Foresight: Fifty Years to Think Your Futures

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Abstract Foresight started with the notion of (Science and) Technology Foresight as a part of Technology Assessment (TA) but is now an independent scientific area. For a long time, Foresight mainly aimed at detecting determined futures but has developed into different directions under different headings. Most processes make use of a combination of methods to explore and develop different possible, probable or desirable futures. Foresight is more and more embedded in different institutions. There, it is carried out together with clients, and serves their specific purposes in the preparation of decision-making or science, technology and innovation policies. It offers the space to bring the different actors in the respective innovation system together. Foresight concepts are more and more accepted, and the results are distributed and used—in companies, ministries, associations, NGOs or the European Commission. Our contribution describes how Foresight has changed during the last 50 years and explains some of the aspects researchers have addressed. We conclude by highlighting two crosscutting emerging dimensions of change in Foresight, i.e. the engagement with transformative, mission-oriented agendas and the meaningful integration of machine-based approaches. Foresighters have to be aware that not only the results of their projects change but also the methods and the actors who work with them.

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1 Introduction

Preparing for the future, dealing with futures' uncertainty and the question of what may be in store for us is what drives people to engage in looking forward. Like Futures Research, Foresight does not aim to predict a determined single future, but supports people in exploring alternative future pathways (Amara 1974; Kreibich 2006; Voros 2017, 2019): possible, probable and desirable futures open up different perspectives and approaches. With each perspective, different objectives in science, technology and innovation (STI) are addressed. "Foresight" in a broader sense started in operations research of the 1950s, especially in military support (RAND Corporation, Santa Monica, see e.g. Helmer 1975, 1983; Helmer and Rescher 1959. And with expert support (Dayé 2020) to consider the future of science and technology as a driver of the economy and societal development. During the 1960s, many researchers in the world assumed that it could be possible to develop world simulation models even though the first models at that time were only able to process a limited number of variables (Forrester 1961; Meadows et al. 1972). A milestone in this way of futures thinking was the report "Limits of Growth" written by the Club of Rome, which raised the awareness of resource limits. This coincided with new institutional foundations, for example, in Germany, the Fraunhofer Institute for System Technology and Innovation (ISI) or the Science and Policy Research Unit (SPRU) in the United Kingdom. Although working on the long-term view, the researchers in the early 1970s were already aware that predictive outlooks are assumptions about the future, mere means or "working material", not facts, and the major task of a Foresight researcher is to deal with uncertainties about future issues and transfer new ideas and technology into real life (Krupp 1972; ISI 1973).

While the existing simulation models were updated (see, e.g., in Meadows et al. 2009) and new models were added, the toolbox of searching for potential futures, assessing assumptions about or consequences of these different futures as well as developing new options has been growing tremendously over time and was discussed internationally, most visibly in the AGARD project for NATO in 1977 (Hetman 1977). Under the umbrella of "technology assessment" (see Heyen et al. 2024 in this anthology), many Foresight studies were performed during the 1970s and early 80s to assess the future impacts of certain technological developments on the economy, society and policy-making (see, e.g., Jochem 1973, 1975; Jochem and Wiesner 1977; Krupp 1984 and many others). The 1980s rather saw a decrease in science and technology-based foresight, whereas participatory future workshops (Zukunftswerkstätten) were still actively used in civil society and spatial planning (Jungk and Müllert 1987).

At that time, Foresight and Futures Research of all kinds were often perceived as predictive (Which future may come true?), as part of planning processes (strict planning in the sense of the "planning decade"), but also as policy and political processes (Flechtheim 1966; Jungk 1986; Toffler 1990; Steinmüller 2012, 2013, 2014a, b, Godet 1986; Radkau 2017; Seefried 2015). Even the notion of "social technology" was used (Helmer 1966), but sociologists were not very active in Foresight, "the analysis of the future has been ... neglected in sociological theory and research" (Mische 2009). First overview studies in early Foresight were scenarios (Kahn and Wiener 1977) or Delphi surveys (Helmer 1967, 1983). After a single broad study in the USA (Dalkey and Helmer 1963; Helmer 1983; Helmer-Hirschberg and Gordon 1964), Japan was the first country to establish regular Delphi surveys and later fully-fledged Foresight processes in science, technology, innovation and society on a national level (Cuhls 1998; Kuwahara et al. 2008; NISTEP 2019). In other countries, Delphi surveys fell into oblivion after harsh criticism by Sackman (1975), a criticism that rather aimed at the practical use of surveys, less at the method itself.

