrated by the EU Commission;
- configuration of a legal and regulatory framework for efficient supply chains;
- innovating through Public-Private Partnerships: encouraging closer partnerships between cooperatives, farmers and environmental campaigners so that they rethink their stance on many issues, like soil degradation and all other human problems caused by industrial agriculture. (For instance, those farmers who cannot access and benefit from permanent irrigation facilities urgently need targeted assistance from experts, to help them innovate their traditional farming techniques and adapt to climate change. Companies should consider partnering with specialists who have sustainability accreditation and expertise to manage ESG goals for 2023);
- introducing a tax (penalty) for uncultivated arable land;
- establishing and controlling the legislative system and the system of traceability and quality control of food products.

Table 5: Policy option 4. Creating regulations to foster resilience in food supply chains

Criterion	Description
Social impact	Benefits: clear and unified rules for farmers on how to run self-sufficient farms Costs: lack of awareness of the legal changes among some farmers resulting in the exclusion of a group of farmers with less knowledge of running self-sufficient farms and applying modern technologies in agriculture; resistance to implementing the regulation; costs associated with adjustments (smaller entities)
Economic effects	Benefits: unifying barriers to entry into self-sufficient agriculture through high-tech subsidies in countries with lower economic development indicators Costs: taxes or penalties for farmers for uncultivated arable lands
Environmental impact	Benefits: harmonised regulations for a circular economy Costs: risk of exclusion of certain production areas, need to change the production profile
Knowledge effects	Benefits: farmers' increased awareness of the existing and emerging regulations Costs: challenging mental models for farmers
Regulatory effects	Benefits: creating a Common European policy, as well as Member State policies fostering resilience in food supply chains to be integrated by the EU Commission; establishing regulations in the scope of targeted assistance from experts in line with ESG goals Costs: costs of introducing regulations and policies

5.2. Energy

The research carried out has led to the development of policy options that will ensure the building of resilience in energy supply chains, where resilience is understood as the ability to secure the energy supply despite shocks and disruptions. The policy options in the area of energy revolve around three main spheres, namely: transformation towards energy communities, greater energy integration of EU countries, and shortening and diversifying energy supply chains in the EU.

For each policy option, possible actions, the main benefits and costs in terms of social, economic, environmental, knowledge and regulatory effects have been proposed, as follows:

Policy option 1. Transformation towards energy communities/distributed energy/development of distributed energy

- taking actions aimed at creating local energy communities in all EU Member States, e.g. by creating financial incentives, tax reliefs, opportunities to apply for financial resources from EU funds;
- increasing financial resources for investing in microgrids;
- making the public aware of the need to actively participate in the process of creating distributed energy;
- greater emphasis on the part of the EU on creating legal opportunities in individual Member States for bottom-up initiatives in the field of distributed energy;
- abandonment of legal impediments for distributed energy systems at national and EU levels;
- increasing funding for research on technological solutions enabling greater permeability, use and switching to self-production of energy;
- establishing a network of energy consultants who would advise on technologies that can be used to create energy communities as well as on legal and economic aspects of such investment;
- increasing expenditure on the search for alternative energy sources, renewable energy (mainly wind energy).

Table 6: Policy option 1. Transformation towards energy communities/distributed energy/development of distributed energy

Criterion	Description
Social impact	<p>Benefits: greater energy security and energy independence of energy community members and energy prosumers; EU citizens will gain access to appropriate levels of clean energy faster; improvement of living conditions and standards; fair transition of energy</p> <p>Costs: social exclusion of people who are unable to participate in energy communities, the risk of increasing existing social and economic inequalities due to differences in the use of renewables and creating energy communities in individual countries, social fears of self-determination about the directions of development of energy communities</p>
Economic effects	<p>Benefits: if the EU does not carry out the energy transformation, the costs of this decision will reach 5.6 % of the EU's GDP in 2050 (Heflich and Saulnier, 2021); increased international competitiveness of products from the EU; increased purchasing and consumption power for EU consumers</p> <p>Costs: costs of adapting energy networks, costs of social campaigns, aid programmes for entities starting transformation</p>
Environmental impact	<p>Benefits: significant acceleration of the achievement of climate neutrality of the EU; development of renewable energy; positive impact on limiting increases in global temperature; transformation will allow elimination of a number of threats to the natural environment</p> <p>Costs: hard to estimate consequences for individual animal species, e.g. wind farms change the activity of bats and birds</p>
Knowledge effects	<p>Benefits: pushing necessary green technologies on the market and other necessary technologies, accelerating numerous innovations, forcing the acquisition of new competences and knowledge</p> <p>Costs: costs of informing the public about opportunities related to energy communities and distributed energy, costs of reducing resistance to change</p>

Regulatory effects	<p>Benefits: independence from external energy suppliers, increased security of supply chains, greater flexibility of the EU energy market, increased energy efficiency, benefits from taxonomy regulation</p> <p>Costs: reduced state control, smaller possibility of state intervention in crisis situations; each country has a different starting point, which may cause problems with the introduction of individual regulations due to the need to undertake ambitious and united EU actions; the risk of the impossibility of achieving consensus among countries; the need to unify national regulations and adapt them to the EU vision of energy transformation</p>
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Policy option 2. Greater energy integration of EU countries/deepening activities for the energy union

- unification of detailed provisions in the Member States concerning the energy market;
- enabling private entities to sell the energy they produce (e.g. within local energy communities / distributed energy) to other EU countries, e.g. in border regions;
- acceleration of legislative paths and faster implementation of projects integrating the EU's energy network (e.g. TEN-E Regulation ((EU) 2022/869));
- increasing investments for the integration of the EU's energy grid.

Table 7: Policy option 2. Greater energy integration of the EU countries/deepening activities for the energy union

Criterion	Description
Social impact	<p>Benefits: a common internal energy market would enable a better allocation of production factors, in line with the fourth energy package; speeding up the provision of clean energy for all inhabitants of the EU</p> <p>Costs: regulations of the common market may raise social concerns related to the type and method of intervention in the common energy market due to large differences in the energy mix of individual EU Member States, individual interventions on the market would be more favourable for some countries and less favourable for others</p>
Economic effects	<p>Benefits: the possibility of creating a fully integrated and well-functioning internal energy market that will ensure affordable energy prices, provide the necessary price signals for investments in green energy, secure energy supply, and create the least costly opportunity to achieve climate neutrality</p> <p>Costs: costs of unification of energy systems and their adaptation to the common internal energy market, costs of limiting and removing a number of barriers to trade, costs of unification in the area of EU Member States' tax and pricing policies, the common energy market imposes the need to unify energy prices, which could, in some parts of the EU, actually lead to their growth</p>
Environmental impact	<p>Benefits: achieve more quickly the goals of the 5th energy package, "Ready for 55", reducing emissions by at least 55 % compared to 1990 levels and becoming carbon neutral</p> <p>Costs: N/A</p>
Knowledge effects	<p>Benefits: accelerating the roll-out and uptake of a climate-neutral energy system by further developing and designing low-carbon technologies</p> <p>Costs: N/A</p>
Regulatory effects	<p>Benefits: strengthening internal market regulations, which is a natural consequence of the regulations introduced from the third energy package</p>

Costs: costs of harmonisation and changes in the national regulations of EU Member States, concerns about limiting the sovereignty of Member States and transferring more powers to EU institutions, resistance, especially in countries traditionally seeking less interference by the EU in their policy and in countries with the highest degree of Energy import dependency, costs of approximating tax and pricing policies of EU Member States as well as their norms and standards

