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Hindsight to foresight: an AI-powered analysis of future events in EJFR in 10 years

Carlos Eduardo Barbosa[1,2*], Alan Lyra[1], Jano Moreira de Souza[1], Yuri Lima[1], Herbert Salazar[1] and Matheus Argôlo[1]

Abstract

The world is changing increasingly faster, bringing uncertainty and complexity to many processes, and this acceleration leads to the rise of demand for studies regarding the future. Futures Studies have been widely used to support decision-making, emphasizing forecasting technologies' timing, diffusion, and life cycle. Therefore, evaluating previous forecasts to understand their proposed scenarios better is often necessary. This work analyzes all articles published until the end of 2023 in one of the most relevant journals of this field of study, the European Journal of Futures Research (EJFR). The EJFR is among the main contributors to fostering dialogue among scholars, practitioners, and policymakers interested in anticipating and shaping the future. We streamlined the uncovering of future events written on EJFR articles using NERMAP, a software we designed to semi-automate the roadmapping process. We built five simple scenarios and associated each of the 214 future events found into a scenario. Then, we analyzed the 52 events that were supposed to happen until 2023 to discover how the expected possible events did occur in real life. Therefore, we expect to provide insights, better understand how expected possible events occur in real life, and write a novel way to understand the journal's history. The methodology used in this study is novel and applicable to other studies to reduce the time and risk of errors when developing large-scale roadmaps. This work provides valuable information for decision-makers in organizations and governments. The Futures Research scientific community can use the results to improve their research frameworks.

Keywords Futures studies, Roadmapping, Scenarios, Decision-making process, Fact-checking, European Journal of Futures Research

Introduction

We are going through accelerated changes in the world, accentuating the levels of uncertainty and the complexity of the involved processes [1–4]. This situation increases the demand for studies related to planning, foresighting, and creating future visions. Despite their intrinsic differences, European countries have shared experiences, divisions, and conflicts, providing a rich opportunity to examine their future visions critically. European countries face numerous internal problems; simultaneously, they seek to contribute to solving global challenges [5, 6].

Technology Roadmapping (TRM) [7] – or simply, Roadmapping – is one of the several Foresight methods in which the expected final product is the roadmap. Technology Roadmapping emerged in the 1970s, with Motorola being one of the first companies to apply it to improve the development of its products [8]. Roadmapping can be time-consuming and error-prone when performed manually, and its complexity scales linearly with the number of documents analyzed. Therefore, large-scale studies are arduous to be performed manually [9].

*Correspondence:
Carlos Eduardo Barbosa
eduardo@cos.ufrj.br
[1] Program of Systems and Computer Engineering, Universidade Federal do Rio de Janeiro, Avenida Horácio Macedo, Bloco H, Sala H307 – Centro de Tecnologia – Cidade Universitária, Rio de Janeiro – RJ 21941-450, Brazil
[2] Centro de Análises de Sistemas Navais – Marinha do Brasil, Praça Barão de Ladário S/N – Ilha das Cobras, Rua da Ponte, Ed. 23 do AMRJ – Centro, Rio de Janeiro – RJ 20091-000, Brazil

Many authors described several future events in European Journal of Futures Research (EJFR) articles in the last ten years. Collecting and organizing the information about the conclusions drawn by researchers can provide helpful information for decision-makers in organizations and governments, and for the Futures Research scientific community. The TRM process can be applied to manage the knowledge embedded into forecasts, providing a timeline for the future and analyzing the reasonableness of the events that *should* have happened by 2023.

In this research, we employed NERMAP [9], a software we designed to semi-automate the roadmapping process to analyze all articles until the end of 2023 from the EJFR database to extract insights published during the history of the journal, organized into the form of a roadmap. Further, we analyze the events expected to happen until 2023 to discover how the expected possible events did occur in real life. Finally, we develop scenarios and roadmaps based on the future events found. The roadmap integrates the shared view of the researchers during this 10-year lifespan of EJFR. The developed scenarios show speculative futures to raise questions. We named the five scenarios *Green Renaissance*, *Digital Divide*, *Populist Backlash*, *Techno-dystopia*, and *Geopolitical Turmoil*. Therefore, we aim to answer the following research questions:

RQ1. What insights can be extracted from articles published in the EJFR up to 2023 regarding future events?
RQ2. What events are expected to happen according to the EJFR literature?
RQ3. How do events expected to happen until 2023 compare with real-world outcomes?

In our contribution to Futures Research, we collect and examine numerous articles on the EJFR literature. This analysis thoroughly reviews all articles published in the EJFR until 2023, allowing us to build a comprehensive understanding by connecting different pieces of literature and deriving valuable insights. The applied methodology is novel and can be replicated using different sources. We also produce scenarios for researchers to motivate further studies and for organizations and governments to support their decision-making process.

This work is divided as follows: in the Methodology section, we discuss the methodology utilized, and in the Results section, we present the results, such as the list of events found, their classification, and metadata analysis. In the Roadmap analyses section, we perform two analyses of the events. First, we perform a fact-checking of the events expected to happen until 2023. Then, we associate future events found with five scenarios. Finally, in the Conclusions section, we make our final remarks and present our conclusions.

Methodology

This research aimed to analyze all articles from the EJFR to build future scenarios of the main areas presented in the literature. Through the TRM method, we can create roadmaps about the main trends in the scope of EFJR, enabling an expanded vision of the future. These roadmaps can provide insights to inform recommendations or decisions. Additionally, they can highlight existing gaps in research, indicating the type of further research needed, which facilitates a more comprehensive understanding of future developments.

The research methodology has six steps, which we summarized in Fig. 1:

1. Gather publications from the EJFR database;
2. Upload articles in the NERMAP tool;

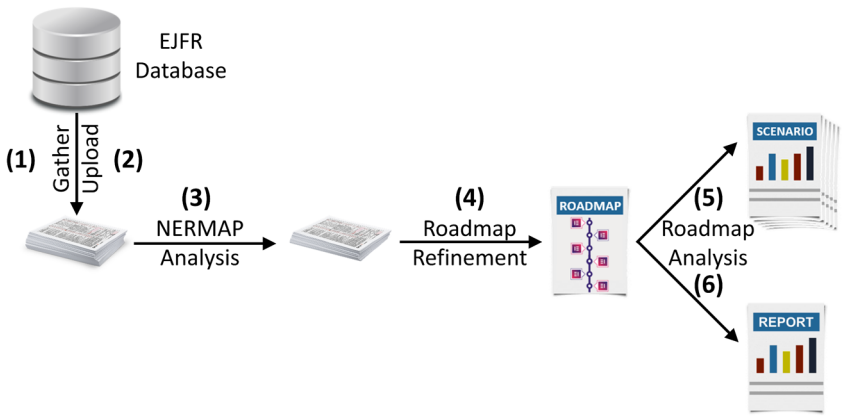

Fig. 1 Research methodology flow

3. Automated assembly of the initial Roadmap with a timeline of future events depicted in submitted articles;
4. Refine the roadmap and adjust it manually to ensure that each event is comprehensive, distinct, and accurate;
5. Analysis of the final roadmap and development of scenarios;
6. Analysis of the events expected to occur until 2023 to understand better how the expected possible events did occur in real life.

In the first step, we gathered all the European Journal of Futures Research (EJFR) papers, totaling 203 articles from 2013 to 2022.

In the second step, we uploaded the collected articles to NERMAP to process the PDF files into the initial roadmap. NERMAP [9–11] was designed to support and facilitate the roadmapping process, semi-automating it and allowing the researcher to analyze a large volume of prospective documents, optimizing time and costs during a Futures Study. NERMAP uses the Named Entity Recognition technique [12] to identify events in documents. We based the identification on three parts:

1. Temporal Space: Term that designates a date, which can be a year or an expression of time (e.g., "*next year*", "*century*", and "*decade*");
2. Future-indicating terms: Words or expressions that indicate that an event will happen in the future, always associated with a temporal space (e.g., "*In* 2050", "*By* 2050", and "*Around* 2050");
3. Event: Fragment of text that indicates the expected possible event (e.g., "The *unemployment rate in India will increase by 3%*", "*Europe will have WiFi everywhere*"). While parts 1 and 2 focus on "when" the events happen, this part focuses on "what" will happen.

In the third step, the NERMAP tool generated an initial timeline of future events in the articles. The tuple (year, event) is gathered from the text of the article. The definition of the year of the identified event is based on the text and the article publication date. NERMAP identifies fixed dates and relative dates. Fixed dates refer to those explicitly stated in the text – e.g., "In 2050 will be…". Relative dates refer to text that includes terms such as "In the next two decades", "For the next year", among others. In relative dates, we rely on the article's publication date to estimate a future date for the event. For example, "In the next two decades" for an article published in 2015 refers to a future event in 2035. However, the initial roadmap generated by the NERMAP tool is a rough representation of the timeline of events and requires refinement.

In the fourth step, we manually fine-tuned the roadmap by ensuring that each event was comprehensive, distinct, and accurate. This refinement step involves post-processing tasks to convert the initially generated list of potential future events from the articles into a refined list that eliminates false positives and presents events in a more standardized written style. Occasionally, articles contained repetitions of certain future events, leading to duplicates in the automated process, which we manually removed.

We also included a classification of each event for further segmented analysis in the categories described in Table 1.

In the fifth step, we analyzed the refined roadmap and developed five future scenarios using all the events gathered, using literature-based design fiction [13]. We interpret the timeline to develop consistent scenarios about the future. Scenarios provide insights and better communicate the findings and future trends to people. They are beneficial for decision-makers and laypeople in general.

In the sixth step, we checked the events expected to occur from 2013 to 2023 to understand better how the expected possible events occurred in real life. This step involves comparing the event found in the publications with recent information to assess how the expected possible events developed. This "fact-checking" provides insights into the projections' relatively short-term accuracy and how fast the expected possible events drift from reality. The sixth step can be performed concurrently with the fifth step.

After conducting this research, we highlight that RQ1 is addressed in sections Results and Roadmap analyses, providing various insights from articles published in the EJFR, from statistics of future events gathered to deeper analyses that include roadmaps, fact-checking, and scenarios. To address RQ2, we extensively discuss the future events, according to the EJFR literature, in section Roadmap and elaborate them upon a roadmap, presented in Appendix A. Finally, the comparison between the expected events until 2023, as outlined in the EJFR literature, and real-world outcomes is thoroughly examined in section Scenarios, providing insights into RQ3.

Results

This research analyzed the EJFR database, totaling 203 publications from 2013 to 2022. After our analysis, we found 214 future events in 53 articles. From the future events found, 52 were expected to happen until the end of 2023.

This section comprehensively analyzes the journal's publications, presenting an extensive overview of temporal trends and identifying discerning countries with more publications, among other pertinent considerations

Table 1 Categories of events and their descriptions

Category	Description
Agricultural	Events related to food production and other crops. Include crop yields and agricultural policies.
Demographic	Events about population characteristics. Include age, gender, race, and ethnicity.
Economic	Events related to production, distribution, and consumption of goods and services. Include employment rates, economic growth, and income inequality.
Education	Events about the educational system. Include school enrollments, test scores, and graduation rates.
Environmental	Events about the environment. Include climate change, natural disasters, and environmental degradation.
Government	Events related to actions and policies of government agencies. Include regulatory changes and public spending.
Health	Events related to the health of individuals or populations. Include incidence of disease, access to healthcare, and health outcomes.
Industrial	Events related to the production of goods. Include manufacturing trends and industrial accidents.
Infrastructure	Events related to physical structures and systems that support a society. Include transportation networks, energy grids, and water systems.
Legal	Events about the enforcement of laws and the administration of justice. Include court cases and legislation.
Military	Events about the defense and security of a country or region. Include military operations and arms control agreements.
Political	Events about society's governance and decision-making. Include elections, policy debates, and protests.
Social	Events about social interactions and relationships. Include family structure, social support networks, and community involvement.
Technological	Events related to the development and usage of new technologies. Include the adoption of new software or devices.

regarding the events in the articles. Next, we present the complete roadmap of events. The presented results are a substantive contribution to the research and are the basis for the roadmap analyses.

Publications

With the publications gathered in our research, NERMAP found 214 future events in 53 EJFR articles. We examined these 53 articles and extracted the following information.

As shown in Fig. 2, we observe a peak in the number of articles in 2014 and 2015, with 11 and 10 articles, respectively. A slight decrease followed this peak in articles with events in the following years, reaching a lower point in 2020. This downward trend in the number of future events can be partially explained by the higher number of published articles in 2014 (33 articles) and 2015 (23 articles) when compared to 2019 (7 articles) and 2020 (10 articles). However, 2021 and 2022 had more articles published, 17 and 25 articles, respectively, and the number of articles with events found was only marginally bigger.

When we analyze the countries of filiation of all authors of the publications, the data shows that Finland and Germany lead the way with 14 and 12 articles, respectively. We also highlight Austria with eight articles, while Norway and the UK have four articles each, as shown in Table 2. The choropleth map, shown in Fig. 3, provides a clearer understanding of the geographical concentration of the articles. It is worth noting that the sum of articles presented in Table 2 surpasses the total number of articles, as articles may involve authors from multiple countries – underscoring the international collaboration within the research community in this field.

Events

Our research found 214 events in the EJFR publications. The most events (162 or 76%) were found in round years, with 29 events in 2020, 51 in 2030, 20 in 2035, 14 in 2040, and 44 in 2050. We found only three events for 2080 and one for 2100. We present the number of events by year in Fig. 4. We conjecture that researchers are biased in estimating the date, rounding the year to a multiple of 5 – or even 10 for long-term projections – to make the future events more impactful or enhance future initiatives' visibility. This tendency to round estimates is particularly prevalent in long-term projections, where their precision is expected to be lower than in short-term projections. Long-term predictions introduce greater uncertainty with the possibility of unforeseen events and the inherently chaotic nature of future developments due to their extended timeframe.

The top 10 publications with the most events contain 120 (56%) out of 214 events. On the other hand, 22 of the 53 articles have only one event. We present the complete list of publications with events in Table 3.