From the content point of view, science, technology and innovation were often at the forefront of Foresight-like activities—human-induced and described as drivers for "progress". Policy advice based on the findings and to support innovation policy beyond pure science and technology policy was and is still intertwined with Foresight. Triggered by Irvine and Martin's report on comparing Foresight in several countries in 1984, a broad way of conducting science and technology outlook studies with Key Technologies approaches to learn for the present attained momentum at the beginning of the 1990s and gained traction when the first national Foresight activities in Japan were taken over to be repeated at first in Germany, then in the UK, France and South Korea. This marks the beginning of national Foresight activities all over the world (Georghiou et al. 2008; Grupp 1999) and the enhancement of the methodological toolbox, encompassing analytical, participatory and anticipatory tools (Cuhls et al. 2002; Cuhls 2008; Glenn and Gordon 2009; Slaughter 2005; UNIDO 2002). First regional, national and international networks emerged. International collaborations started with the exchange of knowledge and were extended to framework contracts and nowadays cooperative online projects.

Several aspects and dimensions of Foresight have changed drastically over time, for example the development from more deterministic views to open and diverse future perspectives, or the tools and the way researchers collaborate and with whom, from single projects in teams to participative approaches, even integrating the clients or the general public. Foresight started struggling with the scarcity of data and is now integrating AI approaches in a flood of "big data". Foresight is more and more (also) working in virtual settings. With hindsight, we point at some of these developments during the last 50 years.

We structure the sections according to key aspects of change and proceed chronologically within the subsections. The key aspect in the first section explains how Foresight started without a theory by researchers who had the will to practically apply first methods. The terminology they used was still scattered and—at least in Germany—it took until 2020 to be officially acknowledged as a scientific area "futures research" at all. The second section describes the way towards a broad variety of perspectives and different conceptions of futures with open processes that also demand different methodological concepts. Section 2.3 highlights the evolution of participatory approaches within Foresight. At the same time, new ways of making use of data and information in the digital age developed (Sect. 2.4), leading to a certain degree of automation in Foresight. The underlying struggle between quantitative and qualitative approaches is illustrated in Sect. 2.5. Foresight has played different roles in innovation systems research and policy—in Sect. 2.6, we describe this development. Networks in Foresight supported all the developments (Sect. 2.7) and changed in nature over time. In the last section, we offer a summary and give a brief outlook on potential further developments of the field.

2 50 Years of Exploring Futures and Dealing with Uncertainty

Foresight—starting with the notion of (Science and) Technology Foresight as a part of technology assessment—has broadened and developed in different directions under different headings. Foresight is dealing with different, complex futures and some uncertainties in imagining and assessing the different issues or "things to come". The following sections describe some of the changes over time having selected different aspects and following them over historical times.

2.1 Towards a Scientific Discipline with Accepted Terminology

The terminology for Foresight, Futures Research or Futures Studies has always been in flux and developed in different communities all over the globe (cf. Gransche 2015). In France, "la prospective" emerged as a similar concept (Godet 1986, 2000). Since 1992, the term "Foresight" has been used more often in the sense Martin (1995) defined it: "(technology) foresight is the process involved in systematically attempting to look into the longer-term future of science, technology, the economy and society with the aim of identifying the areas of strategic research and the emerging of generic technologies likely to yield the greatest economic and social benefits" or Coates (1985, p. 30) who formulated more broadly "Foresight is the overall process of creating an understanding and appreciation of information generated by looking ahead. Foresight includes qualitative and quantitative means for monitoring clues and indicators of evolving trends and developments and is best and most useful when directly linked to the analysis of policy implications. Foresight prepares us to meet the needs and opportunities of the future. Foresight in government cannot define policy, but it can help condition policies to be more appropriate, more flexible, and more robust in their implementation, as times and circumstances change. Foresight is, therefore, closely tied to planning. It is not planning—merely a step in planning". Thus, Foresight is "the systematic debate of complex futures" (Cuhls 2013), contains much more than scenario building (see examples in Jochem et al. 2024 in this anthology) and includes full processes (EFFLA 2013).