Policy option 3. Reducing the energy needs of the EU/shortening and diversifying energy supply chains in the EU/greater flexibility of the energy system in the EU

- legal regulations encouraging the use of energy-saving technologies in construction;
- cross-industry pooled procurement of raw materials;
- increased financing for the development of smart grids;
- advances in research enabling the development of low-environmental impact electrification;
- increasing funding for research enabling greater efficiency in energy utilisation (both thermal and electrical);
- creating energy storage facilities (thermal and electrical), including biomass utilisation;
- increasing funding for research on energy sources that enable energy consumption at the point of origin, without any transport whatsoever (this applies to wood biomass, electricity from the sun, wind, etc.; the use of locally available energy sources significantly reduces potential security threats caused by external factors);
- intensification of research on recycling and innovation in order to find an alternative to critical materials;
- introduction of regulations encouraging increased OEM recycling of raw materials;
- exploration opportunities for vertical integration to secure critical raw materials and decrease price volatility, either through alliances and partnerships or through targeted acquisitions;
- putting more emphasis on creating regulations enabling the decentralisation of energy transactions in individual EU countries;
- development of smart grids;
- development of programmes, e.g. CETPartnership & DUTPartnership.

Table 8: Policy option 3. Reducing the energy needs of the EU/shortening and diversifying energy supply chains in the EU/greater flexibility of the energy system in the EU

Criterion	Description
Social impact	<p>Benefits: higher comfort and standard of living, new jobs, faster access to clean energy for all EU residents</p> <p>Costs: the risk of energy poverty in the poorest regions of the EU, social exclusion of people with smaller energy knowledge and awareness</p>
Economic effects	<p>Benefits: strengthening the internal energy market, benefits related to greater energy efficiency, reduction of future costs related to climate change, structural transformation of the EU economy</p> <p>Costs: costs of renovation of the national stock of residential and non-residential buildings, both public and private, to ensure high energy efficiency and low-emissions of building stock by 2050; costs of construction of energy storage facilities and integration with individual energy systems of the countries; costs of development of smart grids; costs of replacing cheaper but less reliable energy partners with more expensive but more stable and reliable solutions</p>

Environmental impact	<p>Benefits: less environmental pollution, increased ecological and energy awareness of EU citizens, faster introduction of ecological energy solutions, new technologies for the use of renewables</p> <p>Costs: N/A</p>
Knowledge effects	<p>Benefits: pushing necessary innovations and technologies regarding the energy intensity of buildings (currently 40 % of the EU's energy needs are related to the energy intensity of buildings), utilisation and recycling, development of smart grids</p> <p>Costs: costs of training and energy consulting, information campaigns promoting energy-saving solutions</p>
Regulatory effects	<p>Benefits: reduced dependence on external energy suppliers, reduced import dependency, greater diversification of energy sources, improved security of energy supplies, increased security and durability of supply chains</p> <p>Costs: costs of changes in the energy systems of individual countries, costs of unification of energy systems and legislation in individual EU countries, potential difficulties for some countries in meeting their annual energy savings obligations</p>

5.3. Satellite communications

The research led to the development of policy options to build resilience to infrastructural and geopolitical disruptions in satellite communications supply chains and to mitigate and counter the effects of crises resulting from such disruptions. In the area of satellite communications, two policy options were developed that address the following issues: supporting the decisions of the EU institutions managing the Copernicus programme, and supporting end-users (non-experts) and intermediate users – experts in Copernicus data analytics and Earth observation.

For each option, possible actions, the main benefits and costs in terms of social, economic, environmental, knowledge and regulatory effects have been proposed, as follows:

Policy option 1. Supporting the decisions of the EU institutions managing the Copernicus programme

- giving the Copernicus programme priority status (as a key source of Earth observation) – especially in the formulation and implementation of various EU policies and in the creation of European data spaces supporting the optimisation of supply chains;
- involvement and synchronisation with the Copernicus programme of selected relative EU framework programmes such as Horizon Europe, Digital Europe
- ensuring secure access by individual EU Member States to systems, services and applications based on reliable, comparable and verifiable information and data in the Copernicus programme;
- promotion of the management of supply chains that depend entirely on EU countries, from semiconductors to providers of Copernicus data and analytics-based services;
- institutional support towards the creation of a 'Copernicus data scientist' profession based on interdisciplinary competences;
- encouragement through various benefits to co-create citizen in-situ networks and introduction of EU-level regulations in the in-situ component, ensuring that only reliable data is used;
- introduction of regulations for non-dependence on non-EU technologies;
- introduction of regulations for mergers, acquisitions, cooperation of Earth observation companies from the EU with non-EU companies (USA, China, Russia, etc.);
- creation of a solid bridge (e.g. in the form of an institutional broker) between the data provided by Copernicus and the decision-making activities that are carried out using

these data. To achieve this, it is necessary to: (1) put in place a broad programme for achieving competence in the area of data analysis and geospatial information literacy; (2) produce information aimed at decision-makers, which should be easy to use, requiring no further processing;

- geospatial information based on open-source architectures, with an emphasis on open code and open results. This is necessary to ensure that satellite data products are as widely available and usable as possible to support a variety of applications;
- support for EU companies specialising in critical technologies and providing value-added services, operating in the EO sphere and relying on Copernicus data;
- introduction of transparent control over raw material procurement and supply chains for critical technologies, from the EO sphere;
- increased flexibility and adaptability of both satellites and in-situ ground stations, either through diversification (secure addition of new satellites and ground sensors) or through the design of secure satellite networks;
- increased numbers of satellites and the strengthening of measures to protect them against hostile hacking attacks;
- full control, protection and servicing by the EU of its satellites and all space infrastructure;
- construction of new satellites so that they can be serviced and repaired directly in space;
- increased use of Copernicus data, services and technologies for EU Earth observation in positioning, navigation or timing projects.

Table 9: Policy option 1. Supporting the decisions of EU institutions managing the Copernicus programme

Criterion	Description
Social impact	<p>Benefits: offering EU citizens secure (monitored by EU institutions) information, systems, services and applications based on Copernicus data</p> <p>Costs: difficulty in managing the dissemination of Copernicus initiatives to various user communities due to their high heterogeneity as well as geographical dispersion</p>
Economic effects	<p>Benefits: increased competitiveness of EU companies, organisations, thanks to institutional support for those entities, which will base their strategies, activities on free, original Copernicus data; benefits for EU space economy primarily through increased competitiveness of EU space industry based on affordable and cost-effective technologies to operate satellites in orbit</p> <p>Costs: Copernicus data analysis training costs; costs of building innovative, critical technologies based on systems, services, applications from Copernicus; costs of information campaigns; loss of strategic autonomy for EU space assets if viable ways of inspecting and protecting satellites are not found</p>
Environmental impact	<p>Benefits: more precise monitoring of environmental and agricultural conditions; accurate decision-making on investment and agricultural production and intelligent environmental management based on accurate prediction of phenomena affecting agricultural and environmental processes</p> <p>Costs: potential negative impacts on the state of agriculture and/or the environment prevailing in a given area, e.g. by prohibiting existing production on the basis of new geospatial data; littering of space with non-functioning satellites</p>
Knowledge effects	<p>Benefits: improved quality of decision-making based on innovative solutions concerning services or technologies for Earth observation, positioning, navigation or timing based on Copernicus data; increase in the prestige of educational systems in the EU aimed at raising competence in the area of multidimensional data analytics; development of initiatives and cooperation within the Copernicus Academy</p>