Still on the top 10 publications, we can identify three groups of events. The first group concerns political and social trends in global security, and it includes four articles. The article with the most events identified (27) is a meta-study of perspectives in Europe and North America about the future of global security [14]. Other articles explore sociotechnical imaginaries of a secure future [17], perform a foresight about addiction and lifestyles in Europe [21], and analyze the magnitude and persistence of instability trends in the European Union,

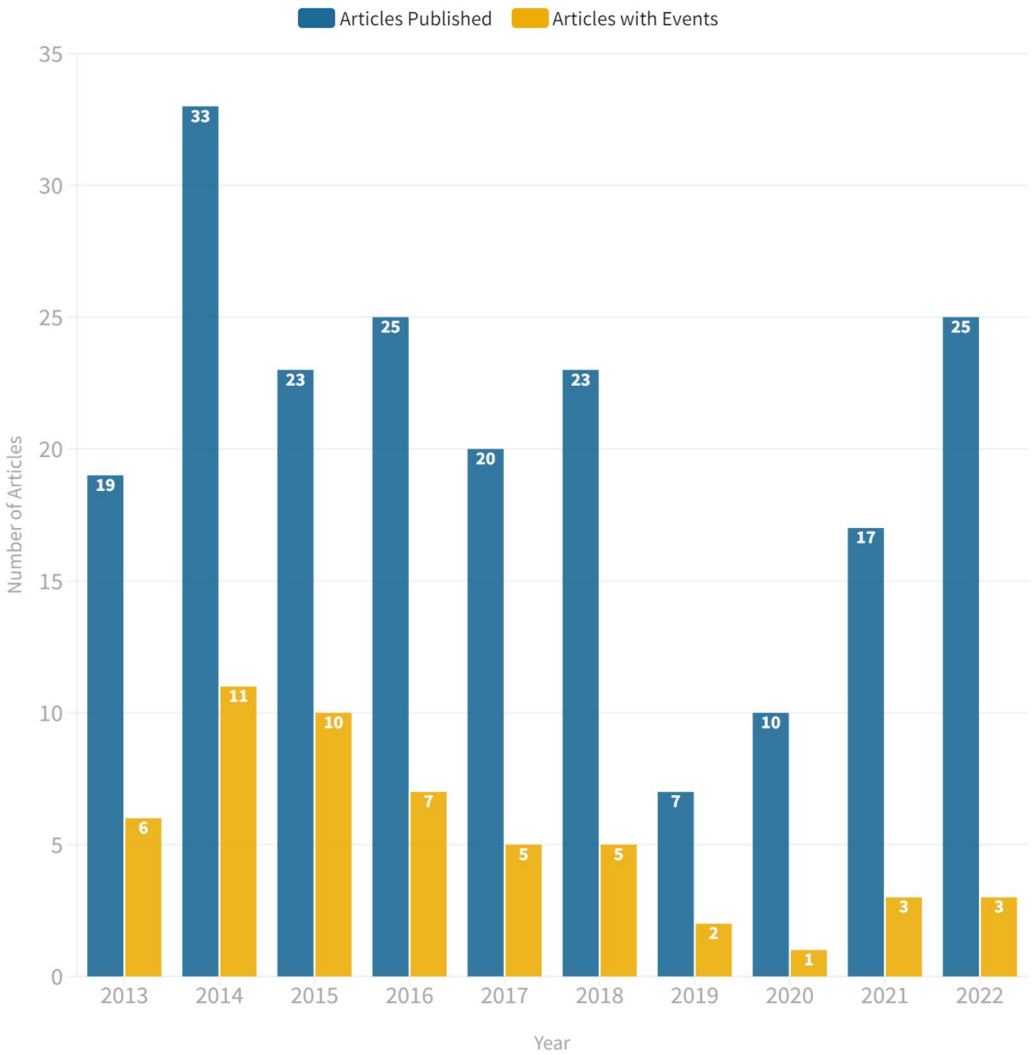

Fig. 2 Total of published articles and articles with events per year

including social, economic, and political impacts on the EU member states [20].

The second group is concerned with CO2 reduction in transportation and mobility. It includes five articles examining the transformation in transportation [16] and the related costs and benefits of reducing CO2 emissions in this sector [15]. These articles delve into topics such as the impact of autonomous cars on low-carbon mobility [22] and the transition towards biofuels in Finnish road transport [19] while producing scenarios for a resource-efficient and sufficient future mobility system for improved well-being in Europe [23]. These articles comprehensively examine the transportation sector's challenges and opportunities as it moves towards more sustainable and efficient practices.

The remaining article on the top 10 concerns scenarios for the future of European industries, including a single article [18] focusing on the future and governance of the chemical industry. This article offers a valuable look at the future of a critical European industry and the impact that various factors may have on its development and stability.

We also organized a heatmap to find and highlight correlations between the year of publication and the year of the future event, as shown in Fig. 5. We limited the heatmap to 2050 due to the sparsity of the events between 2051 and 2100 – a total of five events, one for 2052, three for 2080, and one for 2100. In the case of events projected for 2020, the majority were anticipated in articles published between 2014 and 2016. Looking at 2030, we observed a distribution of events across various years, with the highest concentration between 2013 and 2018, ranging from 8 to 14. In the

Table 2 Publications with events by country of research

Country	Number of Articles
Austria	8
Australia	1
Belgium	2
Finland	14
France	2
Germany	12
Hong Kong	1
Iceland	1
India	1
Israel	3
Netherlands	3
Norway	4
Singapore	1
Slovak Republic	1
Slovenia	1
Spain	3
Sweden	1
Switzerland	2
UK	4
USA	1

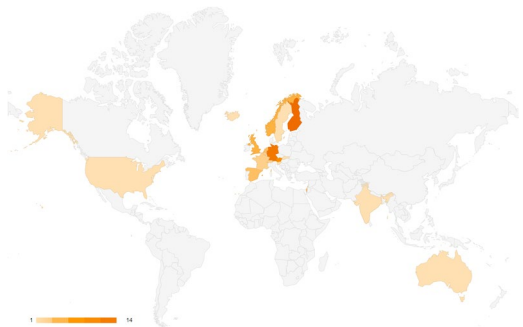

Fig. 3 Map of publications with events by country of research

case of 2035, two specific years, 2017 and 2021, stood out as having the highest number of events, indicating that a few articles are making the most expected possible events. For 2040, the number of events decreased, with the earliest articles with events starting only in 2017. For 2045, all expected possible events were found in articles from 2017. Lastly, for 2050, all the events gathered were published in articles from 2014 to 2019.

Our analysis of events in the EJFR publications found a wide range of events falling into the 14 categories we established in Table 1. We summarize the events seen in Fig. 6.

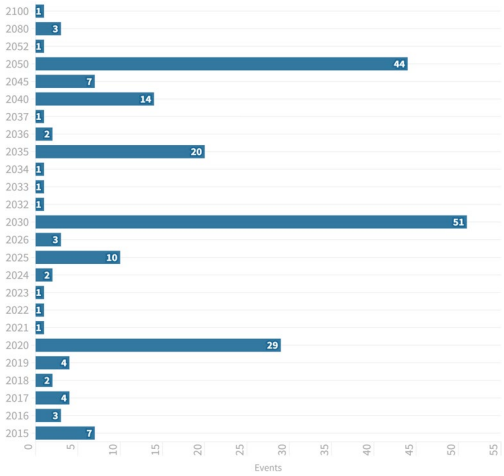

Fig. 4 Events per year

We found the most significant occurrences starting with technological events, with 38 expected possible events in articles. This high number reflects technology's rapidly changing and advancing nature and underscores the importance of understanding its impact on society.

Environmental events took the second spot with 36 occurrences. This number highlights the concern about the impact of human activity on the natural environment and the pressing need to understand and understand its consequences.

Next is the demographic category, where we found 32 events. This number suggests a strong interest in understanding trends and changes in population characteristics and their impact on various aspects of society. Economic events also garnered significant attention, with 25 expected possible events in articles. These events likely encompass changes in employment rates, economic growth, and income inequality, reflecting the profound impact of the economy on people's lives and the overall functioning of society.

Social events totaled 16, followed by industrial and infrastructure events, with 13 occurrences each. These numbers indicate a moderate interest in these areas, encompassing changes in societal dynamics, manufacturing trends, and the functioning of critical systems like transportation networks and energy grids.

Political, government, and education had nine events each. The fewer events in these categories could indicate less focus on anticipating changes in government policies or the education system, suggesting they might not be as extensively covered as other areas.

In the lower end of the spectrum, military events account for five occurrences, while legal and health events tie at four

Table 3 Number of events per publication

Year	Title	Events	Reference
2017	Political and social trends in the future of global security. A meta-study on official perspectives in Europe and North America	27	[14]
2018	CO2 reduction costs and benefits in transport: sociotechnical scenarios	22	[15]
2014	Transformation in transportation?	14	[16]
2021	Sociotechnical imaginaries of a secure future	11	[17]
2013	Scenarios for the future of the European process industry - the case of the chemical industry	10	[18]
2015	Participatory and prospective value network analysis: supporting transition towards biofuels in Finnish road transport	8	[19]
2014	We are family? governance and the prospects for instability in Europe	8	[20]
2013	Foresighting addiction and lifestyles in Europe 2030+	7	[21]
2015	The autonomous car—a blessing or a curse for the future of low carbon mobility? An exploration of likely vs. desirable outcomes	7	[22]
2015	A resource-efficient and sufficient future mobility system for improved well-being in Europe	6	[23]
2016	Using strategic foresight methods to anticipate and prepare for the jobs-scarce economy	6	[24]
2021	Five transition pathways to renewable energy futures—scenarios from a Delphi study on key drivers and policy options	5	[25]
2019	How much can societal turning points affect forecasts' accuracy in Europe? Case of post-communistic transformation in Slovakia and the Czech Republic	5	[26]
2014	Innovation in higher education; will there be a role for "the academe/university" in 2025?	5	[27]
2015	The changing nature of city tourism and its possible implications for the future of cities	5	[28]
2017	Futuribles of learning 2030 - Delphi supports the reform of the core curricula in Finland	4	[29]
2014	Living within the safe operating space: a vision for a resource efficient Europe	4	[30]
2014	Two futures: EU-Russia relations in the context of Ukraine.	4	[31]
2018	Urban energy futures: a comparative analysis	4	[32]
2017	Disquieting uncertainty. Three glimpses into the future	3	[33]
2017	Food safety and nutrition – how to prepare for a challenging future? New approaches for using scenarios for policy-making	3	[34]
2019	Hybrid leadership councils: envisioning inclusive and resilient governance	3	[35]
2016	Scenarios for crime and terrorist attacks using the Internet of things	3	[36]
2013	Scenarios for selected maritime economic functions	3	[37]
2014	The future of individualization in Europe: changing configurations in employment and governance	3	[38]
2014	Democratization and elitism in the EU: two opposing trends (Guest-Editor's introduction to the topical collection on "The Future of Europe")	2	[39]
2014	Leadership in the sixth wave—excursions into the new paradigm of the Kondratieff cycle 2010–2050	2	[40]
2013	Limits to prediction: Europeanizing technology in an expert forum	2	[41]
2016	Peer-to-peer work in the digital meaning society 2050	2	[42]
2018	Satellite solar wireless power transfer for baseload ground supply: clean energy for the future	2	[43]
2013	Scenarios to explore the futures of the emerging technology of organic and large area electronics	2	[44]
2014	Controversial futures—discourse analysis on utilizing the "fracking" technology in Germany	1	[45]
2021	Data-driven smart eco-cities and sustainable integrated districts: A best-evidence synthesis approach to an extensive literature review	1	[46]
2020	Development of a circular economy and evolution of working conditions and occupational risks—a strategic foresight study	1	[47]
2018	Drivers, trends and scenarios for the future of health in Europe. Impressions from the FRESHER project	1	[48]
2016	Educational change, inertia and potential futures: Why is it difficult to change the content of education?	1	[49]
2015	EU mobility partnerships: a smart instrument for the externalization of migration control	1	[50]
2018	European Business Ethics agenda based on a Delphi analysis	1	[51]
2014	European packaging industry foresight study—identifying global drivers and driven packaging industry implications of the global megatrends	1	[52]
2016	Forecasting potential innovation activities in high-tech industries triggered by merger and acquisition deals: a framework of analysis	1	[53]
2016	Human centred science and technology—transdisciplinary foresight and co-creation as tools for active needs-based innovation governance	1	[54]

Table 3 (continued)

Year	Title	Events	Reference
2015	Integrating Delphi methodology to some classical concepts of the Boston consulting group framework: arctic maritime technology BCG Delphi foresight—a pilot study from Finland	1	[55]
2014	Neglected futures. Considering overlooked poverty in Europe	1	[56]
2022	Radical Technology Inquirer: a methodology for holistic, transparent and participatory technology foresight	1	[57]
2013	Requirements for innovation policy in emerging high-tech industries	1	[58]
2022	Stage performances as means for linking sociotechnical imaginaries and projective genres in the discourse around urban air mobility	1	[59]
2017	Surprise as the new normal – implications for energy security	1	[60]
2015	Technopolis, shared resources or controlled mobility? A net-based Delphi-study to explore visions of future urban daily mobility in Norway	1	[61]
2016	The ambiguity of intelligent algorithms: job killer or supporting assistant	1	[62]
2015	The futures Map and its quality criteria	1	[63]
2015	The Radical Technology Inquirer (RTI) tool for technology anticipation and evaluation: introduction and quality criteria analysis	1	[64]
2015	Wild cards in transport	1	[65]
2022	Young people's technological images of the future: implications for science and technology education	1	[66]

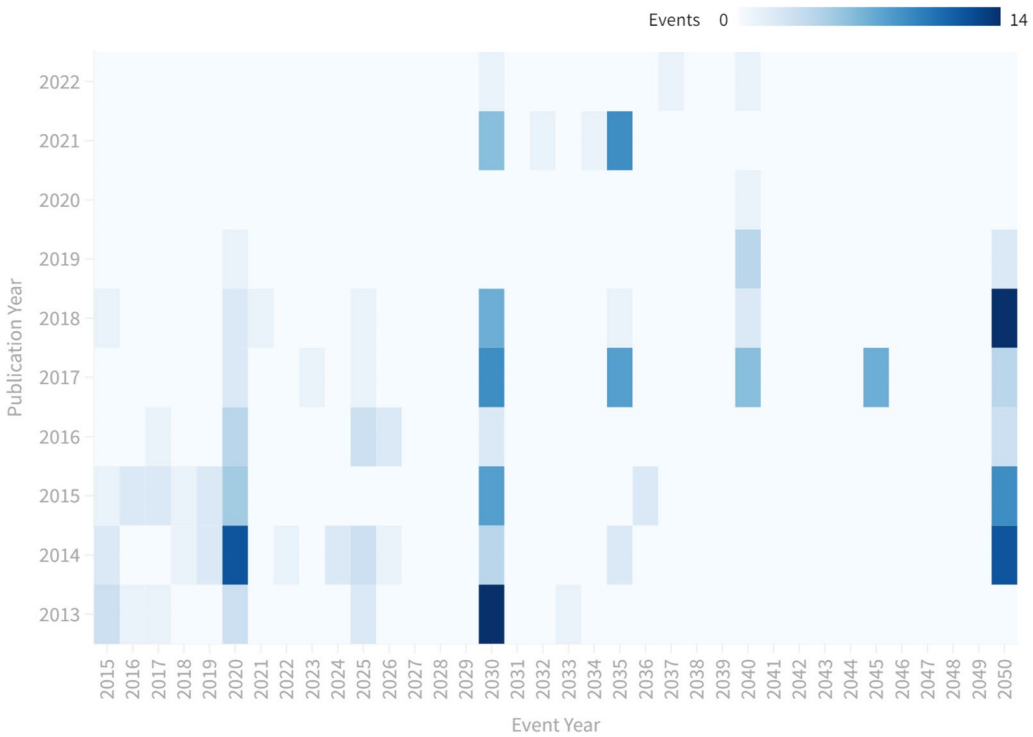

Fig. 5 Publication Year x Event Year (limited to 2050) heatmap

occurrences each. At the bottom, We found a single agricultural event. These numbers may suggest a comparatively lower focus on anticipating changes in laws and regulations or health outcomes, as well as the actions of defense and security agencies.

Finally, with the agricultural category, we found only one event related to food production and crops. This low number could indicate that few articles focused specifically on this area or that the expected possible events were not significant enough to be noted.