The need to be clearer in the definition, to explain why Foresight needs an epistemological explanation or theory behind it, and the need to communicate this to others (disciplines, communities, institutions) became obvious when researchers of the field met at conferences worldwide and had to explain what they are doing. It was also observed during the 1990s that it was difficult to be accepted by other fields or by scientific disciplines. At this time, first projects, processes and communities started to reflect on this epistemological area. Whether or not Foresight should be a discipline that is taught at universities was not yet discussed and is even now, in 2024, up for debate.[1] But what became clear was that Foresight needs an epistemic frame to be understood and to be taught—otherwise, it would be difficult to apply for projects or to recruit personnel for further projects. During the 1990s, Foresight also became institutionalised in academic journals with rigorous peer reviews, dedicated conferences, specialised networks of professionals (see below) and acknowledged in public research organisations and universities but was still belittled as "unscientific" or an "art" (de Jouvenel 1967).

Within a European network (ASTPP-TSER, see Kuhlmann et al. 1999) and a special issue about "Foresight" in the Journal of Forecasting (Cuhls and Salo 2003), more agreement was achieved on terminology, especially concerning Foresight, Planning and Strategic or Anticipatory Intelligence. Foresight and Forecasting were competing notions at that time, and although there was an agreement to differentiate in framing both notions in the EU context (Cuhls 2003; Kuhlmann et al. 1999), in many regions of the world, Forecasting and Foresight terminology remained the same. In the first decades of this century, "Futures Studies" has been more and more used in other regions of the world (especially in Australia, the term is congruent with Foresight, see, e.g., Slaughter 2005, etc.) by researchers organised in the World Futures Studies Federation (WFSF). "Futures Literacy" (Miller 2018) and "Anticipation Studies" (Poli 2017, 2019) represent another part of the more recent communities in rather qualitative future-oriented studies framing futures thinking and working on the present by "using the future" (Miller 2018). For 30 years, the UNESCO has been active in Foresight and since 2012 has gained influence again (https://en.unesco.org/futuresliteracy/about). Since then, UNESCO chairs have been nominated in all regions of the world and a High-level Committee on Programmes (HLCP) Strategic Foresight Network was established in 2020 to coordinate global activities (https://unsceb.org/foresight-network). The discussions on Futurology or Futures Research as "a real discipline" in the scientific sense or as a scientific subject (Seefried 2015; Steinmüller 2012, 2013, 2014a) are thus still ongoing and the research community is highly interdisciplinary. They rarely use the term "anticipation", which experiences a renaissance in the context of RRI and mission-oriented innovation policy (OPSI 2020; Poli 2017).

With time, the number of communities and scientific literature in Foresight has increased. The first journals, in which Foresight results were published, came from

[1] For example, the Bundesakademie für Sicherheitspolitik (BAKS) started new online events called "Foresight Breakfast" with the question if Foresight needs to be a discipline (May 10, 2022, 8:30).

operations research, modelling and quantitative approaches (*Long-Range Planning* since 1968, *European Journal of Operational Research* since 1977 or the *International Journal of Forecasting* which started in 1985), or Business Administration journals (e.g. *Business Horizons* since 1957; *Journal of Business Research* since 1973). Later, a more strategic focus was in the forefront of publications (like the *Strategic Management Journal* since 1980 or *Technology Analysis & Strategic Management* since 1989). Foresight articles were also included in policy-oriented journals (like in *Research Policy*, which started in 1971) and more general societal, economic, political and technology discussions (*Technological Forecasting & Social Change* since 1969, *Futures* since 1968 and *Foresight* since 1999, or the *Russian Foresight Journal*), often with a partly quantitative "touch" were established. Others have a more technological or engineering direction like *Technovation* since 1981, or *IEEE Transactions on Engineering Management* since 1968.

To establish a community and to further strengthen and institutionalise Foresight towards a "scientific discipline", the *European Journal of Futures Research* was founded in 2013 at the same time as the *German Zeitschrift für Zukunftsforschung*. The latest journal is *Futures & Foresight Science*, which started in 2019. All three journals address methods, theoretical approaches and scientific projects on futures.