	Costs: potential resistance to change in education systems; staff shortages as to training current teachers, few trainers in the area of data science
Regulatory effects	Benefits: increased credibility of EU policies, e.g. with regard to the main framework programmes (such as Horizon Europe, Digital Europe) and the development of European data spaces based on reliable and accurate data, such as Copernicus Costs: potential resistance by EU Member States to the obligation to inspect, protect and maintain space infrastructure and the need to adapt national legislation to prioritise Copernicus as a key EU Earth observation resource

Policy option 2: Supporting end-users (non-expert) and intermediate users – experts in Copernicus data analytics and Earth observation

- building a platform for monitoring all case studies of good and bad practices from past activities on increasing awareness, dissemination and competence of the Copernicus programme, business, administrative, service, civic, IT solutions based on Copernicus data, and trying to translate them (enabling us to start working with institutions that have carried out previous tasks) into the context of humanitarian crises and ensuring the resilience of our satellite communications and the optimisation of Copernicus supply chains;
- in the case of using Copernicus data and services, the implementation of one of the key areas of the EU (e.g. building crisis-proof supply chains) – providing concessions, benefits, grants, etc.;
- in the Framework Partnership Agreement on Copernicus User Uptake (FPCUP), involvement of a member(s) of the FPCUP consortium and/or applying for projects on building resilience in the framework of expected supply chain disruptions;
- either as part of the Copernicus User Uptake Initiative or as part of other stand-alone/dedicated activities, it is recommended to carry out a broad promotional campaign of the Copernicus programme showing benefits, in terms of strengthening the functioning of supply chains, the use of free Copernicus data and services it can bring.

Table 10: Policy option 2. Supporting end-users (non-experts) and intermediate users (experts in Copernicus data analytics and Earth observation)

Criterion	Description
Social impact	Benefits: increased accessibility for EU citizens to secure systems, services and applications based on reliable, comparable and verifiable information and data from Copernicus; increase in importance of citizen scientists Costs: digital exclusion of people (e.g. Silver Generation) unable to use services and applications based on Copernicus data; resistance from users due to existing popular systems, e.g. Google Maps
Economic effects	Benefits: increased resilience under expected disruptions to the Copernicus satellite communications supply chain, e.g. through acquisition (by intermediate users) of new projects under the Framework Partnership Agreement on Copernicus User Uptake Costs: costs of ensuring data cyber security within Copernicus-based information, systems and applications provided by intermediate users
Environmental impact	Benefits: greater ability of end-users to anticipate natural phenomena and, on that basis, rationalise agricultural production Costs: disruption to biodiversity as a result of decisions based on Copernicus data; excessive interference with the environment through uncontrolled in-situ facilities

Knowledge effects	<p>Benefits: increased awareness among EU residents of opportunities and risks (based on good and bad practices) regarding the Copernicus programme; intensification of contacts and scientific/business cooperation within the Framework Partnership Agreement on Copernicus User Uptake</p> <p>Costs: danger of users basing their decisions on falsified data, e.g. resulting from hacking activities; communication disruption caused by citizen networks based on in-situ device architecture</p>
Regulatory effects	<p>Benefits: more user-friendly regulations – for end-users and intermediaries – for the use of systems and applications based on Copernicus data</p> <p>Costs: changes in the regulations on arable crops that are unfavourable to farmers</p>

5.4. Semiconductors

The research carried out has led to the development of policy options that will ensure the building of resilience in semiconductor supply chains. The policy options in the area of semiconductors revolve around four main spheres, namely: global partnering supporting cutting-edge semiconductor mega fabs, supporting local semiconductor ecosystems and the modern semiconductor sector, STEM and R&D orientation and increased protection of the EU market against security and safety threats.

For each policy option, possible actions, the main benefits and costs in terms of social, economic, environmental, knowledge and regulatory effects have been proposed, as follows:

Policy options 1. Global partnering supporting cutting-edge semiconductor mega fabs

- developing strategic partnerships: the EU could work with other countries and organisations to share resources and expertise in the semiconductor industry; increasing competitiveness and resilience;
- establishing agreements with large companies to create factories in the EU (e.g. Samsung TSMC, Wolfspeed fab in Ensding or Intel in Magdeburg);
- financial support to pilot lines and design infrastructures for cutting-edge semiconductors;
- introducing investment tax credits for capital expenditures on the production of cutting-edge semiconductors and related equipment;
- creating privileged access to R&D services for manufacturers in Europe;
- establishing transnational actions related to improvement of extraction and purification of critical raw materials through third-party agreements with other non-EU countries;
- introducing grants and taxpayer-funded incentives, advanced manufacturing investment tax credits to a semiconductor company (e.g. Taiwan's government has passed legislation allowing local chip companies to convert 25 % of their R&D expenses into tax credits, as part of efforts to support the country's semiconductor industry).

Table 11: Policy options 1. Global partnering supporting cutting-edge semiconductor mega fabs

Criterion	Description
Social impact	<p>Benefits: creation of new high-income full-time jobs, rebuilding Europe's leading role and image in the semiconductor supply chain, partially fulfilling the ever-increasing demand among European citizens' and businesses' for semiconductors</p> <p>Costs: disagreement of certain social groups depending on the preference of support given to modern or cutting-edge fabs, social dissatisfaction resulting from the location of factories</p>

Economic effects	<p>Benefits: increase the number of innovative fabless start-ups and semiconductor IP companies in the EU; trigger EUR 2 bn worth of additional investments, diversify EU economy and earn a strong position at the technological frontier, growth in profitability of local suppliers in the semiconductor market, innovation development outside the semiconductors industry due to the development of highly skilled talents, GDP expansion</p> <p>Costs: very high investment required, dedicated capital for semiconductor fabless companies in their early stages, high risk associated with leading-edge manufacturing capabilities, cost of land preparation, production of semiconductors requires a huge amount of unique materials and chemicals, where the number of their suppliers (manufacturers) may not suffice when increasing the production of semiconductors in Europe</p>
Environmental impact	<p>Benefits: investing in responsible electronics will uphold sovereignty in terms of EU semiconductor technology, reduction of environmental impact due to the energy efficiency of semiconductors and environmentally friendly production technology, fostering environmentally sustainable technologies, environmental protection due to the low level of hazardous impact, from the global perspective - reducing the concentration of natural hazards</p> <p>Costs: environmental costs associated with the location of the investment, e.g. land use change; chip manufacturing contributes to the climate crisis as it requires huge amounts of energy and water – a chip fabrication plant, or fab, can use millions of gallons of water a day and hence creates hazardous waste</p>
Knowledge effects	<p>Benefits: development of highly skilled talents, maintaining Europe's position in the highly-educated expert market, increased attractiveness of Europe to non-European investors, driven by access to STEM talent</p> <p>Costs: support-targeted research in semiconductors using Horizon Europe 2021-2027, the risk of an outflow of talents from Europe, expensive talent incentive programmes</p>
Regulatory effects	<p>Benefits: improved semiconductor manufacturing cost competitiveness, reduced risk of market access</p> <p>Costs: costs of implementation of incentives (tax, regulatory, private and public investment), costs of implementation legal system that protects the environment with a relatively low level of natural hazards</p>

Policy option 2. Supporting local semiconductor ecosystems and the modern semiconductor sector

- the EU could incentivise companies to increase their semiconductor production within the EU, reducing dependence on imports from other countries;
- supporting start-ups in chips design and development;
- financing pilot series of new technologies based on cooperation between R&D, industry and central financial agencies;
- supporting local semiconductor manufacturers and SMEs in terms of financing, training and access to new technologies;
- improving logistics and transportation systems, which can increase the speed and efficiency of the supply chain and reduce the impact of disruptions;
- investing in recycling and design-for-recycling activities establishing end-of-life electronic devices;
- ensuring the supply of raw materials through the development of mining and refining activities in Europe, but more importantly through third-party agreements with other non-EU countries;

- investing in advanced-packaging facilities which rely more on manual labour and with less capital expenditure (capex);
- promoting a wider use of the CIRCABC (Communication and Information Resource Centre for Administrations, Businesses and Citizens) to build a network of semiconductor ecosystems CIRCABC.