In summary, the events are ordered in descending order of occurrences, highlighting the varying degrees of attention and interest in anticipating changes across different categories. Overall, our analysis of events in the EJFR

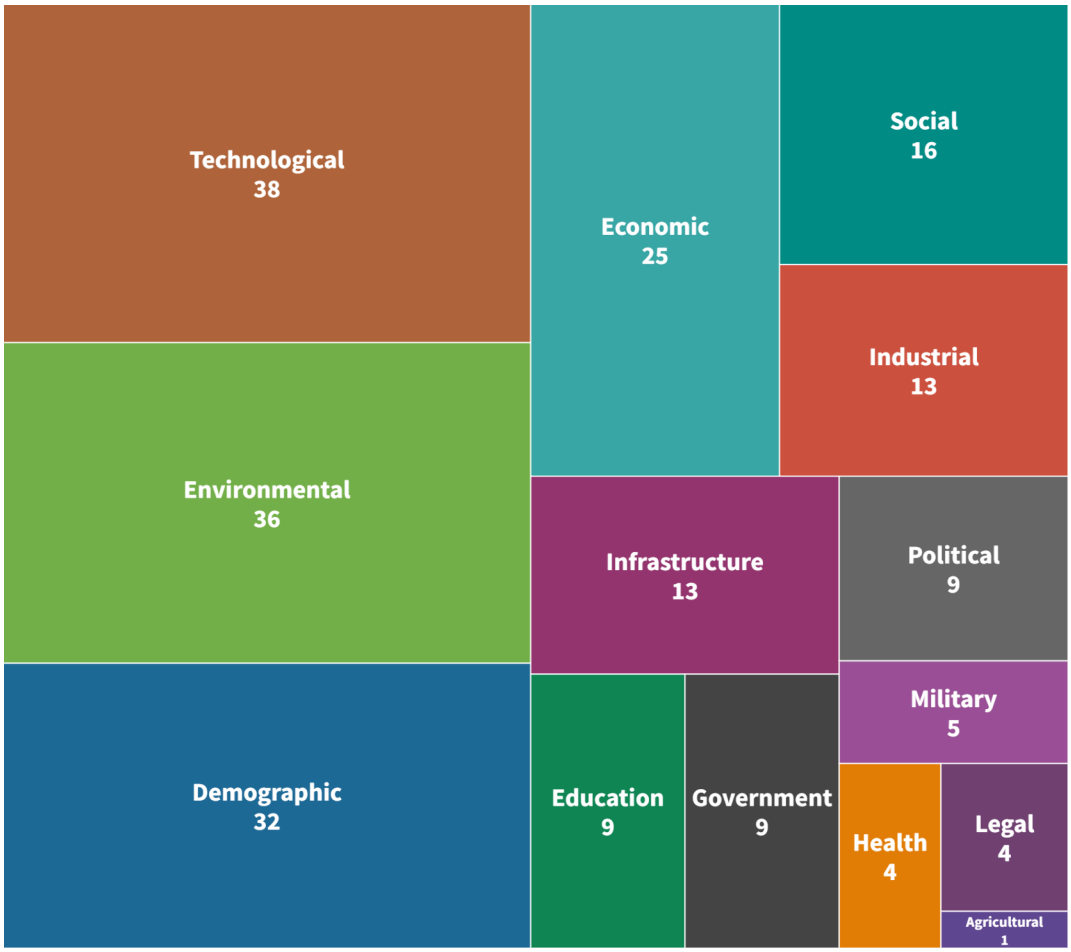

Fig. 6 Event by category

publications suggests a diverse range of expected possible events, reflecting various interests and concerns about the future. Some areas, such as technology and environment events, received significant attention, while others, such as legal and military events, were less emphasized.

Roadmap

We can summarize our analysis in the complete roadmap shown in Appendix A. We list the events found, ordered by year, classifying each event according to the categories described in Table 1. This section presents the future events (starting in 2024) associated with a specific scenario. Future events expected to happen until 2023 are discussed and analyzed in the Fact-checking past predictions section. In the *Green Renaissance* scenario (Appendix B), efforts to combat climate change led to significant investments in renewable energy and energy efficiency. In the *Digital Divide* scenario (Appendix C), the world becomes increasingly divided between those with access to technology and those without access. In the *Populist Backlash* scenario (Appendix D), a rise in nationalism and protectionism challenges the democratic order. Technology creates new forms of addiction, alienation, and inequality in the *Techno-dystopia* scenario (Appendix E). Multiple crises and conflicts challenge the global order in the *Geopolitical Turmoil* scenario (Appendix F). We present all scenarios in detail in the Scenarios section.

Roadmap analyses

In this section, we performed analyses based on different time horizons. The first analysis focused on fact-checking the expected events by the end of 2023 and understanding how they may impact society in the short term. We critically examined the available information about these expected possible events and evaluated the likelihood of their occurrence. The second analysis explored the events expected to happen until 2100, a much broader time horizon with more uncertainties and variations in potential scenarios. We examined long-term trends and potential events that

may shape the future, considering different variables such as technological advancements, climate change, demographic shifts, and economic changes. Using this information, we assembled scenarios to understand how the future may unfold and the implications for different sectors of society. We expect to provide valuable insights to help individuals and organizations prepare for future challenges.

Fact-checking past predictions

This section provides a detailed and comprehensive analysis of events expected to occur until the end of 2023. We verify whether these predictions came to fruition using the most reliable source available. We used official statistics and news to verify each event's development and actual outcome, as shown in Table 4. This analysis aims to provide a clearer understanding of the actual context surrounding each event. We have not judged whether the expected possible events occurred, as in Futures Research, events often unfold slightly differently than expected. Attaining an exact prediction of an event is rare.

During our fact-checking process, we prioritize three primary sources of information. Firstly, we analyze the official source, considered the most reliable and our gold standard. Secondly, we reference academic papers for relevant data. Thirdly, we consult news outlets and data aggregators. If no official information is available, we prioritize recent peer-reviewed articles. Finally, we rely on news coverage for events not notable in academic literature.

As expected, in the fact-checking analysis findings, we highlight that only a few events occurred *exactly* as expected in the articles. Among the rest, a significant portion aligns with the expectation to some extent but falls short of achieving the stated goal. Another substantial group comprises events that simply did not occur. Finally, a smaller subset consists of events that failed to happen and manifested in a manner opposite to what was anticipated.

However, this should not be seen as a critique of the Futures Research field, as this area of research deals with uncertainties for anticipating and mitigating problems. There are several reasons – in our understanding – for a part of the missing events. The first is the paradox of preparedness [159], which suggests that the more extensively we prepare for a negative event, the lower the likelihood of its occurrence. The second is the COVID-19 pandemic, a wildcard that impacts all expected possible events for 2020, 2021, and 2022. The third is that several events collected came from alternative (often contradictory) scenarios within the same exploratory article, which invariably causes a lower occurrence. Therefore, we must always take isolated events skeptically – understanding the trends that drive the world can be more important than predicting isolated events right for decision-making.

Additionally, it's crucial to emphasize the need for regular assessments in Futures Research. These assessments act as crucial checkpoints, refining forecast models and enhancing our understanding of future events. By consistently comparing expected outcomes with real-world happenings, researchers improve short-term forecasts and enhance their understanding of future trends. Integrating these assessments into foresight frameworks implements a validation and calibration system, strengthening the reliability of foresight tools. Through rigorous assessment practices, we acknowledge the inherent uncertainties of foresight and gain valuable insights into how our world operates.

Scenarios

In this section, we examine five possible future scenarios that may influence the course of our world. These scenarios are not tied to specific timeframes, as the contributing events occurred at different times. Based on the collected events, these scenarios should be viewed as potential directions our society could take. We built scenarios based on the events in the roadmap, using literature-based design fiction [13]. According to Cox [13], while "fictions are the output themselves," they are employed to gather research data and often include the public to raise awareness. Design fiction in the literature [160, 161] aims to raise questions by showing a future speculative scenario. Each scenario represents a relevant grouping of events. Although some events could be associated with multiple scenarios, we associate each event with a single scenario, as seen in Appendix A. We also highlight that our future landscape will likely amalgamate elements from multiple scenarios. Rather than following strictly one predetermined path, our evolving reality will integrate facets from various potential trajectories. Therefore, we expect the unfolding narrative to be nuanced and multifaceted, reflecting the complexity of shaping our future. These scenarios offer a glimpse into the possible futures we may face and the challenges and opportunities they present.

Green Renaissance

A global consensus on climate change leads to unprecedented investments in renewable energy and energy efficiency. The EU, the US, and China are transitioning to a low-carbon economy, creating new industries and green jobs. The public and private sectors collaborate to create innovative technologies, such as carbon capture and storage, smart grids, and advanced batteries. However, not all

Table 4 List of events expected to happen until 2023 and their actual outcomes

Year	Event	Actual Outcome
2015	Emerging markets make 26% of the European steam cracker capacity unprofitable. Steam Cracking is the petrochemical process in which saturated hydrocarbons are broken down into smaller, often unsaturated, hydrocarbons [67].	According to data from S&P Global, the utilization rates in European refineries were reported to be 86% [68]. The European steam cracker growth was expected to be less heavy than in 2019, so supply in the first half of 2020 would be healthy and not heavy, given the weak macroeconomic environment [69].
2015	Europe will have WiFi everywhere.	Data from Eurostat show that WiFi was available in many parts of Europe, but it was not available everywhere. Many rural areas still did not have access to WiFi, and some urban areas had spotty coverage. In 2021, high-speed internet coverage in rural areas reached 37% [70].
2015	About 80% of Europeans will have small computation devices with touch screens.	Except for China, which achieved above 80%, other countries did not reach 80% of smartphone adoption [71].
2015	Additional costs for plug-in hybrid and battery electric car is 16,500€. For hydrogen cars, additional costs sum up to 35,000€.	In 2021, according to the Argonne National Laboratory [72], hybrid electric vehicles (HEVs) are the most affordable choice in most cases, followed by battery electric vehicles (BEVs). However, BEVs become more economical when considering factors like a midsize car instead of a small SUV, used vehicles, long drives, or tax credits. Internal combustion engine vehicles (ICEVs) are never the cheapest option when considering the total cost of ownership. If owned for five years and driven lightly, an ICEV can be cheaper than a similar HEV. On the other hand, a BEV owned for five years is usually the most expensive unless it's driven significantly more than average. Generally, HEVs become cost-competitive in about five years, with fuel cell electric vehicles (FCEVs) and BEVs trailing closely based on hydrogen and battery cost changes.
2015	Year of peak oil extraction.	The IEA's World Energy Outlook 2016 report [73], which provides data on global energy trends, showed that global oil production continued to increase after 2015. Oil production reached a record 97.3 million barrels per day (mb/d) in 2015, and according to data from the US Energy Information Administration (EIA), global oil production reached a record 100.3 million barrels per day (b/d) in 2019 before falling to 91.6 million b/d in 2020 due to pandemic.
2015	According to the law, the share of biofuels in the fuel mix delivered by the service stations should be at least 8%.	According to the Annual Energy Outlook 2021 report [74], the share of biofuels in the fuel mix was 8.00% in 2015.
2015	The demand for additional ICT practitioners in the EU is estimated to increase, reaching 500,000.	According to Eurostat [75], the EU's estimated number of ICT specialists rose from 6,328,400 in 2014 to 6,550,200 in 2015.
2016	The market opportunities for the transparent conducting oxides, polymers, and nanomaterials used in displays, photovoltaics, and other applications exceed 6.9 billion US dollars in revenues.	Different sources disagree about the Transparent Conductive Film Market revenue. They reported revenue of 4.7 billion US dollars in 2018 [76], 5.6 billion US dollars in 2019 [77], and 4.6 billion US dollars in 2020 [78]. However, all values are below the estimated 6.9 billion US dollars for 2016.
2016	Exclusive use of biometric passports.	All EU countries, except for Ireland and Denmark, must issue biometric passports as a standard requirement for all citizens. However, Ireland and Denmark are the only countries not required to contain fingerprint biometrics, although this will likely change soon [79].
2016	According to the law, the share of biofuels in the fuel mix delivered by the service stations should be at least 10%.	According to the Annual Energy Outlook 2021 report [74], the share of biofuels in the fuel mix was 8.36% in 2016.
2017	The market potential for printed electronics will increase to US$48.2 billion.	Data from the Market Research Report shows that the global printed electronics market, in terms of revenue, was estimated to be worth USD 9.9 billion in 2021 and is poised to reach USD 23.0 billion by 2026 [80].
2017	The unemployment rate in India will increase to 7.5%.	According to Macro Trends [81], with data from the World Bank, India's unemployment rate for 2017 was 5.36%.
2017	Gothenburg, in Sweden, aims to have 100 self-driven cars.	Volvo's "Drive Me" project delivered the first self-driven car [82] and got the approval for the tests granted [83, 84] in 2019.
2017	According to the law, the share of biofuels in the fuel mix delivered by the service stations should be at least 12%.	According to the Annual Energy Outlook 2021 report [74], the share of biofuels in the fuel mix was 8.33% in 2017.
2018	Germany and Italy, the EU's first and third largest gas markets, are planning new LNG facilities, and the US is expected to begin exporting LNG at scale.	Germany deployed floating terminals by the end of 2022, responding to Russia's invasion of Ukraine [85]. Besides, operations have already commenced at the Wilhelmshaven and Lubmin LNG terminals. The Brunsbüttel LNG terminal is expected to start operations shortly, initially accommodating 3.5 Bcm/year and increasing to 7.5 Bcm/year between 2024 and 2026 [86]. Italy inaugurated the Livorno terminal in 2015 [87] and the Piombino terminal in 2023 [88]. In 2022, Italy approved the expansion of the Livorno terminal, and the Ravenna terminal is expected to become operational by the end of 2024 [89]. The US has started exporting LNG at scale and became the world's largest LNG exporter during the first half of 2022, surpassing Qatar and Australia [90].