Since 2019, Futures Research is an official "Small Scientific Subject" acknowledged by the German Federal Ministry for Research and Education (BMBF) even though chairs at universities labelled "Foresight" are still rare. There is no UNESCO Chair of Futures Literacy or similar in Germany yet, although there are more and more departments at universities offering courses or integrating Foresight knowledge—as well as many faculties working in Foresight-like thematic areas without calling it Foresight (e.g. in environmental studies, climate change modelling, innovation research or philosophy).

In sum, the field of Foresight has seen a growing institutionalisation in different research organisations and into a scientific area acknowledged by universities. Foresight and futures research are now highly differentiated and have developed from more forecasting-like activities in models, assessments of future topics or clear trend lines to methods working with open and varied future perspectives and combinations thereof.

2.2 From Detecting "the" Future to Exploring Multiple Open Futures

Looking back on looking forward, two major approaches to Foresight can be distinguished (van Asselt et al. 2012: 24–25): The *predictive approach* to Foresight (forecasting) dominated from the 1950s to the 1970s—and is still prevalent today (Kreibich 2007c), in particular in the realm of business economics and macro-economics, and the *explorative approach* to Foresight that surveys multiple futures (scenarios) which emerged in the 1960s (e.g. Godet 1986). Foresight researchers worked towards a view that sees the future as essentially open, and Foresight processes as a way of reflecting on possible futures to derive insights for the present. The first modern futures science and futures research approaches emerged during the 1930s–1940s in the USA. The pioneers of "Futurology", children of their time, assumed a linear trajectory of human development and tried to predict that trajectory accurately. Not surprisingly, the focus was on the perceived main driver of change of modern societies: scientific and technological progress, its expectations and assessments. The 1950s were the time, when the RAND Corporation—founded in 1948—developed scenarios (Kahn 1977; Kahn and Wiener 1977), Delphi surveys (Dalkey 1968; Dalkey and Helmer 1963; Helmer 1983), models and simulations.

The original "forecasting approaches" (Cetron 1970) broadened into general societal questions, and emerging science and technology were identified (Helmer and Rescher 1959; Jantsch 1967; de Jouvenel 1967). In the 1960s, the early years of Foresight and Futures planning in West Germany, the Batelle-Institute was leading in the development of new methods, combining quantitative and qualitative approaches. In East Germany, Foresight as such did not exist (Steinmüller 2014a) but deterministic future planning was an integral part of state policy. All over the world, different prognostic (Beinhauer and Schmacke 1970; Picht 1967) and forecasting approaches (Martino 1983) were tested. It took until the 1960s, when futures conceptions were developed more openly, identifying impacts and risks of the technological-economic dynamics were brought into play mainly by citizen movements (Kreibich 2007a, b: 177–181).

Although not explicitly framed as a scenario study, "The Limits of Growth" explored different futures through various prospective simulations (Meadows et al. 1972). It is considered to be one of the earliest scenario studies in policy-oriented Foresight (Kosow and Gaßner 2008; van Asselt et al. 2012). It is no coincidence that at the time, when global environmental and climate concerns were first systematically assessed and widely modelled for contributing to the creation of new policies and attitudinal changes. Research institutes with similar missions like the Fraunhofer ISI (in Germany) and SPRU (in the UK) were founded. Following the example of other international institutions, innovation researchers already worked with world models and "modelling the future" approaches, mainly by extrapolating variables from the present (Krupp 1972). The ISI founding proposal (Krupp 1972) mentions the collection, inventory and assessment of research issues, connected with technological foresight and technology transfer, as a principal task. Accordingly, complex systems were to be viewed with system technology methods, in particular dynamic simulation, to fill a gap for future modelling in applied research at that time (ISI 1973; Krupp 1972), which required interdisciplinary competences.

The earliest projects in the 1970s were still US-dominated, but first German contributions to a world model with decision layers existed, and technology assessment with the support of dynamic simulation started (Bossel and Hughes 1973). At the same time, the relevance of technological forecasts for industrial long-term planning was reflected (Fischer 1976). Not surprisingly, there was no uniform reasoning about the future at that time. While the exploration of the potential of deterministic simulations was attempted, the limitations of dynamic systems modelling to represent complex systems have been apparent right from the beginning. The contingency of perceptions and of future developments was already considered. However, at that time, researchers searched for *likely* scenarios in-between "cornerstone scenarios" and the deliberation of viewpoints rather than fully-fledged participatory scenario processes (e.g. on a morphological basis or at least thinking in alternative pathways into the future) embracing the uncertainties in assessing "the future".