Table 12: Policy options 2. Supporting local semiconductor ecosystems and the modern semiconductor sector

Criterion	Description
Social impact	<p>Benefits: increase in the number of small and medium-sized enterprises, increase in high-income full-time jobs, new jobs creation, partially fulfilling the ever-increasing demand among European citizens' and businesses' for semiconductors, building strategic autonomy of Europe in the semiconductor market, strong ties of local start-ups with big semi-conductor players, easier and more affordable consumer access to semiconductor-based products, improving cooperation between semiconductor design and manufacturing companies</p> <p>Costs: disagreement of certain social groups depending on the preference of support given to the local semiconductor ecosystem or global cutting-edge fabs</p>
Economic effects	<p>Benefits: foster the development of the semiconductor chip design ecosystem in Europe, increase the number of semiconductor start-ups, growth in profitability of local suppliers in the semiconductor market, regional economic development driven by spending on local suppliers, wages paid to employees and employees' consumption</p> <p>Costs: financial incentives to boost the regional semiconductor ecosystem, development of the start-up financing system, low transparency of the tax system and insufficient speed of start-up establishment, start-up valley of death, problems with scaling up innovative start-ups and SMEs through its Accelerator scheme</p>
Environmental impact	<p>Benefits: opportunities for discovery of new environmentally-friendly electronic materials, reduction of environmental impact due to the energy efficiency of semiconductors, building environmental awareness among actors on the semiconductor market</p> <p>Costs: cost of environmental impact assessment of new solutions</p>
Knowledge effects	<p>Benefits: development of highly skilled talents, knowledge acquisition, transformation, storage and knowledge creation</p> <p>Costs: risk of an outflow of talents from Europe, expensive talent incentive programmes</p>
Regulatory effects	<p>Benefits: implementation of regulations that improve cost competitiveness of semiconductor manufacturing and reduce the risk of market access</p> <p>Costs: costs of implementation of incentives to overcome the so-called "valley of death"</p>

Policy option 3. STEM and R&D orientation

- funding the fundamental research and an open discussion with all the interested sectors – from material science to industry;
- establishing a national microelectronics training network to develop semiconductor "skills" at the university level;
- building European Semiconductors Competence Network (ESCN);
- expanding technological capacity among European researchers and companies while cultivating robust and diversified relationships with producers and material suppliers from other countries;

- setting out Work Programme European Semiconductors Innovation Hubs within the Digital Europe Programme;
- establishing national semiconductor research programmes;
- conducting research on foresight of emerging semiconductor technologies.

Table 13: Policy option 3. STEM and R&D orientation

Criterion	Description
Social impact	<p>Benefits: increase in the number of researchers, providing demand for STEM skills in society, highly qualified resources in the semiconductor labour market, improving Europe's attractiveness to external investors due to the advanced STEM talent, better access to human resources, development of interorganisational technological collaborations</p> <p>Costs: social exclusion of non-STEM oriented people, increased investment in experts in the field of semiconductor production may result in a decrease in the number of experts from similar industries (talented employees will start working in the semiconductor industry due to well-paid work and demand, whereas in related industries there will be a deficit of intellectual capital)</p>
Economic effects	<p>Benefits: development of innovative economy, development of areas and sectors not directly related to the semiconductor market, opportunities for companies to take advantage of tax incentives related to their R&D activities, emerging innovation in the semiconductor area, especially for chips for artificial intelligence applications, semiconductor innovations can help unlock new life science technologies</p> <p>Costs: tremendous investment in targeted R&D, change in R&D funding model and greater participation of enterprises in the implementation of research, education costs for the STEM talent needed in semiconductor markets</p>
Environmental impact	<p>Benefits: increase in the use of sustainable and energy-efficient semiconductors, building environmental awareness related to the life cycle of semiconductors, more sustainable society and industry</p> <p>Costs: cost of analysing the environmental impact of new semiconductor technologies</p>
Knowledge effects	<p>Benefits: understanding the concepts and encouraging knowledge application due to STEM education, expanding research and collaborative activities between science and companies, openness to new opportunities, branding Europe's R&D sector</p> <p>Costs: the risk of future negative environmental effects resulting from the use of new products and technologies</p>
Regulatory effects	<p>Benefits: transparent and clear procedures for applying funds</p> <p>Costs: costs of launching procedures to obtain funding for R&D and education programmes</p>

Policy option 4. Increase protection of the EU market against security and safety threats

- restricting the import of "semiconductor" products, which are not purchased according to safety rules and good production practices;
- establishing a certification procedure for energy-efficient and trusted chips to guarantee their quality and security for critical sectors;
- prioritising cybersecurity in its semiconductor market, including measures to secure the supply chain and protect against intellectual property theft;
- establishing strategic stock-piling of semiconductors for such strategic sectors as: health, transportation, energy, defence, security and space;
- creating long-term contracts with countries/enterprises in order to have access to semiconductors in case of a crisis;

- establishing long-term contracts for raw materials;
- increasing taxation on finished products to ensure balance between EU and Asia/US suppliers;
- implementing trade policies that encourage fair competition and protect the interests of European semiconductor manufacturers. This could include tariffs or restrictions on imports of semiconductors from countries that engage in unfair trade practices;
- implementing robust risk management strategies that can help to identify and mitigate potential supply chain risks, and ensure that the supply chain remains resilient in the face of unexpected events.

Table 14: Policy option 4. Increase protection of the EU market against security and safety threats

Criterion	Description
Social impact	<p>Benefits: EU market protection; consumer safety by preventing the marketing of products that do not meet quality and safety standards, increasing consumer confidence in products offered on the market; reducing the risk of accidents or other damage caused by faulty uncertified semiconductors, which contributes to improving the quality of life for consumers; greater consumer protection (raising safety standards)</p> <p>Costs: costs which may affect consumer prices; lower availability of semiconductors due to the need to ensure balance between EU and Asian/US suppliers, which may result in extended waiting times for deliveries</p>
Economic effects	<p>Benefits: improving the quality of chips in the context of energy-efficient and trusted chips, building a key strategic position in the semiconductor value chain due to the unique intellectual property generated by European semiconductor payers</p> <p>Costs: high IP licencing costs; a decrease in trade, as some countries or companies may not comply with the new requirements and can be excluded from the EU market; greater dependence on imports (fewer products meet the EU requirements); smaller competition (implementation of stricter regulations may prevent new companies from entering the market); the need to ensure a balance between EU and Asian/US suppliers will result in higher semiconductor production costs in the EU, leading to a general increase in their prices.</p>
Environmental impact	<p>Benefits: improving the quality of chips in the context of energy efficiency; product safety requirements can lead to improved production technologies and increased innovation, which can contribute to the development of greener technologies and products; more efficient production processes, recycling of raw materials, production using renewable energy or the use of more ecological substitutes for raw materials</p> <p>Costs: N/A</p>
Knowledge effects	<p>Benefits: increase in social awareness</p> <p>Costs: N/A</p>
Regulatory effects	<p>Benefits: transparent and clear certification procedures for energy-efficient and trustworthy chips; implementation of regulations improving trade policy that favour fair competition and protect the interests of European semiconductor producers</p> <p>Costs: costs of implementing a legal system that protects investors' property rights, cost of implementing legal regulations that protect the EU semiconductor market, costs of certification procedures for energy-efficient and trusted chips</p>