Table 4 (Continued)

Year	Event	Actual Outcome
2018	According to the law, the share of biofuels in the fuel mix delivered by the service stations should be at least 15%.	According to the Annual Energy Outlook 2021 report [74], the share of biofuels in the fuel mix was 8.18% in 2018.
2019	Fully autonomous cars are expected to be deployed	Volvo's "Drive Me" project delivered the first self-driven car [82] and got the approval for the tests granted [83, 84] in 2019. California launched the Autonomous Vehicle Tester (AVT) Driverless Program in 2018 [91], while Oxbotica's project Driven started Level 4 Autonomous testing in Oxford in 2020, among other initiatives. However, their fully autonomous cars still cannot be used in cities.
2019	The share of anti-European parties, especially from the nationalist right-extremists, will increase in the next European Parliament.	The share of far-right, nationalist, and anti-immigration parties increased in the European Parliament in the 2019 elections but struggled to form a coherent bloc [92]. This trend has been stronger since then [93].
2019	Two-thirds of all adults living in the European Union will not participate in the elections to the European Parliament.	In 2019, the European Parliament elections had 198,352,638 votes counted [94], with a turnout of 50.66% [95].
2019	In the UK, the overall car use per person will increase by 1% compared to 2013.	Data from the UK Department for Transport statistics shows that the number of cars increased by 6.7%, from 0.60 cars/adult in 2013 to 0.64 cars/adult in 2019 [96].
2020	The joint economic product of the EU and the US declined to approximately 30% of the world GDP, while China alone should rise to 19%.	According to the World Bank, the US GDP in 2020 was 21.06 Trillion USD [97], while the EU GDP was 15.37 Trillion USD [98]. Finally, the world's GDP was 85.22 trillion USD [99]. Therefore, the joint EU and US GDP corresponded to 42.74% of the World GDP in 2020. Meanwhile, China's GDP was 14.69 trillion USD [100], representing 17.23% of the world's GDP in 2020.
2020	Google's autonomous car will go into mass production.	In 2019, Waymo announced a partnership with American Axle & Manufacturing in Detroit to retrofit Chrysler Pacifica minivans for its robotaxi fleet, which is already operating in Arizona [101]. Despite the tests on the roads with different car models, Waymo has focused on the safety of these vehicles, even if it takes longer to reach commercialization [102].
2020	About 50.1 billion objects will be connected to the IoT.	There were approximately 12 billion IoT devices. This number surpassed non-IoT for the first time but did not reach 50.1 billion [103].
2020	Natural gas will replace the coal consumption in local power plants with natural gas. Hong Kong would import natural gas through a long-distance pipeline from central Asia and by liquefied natural gas arriving by ship from gas fields in the region and overseas.	Europe made efforts to substitute its coal consumption for natural gas. In 2019, the European Union already implemented policies and measures to reduce greenhouse gas emissions and promote the transition to cleaner energy sources [104]. However, the EU's coal consumption has risen since 2020 [105], before the Russo-Ukrainian War.
2020	The EU member countries will be bound to significant reductions in greenhouse gas emissions and increases in the use of renewable energy.	To tackle climate change, the European Parliament adopted the European Climate Law, which raises the EU's target of reducing net greenhouse gas emissions [106].
2020	The EU will facilitate the strengthening of the knowledge-based economy by investing EUR 80 billion through the Horizon 2020 program.	The European Commission has presented an €80 billion package for research and innovation funding as part of the drive to create sustainable growth and new jobs in Europe [107].
2020	The South Stream project, led by Gazprom and with major EU shareholders, will potentially provide 63 billion cubic meters of Russian-controlled gas directly to the EU.	The South Stream project was canceled by Russia in December 2014, which blamed the European Union [108].
2020	The demand for additional ICT practitioners in the EU is estimated to increase, reaching 900,000.	According to Eurostat [75], the EU's estimated number of ICT specialists rose from 6,328,400 in 2014 to 8,422,700 in 2020.
2020	LNG may not be a viable alternative to piped Russian gas. Still, the market is expected to mature to the point where it could offer an alternative during negotiations with Russia.	Germany's dependency on piped Russian gas lasted until 2022, when they ended their reliance on Russian gas due to the Russo-Ukrainian War [109].
2020	Approximately 90% of the world's population will have access to mobile broadband networks.	93% of the world population has access to a mobile broadband network, less than half a percentage point higher than a year ago [110].
2020	Policies to increase local government and community ownership of electricity grids will support the overall vision.	In 2019, according to the Council of European Energy Regulators [111], energy communities' ownership of grid infrastructure remains optional for member states. In 2022, the European Commission launched the Energy Communities Repository [112] to assist local actors and citizens willing to set up a Citizens Energy Community or a Renewable Energy Community. However, such initiatives have not yet brought a significant portion of electricity grids under local government or community ownership.

Table 4 (Continued)

Year	Event	Actual Outcome
2020	Connected devices will increase from 5 to around 25 billion, with a significant portion coming from automotive-related devices.	There were approximately 10–11 billion connected devices, with a significant portion coming from automotive-related devices [113].
2020	There will be an increase in the use of renewable energy to 15% in China – compared to 9.5% in 2008 – of the total and specific targets for reducing energy consumption and CO2 emissions.	In early 2020, renewable energy comprised about 40% of China's installed electric power capacity and 26% of total power generation. By 2021, it had grown to 29.4% of total power generation. The share of renewables in total power generation is expected to increase to 36% by 2025 [114]. However, China's CO2 emissions have been growing since 2015 [115], partially due to China's rapid economic growth, which causes an increased demand for energy.
2020	There will be a ratio of non-fossil energy to primary energy consumption of 11.4% in China, decreasing energy consumption per unit of GDP by 16% and reducing carbon dioxide emissions per unit of GDP by 17%.	The event is part of the China's 12th Five-Year Plan (2011–2015) main targets [116]. The proportion of non-fossil energy in total power generation was 27.2% in 2015 [117]. In 2020, the electricity consumption of the primary industry was expected to be 85.9 billion kWh, a year-on-year increase of 10.2% [117]. However, China's energy consumption grew faster than expected, outpacing the supply chain's ability to meet demand [118]. In 2021, households and businesses experienced power outages in multiple north-east provinces [119]. According to the World Bank, China's carbon dioxide emissions per unit of GDP decreased from 0.68 kg in 2010 to 0.55 kg in 2015 and 0.45 kg in 2020 [120].
2020	Most of the world's top 20 mega-cities will be in non-OECD countries.	The world's top 20 megacities in 2020 were: Tokyo (Japan), Delhi (India), Shanghai (China), São Paulo (Brazil), Mexico City (Mexico), Cairo (Egypt), Mumbai (India), Beijing (China), Dhaka (Bangladesh), Osaka (Japan), New York-Newark (United States), Karachi (Pakistan), Buenos Aires (Argentina), Chongqing (China), Istanbul (Turkey), Kolkata (India), Manila (Philippines), Lagos (Nigeria), Rio de Janeiro (Brazil), and Tianjin (China) [121]. According to the list of countries belonging to the OECD [122], only Tokyo, Mexico City, Osaka, New York, and Istanbul are in OECD countries. The majority are in non-OECD countries.
2020	China is expected to have 500 new mid-sized cities.	As of June 2020, the PRC has a total of 687 cities. According to China's 7th National Population Census, among 297 cities analyzed, there are 17 megacities, 73 super large cities, 107 Type-I large cities, 79 Type-II large cities, and 21 medium and small-sized cities [123].
2020	Smartphone subscriptions are forecast to have more than doubled, and 70% of the world's population will own a smartphone.	Smartphone users reached 5.22 billion by the end of 2020, representing 66% of the world's population [124].
2020	Through energy technology and innovation, we will see a reduction in greenhouse gas emissions of 20% compared to 1990 levels.	Global GHG emissions dropped from 52.4 gigatons of CO2e in 2019 to 50.1 gigatons in 2020 but are still above 1990 levels [125].
2020	Through energy technology and innovation, we will see the share of renewable sources grow to 20%.	According to Eurostat [126], the EU's share of renewable sources in 2020 was 22.1%. However, the global share is still around 10% [127].
2020	Individuals who have access to resources can and will make decisions about the size of their families. However, programs that support these decisions are underfunded, impacting low-income families.	The United Nations Population Fund (UNFPA) [128] states that 232 million women in developing countries want to prevent their pregnancies but are not using modern contraceptives. The global cost for ending unmet needs is 0.20 cents per person per day between 2020 and 2030, from about $6.3 billion annually by 2020 to about $10.8 billion annually by 2030 [128].
2020	The Finnish biofuel production pursues the target to achieve a 20% share of renewables in transport.	EU achieved the 2020 renewable energy in transport target of 10% (including liquid biofuels, biomethane, and 'green' electricity). Finland was the second among the EU member states, with 13.4% [129].
2020	People affected by poverty and social exclusion are reduced by 20 million through poverty policy programs in line with the EU strategy.	In 2014, the EU population was around 442.88 million, and 27.8% (approximately 123 million) of people affected by poverty and social exclusion were reported in the EU-28 [130]. In 2020, 96.5 million people in the EU were at risk of poverty or social exclusion, representing 21.9% of the population – a reduction of more than 26 million people [131].
2020	Achieve zero emissions from fossil fuel power plants through EU and member state research support and industry investment in Carbon Capture and Storage to stimulate public understanding of the safety and reliability of the technology and its benefits.	Carbon Capture and Storage can be applied to industrial installations, such as cement or steel plants and power plants [132]. EU's Innovation Fund and Horizon EU support research, development, and innovation for carbon capture and storage and carbon and utilization technologies to boost further industrial solutions' deployment to decarbonize Europe [132]. Data from the European Environment Agency [133] show a decline in emissions from large combustion plants between 2004 and 2021: sulfur dioxide (SO2) and dust by 92%, and nitrogen oxides (NOx) by 70%, while the amount of fossil fuels used decreased by 35%.
2020	New regulations that require a 20% contribution of biofuels to transport energy reduce the CO2 content of gasoline and diesel to 193 g/kWh and 231 g/kWh, respectively.	The CO2 content in gasoline was 66.8 g/MJ (approx.: 240 g/kWh) with a default 9% biofuel share, and in diesel, it was 63.9 g/MJ (approx.: 230 g/kWh) with a default13% biofuel share [134].

Table 4 (Continued)

Year	Event	Actual Outcome
2020	We will have 75 billion networked devices.	There were approximately 10–11 billion connected devices, with a significant portion coming from automotive-related devices [113].
2020	About 5% of the world's precious minerals, including cobalt, copper, zinc, and rare earth, can come from ocean floors.	In 2023, the International Seabed Authority (ISA) failed to establish a regulatory framework for deep-sea mining. Therefore, companies can apply for licenses before the final rules [135]. The Metals Company intended to apply for mining the deep seafloor after the July 2024 ISA meeting [136]. There are several known resources of manganese nodules, Cobalt-rich ferromanganese crusts, and metal-sulfur compounds in the deep sea [137], while new mineral resources are still being found [138]. Marine biologists claim that the damage mining causes to the seafloor will be "irreversible" [136]. Among this environmental discussion, deep-sea mining hasn't started yet [139].
2020	International tourist arrivals worldwide are expected to rise to 1.4 billion people, compared with 1.1 billion in 2014.	International tourist arrivals worldwide dropped sharply in 2020 to approximately 406.89 million due to the COVID-19 pandemic and only recovered in 2022. Despite the significant annual increase, international tourism arrivals remained below pre-pandemic levels, totaling approximately 963 million in 2022 [140].
2020	Enrollment numbers significantly declined, and second-tier universities needed to change their model of provision quickly to stay viable.	According to the National Center for Education Statistics [141], 4-year college enrollments had 10.4 million students in 2010 and 11.0 million in 2020 in the US. However, 2-year college enrollments significantly decreased from 7.7 million students in 2010 to 4.9 million in 2020. However, according to the OECD [142], the number of tertiary students in member states increased 1.45% between 2015 and 2019. EU data show an increase from 17.2 million enrollments in 2015 to 18.0 in 2020 [143]. The data suggests that the struggle of higher education institutions is a US phenomenon. The high costs of a degree associated with the economic crisis and lower birth rates are among the reasons for the decline in students [144, 145].
2020	Universities are shrinking their offerings.	During challenging periods, universities often reduce the number of courses they offer and raise tuition fees [146, 147]. In the US, the trend for eliminating course offerings and closing campuses occurred before [146, 147], during [148], and after [149–151] the COVID-19 pandemic. The enrollment in 2-year colleges decreased from 7.7 million students in 2010 to 4.9 million in 2020 [74]. In the UK, university enrollments increased by around 10% between the 2019/20 and 2020/21 academic years despite COVID-19 [152].
2021	Stability and reduction in energy consumption of new passenger cars to 0.36 kWh/km (CO2 emissions 95 g/km) through advances in automotive technology.	In 2021, the manufacturer's CO2 performance was determined using the WLTP instead of the New European Driving Cycle (NEDC). The 95 g/km fleet-wide target above NEDC has been converted into manufacturer-specific WLTP targets based on the manufacturers' average vehicle mass in 2020 and 2021 and the manufacturers' average WLTP-to-NEDC CO2 emissions ratio in 2020. The European Environment Agency data [153] show that WLTP-weighted average CO2 emissions from new passenger car sales in 2021 were 115 g/km and 16 g/km (12%) lower than in 2020. Including flexible compliance mechanisms, emissions decreased by 2 g/km (1.7%).
2022	Germany aims for a drastic reduction in CO2 emissions and the termination of nuclear energy production.	Despite the reduction from 2014 (from 287.1 to 224.45 million metric tons), CO2 emissions have risen again since 2020 [154, 155]. In April 2023, Germany shut down its three remaining nuclear power plants, abandoning nuclear energy production [156].
2023	The processing capacity of computers will match that of the human brain.	The processing capacity of supercomputers is expected to match the scale of the human brain in 2024 with the launch of the DeepSouth, a neuromorphic supercomputer capable of performing 228 trillion synaptic operations per second [157, 158].

countries are willing to commit to the global consensus, and some conflicts arise over access to scarce resources.

In 2026, global oil production peaks, marking the onset of a decline [16]. Simultaneously, ethical and social concerns take center stage, extending beyond technical circles [49], while 2035 marks the peak of natural gas extraction [16]. By 2052, coal extraction peaks, signaling a shift in energy sources [16]. In 2080, Indonesia commences decommissioning nuclear power plants [32].

By 2030, China's energy mix reach about 30% of renewable energy production [16], and renewables cover three-quarters of the nation's energy needs, aligning with the European Union's target of 32% renewable energy [25]. Finland is undergoing a transformative shift with a drastic reduction in energy consumption due to improved efficiency. The European chemical industry retains its competitive position [18] while new initiatives in sustainable urban mobility

emerge [59]. The extra expenses associated with advanced vehicle technologies vary between 10,000€ and 15,000€, while the established CO2 reduction goals are set at 22% [15].

The year 2035 witnessed Finland achieving carbon neutrality [25], and Germany established legal guidelines for security technologies with ethical standards [17]. In 2050, there's a global shift away from fossil fuels, with renewable electricity nearing 50%. The length of the road and rail transportation network increases by 60%, while urban planning fosters alternative transportation methods [32]. European cities become more attractive, leading to a decrease in cars per household. Public transportation is expanded and free for all, while CO2 emissions from transport are reduced by 60% [23]. The decision-makers generation embraces post-material values [40].

In 2032, Germany incorporates the European Directive on the Ethical Use of Artificial Intelligence into its legal system [17]. By 2035, the price of autonomous vehicle technology will reach $3,000 [15].

Digital divide

The world is increasingly divided between the connected and the disconnected. While some countries have embraced the digital revolution, others are left behind due to a lack of infrastructure, poverty, or political reasons. Smart cities, autonomous vehicles, and the Internet of Things are transforming how we live and work and creating new challenges like privacy, cybersecurity, and job displacement. The rise of artificial intelligence and robotics further exacerbates the digital divide, as highly-skilled workers are in demand while low-skilled jobs are disappearing. The social and economic consequences of the digital divide are hard to predict, but they are likely to be significant.

In 2023, a significant technological milestone will be achieved as the processing capacity of computers matches that of the human brain [14]. The year 2026 marks a technological breakthrough with the growth of legged robotics [53].

By 2025, a global shift is expected, with an estimated 1.8 billion people residing in water-scarce areas due to climate change and population growth [51]. In the economic landscape, Asia dominates, accounting for 45% of the global GDP, primarily driven by having the largest fraction of the world's middle class [33]. However, this economic growth comes at the cost of technological advancements, with 100 billion networked devices expected to be used [36], potentially leading to widespread job displacement [42].

In 2030, a transformative era unfolds. Automation takes center stage, with robots, drones, and automatons poised to revolutionize daily life, from delivering parcels to serving food [62]. The education landscape is shifting, focusing on action-oriented competencies and diversely assessed meta-skills [29]. This period also witnesses a rise in international tourism, reaching 1.8 billion people globally [28]. By 2035, new regulations demand comprehensive impact assessments for security technologies, addressing ethical concerns and unintended side effects [17].

However, we still have global issues. In 2035, half of the world's population faces restrictions on water consumption [14]. By 2040, hydrocarbons remain dominant, supplying around 80% of global energy demand [14].

By 2040, technological advancements will become increasingly integrated with daily life, allowing devices to be operated through thoughts and showcasing the profound impact of brain-focused technology [66].