The following three examples illustrate how uncertainty was dealt with in the early 1970s: In a study on waste, three alternative future scenarios were built based on an analysis of statistics and trends—however without describing in detail how[2] and to what end the scenarios were built (Jochem 1973). The implications were discussed and assessed against a set of criteria. The author concluded that the most likely scenario would be somewhere in-between. From today's point of view, these scenarios are the single author's personal plausible assumptions on how particular single trends or developments could unfold in the future, but at that time, it was already a huge achievement to figure out futures at all. In 1976, "chemical scenarios" were published, that already used a terminology similar to environmental factors ("Umfeldbereiche") and included different experts in the scenario creation (Batelle Institut e.V. 1976).

In a second project, a value-controlled decision-making process on energy policy was modelled and simulated (Bossel and Hughes 1973) with the flow of decision-making represented as a causal logical sequence (e.g. "Is Dissatisfaction Less Than 100?"—YES/NO, p 73). In addition, three scenarios were built to account for the complexity of the energy system: worst case, best case and most likely case. These scenarios had the nature of plausible sets of parameter values, and it was simulated how these assumptions propagated to the results. According to the authors, who were aware of the pioneering character of their work, "A great deal remains to be done in the creation of a fully acceptable value-based decision-making structure" (Bossel and Hughes 1973). This kind of Foresight work was not very actively followed in the next 10 years and the communities split into those who worked on a sectoral basis (mainly in the field of energy) with new ways of modelling, and those who were searching for future issues in a broader sense.

In the 1980s, new indicators for measuring progress in science and technology, competitiveness studies and innovation for a new ecosociety (Krupp 1989) were paramount. Indicators described the presence, the here and now. They could only be extrapolated into one single future. Country comparisons and outlooks for the different regions of the world (Bierhals 1980; Grupp et al. 1987)—always with a view to staying competitive ("Standortpolitik")—were started to guarantee growth and jobs. Under the heading of "early detection of technologies" (Technologiefrüherkennung) the development levels of industrial countries were

[2] Today, one would ask if they are constructed as desk research or with expert participation, combining different pathways systematically or just assuming one most likely pathway etc.

measured by technometrics, patent analysis, bibliometric studies and literature reviews (e.g. Grupp et al. 1987; Grupp 1997; Schmoch 1988, 1990, see also Frietsch et al. 2024 in this anthology). The community of futures researchers was split into those coming from academia, making use of indicators and data, and others who emphasised the diverse interests of actors in different futures and the empowerment of civil society in shaping futures (like Flechtheim or Jungk, see, e.g., Flechtheim 1990; Jungk 1983, 1986; Seefried 2015; Steinmüller 2014a).

During the later years of the 1980s with the experience of nuclear accidents (esp. Harrisburg, Chernobyl), the discussions shifted towards problems and negative effects of technology. But it remained obvious that also the opportunities of science and technology needed attention. Researchers started to learn from other countries, especially Japan, which was en vogue at that time—partly propagated as a threat, a competitor on global markets, and partly admired, as Japanese scientists were successful in learning from others and getting more out of the lessons. Thus, the idea was to learn from the USA and Japan by performing Foresight—regarded as a positive view towards futures, to induce complementary thinking to the more negative aspects often dealt with in TA and to learn their way of shaping futures with innovation.

Therefore, in the 1990s, Delphi expert surveys[3] were added to the German and later to other European countries' Foresight repertoire (again), this time on a larger level and with communication purposes. Studies on the national level to gain an overview of future science and technology developments and their potential became well-known, especially in industry. Corporate and organisational Foresight also spread (Gordon et al. 2020) with the aim of competitiveness in a global world and the identification of strengths and weaknesses of the innovation system to support "basic technologies" or foster those science areas in one's own country. As in Delphi surveys, the time horizon of realisation is one major estimation to ask for, the method was criticised as being predictive and/or too specific. This led to the attempt of integrating a "megatrend" assessment to analyse the participants' views on large societal developments as well (Cuhls et al. 1998, 2002). The factor analysis on the megatrends made it also possible to raise the question if there were hidden biases or values behind the judgements on science and technology in general (Blind et al. 2001).