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Annex

Delphi survey questionnaire

Invitation letter:

Dear Sir or Madam,

We invite you to take part in the Delphi survey, as a part of a research task entitled: *A preparedness plan for Europe: Addressing food, energy and technological security*. The study is being conducted by the research team from the Faculty of Management Engineering at the Bialystok University of Technology (Poland) on request of the European Parliament. The main aim of the study is to identify weaknesses, assess risks, and recommend coordinated solutions and alternatives for building up open strategic autonomy at EU level, and address expected supply chain disruptions in the above-mentioned four critical areas. This research will contribute to the future work of the EP, explaining how to protect the European agricultural sector and prepare for food shortages and supply chain disruptions. The study will also assess how Copernicus's capabilities can be improved and how satellite communications can be made more resilient.

The survey is addressed to experts representing one or more of the four considered areas, mainly to: scientists, academics, policy-makers, representatives of industry, government agencies, politicians, and others. The questionnaires comprise Delphi theses on the shaping of phenomena in the four studied areas (food security, energy security, semiconductors and satellite communication) as well as enablers and barriers to their implementation. You can declare willingness to choose one or more areas of consideration. Please read the formulated theses related to the four areas. You will be asked to evaluate enablers and barriers related to the considered theses in the four critical areas.

Please read the brief description below of each of the analysed areas before answering the questions in the Delphi questionnaire.

Food. The unprovoked Russian invasion of Ukraine has further destabilised already fragile agricultural markets. Ukraine is the EU's fourth biggest external provider of food, covering half of the EU's demand of corn, a fifth of its soft wheat demand and a quarter of its vegetable oil. The war in Ukraine dramatically changed market expectations, affecting prices in all commodities, including for agri-food primary products. The global wheat market is where food security concerns are mainly concentrated. Prices in wheat futures markets have increased by 70 % since the invasion. Under the current circumstances, all trade has stopped between Ukraine and the EU because ships have difficulties leaving the Black Sea. This study will explore ways to ensure food security for the citizens of the EU and safeguard the agricultural sector in light of these developments.

Energy. Russia's attack on Ukraine proves that Russia is an energy partner the EU cannot rely on. The union should therefore become independent of Russia's fossil fuels and secure its energy independence in general. At the same time, there is a need to find solutions to rising energy prices by diversifying energy supplies, boosting renewables and energy efficiency, and creating renewable energy communities (RES communities). A complete analysis of the current situation and the alternatives ahead will help Members of the EP to respond effectively to this emergency by exploring future-proof existing strategies.

Satellite communications. The study in the area of satellite communications focuses on the potential to leverage the Copernicus programme. Analysis of the Copernicus programme could provide insights into how we can better leverage its services in the face of humanitarian crises, while at the same time ensuring the resilience of our satellite communications – an indispensable tool for our technological sovereignty. Copernicus is the EU's Earth observation programme, providing free access to near real-time data. It offers information services that draw on satellite observations of the

Earth and in-situ (non-space) data. Copernicus data includes, among other things, basic topographic information such as maps of the transportation network, administrative boundaries and digital terrain models, and more recently the Copernicus programme has allowed us to monitor images of migration flows. In-situ data relies, in addition to ground-based weather stations, ocean buoys and air quality monitoring networks, on novel data sources such as sensors and images collected by drones and information gathered by volunteers or citizen scientists (on the basis of crowdsourcing).

Semiconductors. Chips are the building blocks of the digital economy, which is the reason why the EU wants to become a global player in the semiconductor ecosystem and ensure its technological sovereignty. By pooling large-scale investments, the EU aims to double its global market share of semiconductors to 20 % by 2030 and ensure that the benefits are evenly distributed among all MS. However, these ambitions are currently at risk. On one hand, Ukraine supplies the EU with 70 % of the neon gas used to produce semiconductors, while Russia is a leading exporter of this material; on the other hand, MS have different capacities, needs, dependencies and infrastructures when it comes to semiconductors.

We really appreciate your valuable contribution and thank you very much in advance for your answers!

Research instrument:

DELPHI SURVEY QUESTIONNAIRE

Please select area where you have experience and expert knowledge

- ☐ Food
- ☐ Energy
- ☐ Satellite communications
- ☐ Semiconductors

FOOD

DELPHI THESES

Thesis 1. Wheat production in EU countries will be independent of Ukraine and Russia

Thesis 2. EU countries will be leaders in the production of the sunflower oil

Thesis 3. European Union countries will invest additional financial resources in the production of NPK fertilisers in order to become independent from Russia

Thesis 4. There will be a reversal of the previous policy of limiting agricultural production

AUXILIARY QUESTIONS FOR THESES

1. How do you assess the significance of the thesis for supply chain resilience? (1 indicates very low significance of the thesis, whereas 5 stands for very high significance)

☐ 1 – very low significance ☐ 2 ☐ 3 ☐ 4 ☐ 5 – very high significance

2. When, in your opinion, will the thesis be realised or when will the phenomena/processes described in the thesis occur?

- ☐ by the end of 2025
- ☐ in the years 2026-2030
- ☐ in the years 2031-2050
- ☐ after 2050
- ☐ never

3. What is the impact of the following enablers on the implementation of the thesis?

Enablers	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
The approval of state aid fertiliser subsidies						
Release of the financial reserve from the budget of the European Commission's Common Agricultural Policy						
Allowing hitherto set-aside land to be used for food and feed production						

Moving towards more environmentally friendly and sustainable activities						
Promoting the use of advanced technologies in agriculture (such as artificial intelligence, remote sensing, geographic information software, virtual reality, drones, application programming interfaces)						

4. What is the impact of the following barriers on the implementation of the thesis?

Barriers	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Insufficient financial support to farmers						
Too slow utilisation of biogas production from agri-food waste						
Occurrence of extreme weather conditions such as droughts, floods and other natural disasters						
Lack of favourable legislation at national level						

5. Determine the extent to which the thesis statement will affect the following actors, where 1 indicates that the impact of the thesis is very low, and 5 that it is very high

Actors	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Companies/Industry						
UE policy-makers						
National policy-makers						
Regional and local government/policy-makers						
End users, e.g. households, customers, consumers						
Farmers						
NGOs						
Special interest groups e.g. volunteer contributors and citizen scientists						
Scientists						
Society						
Special pressure groups e.g. lobbying groups						

6. Determine the extent to which the thesis statement will affect the following functions of supply chains, where 1 indicates that the impact of the thesis is very low, and 5 that it is very high

Function of the supply chain	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Minimising the cost of product and information flow while maintaining the level of service desired by the customer						
Ensuring short order processing times						
Improving reliability, frequency and flexibility of supply						
Optimisation of stock levels throughout the supply chain with adaptation to the preferences of individual market segments						

7. What actions need to be taken to build resilience of food supply chains in Europe?

8. Rate on a seven-point scale how important the following factors are for building resilience in food supply chains, where 1 means the factor is of very low importance and 7 means the factor is of very high importance.