In 2050, demographic shifts will occur as the global population of 65 and older triples compared to 2012 [24]. European countries experience lifestyle changes, becoming less resource-intensive and more fulfilling [30]. Moreover, basic income policies have gained traction in several nations, though universal adoption is yet to be achieved [42].

Finally, by 2080, societal challenges will emerge as the population of those over the age of 80+will more than double in the EU compared to 2014 numbers. Meanwhile, fewer workers increase the burden of social support [20].

Populist Backlash

A populist backlash against globalism and multiculturalism is rising in many parts of the world. The EU, the US, and other countries are experiencing a surge in nationalism, protectionism, and xenophobia fueled by economic stagnation, immigration, and terrorism. Anti-establishment parties and leaders are gaining ground, challenging the liberal democratic order and the rules-based international system. The EU faces internal divisions over immigration, fiscal policy, and sovereignty, while the US retreats from its global leadership role. The rise of populism is creating a more fragmented and unstable world with unpredictable outcomes for trade, security, and human rights.

In 2024, the European security landscape faces challenges as the workforce shrinks and European workers disappear [20] while China and India emerge as global education and qualification powerhouses [40]. Uncertain economic developments in Europe occur despite

expected growth and recovery from the financial crisis in 2025 [37]. By 2030, a global workforce divide is projected, with 2 billion employed, 2 billion self-employed, 1 billion in the informal economy, 1 billion unemployed or in transition, and 2.5 billion people not part of the workforce [24]. Simultaneously, urbanization trends indicate that five billion people will inhabit urban areas [28].

In 2035, societal resistance to mass surveillance and a heightened awareness of data privacy are becoming prominent features [17]. Security technologies evolve to incorporate local demographics, urban structures, income statistics, and socio-cultural characteristics for crime predictions [17].

The year 2040 brings about significant demographic shifts and environmental challenges. Climate change leads to an estimated 220 million regional and transcontinental refugees [14]. Life expectancy in Slovakia and the Czech Republic surpasses that of Western European countries, and fertility rates stabilize at 1.5 to 1.6 children per woman [26].

By 2045, weak states struggling to govern their territories persist, contributing to political and social instability [14]. In 2050, there will be a substantial increase in transcontinental migrants, reaching 450 million, due to political, economic, or environmental reasons [14]. Meanwhile, Slovakia and the Czech Republic have the peak of their sexually active population, with a further decline in the birth rates [26]. Additionally, the likelihood of mass migration between the EU and the US shows a slight upward trajectory [65].

Techno-dystopia

Technology has created a new kind of dystopia in which humans increasingly depend on machines and algorithms daily. Smartphones, social media, and virtual reality have blurred the lines between reality and fiction, creating a new form of addiction and alienation. Surveillance, biometric identification, and predictive analytics are used to monitor and control people's behavior, leading to a new kind of authoritarianism. The divide between the rich and poor is widening as automation and robotics replace human workers, creating new forms of inequality and social unrest. The ethical and legal frameworks for regulating technology struggle to keep up with innovation, leading to unintended consequences and risks.

In 2030, the chemical industry rely heavily on oil-based raw materials while promoting sustainability as a key value driver. This dual emphasis reflects a delicate balance between traditional practices and a growing commitment to environmentally conscious approaches [18]. An eightfold increase in road vehicles in China compared to current numbers, signaling significant economic growth and a shift in transportation patterns [16].

Moreover, the year 2030 will witness the emergence of new fields, with their roots likely already visible, shaping various industries and redefining innovation [55]. Simultaneously, a substantial global increase in energy demand, dominated by fossil fuels in the power generation market, is projected [41]. Despite initiatives such as the EU Action Plan on Childhood Obesity, OECD projections indicate a concerning rise in obesity levels [34].

In 2033, the typical consumer utilizes the Internet for diverse activities, ranging from regular buying and gaming to purchasing psychoactive drugs and seeking recovery from addictions through telemedicine [21]. By 2035, criminal gangs exploit technology to identify lucrative targets, manipulating predictive police software and eroding public confidence in security technologies [17]. In the same year, law enforcement will heavily rely on technological solutions to combat various forms of crime [17].

In 2040, the Satellite Solar Power Station will become financially feasible due to reduced space launch costs, potentially revolutionizing the energy sector [43]. Simultaneously, world energy demand grow exponentially, emphasizing the persistent reliance on traditional energy sources [43]. However, technological advances in energy-saving and renewable energies fall short of curbing the increase in CO2 emissions during the 2030s [14].

In 2045, the processing capacity of computers become 100,000 times higher than the human brain's, signifying a significant milestone in technological development [14]. Finally, by 2050, European companies are set to employ sophisticated analyses such as material flow analysis and life-cycle assessments to inform business strategies, particularly concerning end-of-life product options [30]. Despite technological innovations, there have been no substantial reductions in emissions, underscoring the persistent challenges in achieving environmental sustainability [23]. Additionally, consumers take control of their diets using digital diet coaches [34].

Geopolitical turmoil

The world faces multiple crises and conflicts, ranging from terrorism and cyberwarfare to nuclear proliferation and territorial disputes. The EU, US, Russia, and China compete for influence and resources, creating new fault lines and alliances. The Middle East is still in turmoil, with multiple failed states and proxy wars. The Korean peninsula is on the brink of nuclear war, and the South

China Sea is a hotspot of tensions between China and its neighbors. The rise of non-state actors – such as terrorist groups and multinational corporations – challenges the global order, exploiting the weaknesses of the traditional state system. The risk of a major war or catastrophic event is high, and the international community struggles to find common solutions.

In 2030, projections indicate that approximately 10% of the world's precious minerals, such as cobalt, copper, zinc, and rare earth, could be sourced from ocean floors, reflecting a transformative shift in mineral extraction methodologies [37]. Simultaneously, the European Union faces a critical juncture as its fossil fuel reserves are about to be depleted, posing challenges to energy security and necessitating strategic policy adjustments [22]. China emerges as a pivotal player, poised to ascend to the world's leading economic position, presenting a paradigm shift in global economic dynamics with potential implications for geopolitical stability [14]. Moreover, European petrochemical investments of around 2.7 billion in Chinese plants signify a deepening economic interdependence between Europe and China, indicative of evolving global economic landscapes [18]. However, concerns arise over Europe's continued reliance on energy imports, accounting for 65 to 70% of its needs, potentially escalating geopolitical tensions centered around maritime trade routes essential for global commerce [14]. The European chemical industry experiences significant growth within this context, with total revenue reaching €477 billion, underlining its economic significance [18]. In the same year, challenges persist in the chemical industry, marked by a high dependency on oil and naphtha as primary raw materials, fostering market volatility and stimulating research endeavors for sustainable, non-oil-based processes [18]. The emergence of Asian dominance in the chemical sector underscores shifting dynamics in a multi-polar industry landscape, reflecting the globalization of economic forces [18]. Additionally, Sub-Saharan Africa's working-age population surpassing that of China suggests demographic shifts that may influence regional and global socio-economic dynamics [14]. Simultaneously, the world population surpasses 8 billion, signifying continued global demographic changes [14].

Fast forward to 2035, and the global liquefied natural gas trade is projected to surge by 46%, reflecting shifts in global energy consumption patterns [31]. Geopolitical tensions intensify as the United States contends with increasing competition from China while maintaining its position as the world's leading military power [14]. Demographic changes become more pronounced with a 50% rise in coastal population and the working-age population in Sub-Saharan Africa surpassing that of India, highlighting regional demographic complexities [14].

Moving into 2040, the United States remains a dominant force in military and economic realms [14], while Slovakia experiences a demographic shift due to declining fertility rates in the preceding decades [26]. Energy demand escalates by 50%, reflecting growing global needs and potential challenges [14]. The world population nears 9 billion, indicating persistent demographic expansion and associated socio-economic implications [14].

By 2045, urbanization will accelerate, with 65% of the global population residing in urban areas, particularly mega-cities in developing countries [14]. The world population peaks at 10.5 billion, while energy demand doubles compared to 2015, underscoring the challenges posed by increasing global energy consumption [14]. Geopolitical dynamics continue to shift, with China matching the U.S. military spending, accounting for a substantial portion of the world's military budget, and India's defense spending surpassing that of the entire European continent [14].

In 2050, Africa contribute nearly 50% to global population growth, emphasizing the continent's demographic significance [35]. Economic prosperity becomes evident in China, India, and other developing economies, particularly in Africa, driven by advancements in energy technologies [60]. China's commitment to renewable energy production, reaching 30–45% of its overall energy mix, signifies a pivotal moment in global environmental efforts [16]. The world population will stabilize at nearly 9 billion, offering a glimpse into the potential effects of demographic transitions and global policy interventions [30].

Looking ahead to the year 2100, the world population exceeds 11 billion, showing a significant rise and prompting concerns about the sustainability of this demographic expansion [35].

Conclusions

The rapidly changing world accentuates the levels of uncertainty and complexity in processes, thereby increasing the demand for future-related studies. European regions face substantial problems while seeking to contribute to solving global challenges. This scenario creates a rich resource for critical examination and forward-looking renewal. Futures Studies and technology roadmapping have been widely used in organizations to support decision-making. The European Journal of Futures Research has published several future events produced by academics over the past ten years.

In this work, we analyzed all articles published in the European Journal of Futures Research until 2022. We presented an extensive overview of temporal trends and identified pertinent considerations regarding the events in the articles. Next, we used NERMAP software to semi-automate the roadmapping process and presented the complete roadmap of events. Finally, we used the roadmap to perform two analyses. First, we created scenarios to provide researchers, organizations, and government insights. By interconnecting and summarizing the future-related literature, our research contributes significantly to Futures Research. Second, we analyzed the events that were expected to occur until 2023 and assessed how they developed in reality. These analyses provide a comprehensive understanding of the history of the European Journal of Futures Research and assess the reasonableness of future events.

Of the 203 articles analyzed in the EJFR database, we could gather future events in only 53 (26%) articles. We expect this low value is due to the lack of detected events in many articles and limitations on NERMAP's capability to gather *all* expected possible events made in each article. We highlight that the analysis produces a roadmap, a set of scenarios, and a detailed analysis of the future events expected to happen until 2023. Another contribution we provide is the methodology that can be used to analyze other Journals or specific fields of study, gathering information from multiple sources. One of the advantages of employing NERMAP lies in its ability to efficiently manage large volumes of documents, resulting in significant time savings compared to manual processing. This increased processing speed allows for the analysis of content that would be impractical to perform manually. However, there are other AI tools, such as Large Language Models (LLMs), available as alternatives, like GPT-4 [162], Bard [163], Llama 2 [164], and Grok [165] (among others) capable of extracting information from texts, but with a disadvantage of high cost. The analysis of extensive data sets using these LLMs can become excessively expensive due to the necessary computational resources and cloud services. Such models frequently entail considerable operational expenses, rendering them less practical, particularly for projects with budget limitations.

Our findings can improve the decision-making process for governments, researchers, enterprises, and people in general. Governments can benefit from the insights extracted from this research to inform policymaking processes. By understanding possible future events and trends, policymakers can anticipate challenges and opportunities and develop strategies to address them effectively. Researchers can use the synthesized insights to identify gaps in knowledge and areas for further exploration. By understanding the trajectory of future events as expected in the literature, researchers can prioritize their efforts and focus on areas likely to have significant impact or require attention. Enterprises can leverage the foresight generated from this research to inform their strategic planning processes. By understanding the potential future developments and disruptions, businesses can adapt their strategies to remain competitive and resilient in an uncertain environment. Finally, the scenarios and roadmaps can also serve as educational tools to raise public awareness about potential future trajectories and their implications. By disseminating the findings to the general public, individuals can make more informed decisions about their lives, careers, and civic engagement.

A main takeaway from this work is the importance of regularly assessing the expected outcomes against real-world events. Such assessments can enhance the accuracy of short-term foresight and the reliability of researchers' foresight tools. An important avenue of research emerges in developing frameworks that incorporate built-in "reality checks" to improve their precision. Nowadays, we usually update our future vision by cycling through the foresight process without revisiting our past predictions.

This work has some limitations. First, the fact-checking analysis covers only the ten years of the EJFR's existence. We could have a broader understanding if we used a more extensive dataset, which implies assessing multiple journals. Second, we did not make any evaluation beyond the text excerpts gathered and their surroundings (when needed to increase our understanding). Therefore, we do not assess the methodology or the researchers' specific goals while trying to predict a future event.

Future work may extend our study to other future-related journals and incorporate additional information, such as expert opinions for several fields, to improve the analysis of our results and develop broader and more complex scenarios. Additionally, comparing our results with other roadmapping studies would be interesting to see the similarities and differences in applications and results produced. Finally, we can use our methodology to support decision-making processes in different domains.

Appendix A: Timeline produced from the EJFR articles

Year	Event	Category	Scenario	Source
2015	Emerging markets make 26% of the European steam cracker capacity unprofitable. Steam Cracking is the petrochemical process in which saturated hydrocarbons are broken down into smaller, often unsaturated, hydrocarbons [67].	Industrial	Green Renaissance	[18]
2015	Europe will have WiFi everywhere.	Technological	Digital Divide	[21]
2015	About 80% of Europeans will have small computation devices with touch screens.	Technological	Digital Divide	[21]
2015	Additional costs for plug-in hybrid and battery electric car is 16,500€. For hydrogen cars, additional costs sum up to 35,000€.	Economic	Green Renaissance	[15]
2015	Year of peak oil extraction.	Industrial	Green Renaissance	[16]
2015	According to the law, the share of biofuels in the fuel mix delivered by the service stations should be at least 8%.	Environmental	Green Renaissance	[19]
2015	The demand for additional ICT practitioners in the EU is estimated to increase, reaching 500,000.	Economic	Digital Divide	[38]
2016	The market opportunities for the transparent conducting oxides, polymers, and nanomaterials used in displays, photovoltaics, and other applications exceed 6.9 billion US dollars in revenues.	Economic	Digital Divide	[44]
2016	Exclusive use of biometric passports.	Government	Techno-dystopia	[50]
2016	According to the law, the share of biofuels in the fuel mix delivered by the service stations should be at least 10%.	Environmental	Green Renaissance	[19]
2017	The market potential for printed electronics will increase to US$48.2 billion.	Economic	Digital Divide	[44]
2017	The unemployment rate in India will increase to 7.5%.	Economic	Geopolitical Turmoil	[24]
2017	Gothenburg, in Sweden, aims to have 100 self-driven cars.	Technological	Digital Divide	[22]
2017	According to the law, the share of biofuels in the fuel mix delivered by the service stations should be at least 12%.	Environmental	Green Renaissance	[19]
2018	Germany and Italy, the EU's first and third largest gas markets, are planning new Liquefied Natural Gas (LNG) facilities, and the US is expected to begin exporting LNG at scale.	Infrastructure	Geopolitical Turmoil	[31]
2018	According to the law, the share of biofuels in the fuel mix delivered by the service stations should be at least 15%.	Environmental	Green Renaissance	[19]
2019	Fully autonomous cars are expected to be deployed	Technological	Digital Divide	[22]
2019	The share of anti-European parties, especially from the nationalist right-extremists, will increase in the next European Parliament.	Political	Populist Backlash	[39]
2019	Two-thirds of all adults living in the European Union will not participate in the elections to the European Parliament.	Political	Populist Backlash	[39]
2019	In the UK, the overall car use per person will increase by 1% compared to 2013.	Technological	Populist Backlash	[22]
2020	The joint economic product of the EU and the US declined to approximately 30% of the world GDP, while China alone should rise to 19%.	Economic	Geopolitical Turmoil	[33]
2020	Google's autonomous car will go into mass production.	Technological	Techno-dystopia	[33]
2020	About 50.1 billion objects will be connected to the IoT.	Technological	Techno-dystopia	[36]
2020	Natural gas will replace the coal consumption in local power plants with natural gas. Hong Kong would import natural gas through a long-distance pipeline from central Asia and by liquefied natural gas arriving by ship from gas fields in the region and overseas.	Infrastructure	Geopolitical Turmoil	[32]
2020	The EU member countries will be bound to significant reductions in greenhouse gas emissions and increases in the use of renewable energy.	Environmental	Green Renaissance	[58]
2020	The EU will facilitate the strengthening of the knowledge-based economy by investing EUR 80 billion through the Horizon 2020 program.	Government	Green Renaissance	[38]
2020	The South Stream project, led by Gazprom and with major EU shareholders, will potentially provide 63 billion cubic meters of Russian-controlled gas directly to the EU.	Infrastructure	Geopolitical Turmoil	[31]
2020	The demand for additional ICT practitioners in the EU is estimated to increase, reaching 900,000.	Economic	Digital Divide	[38]