Factors	1 – very low	2	3	4	5	6	7 – very high
Social							
Prevailing dietary patterns and habits							
The level of social trust in modern technologies							
Technological							
The use of advanced technologies in agriculture (such as artificial intelligence, remote sensing, geographic information software, virtual reality, drones, application programming interfaces)							
The level of utilisation of biogas production from agri-food waste							
Economic							
The approval of state aid fertiliser subsidies							
Release of the financial reserve from the budget of the European Commission's Common Agricultural Policy							
The level of financial support to farmers							
Environmental							
The use of set-aside land for food and feed production							
Moving towards more environmentally friendly and sustainable activities							
The occurrence of extreme weather conditions such as droughts, floods and other natural disasters							
Political							
The level of legislation at the national level							
The quality of legislation on the use of digital data in agriculture							
Ethical							
Openness to change dietary patterns and habits							
Conscious consumerism							
Demographic							
Aging society							
The level of the international migration							

9. Rate on a seven-point scale how predictable the following factors are for building resilience in food supply chains in the 2030 horizon, where 1 means the factor has very low predictability, while 7 means the factor has very high predictability.

Factors	1 – very low	2	3	4	5	6	7 – very high
Social							
Prevailing dietary patterns and habits							
The level of social trust in modern technologies							
Technological							
The use of advanced technologies in agriculture (such as artificial intelligence, remote sensing, geographic information software, virtual reality, drones, application programming interfaces)							
The level of utilisation of biogas production from agri-food waste							
Economic							
The approval of state aid fertiliser subsidies							
Release of the financial reserve from the budget of the European Commission's Common Agricultural Policy							
The level of financial support to farmers							
Environmental							
The use of set-aside land for food and feed production							
Moving towards more environmentally friendly and sustainable activities							
Occurrence of extreme weather conditions such as droughts, floods and other natural disasters							
Political							
The level of legislation at the national level							
The quality of legislation on the use of digital data in agriculture							
Ethical							
Openness to change dietary patterns and habits							
Conscious consumerism							
Demographic							
Aging society							
The level of the international migration							

ENERGY

DELPHI THESES

Thesis 1. The growth of renewables in the energy-mix in EU countries will be more dynamic

Thesis 2. The role of Russia as a supplier of fossil fuels to the EU market will diminish

Thesis 3. There will be closer integration of EU countries within European Energy Security

Thesis 4. The importance of hydrogen and biomethane as energy sources will increase

Thesis 5. There will be a transformation of the energy market in the EU towards distributed energy

AUXILIARY QUESTIONS FOR THESES

1. How do you assess the significance of the thesis for supply chain resilience? (1 indicates very low significance of the thesis, whereas 5 stands for very high significance)

☐ 1 – very low significance ☐ 2 ☐ 3 ☐ 4 ☐ 5 – very high significance

2. When, in your opinion, will the thesis be realised or when will the phenomena/processes described in the thesis occur?

- ☐ by the end of 2025
- ☐ in the years 2026-2030
- ☐ in the years 2031-2050
- ☐ after 2050
- ☐ never

3. What is the impact of the following enablers on the implementation of the thesis?

Enablers	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Technological progress in the field of alternative energy sources (e.g. technologies using space-based solar power, human power, tidal power, hydrogen power, magma power, flying wind power, algae power, fusion power)						
Coherent policy on sanctions against Russia/effective application of sanction against Russia						
Integration of AfCFTA countries						

Decarbonisation						
Create energy management clusters and cooperatives						

4. What is the impact of the following barriers on the implementation of the thesis?

Barriers	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Low stocks of energy resources in many countries of the EU						
High cost of creating new transport infrastructure for fossil fuels						
Reluctance of some EU Member States to cooperate on energy due to different energy goals						
Environmental threats related to the construction of new fossil fuels transport infrastructure						
Difficulties in finding an alternative to the Russian supplies of fossil fuels						

5. Determine the extent to which the thesis statement will affect the following actors, where 1 indicates that the impact of the thesis is very low, and 5 that it is very high

Actors	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Companies/Industry						
UE policy-makers						
National policy-makers						
Regional and local government/policy-makers						
End users, e.g. households, customers, consumers						
Farmers						
NGOs						
Special interest groups e.g. volunteer contributors and citizen scientists						
Scientists						
Society						
Special pressure groups e.g. lobbying groups						

6. Determine the extent to which the thesis statement will affect the following functions of supply chains, where 1 indicates that the impact of the thesis is very low, and 5 that it is very high

Function of the supply chain	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Minimising the cost of product and information flow while maintaining the level of service desired by the customer						
Ensuring short order processing times						
Improving reliability, frequency and flexibility of supply						
Optimisation of stock levels throughout the supply chain with adaptation to the preferences of individual market segments						

7. What actions need to be taken to build resilience of energy supply chains in Europe?

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8. Rate on a seven-point scale how important the following factors are for building resilience in energy supply chains, where 1 means the factor is of very low importance and 7 means the factor is of very high importance.

Factors	1 – very low	2	3	4	5	6	7 – very high
Social							
Quality of life and security of citizens							
Energy management clusters and cooperatives							
Technological							
Technological progress in the field of alternative energy sources (e.g. Technologies using space-based solar power,							

human power, tidal power, hydrogen power, magma power, flying wind power, algae power, fusion power)							
Decarbonisation through the use of carbon-eliminating technologies							
Economic							
The level of stocks of energy resources in many countries of the EU							
The cost of creating new transport infrastructure for fossil fuels							
Environmental							
Development of the circular economy							
Environmental threats related to the construction of new fossil fuels transport infrastructure							
Political							
The level of geopolitical instability							
Reluctance of some EU Member States to cooperate on energy due to different energy goals							
Ethical							
Openness to technological innovations that improve the comfort of life (e.g. In terms of reducing environmental pollution)							
Conscious consumerism							
Demographic							
Aging society							
The level of international migration							

9. Rate on a seven-point scale how predictable the following factors are for building resilience in energy supply chains in the 2030 horizon, where 1 means the factor has very low predictability, while 7 means the factor has very high predictability.

Factors	1 – very low	2	3	4	5	6	7 – very high
Social							
Quality of life and security of citizens							
Energy management clusters and cooperatives							
Technological							
Technological progress in the field of alternative energy sources (e.g. technologies using space-based solar power, human power, tidal power, hydrogen power, magma power, flying wind power, algae power, fusion power)							

Decarbonisation through the use of carbon-eliminating technologies							
Economic							
The level of stocks of energy resources in many countries of the EU							
The cost of creating new transport infrastructure for fossil fuels							
Environmental							
Development of the circular economy and sustainable development							
Environmental threats related to the construction of new fossil fuels transport infrastructure							
Political							
The level of geopolitical instability							
Reluctance of some EU Member States to cooperate on energy due to different energy goals							
Ethical							
Openness to technological innovations that improve the comfort of life (e.g. In terms of reducing environmental pollution)							
Conscious consumerism							
Demographic							
Aging society							
The level of international migration							

SATELLITE COMMUNICATION

DELPHI THESES

Thesis 1. There will be rapid development of the market for free applications based on Copernicus data, which will increase the scale of stand-alone satellite data analytics by end-users

Thesis 2. Multidimensional analysis of data provided by Copernicus will enable environmentally friendly management of supply chains by providing safe transportation, eco transportation and meteorological forecasts for transportation

Thesis 3. In the face of socio-political crises (wars, migration, economic crises), the importance of Copernicus data analytics will increase, providing supply chain optimisation

AUXILIARY QUESTIONS FOR THESES

1. How do you assess the significance of the thesis for supply chain resilience? (1 indicates very low significance of the thesis, whereas 5 stands for very high significance)

☐ 1 – very low significance ☐ 2 ☐ 3 ☐ 4 ☐ 5 – very high significance

2. When, in your opinion, will the thesis be realised or when will the phenomena/processes described in the thesis occur?

- ☐ by the end of 2025
- ☐ in the years 2026-2030
- ☐ in the years 2031-2050
- ☐ after 2050
- ☐ never

3. What is the impact of the following enablers on the implementation of the thesis?

Enablers	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Broad promotion of the Copernicus programme						
The increase of the scope and quality of education of current and potential Copernicus end-users						
Mutual and effective cooperation among key stakeholders in the Copernicus programme						

4. What is the impact of the following barriers on the implementation of the thesis?

Barriers	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Low competences of end-users using Copernicus data and services						
High level of uncertainty in data provided by citizen measurement networks (managed by volunteer contributors or citizen scientists) in the in-situ component						
Low level of public confidence in modern technologies						

5. Determine the extent to which the thesis statement will affect the following actors, where 1 indicates that the impact of the thesis is very low, and 5 that it is very high

Actors	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Companies/Industry						
UE policy-makers						
National policy-makers						
Regional and local government/policy-makers						
End users, e.g. households, customers, consumers						
Farmers						
NGOs						
Special interest groups e.g. volunteer contributors and citizen scientists						
Scientists						
Society						
Special pressure groups e.g. lobbying groups						

6. Determine the extent to which the thesis statement will affect the following functions of supply chains, where 1 indicates that the impact of the thesis is very low, and 5 that it is very high

Function of the supply chain	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Minimising the cost of product and information flow while maintaining the level of service desired by the customer						
Ensuring short order processing times						

Improving reliability, frequency and flexibility of supply						
Optimisation of stock levels throughout the supply chain with adaptation to the preferences of individual market segments						

7. What actions need to be taken to build resilience of satellite communication supply chains in Europe?

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8. Rate on a seven-point scale how important the following factors are for building resilience in satellite communication supply chains, where 1 means the factor is of very low importance and 7 means the factor is of very high importance.

Factors	1 – very low	2	3	4	5	6	7 – very high
Social							
Quality of life and security of citizens							
Social trust in modern technologies							
Technological							
Development of Artificial Intelligence							
Development of Internet of Things systems							
Economic							
Competencies of end-users using Copernicus data and services							
Cooperation between key stakeholders (researchers, entrepreneurs, politicians) of the Copernicus programme							
Environmental							
The level of climate neutrality and biodiversity							
Efficiency in the use of natural resources using modern digital technologies, e.g. Measuring and controlling, monitoring, reporting, etc.							

Political							
The level of geopolitical instability							
The quality of legislation on cybersecurity and the use of digital data							
Ethical							
Openness to technological innovations that improve the comfort of life (e.g. In terms of reducing environmental pollution)							
The role of civil society							
Demographic							
Aging society							
The level of international migration							

9. Rate on a seven-point scale how predictable the following factors are for building resilience in satellite communication supply chains in the 2030 horizon, where 1 means the factor has very low predictability, while 7 means the factor has very high predictability.

Factors	1 – very low	2	3	4	5	6	7 – very high
Social							
Quality of life and security of citizens							
Social trust in modern technologies							
Technological							
Development of Artificial Intelligence							
Development of Internet of Things systems							
Economic							
Competencies of end-users using Copernicus data and services							
Cooperation between key stakeholders (researchers, entrepreneurs, politicians) of the Copernicus programme							
Environmental							
The level of climate neutrality and biodiversity							
Efficiency in the use of natural resources using modern digital technologies, e.g. Measuring and controlling, monitoring, reporting, etc.							
Political							
The level of geopolitical instability							
The quality of legislation on cybersecurity and the use of digital data							

Ethical							
Openness to technological innovations that improve the comfort of life (e.g. In terms of reducing environmental pollution)							
The role of civil society							
Demographic							
Aging society							
The level of international migration							

SEMICONDUCTORS

DELPHI THESES

Thesis 1. EU share of global cutting-edge, innovative and sustainable semiconductors production will increase from 10 to 20 %

Thesis 2. Security of supply of semiconductors to strategic sectors of EU countries will be ensured

Thesis 3. Building a dynamic ecosystem across the EU will strengthen Europe's capabilities to achieve its environmental goals and green transitions while improving the Union's security (semiconductors)

Thesis 4. EU countries have sufficient resources to produce modern integrated chips (made with the 7-nanometre process)

AUXILIARY QUESTIONS FOR THESES

1. How do you assess the significance of the thesis for supply chain resilience? (1 indicates very low significance of the thesis, whereas 5 stands for very high significance)

☐ 1 – very low significance ☐ 2 ☐ 3 ☐ 4 ☐ 5 – very high significance

2. When, in your opinion, will the thesis be realised or when will the phenomena/processes described in the thesis occur?

- ☐ by the end of 2025
- ☐ in the years 2026-2030
- ☐ in the years 2031-2050
- ☐ after 2050
- ☐ never

3. What is the impact of the following enablers on the implementation of the thesis?

Enablers	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Increasing the number of qualified employees by training staff and enhancing knowledge of the semiconductor ecosystem						
Boosting dialogue with semiconductor manufacturers to prioritise production for critical sectors e.g. healthcare, medical sector, electronic, automotive, army sector						
Establish cooperation with relevant third countries (non EU countries)						
Development of common standards and certification for trusted electronics						

Funding of research, development and innovation, implementation of advanced semiconductor, pilot lines for prototyping, testing and experimentation						
Implementation of central purchasing system for semiconductors at EU level						

4. What is the impact of the following barriers on the implementation of the thesis?

Barriers	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Shortage of qualified workers						
Shortages of raw materials for semiconductor manufacturing						
High fluctuation rate of demand for different types of semiconductors						
Changes in technical, regulatory or environmental requirements that reduce manufacturing efficiency						
Concentration of supply with respect to geographic areas and companies, taking into account network and lock-in effects						
Threat due to the lack of authenticity and integrity of semiconductors which will cause possible impact of falsified semiconductors. Negative impact of falsified semiconductors						

5. Determine the extent to which the thesis statement will affect the following actors, where 1 indicates that the impact of the thesis is very low, and 5 that it is very high

Actors	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Companies/Industry						
EU policy-makers						
National policy-makers						
Regional and local government/policy-makers						
End users, e.g. households, customers, consumers						
Farmers						
NGOs						
Special interest groups e.g. volunteer contributors and citizen scientists						
Scientists						

Society						
Special pressure groups e.g. lobbying groups						

6. Determine the extent to which the thesis statement will affect the following functions of supply chains, where 1 indicates that the impact of the thesis is very low, and 5 that it is very high

Function of the supply chain	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Minimising the cost of product and information flow while maintaining the level of service desired by the customer						
Ensuring short order processing times						
Improving reliability, frequency and flexibility of supply						
Optimisation of stock levels throughout the supply chain with adaptation to the preferences of individual market segments						

7. What actions need to be taken to build resilience of semiconductors supply chains in Europe?

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8. Rate on a seven-point scale how important the following factors are for building resilience in semiconductor supply chains, where 1 means the factor is of very low importance and 7 means the factor is of very high importance.