Year	Event	Category	Scenario	Source
2020	LNG may not be a viable alternative to piped Russian gas. Still, the market is expected to mature to the point where it could offer an alternative during negotiations with Russia.	Infrastructure	Geopolitical Turmoil	[31]
2020	Approximately 90% of the world's population will have access to mobile broadband networks.	Technological	Techno-dystopia	[28]
2020	Policies to increase local government and community ownership of electricity grids will support the overall vision.	Infrastructure	Techno-dystopia	[30]
2020	Connected devices will increase from 5 to around 25 billion, with a significant portion coming from automotive-related devices.	Technological	Digital Divide	[22]
2020	There will be an increase in the use of renewable energy to 15% in China – compared to 9.5% in 2008 – of the total and specific targets for reducing energy consumption and CO2 emissions.	Environmental	Green Renaissance	[16]
2020	There will be a ratio of non-fossil energy to primary energy consumption of 11.4% in China, decreasing energy consumption per unit of GDP by 16% and reducing carbon dioxide emissions per unit of GDP by 17%.	Government	Green Renaissance	[16]
2020	Most of the world's top 20 mega-cities will be in non-OECD countries.	Demographic	Geopolitical Turmoil	[24]
2020	China is expected to have 500 new mid-sized cities.	Demographic	Geopolitical Turmoil	[24]
2020	Smartphone subscriptions are forecast to have more than doubled, and 70% of the world's population will own a smartphone.	Technological	Techno-dystopia	[28]
2020	Through energy technology and innovation, we will see a reduction in greenhouse gas emissions of 20% compared to 1990 levels.	Environmental	Green Renaissance	[16]
2020	Through energy technology and innovation, we will see the share of renewable sources grow to 20%.	Environmental	Green Renaissance	[16]
2020	Individuals who have access to resources can and will make decisions about the size of their families. However, programs that support these decisions are underfunded, impacting low-income families.	Government	Digital Divide	[35]
2020	The Finnish biofuel production pursues the target to achieve a 20% share of renewables in transport.	Industrial	Green Renaissance	[19]
2020	People affected by poverty and social exclusion are reduced by 20 million through poverty policy programs in line with the EU strategy.	Government	Green Renaissance	[56]
2020	Achieve zero emissions from fossil fuel power plants through EU and member state research support and industry investment in Carbon Capture and Storage to stimulate public understanding of the safety and reliability of the technology and its benefits.	Environmental	Green Renaissance	[41]
2020	New regulations that require a 20% contribution of biofuels to transport energy reduce the CO2 content of gasoline and diesel to 193 g/kWh and 231 g/kWh, respectively.	Environmental	Green Renaissance	[15]
2020	We will have 75 billion networked devices.	Technological	Digital Divide	[36]
2020	About 5% of the world's precious minerals, including cobalt, copper, zinc, and rare earth, can come from ocean floors.	Technological	Geopolitical Turmoil	[37]
2020	International tourist arrivals worldwide are expected to rise to 1.4 billion people, compared with 1.1 billion in 2014.	Demographic	Digital Divide	[28]
2020	Enrollment numbers significantly declined, and second-tier universities needed to change their model of provision quickly to stay viable.	Education	Digital Divide	[27]
2020	Universities are shrinking their offerings.	Education	Digital Divide	[27]
2021	Stability and reduction in energy consumption of new passenger cars to 0.36 kWh/km (CO2 emissions 95 g/km) through advances in automotive technology.	Technological	Green Renaissance	[15]
2022	Germany aims for a drastic reduction in CO2 emissions and the termination of nuclear energy production.	Environmental	Green Renaissance	[45]
2023	The processing capacity of computers will match that of the human brain.	Technological	Digital Divide	[14]
2024	The shrinking workforce and disappearance of European workers are the most insidious threats to European security and stability.	Economic	Populist Backlash	[20]
2024	Two of the most populous countries in the world, China and India, will become global heavyweights in education and qualification.	Education	Populist Backlash	[40]
2025	An estimated 1.8 billion people will live in areas plagued by water scarcity, with two-thirds of the world population living in water-stressed regions due to use, growth, and climate change.	Environmental	Digital Divide	[51]

Year	Event	Category	Scenario	Source
2025	Asia accounts for 45% of the global GDP, having the largest fraction of the world's middle class.	Economic	Digital Divide	[33]
2025	Despite the expected growth and overcoming of the financial crisis, developments will be uncertain, especially in Europe.	Economic	Populist Backlash	[37]
2025	We will have 100 billion networked devices.	Technological	Digital Divide	[36]
2025	New technologies will replace many blue and white-collar jobs, leaving many unemployed.	Technological	Digital Divide	[42]
2025	We will see the implementation of new policy experiments centered on Universal basic income.	Government	Digital Divide	[24]
2025	Messages will be composed of images and voices instead of writing.	Technological	Digital Divide	[21]
2025	Many schools/faculties will become nonviable, resulting in the closure of courses.	Education	Digital Divide	[27]
2025	A collaborative effort among universities introduced Massive Open Online Courses (MOOCs) that provide enrollment, assessment, and certification opportunities, eventually leading to degree awards.	Education	Digital Divide	[27]
2025	Universities integrate digitization, ICT, internationalization, and the impact of demographic trends to survive.	Education	Digital Divide	[27]
2026	The peak oil year, i.e., the year in which global oil production reaches its maximum point and starts to decline.	Industrial	Green Renaissance	[16]
2026	Clear ethical and social concerns will become a topic of a very general debate, not only among technical experts.	Social	Green Renaissance	[49]
2026	Legged robotics grows thanks to several technological breakthroughs.	Technological	Digital Divide	[53]
2030	The energy consumption in Finland will drastically decrease especially because of advances in energy efficiency.	Technological	Green Renaissance	[25]
2030	The share of renewables will grow and cover almost three-quarters of the total energy consumption in Finland.	Technological	Green Renaissance	[25]
2030	A European Union target for the share of renewable energy sources is at least 32% of all final energy consumption.	Government	Green Renaissance	[25]
2030	About 10% of the world's precious minerals, including cobalt, copper, zinc, and rare earth, can come from ocean floors.	Technological	Geopolitical Turmoil	[37]
2030	The chemical industry will still rely heavily on oil-based raw materials and, at the same time, promote sustainability as a key value driver for the industry.	Industrial	Techno-dystopia	[18]
2030	Fossil fuel reserves in the EU will be exhausted.	Industrial	Geopolitical Turmoil	[22]
2030	The Global workforce will be divided into 2 billion employed, 2 billion self-employed, 1 billion in the informal economy, 1 billion unemployed or in transition, and 2.5 billion people not part of the workforce.	Economic	Populist Backlash	[24]
2030	Five billion people will live in urban areas.	Demographic	Populist Backlash	[28]
2030	Robots, drones, and automatons might be able, 24 h a day, to serve food, deliver parcels, transport people, offer supermarket shopping, and answer calls in call centers without queueing, among others.	Technological	Digital Divide	[62]
2030	China is expected to become the world's leading economy when the country's leadership is in a position to turn economic might into solid military power.	Political	Geopolitical Turmoil	[14]
2030	European petrochemical players invest approximately 2.7 billion in plants in China.	Economic	Geopolitical Turmoil	[18]
2030	Europe will still import 65 to 70% of its energy needs, which may be aggravating due to disputes over transit by maritime routes, crucial for world trade.	Political	Geopolitical Turmoil	[14]
2030	The education focus shifts from individual skills and knowledge to more action-oriented competencies and meta-skills, assessed diversely.	Education	Digital Divide	[29]
2030	The consumption of oil will be at a much lower level.	Environmental	Green Renaissance	[63]
2030	The emissions from sectors outside the EU Emission Trading System will need to be cut by 30% below the 2005 level.	Environmental	Green Renaissance	[19]
2030	The way of learning will have changed, such as adapting learning to the learners' talents, the increasing use of virtual environments, and the collective production of knowledge.	Education	Digital Divide	[29]
2030	International tourist arrivals worldwide are expected to rise to 1.8 billion people (compared with 1.4 billion in 2020).	Demographic	Digital Divide	[28]
2030	The number of road vehicles in China might increase eightfold.	Economic	Techno-dystopia	[16]

Year	Event	Category	Scenario	Source
2030	The total revenue of the European chemical industry will increase to €477 billion (compared to €317 billion in 2010).	Infrastructure	Geopolitical Turmoil	[18]
2030	The European chemical industry will still exist and largely resemble the current competitive situation.	Economic	Green Renaissance	[18]
2030	There will be an objective of increasing the share of renewable energy to at least 27% of the EU energy consumption.	Political	Green Renaissance	[19]
2030	There will be new emerging fields whose first steps and roots are probably already seen.	Technological	Techno-dystopia	[55]
2030	The European chemical industry will most likely be a part of European and global value chains, as customer industries will have manufacturing sites in Europe.	Economic	Green Renaissance	[18]
2030	The customer industries will remain strong and grow in Europe.	Economic	Green Renaissance	[18]
2030	The chemical industry will still highly depend on oil and naphtha as essential raw materials for most products.	Industrial	Geopolitical Turmoil	[18]
2030	The working life will be almost entirely based on working in teams, and the transversal task of the school will be to teach the pupils work skills.	Social	Digital Divide	[29]
2030	The world energy demand will increase massively, with fossil fuels continuing to dominate the global power generation market.	Environmental	Techno-dystopia	[41]
2030	The low dependency on oil and a low degree of sustainability orientation in the industry induce volatility in the market, increasing oil prices and leading to research initiatives to create non-oil-based chemical processes.	Industrial	Geopolitical Turmoil	[18]
2030	Asian dominance in the chemical industry due to the customer industries' requirements diverging needs in a multi-polar industry landscape.	Infrastructure	Geopolitical Turmoil	[18]
2030	People and organizations worldwide will satisfy most of their demands or welfare-producing activities through Global Value-Producing Networks.	Social	Digital Divide	[64]
2030	New initiatives of sustainable, modular, and multimodal urban mobility systems as traffic congestion hugely increases.	Technological	Green Renaissance	[59]
2030	The timetable of basic education will be distributed somewhat equally between subject-based (tool and practical subjects) and action-oriented (phenomena, projects, themes) syllabi.	Education	Digital Divide	[29]
2030	Additional costs for plug-in hybrid and battery electric car is 10,000€. For hydrogen cars, additional costs sum up to 15,000€. Internal Combustion Engine cars are estimated to cost up to 4300€ due to lightweight materials.	Technological	Green Renaissance	[15]
2030	OECD projections indicate increasing levels of obesity, even considering the EU Action Plan on Childhood Obesity and the EU Platform for Action on Diet, Physical Activity, and Health.	Health	Techno-dystopia	[34]
2030	CO2 reduction of 22%.	Environmental	Green Renaissance	[15]
2030	Europeans have fewer stigmas towards drug users. Addictions are treated in medical facilities with no discrimination.	Social	Green Renaissance	[21]
2030	New effective pharmacotherapies reduce drug addiction in Europe to almost zero.	Health	Green Renaissance	[21]
2030	Advanced ICT promotes socio-economic development, restores and protects the environment, increases resource efficiency, upgrades legacy infrastructure, and retrofits industries based on sustainable design principles.	Technological	Green Renaissance	[46]
2030	The increase in brain tumors is due to mobile phones and microwave ovens, lowering confidence in the e-society technology platform.	Health	Digital Divide	[21]
2030	The European Directive on the Ethical Use of Artificial Intelligence is ratified.	Legal	Green Renaissance	[17]
2030	Finland abandons the use of coal in energy production and oil in heating.	Environmental	Green Renaissance	[25]
2030	The population of working age in Sub-Saharan Africa will exceed that of China.	Demographic	Geopolitical Turmoil	[14]
2030	The world population exceeds 8 billion.	Demographic	Geopolitical Turmoil	[14]
2030	China's energy mix reaches 28–32% of renewable energy production.	Environmental	Green Renaissance	[16]
2030	The EU working age population (15–64 years) declines by 15% and is trimmed at both ends.	Demographic	Digital Divide	[20]
2030	EU population of those over 80 years will grow by 39% compared to 2014.	Demographic	Digital Divide	[20]
2030	Finland to reduce greenhouse gas emissions by at least 40% compared to the 1990s.	Environmental	Green Renaissance	[15]

Year	Event	Category	Scenario	Source
2030	The additional cost of improved fuel efficiency for trucks is estimated at 15,000€.	Industrial	Green Renaissance	[15]
2030	The additional cost of improved fuel efficiency for vans is estimated at 5,000€.	Industrial	Green Renaissance	[15]
2030	CO2 emissions are reduced by 27% when compared to 2011 figures.	Environmental	Green Renaissance	[15]
2030	CO2 emission reduction of 22% in Finland when compared to 2014 figures.	Environmental	Green Renaissance	[15]
2032	The European Directive on the Ethical Use of Artificial Intelligence has been adopted into German law.	Legal	Green Renaissance	[17]
2033	The typical consumer uses the Internet for several relations, from regular buying and gaming to buying psychoactive drugs and recovering from their addictions through telemedicine.	Technological	Techno-dystopia	[21]
2034	New laws make the data collected by credit-reporting agencies, health insurers, and other companies more transparent. In addition to viewing stored data, individuals can request information about scoring methods and can also have incorrect data revised or, in some cases, deleted.	Legal	Digital Divide	[17]
2035	Finland achieves carbon neutrality for the whole society.	Environmental	Green Renaissance	[25]
2035	Global trade in LNG will rise to as much as 46% compared to 2014.	Economic	Geopolitical Turmoil	[31]
2035	The US will continue to be the world's leading military power, although facing increasing competition from China.	Military	Geopolitical Turmoil	[14]
2035	Society at large is opposed to mass surveillance and associated preventive measures.	Political	Populist Backlash	[17]
2035	Criminal gangs use technology to find lucrative targets while manipulating predictive police software, avoiding their apprehension. Society loses confidence in police security technologies.	Social	Techno-dystopia	[17]
2035	The police now rely extensively on technological solutions when combating all forms of crime.	Technological	Techno-dystopia	[17]
2035	Half of the world's population will suffer restrictions on drinking water consumption.	Infrastructure	Digital Divide	[14]
2035	Germany's legal framework for security technologies entails limitations to data privacy while providing ethical standards for the responsible use of information gathered in surveillance operations.	Legal	Green Renaissance	[17]
2035	New security technologies regulation requires comprehensive impact assessments when the technology is planned, developed, or deployed due to the risk of unintended side effects and ethical concerns.	Government	Digital Divide	[17]
2035	The public is highly aware of their right to data privacy.	Social	Populist Backlash	[17]
2035	The coastal population will have risen by 50% compared to 2000.	Demographic	Geopolitical Turmoil	[14]
2035	The population of working age in Sub-Saharan Africa will exceed that of India.	Demographic	Geopolitical Turmoil	[14]
2035	The energy demand from China, India, and South-East Asia will account for 65% of the world's total.	Infrastructure	Geopolitical Turmoil	[14]
2035	Freedom of movement remains a highly valued good.	Social	Digital Divide	[17]
2035	Security technologies consider local demographics, urban structures, income statistics, and socio-cultural characteristics for crime predictions.	Technological	Populist Backlash	[17]
2035	The world's population is between 7.3 billion and 8.8 billion.	Demographic	Digital Divide	[14]
2035	Russian defense budget exceeds the combined budget of France, Germany, and the UK.	Military	Geopolitical Turmoil	[14]
2035	The price for autonomous vehicle technology is about $3000.	Economic	Green Renaissance	[15]
2035	The world population exceeds 8.5 billion.	Demographic	Geopolitical Turmoil	[14]
2035	Year of peak natural gas extraction.	Industrial	Green Renaissance	[16]
2036	More than 60% of older women (+65) will have access to a car as a driver.	Demographic	Digital Divide	[22]
2036	In the UK, the overall car use per person will decline by 3% compared to 2013 levels.	Social	Digital Divide	[22]
2037	Robotic legs are an alternative to a rollator, enabling a person to climb stairs and access rougher terrain.	Technological	Digital Divide	[57]
2040	Satellite Solar Power Station will become financially feasible due to the reduced space launch costs ($150/kg).	Technological	Techno-dystopia	[43]