Factors	1 – very low	2	3	4	5	6	7 – very high
Social							
Dialogue with semiconductor manufacturers to prioritise production for critical sector							
Demand for leading-edge chips driven by artificial intelligence, autonomous driving and 5G/6G							

Dialogue between semiconductor manufacturers and policy makers							
Technological							
Shortages of raw materials for semiconductor manufacturing							
Funding of research, development and innovation, implementation of advanced semiconductor (such as pilot lines for prototyping, testing and experimentation)							
Economic							
Central purchasing system for semiconductors at EU level							
Fluctuation rate of demand for different types of semiconductors							
Concentration of supply with respect to geographic areas and companies, taking into account network and lock-in effects							
Environmental							
Changes in environmental requirements that reduce manufacturing efficiency							
Development of energy-efficient semiconductors							
Political and legal							
Development of common standards and certification for trusted electronics							
Cooperation with relevant third countries (non EU countries)							
Ethical							
Authenticity and integrity of semiconductors							
Conscious consumerism							
Demographic							
Qualified employees in the semiconductor ecosystem							
STEM (Science, Technology, Engineering, Mathematics) talent investments							

9. Rate on a seven-point scale how predictable the following factors are for building resilience in semiconductor supply chains in the 2030 horizon, where 1 means the factor has very low predictability, while 7 means the factor has very high predictability.

Factors	1 – very low	2	3	4	5	6	7 – very high
Social							
Dialogue with semiconductor manufacturers to prioritise production for critical sectors							
Demand for leading-edge chips driven by artificial intelligence, autonomous driving and 5G/6G							

Dialogue between semiconductor manufacturers and policy makers							
Technological							
Shortages of raw materials for semiconductor manufacturing							
Funding of research, development and innovation, implementation of advanced semiconductor (such as pilot lines for prototyping, testing and experimentation)							
Economic							
Central purchasing system for semiconductors at EU level							
Fluctuation rate of demand for different types of semiconductors							
Concentration of supply with respect to geographic areas and companies, taking into account network and lock-in effects							
Environmental							
Changes in environmental requirements that reduce manufacturing efficiency							
Development of energy-efficient semiconductors							
Political and legal							
Development of common standards and certification for trusted electronics							
Cooperation with relevant third countries (non EU countries)							
Ethical							
Authenticity and integrity of semiconductors							
Conscious consumerism							
Demographic							
Qualified employees in the semiconductor ecosystem							
STEM (Science, Technology, Engineering, Mathematics) talent investments							

CROSS-CUTTING THESES

DELPHI THESES

Thesis 1. The EU economy will become circular and the global value chain will be shifted closer to sites of consumption. As a result, European supply chains (food, energy, satellite technologies and semiconductors) will become shorter and lose its international importance

Thesis 2. Poverty in the EU will be a marginal phenomenon

Thesis 3. Fully self-sufficient European supply chains (food, energy, satellite communications and semiconductors) will generate substantial incremental costs and lead to dramatic increases in EU product prices

Thesis 4. The Copernicus programme will be used in the EU to designate agricultural land suitable for growing crops

Thesis 5. The Copernicus programme will be used in the EU to monitor and assess the potential of alternative (renewable) energy sources, which will enable independence from external energy resources supplies

AUXILIARY QUESTIONS FOR THESES

1. How do you assess the significance of the thesis for supply chain resilience? (1 indicates very low significance of the thesis, whereas 5 stands for very high significance)

☐ 1 – very low significance ☐ 2 ☐ 3 ☐ 4 ☐ 5 – very high significance

2. When, in your opinion, will the thesis be realised or when will the phenomena/processes described in the thesis occur?

- ☐ by the end of 2025
- ☐ in the years 2026-2030
- ☐ in the years 2031-2050
- ☐ after 2050
- ☐ never

3. What is the impact of the following enablers on the implementation of the thesis?

Enablers	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Promoting the use of advanced technologies (such as artificial intelligence, remote sensing, geographic information software, virtual reality, drones, application programming interfaces, Internet of Things)						
Onshoring/reshoring – the practice of transferring a business operation that was moved overseas back to the country from which it was originally relocated						
Nearshoring – the practice of transferring a business operation to a nearby country, especially in preference to a more distant one						
The growth of protectionism in the policy of the EU						
Allocating certain funds in the budget of each EU country to finance services and research based on multidimensional data, including from the Copernicus programme						
Creation of renewable energy communities (RES communities)						
Orientation of countries' policies towards increasing self-sufficiency (energy, food, semiconductors)						
Increasing the importance of reliable partners in supply chains, instead of the most effective ones (change from efficiency first to safety first)						
Policy coherence and common activities of all associated with EU countries in the context of self-sufficiency						

4. What is the impact of the following barriers on the implementation of the thesis?

Barriers	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
The lack of coherent policy in EU countries regarding agriculture						
The lack of coherent policy in EU countries regarding energy						
The lack of coherent policy in EU countries regarding the regulation of the semiconductor market						
Insufficient level of R&D expenses spending on disruptive technologies						
Climate changes (e.g. hurricanes, droughts, floods)						
Speculative use of information						

Rising labour costs (hiring of employees)						
Insufficient competences (knowledge, skills, social competences) of society						
Rising costs of international transport						
Insufficient use of the Copernicus data						

5. Determine the extent to which the thesis statement will affect the following actors, where 1 indicates that the impact of the thesis is very low, and 5 that it is very high

Actors	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Companies/Industry						
UE policy-makers						
National policy-makers						
Regional and local government/policy-makers						
End users, e.g. households, customers, consumers						
Farmers						
NGOs						
Special interest groups e.g. volunteer contributors and citizen scientists						
Scientists						
Society						
Special pressure groups e.g. lobbying groups						

6. Determine the extent to which the thesis statement will affect the following functions of supply chains, where 1 indicates that the impact of the thesis is very low, and 5 that it is very high

Function of the supply chain	1 – very low	2 – low	3 – average	4 – high	5 – very high	not related to the thesis
Minimising the cost of product and information flow while maintaining the level of service desired by the customer						
Ensuring short order processing times						
Improving reliability, frequency and flexibility of supply						
Optimisation of stock levels throughout the supply chain with adaptation to the preferences of individual market segments						

PROFILE OF THE RESPONDENT

Country:

Gender:

- ☐ woman
- ☐ man
- ☐ non-binary
- ☐ prefer not to disclose
- ☐ prefer to self-describe

Age:

- ☐ under 25 years
- ☐ 25-34 years
- ☐ 35-44 years
- ☐ 45-54 years
- ☐ 55-64 years
- ☐ 65 years or older

Education:

- ☐ primary
- ☐ secondary
- ☐ postgraduate
- ☐ higher – BA, BEng, BSc, MA, MSc, etc.
- ☐ higher – PhD
- ☐ higher – Professor

I represent:

- ☐ companies/industry
- ☐ scientists
- ☐ UE policy-makers
- ☐ national policy-makers
- ☐ regional and local government/policy-makers
- ☐ NGOs
- ☐ special interest groups e.g. volunteer contributors and citizen scientists
- ☐ special pressure groups e.g. lobbying groups
- ☐ farmers
- ☐ other, which?

The current situation in Ukraine has led to severe supply chain disruptions, contributing to a sharp increase in food and commodity prices globally and the limitation of fossil fuel imports from Russia to the EU. Moreover, to end Europe's dependence on semiconductor suppliers from Asian countries, it is necessary to take immediate action of a structural nature, involving all EU Member States and all participants in regional supply markets.

The overall aim of this study was to identify drivers of and barriers to building up open strategic autonomy at EU level, before recommending coordinated solutions and addressing supply chain resilience in four critical areas: food security, energy security, semiconductors and satellite communications. This research seeks to contribute to the European Parliament's future work by providing insights into how to protect the European agricultural sector, ensure energy security and the technological sovereignty of semiconductor production, and improve satellite communications.

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