Year	Event	Category	Scenario	Source
2040	World energy demand is increasing continuously, and it is expected to grow multiple times by 2040	Infrastructure	Techno-dystopia	[43]
2040	Technological advances in the fields of energy-saving and renewable energies are insufficient to curb the increase in CO2 emissions in the 2030s.	Environmental	Techno-dystopia	[14]
2040	The US will still be the most powerful actor in military and economic terms.	Military	Geopolitical Turmoil	[14]
2040	Slovakia's demographic pyramid presents a significant cut around age 35 due to a decline in fertility in the 1990s.	Demographic	Geopolitical Turmoil	[26]
2040	Devices can be used just by thinking a few thoughts due to the use of technology for studying the brain and its functional systems.	Technological	Digital Divide	[66]
2040	Energy demand grows to 50% more than 2014's levels.	Economic	Geopolitical Turmoil	[14]
2040	Due to climate change, there will be 220 million regional and transcontinental refugees.	Environmental	Populist Backlash	[14]
2040	Czechs and Slovaks aged 15–20 years increase due to the tertiary wave of births due to the pro-natalist measures implemented by the Czechoslovak government during the presidency of Gustáv Husák (1975–1989).	Demographic	Geopolitical Turmoil	[26]
2040	Life expectancy in Slovakia and the Czech Republic grow slightly higher than the 2019 levels of Western European countries (France, the UK, and Germany).	Demographic	Populist Backlash	[26]
2040	In Slovakia and the Czech Republic, the fertility level reaches 1.5 to 1.6 children per woman.	Demographic	Populist Backlash	[26]
2040	Europe experiences a stable situation due to good coordination at national and regional levels.	Political	Green Renaissance	[47]
2040	Hydrocarbons still supply about 80% of energy demand.	Industrial	Digital Divide	[14]
2040	The world population is nearly 9 billion.	Demographic	Geopolitical Turmoil	[14]
2045	About 65% of the world's population will live in urban areas, primarily due to mega-cities in developing countries.	Demographic	Geopolitical Turmoil	[14]
2045	Weak states, incapable of controlling or governing part or all of their territory, continue to exist while some worsen their political and social situation.	Political	Populist Backlash	[14]
2045	The processing capacity of computers is 100,000 times higher than that of the human brain.	Technological	Techno-dystopia	[14]
2045	The world population peaks at 10.5 billion.	Demographic	Geopolitical Turmoil	[14]
2045	The growing energy demand will double when compared to 2015.	Economic	Geopolitical Turmoil	[14]
2045	China matches the US's military spending, accounting for 45% of the world military budget.	Military	Geopolitical Turmoil	[14]
2045	India's defense spending surpasses that of the whole of Europe.	Military	Geopolitical Turmoil	[14]
2050	End of the fossil fuels era for Oil and Gas, with increasing reduction of their use.	Environmental	Green Renaissance	[32]
2050	Renewable electricity production approaches 50% globally, requiring major expansions and cost reductions in battery-storage systems, but still requires natural gas and nuclear power to supplement the electricity supply.	Environmental	Green Renaissance	[32]
2050	Road and rail transportation network length will increase by 60% compared to 2010.	Infrastructure	Green Renaissance	[16]
2050	Africa is expected to account for nearly 50% of global population growth.	Demographic	Geopolitical Turmoil	[35]
2050	The number of people aged 65 and older tripled compared to 2012 figures.	Demographic	Digital Divide	[24]
2050	The elderly will form 41% of the adult population in Italy, 38% in Germany, 33% in France, and 32% in the UK.	Demographic	Digital Divide	[20]
2050	China, India, and other developing economies, especially in Africa, prosper in unprecedented ways due to multiple new energy technologies and sources.	Economic	Geopolitical Turmoil	[60]
2050	European companies apply material flow analysis, life-cycle assessment, and material input per service unit to compare and identify new business strategies, particularly regarding end-of-life product options.	Environmental	Techno-dystopia	[30]
2050	Europeans have lifestyles that are less resource-intensive and more fulfilling when compared to 2015.	Social	Digital Divide	[30]
2050	Cars designed in 2015 are still in use.	Technological	Digital Divide	[19]
2050	China's overall energy mix could reach 30-45% of renewable energy production.	Environmental	Geopolitical Turmoil	[16]

Year	Event	Category	Scenario	Source
2050	France's Delegation for Strategic Affairs estimates there will be 450 million transcontinental migrants owing to political, economic, or environmental reasons.	Demographic	Populist Backlash	[14]
2050	Fewer people move to inner city areas, avoiding long-distance commuting between cities.	Social	Green Renaissance	[61]
2050	Cities have become more attractive places to live.	Social	Green Renaissance	[23]
2050	European number of cars per household decreases.	Social	Green Renaissance	[23]
2050	European public transportation system has been expanded to include low-carbon buses, trams, and metros, becoming free and available for everyone.	Government	Green Renaissance	[23]
2050	The world population stabilizes at nearly 9 billion.	Demographic	Geopolitical Turmoil	[30]
2050	Conventional fuels do not motorize vehicles for passenger and freight transport but by a mix of renewable fuels for internal combustion engines, electricity, and hydrogen fuel cells.	Technological	Green Renaissance	[23]
2050	Transport emissions were reduced by 60% when compared to 1990 levels.	Environmental	Green Renaissance	[23]
2050	Basic income policies exist in several countries but are not yet universal.	Economic	Digital Divide	[42]
2050	Many countries raised the pension age to 70 + years to avoid cutting pensions.	Economic	Digital Divide	[20]
2050	In Slovakia and the Czech Republic, the sexually active population will reach the peak age for reproduction, with a decrease in the number of births after this point.	Demographic	Populist Backlash	[26]
2050	The decision-makers generation, born in the 1990s and later, is likely to present post-material values.	Social	Green Renaissance	[40]
2050	Technological innovations and developments have not achieved substantial reductions in emissions.	Technological	Techno-dystopia	[23]
2050	Technology provides more free time for focusing on personal and collective development, tremendously improving the quality of life for senior citizens.	Social	Digital Divide	[54]
2050	Renewable energy covers 80% of the US's electricity demand.	Environmental	Green Renaissance	[16]
2050	The EU working age population (15–64 years) declines by 19% and is trimmed at both ends.	Demographic	Digital Divide	[20]
2050	The likelihood of mass migration between the EU and the US is increasing slightly.	Political	Populist Backlash	[65]
2050	Urban planning also supports people walking, cycling, and using public transport supported by a vast set of policy measures, which reduces the car mileage by 27% when compared to not taking action, reducing the required car fleet to 550,000 cars.	Environmental	Green Renaissance	[15]
2050	Finland reduced greenhouse gas emissions by at least 80% compared to the 1990s.	Environmental	Green Renaissance	[15]
2050	Large-scale modal shifts from cars to other transport modes and a significant increase in car occupancy reduce car mileage by 45% compared to taking no action.	Social	Green Renaissance	[15]
2050	The additional cost of improved fuel efficiency for trucks is estimated at 30,000€.	Economic	Green Renaissance	[15]
2050	Europe's population living in cities reaches about 86%.	Demographic	Digital Divide	[48]
2050	Plug-in hybrid cars sold reach 60% worldwide, battery electric cars 30%, and hydrogen-powered 10%.	Technological	Green Renaissance	[15]
2050	Global CO2 emissions from transport are 9000 billion tons, which is 18% of human-made emissions, and these are expected to grow by 60% until 2050.	Environmental	Green Renaissance	[15]
2050	CO2 emissions are reduced by 36% when compared to 2011 figures.	Environmental	Green Renaissance	[15]
2050	Consumers control their diets using digital diet coaches.	Health	Techno-dystopia	[34]
2050	The population will have access to a broad range of food products to buy 24/7.	Agricultural	Green Renaissance	[34]
2050	CO2 emission reduction of 30% in Finland when compared to 2014 figures.	Environmental	Green Renaissance	[15]
2050	The world population in urban areas reaches 70%.	Demographic	Digital Divide	[52]
2050	Additional costs for plug-in hybrid and battery electric car is 2500€. For hydrogen cars, additional costs sum up to 4000€.	Technological	Green Renaissance	[15]
2050	CO2 reduction of 30%.	Environmental	Green Renaissance	[15]

Year	Event	Category	Scenario	Source
2050	Construction, operation, and maintenance costs of road and rail transportation networks will represent 2% of global GDP.	Infrastructure	Green Renaissance	[16]
2050	The additional cost of improved fuel efficiency for vans is estimated at 10,000€.	Economic	Green Renaissance	[15]
2052	Year of peak coal extraction.	Industrial	Green Renaissance	[16]
2080	Indonesia starts decommissioning its nuclear power plants.	Infrastructure	Green Renaissance	[32]
2080	Fewer workers increase the burden of social support. EU's age dependency ratio reaches 77.9%, i.e., about one and a half workers for every dependent.	Social	Digital Divide	[20]
2080	EU population of those over the age of 80 + will more than double when compared to 2014 numbers.	Demographic	Digital Divide	[20]
2100	The global population surpasses 11 billion.	Demographic	Geopolitical Turmoil	[35]

Appendix B: the timeline for the *Green Renaissance* scenario

Year	Event	Category	Source
2026	The peak oil year, i.e., the year in which global oil production reaches its maximum point and starts to decline.	Industrial	[16]
2026	Clear ethical and social concerns will become a topic of a very general debate, not only among technical experts.	Social	[49]
2030	The energy consumption in Finland will drastically decrease especially because of advances in energy efficiency.	Technological	[25]
2030	The share of renewables will grow and cover almost three-quarters of the total energy consumption in Finland.	Technological	[25]
2030	A European Union target for the share of renewable energy sources is at least 32% of all final energy consumption.	Government	[25]
2030	The consumption of oil will be at a much lower level.	Environmental	[63]
2030	The emissions from sectors outside the EU Emission Trading System will need to be cut by 30% below the 2005 level.	Environmental	[19]
2030	The European chemical industry will still exist and largely resemble the current competitive situation.	Economic	[18]
2030	There will be an objective of increasing the share of renewable energy to at least 27% of the EU energy consumption.	Political	[19]
2030	The European chemical industry will most likely be a part of European and global value chains, as customer industries will have manufacturing sites in Europe.	Economic	[18]
2030	The customer industries will remain strong and grow in Europe.	Economic	[18]
2030	New initiatives of sustainable, modular, and multimodal urban mobility systems as traffic congestion hugely increases.	Technological	[59]
2030	Additional costs for plug-in hybrid and battery electric car is 10,000€. For hydrogen cars, additional costs sum up to 15,000€. Internal Combustion Engine cars are estimated to cost up to 4300€ due to lightweight materials.	Technological	[15]
2030	CO2 reduction of 22%.	Environmental	[15]
2030	Europeans have fewer stigmas towards drug users. Addictions are treated in medical facilities with no discrimination.	Social	[21]
2030	New effective pharmacotherapies reduce drug addiction in Europe to almost zero.	Health	[21]
2030	Advanced ICT promotes socio-economic development, restores and protects the environment, increases resource efficiency, upgrades legacy infrastructure, and retrofits industries based on sustainable design principles.	Technological	[46]
2030	The European Directive on the Ethical Use of Artificial Intelligence is ratified.	Legal	[17]
2030	Finland abandons the use of coal in energy production and oil in heating.	Environmental	[25]
2030	China's energy mix reaches 28–32% of renewable energy production.	Environmental	[16]

Year	Event	Category	Source
2030	Finland to reduce greenhouse gas emissions by at least 40% compared to the 1990s.	Environmental	[15]
2030	The additional cost of improved fuel efficiency for trucks is estimated at 15,000€.	Industrial	[15]
2030	The additional cost of improved fuel efficiency for vans is estimated at 5,000€.	Industrial	[15]
2030	CO2 emissions are reduced by 27% when compared to 2011 figures.	Environmental	[15]
2030	CO2 emission reduction of 22% in Finland when compared to 2014 figures.	Environmental	[15]
2032	The European Directive on the Ethical Use of Artificial Intelligence has been adopted into German law.	Legal	[17]
2035	Finland achieves carbon neutrality for the whole society.	Environmental	[25]
2035	Germany's legal framework for security technologies entails limitations to data privacy while providing ethical standards for the responsible use of information gathered in surveillance operations.	Legal	[17]
2035	The price for autonomous vehicle technology is about $3000.	Economic	[15]
2035	Year of peak natural gas extraction.	Industrial	[16]
2040	Europe experiences a stable situation due to good coordination at national and regional levels.	Political	[47]
2050	End of the fossil fuels era for Oil and Gas, with increasing reduction of their use.	Environmental	[32]
2050	Renewable electricity production approaches 50% globally, requiring major expansions and cost reductions in battery-storage systems, but still requires natural gas and nuclear power to supplement the electricity supply.	Environmental	[32]
2050	Road and rail transportation network length will increase by 60% compared to 2010.	Infrastructure	[16]
2050	Fewer people move to inner city areas, avoiding long-distance commuting between cities.	Social	[61]
2050	Cities have become more attractive places to live.	Social	[23]
2050	European number of cars per household decreases.	Social	[23]
2050	European public transportation system has been expanded to include low-carbon buses, trams, and metros, becoming free and available for everyone.	Government	[23]
2050	Conventional fuels do not motorize vehicles for passenger and freight transport but by a mix of renewable fuels for internal combustion engines, electricity, and hydrogen fuel cells.	Technological	[23]
2050	Transport emissions were reduced by 60% when compared to 1990 levels.	Environmental	[23]
2050	The decision-makers generation, born in the 1990s and later, is likely to present post-material values.	Social	[40]
2050	Renewable energy covers 80% of the US's electricity demand.	Environmental	[16]
2050	Urban planning also supports people walking, cycling, and using public transport supported by a vast set of policy measures, which reduces the car mileage by 27% when compared to not taking action, reducing the required car fleet to 550,000 cars.	Environmental	[15]
2050	Finland reduced greenhouse gas emissions by at least 80% compared to the 1990s.	Environmental	[15]
2050	Large-scale modal shifts from cars to other transport modes and a significant increase in car occupancy reduce car mileage by 45% compared to taking no action.	Social	[15]
2050	The additional cost of improved fuel efficiency for trucks is estimated at 30,000€.	Economic	[15]
2050	Plug-in hybrid cars sold reach 60% worldwide, battery electric cars 30%, and hydrogen-powered 10%.	Technological	[15]
2050	Global CO2 emissions from transport are 9000 billion tons, which is 18% of human-made emissions, and these are expected to grow by 60% until 2050.	Environmental	[15]
2050	CO2 emissions are reduced by 36% when compared to 2011 figures.	Environmental	[15]
2050	The population will have access to a broad range of food products to buy 24/7.	Agricultural	[34]
2050	CO2 emission reduction of 30% in Finland when compared to 2014 figures.	Environmental	[15]
2050	Additional costs for plug-in hybrid and battery electric car is 2500€. For hydrogen cars, additional costs sum up to 4000€.	Technological	[15]
2050	CO2 reduction of 30%.	Environmental	[15]
2050	Construction, operation, and maintenance costs of road and rail transportation networks will represent 2% of global GDP.	Infrastructure	[16]
2050	The additional cost of improved fuel efficiency for vans is estimated at 10,000€.	Economic	[15]
2052	Year of peak coal extraction.	Industrial	[16]
2080	Indonesia starts decommissioning its nuclear power plants.	Infrastructure	[32]

Appendix C: the timeline for the *Digital divide* scenario

Year	Event	Category	Source
2025	An estimated 1.8 billion people will live in areas plagued by water scarcity, with two-thirds of the world population living in water-stressed regions due to use, growth, and climate change.	Environmental	[51]
2025	Asia accounts for 45% of the global GDP, having the largest fraction of the world's middle class.	Economic	[33]
2025	We will have 100 billion networked devices.	Technological	[36]
2025	New technologies will replace many blue and white-collar jobs, leaving many unemployed.	Technological	[42]
2025	We will see the implementation of new policy experiments centered on Universal basic income.	Government	[24]
2025	Messages will be composed of images and voices instead of writing.	Technological	[21]
2025	Many schools/faculties will become nonviable, resulting in the closure of courses.	Education	[27]
2025	A collaborative effort among universities introduced Massive Open Online Courses (MOOCs) that provide enrollment, assessment, and certification opportunities, eventually leading to degree awards.	Education	[27]
2025	Universities integrate digitization, ICT, internationalization, and the impact of demographic trends to survive.	Education	[27]
2026	Legged robotics grows thanks to several technological breakthroughs.	Technological	[53]
2030	Robots, drones, and automatons might be able, 24 h a day, to serve food, deliver parcels, transport people, offer supermarket shopping, and answer calls in call centers without queueing, among others.	Technological	[62]
2030	The education focus shifts from individual skills and knowledge to more action-oriented competencies and meta-skills, assessed diversely.	Education	[29]
2030	The way of learning will have changed, such as adapting learning to the learners' talents, the increasing use of virtual environments, and the collective production of knowledge.	Education	[29]
2030	International tourist arrivals worldwide are expected to rise to 1.8 billion people (compared with 1.4 billion in 2020).	Demographic	[28]
2030	The working life will be almost entirely based on working in teams, and the transversal task of the school will be to teach the pupils work skills.	Social	[29]
2030	People and organizations worldwide will satisfy most of their demands or welfare-producing activities through Global Value-Producing Networks.	Social	[64]
2030	The timetable of basic education will be distributed somewhat equally between subject-based (tool and practical subjects) and action-oriented (phenomena, projects, themes) syllabi.	Education	[29]
2030	The increase in brain tumors is due to mobile phones and microwave ovens, lowering confidence in the e-society technology platform.	Health	[21]
2030	The EU working age population (15–64 years) declines by 15% and is trimmed at both ends.	Demographic	[20]
2030	EU population of those over 80 years will grow by 39% compared to 2014.	Demographic	[20]
2034	New laws make the data collected by credit-reporting agencies, health insurers, and other companies more transparent. In addition to viewing stored data, individuals can request information about scoring methods and can also have incorrect data revised or, in some cases, deleted.	Legal	[17]
2035	Half of the world's population will suffer restrictions on drinking water consumption.	Infrastructure	[14]
2035	New security technologies regulation requires comprehensive impact assessments when the technology is planned, developed, or deployed due to the risk of unintended side effects and ethical concerns.	Government	[17]
2035	Freedom of movement remains a highly valued good.	Social	[17]
2035	The world's population is between 7.3 billion and 8.8 billion.	Demographic	[14]
2036	More than 60% of older women (+65) will have access to a car as a driver.	Demographic	[22]
2036	In the UK, the overall car use per person will decline by 3% compared to 2013 levels.	Social	[22]
2037	Robotic legs are an alternative to a rollator, enabling a person to climb stairs and access rougher terrain.	Technological	[57]
2040	Devices can be used just by thinking a few thoughts due to the use of technology for studying the brain and its functional systems.	Technological	[66]
2040	Hydrocarbons still supply about 80% of energy demand.	Industrial	[14]
2050	The number of people aged 65 and older tripled compared to 2012 figures.	Demographic	[24]
2050	The elderly will form 41% of the adult population in Italy, 38% in Germany, 33% in France, and 32% in the UK.	Demographic	[20]
2050	Europeans have lifestyles that are less resource-intensive and more fulfilling when compared to 2015.	Social	[30]
2050	Cars designed in 2015 are still in use.	Technological	[19]

Year	Event	Category	Source
2050	Basic income policies exist in several countries but are not yet universal.	Economic	[42]
2050	Many countries raised the pension age to 70 + years to avoid cutting pensions.	Economic	[20]
2050	Technology provides more free time for focusing on personal and collective development, tremendously improving the quality of life for senior citizens.	Social	[54]
2050	The EU working age population (15–64 years) declines by 19% and is trimmed at both ends.	Demographic	[20]
2050	Europe's population living in cities reaches about 86%.	Demographic	[48]
2050	The world population in urban areas reaches 70%.	Demographic	[52]
2080	Fewer workers increase the burden of social support. EU's age dependency ratio reaches 77.9%, i.e., about one and a half workers for every dependent.	Social	[20]
2080	EU population of those over the age of 80 + will more than double when compared to 2014 numbers.	Demographic	[20]

Appendix D: the timeline for the *Populist Backlash* scenario

Year	Event	Category	Source
2024	The shrinking workforce and disappearance of European workers are the most insidious threats to European security and stability.	Economic	[20]
2024	Two of the most populous countries in the world, China and India, will become global heavyweights in education and qualification.	Education	[40]
2025	Despite the expected growth and overcoming of the financial crisis, developments will be uncertain, especially in Europe.	Economic	[37]
2030	The Global workforce will be divided into 2 billion employed, 2 billion self-employed, 1 billion in the informal economy, 1 billion unemployed or in transition, and 2.5 billion people not part of the workforce.	Economic	[24]
2030	Five billion people will live in urban areas.	Demographic	[28]
2035	Society at large is opposed to mass surveillance and associated preventive measures.	Political	[17]
2035	The public is highly aware of their right to data privacy.	Social	[17]
2035	Security technologies consider local demographics, urban structures, income statistics, and socio-cultural characteristics for crime predictions.	Technological	[17]
2040	Due to climate change, there will be 220 million regional and transcontinental refugees.	Environmental	[14]
2040	Life expectancy in Slovakia and the Czech Republic grow slightly higher than the 2019 levels of Western European countries (France, the UK, and Germany).	Demographic	[26]
2040	In Slovakia and the Czech Republic, the fertility level reaches 1.5 to 1.6 children per woman.	Demographic	[26]
2045	Weak states, incapable of controlling or governing part or all of their territory, continue to exist while some worsen their political and social situation.	Political	[14]
2050	France's Delegation for Strategic Affairs estimates there will be 450 million transcontinental migrants owing to political, economic, or environmental reasons.	Demographic	[14]
2050	In Slovakia and the Czech Republic, the sexually active population will reach the peak age for reproduction, with a decrease in the number of births after this point.	Demographic	[26]
2050	The likelihood of mass migration between the EU and the US is increasing slightly.	Political	[65]

Appendix E: the timeline for the *Techno-dystopia* scenario

Year	Event	Category	Source
2030	The chemical industry will still rely heavily on oil-based raw materials and, at the same time, promote sustainability as a key value driver for the industry.	Industrial	[18]
2030	The number of road vehicles in China might increase eightfold.	Economic	[16]
2030	There will be new emerging fields whose first steps and roots are probably already seen.	Technological	[55]
2030	The world energy demand will increase massively, with fossil fuels continuing to dominate the global power generation market.	Environmental	[41]

Year	Event	Category	Source
2030	OECD projections indicate increasing levels of obesity, even considering the EU Action Plan on Childhood Obesity and the EU Platform for Action on Diet, Physical Activity, and Health.	Health	[34]
2033	The typical consumer uses the Internet for several relations, from regular buying and gaming to buying psychoactive drugs and recovering from their addictions through telemedicine.	Technological	[21]
2035	Criminal gangs use technology to find lucrative targets while manipulating predictive police software, avoiding their apprehension. Society loses confidence in police security technologies.	Social	[17]
2035	The police now rely extensively on technological solutions when combating all forms of crime.	Technological	[17]
2040	Satellite Solar Power Station will become financially feasible due to the reduced space launch costs ($150/kg).	Technological	[43]
2040	World energy demand is increasing continuously, and it is expected to grow multiple times by 2040	Infrastructure	[43]
2040	Technological advances in the fields of energy-saving and renewable energies are insufficient to curb the increase in CO2 emissions in the 2030s.	Environmental	[14]
2045	The processing capacity of computers is 100,000 times higher than that of the human brain.	Technological	[14]
2050	European companies apply material flow analysis, life-cycle assessment, and material input per service unit to compare and identify new business strategies, particularly regarding end-of-life product options.	Environmental	[30]
2050	Technological innovations and developments have not achieved substantial reductions in emissions.	Technological	[23]
2050	Consumers control their diets using digital diet coaches.	Health	[34]

Appendix F: the timeline for the *geopolitical turmoil* scenario

Year	Event	Category	Source
2030	About 10% of the world's precious minerals, including cobalt, copper, zinc, and rare earth, can come from ocean floors.	Technological	[37]
2030	Fossil fuel reserves in the EU will be exhausted.	Industrial	[22]
2030	China is expected to become the world's leading economy when the country's leadership is in a position to turn economic might into solid military power.	Political	[14]
2030	European petrochemical players invest approximately 2.7 billion in plants in China.	Economic	[18]
2030	Europe will still import 65 to 70% of its energy needs, which may be aggravating due to disputes over transit by maritime routes, crucial for world trade.	Political	[14]
2030	The total revenue of the European chemical industry will increase to €477 billion (compared to €317 billion in 2010).	Infrastructure	[18]
2030	The chemical industry will still highly depend on oil and naphtha as essential raw materials for most products.	Industrial	[18]
2030	The low dependency on oil and a low degree of sustainability orientation in the industry induce volatility in the market, increasing oil prices and leading to research initiatives to create non-oil-based chemical processes.	Industrial	[18]
2030	Asian dominance in the chemical industry due to the customer industries' requirements diverging needs in a multi-polar industry landscape.	Infrastructure	[18]
2030	The population of working age in Sub-Saharan Africa will exceed that of China.	Demographic	[14]
2030	The world population exceeds 8 billion.	Demographic	[14]
2035	Global trade in LNG will rise to as much as 46% compared to 2014.	Economic	[31]
2035	The US will continue to be the world's leading military power, although facing increasing competition from China.	Military	[14]
2035	The coastal population will have risen by 50% compared to 2000.	Demographic	[14]
2035	The population of working age in Sub-Saharan Africa will exceed that of India.	Demographic	[14]
2035	The energy demand from China, India, and South-East Asia will account for 65% of the world's total.	Infrastructure	[14]
2035	Russian defense budget exceeds the combined budget of France, Germany, and the UK.	Military	[14]
2035	The world population exceeds 8.5 billion.	Demographic	[14]
2040	The US will still be the most powerful actor in military and economic terms.	Military	[14]

Year	Event	Category	Source
2040	Slovakia's demographic pyramid presents a significant cut around age 35 due to a decline in fertility in the 1990s.	Demographic	[26]
2040	Energy demand grows to 50% more than 2014's levels.	Economic	[14]
2040	Czechs and Slovaks aged 15–20 years increase due to the tertiary wave of births due to the pro-natalist measures implemented by the Czechoslovak government during the presidency of Gustáv Husák (1975–1989).	Demographic	[26]
2040	The world population is nearly 9 billion.	Demographic	[14]
2045	About 65% of the world's population will live in urban areas, primarily due to mega-cities in developing countries.	Demographic	[14]
2045	The world population peaks at 10.5 billion.	Demographic	[14]
2045	The growing energy demand will double when compared to 2015.	Economic	[14]
2045	China matches the US's military spending, accounting for 45% of the world military budget.	Military	[14]
2045	India's defense spending surpasses that of the whole of Europe.	Military	[14]
2050	Africa is expected to account for nearly 50% of global population growth.	Demographic	[35]
2050	China, India, and other developing economies, especially in Africa, prosper in unprecedented ways due to multiple new energy technologies and sources.	Economic	[60]
2050	China's overall energy mix could reach 30-45% of renewable energy production.	Environmental	[16]
2050	The world population stabilizes at nearly 9 billion.	Demographic	[30]
2100	The global population surpasses 11 billion.	Demographic	[35]

Abbreviations

AVT	Autonomous Vehicle Tester
BEV	Battery Electric Vehicle
CCS	Carbon Capture and Storage
CO2	Carbon Dioxide
EIA	US Energy Information Administration
EJFR	European Journal of Futures Research
EU	European Union
FCEV	Fuel Cell Electric Vehicle
GDP	Gross Domestic Product
HEV	Hybrid Electric Vehicle
ICEV	Internal Combustion Engine Vehicle
ICT	Information and Communication Technology
IoT	Internet of Things
ISA	International Seabed Authority
LLM	Large Language Model
LNG	Liquefied Natural Gas
MOOCs	Massive Open Online Courses
NEDC	New European Driving Cycle
NOx	Nitrogen Oxides
OECD	Organization for Economic Co-operation and Development
PC	Personal Computer
SO2	Sulfur Dioxide
TRM	Technology Roadmapping
UNFPA	United Nations Population Fund
WLTP	Worldwide Harmonised Light Vehicles Test Procedure

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Authors' contributions
Conceptualization: C.E.B.; Data curation: A.L.; Formal analysis: C.E.B. and A.L.; Funding acquisition: C.E.B.; Investigation: C.E.B., A.L. and J.M.d.S.; Methodology: C.E.B.; Resources: J.M.d.S.; Software: A.L.; Supervision: C.E.B. and J.M.d.S.; Validation: C.E.B., A.L., Y.L., H.S. and M.A.; Visualization: C.E.B.; Writing – original draft: C.E.B. and A.L.; Writing - review & editing: C.E.B., A.L., Y.L., H.S. and M.A.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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