But political questions changed and so did the methods in Foresight—from more forecasting and focusing on the supply side of science and technology to problem- and demand-driven approaches. The German national activities of the 2000s started with more society-oriented (demand-driven) Foresight attempts (e.g. FUTUR of the BMBF, see Cuhls and Georghiou 2004), integrating different participants, broadening the scope of issues in question and even re-uniting the technology assessment of the German TAB with "Future Reports" (ITAS and Fraunhofer ISI 2002). In 2007,

[3] Expert surveys with future statements assessed in several so-called rounds, in which later rounds feedback was given on the assessments so that the same experts could assess once more with the psychological anchor of other results. These surveys started a large communication with many experts from different backgrounds.

BMBF started a first Foresight "programme" to broaden its range of interdisciplinary research themes beginning with the technology fields of the German High-Tech Strategy (Cuhls et al. 2009a, b). In 2012, the second, more demand-driven approach followed (Warnke and Schirrmeister 2016; Zweck et al. 2015a, b). The third German Foresight programme is combined with a "Horizon Scanning", as the search part of Foresight is called meanwhile, supported by a Committee (Zukunftskreis) identifying thematic issues relevant for diving deeper.[4]

One of the major methods in Foresight were and are scenarios. As there are many different scenario methods and "schools" (see for example Bradfield et al. 2005; Fink et al. 2001; Fink and Siebe 2016; Kosow and Gaßner 2008) in Foresight, most of the scenario methods use different inputs to combine future paths into coherent and plausible images of the future. Morphological approaches with different key factors (or drivers) and their potential developments into the future (named also: assumptions, options, projections) involving just data or experts or literature or other sources illustrate how the different pieces of future paths can be combined to new coherent pictures. Scenario work and thinking in different future paths, in fully-fledged processes or as scenario sprints, are the backbone of many Foresight processes nowadays in Germany and all over the world.

On the European Union level, Foresight in RTDI developed along similar lines as in Germany, but started later. Systems dynamics and other models were used for the long-term view of the interconnections in and between different systems in single projects. The same is true for qualitative scenario work, which started in a division called K2, a division that was given up later. The European Forum of Forward-Looking Activities brought Foresight back into the Commission processes in 2012 and the following years. Foresight gained attention by being used in the preparation of Horizon 2020, the Framework programme on RTDI of the European Commission. There were already many qualitative approaches available to identify new topics for science, technology and innovation (policy). Open, facilitated workshops for systematic Foresight were used in the preparation of Horizon Europe, the 9th Framework Programme. All of these processes used assumptions about different futures under uncertainty—to identify futures, to prepare for, or to make them possible, but less to predict them. The European Commission itself got more and more involved in the Foresight processes via workshops, interviews or internal consultations, expert consultations (European Commission 2017b), and the European Commission's Foresight Correspondent's Network, which was later established as the Horizon Europe Network (Cuhls et al. 2021; European Commission 2017a; Kimpeler et al. 2022) to support in-house processes. With a new Commissioner responsible for Foresight, the European Commission broadened its strategic Foresight work and meanwhile also publishes regular reports (European Commission 2020, 2021, 2022).

[4] https://www.bmbf.de/bmbf/de/forschung/zukunftstrends/foresight/mit-foresight-in-die-zukunft-schauen.html

To recapitulate, Foresight started with the expectations of detecting "the" determined "future" but is now—and partly always has been—a debate about futures under uncertainty, with remaining unknowns, not predictive, but about understanding and handling uncertainties, preparing decisions under uncertainty as well as working with different futures (often in form of different kinds of "scenarios"), less with "worst case" and "best case" but with different plausible scenarios "somewhere in between or beyond". Starting with expert involvement, the stakeholder groups that take part in the processes have diversified and expanded over time.

2.3 *From Narrow to Broad Perspectives: Evolving Demand for Participation*

The step-by-step integration of Foresight activities into on-going policy-making and strategy development routines over the past 50 years has developed towards opening up Foresight for different types of actors (Cuhls 2003). Before, it was mainly based on desk research of intelligence units and selected expert assumptions, used for policy or business consultation and planning in the 1970s. Scenarios and futures work were often regarded as part of technology assessment (Verein Deutscher Ingenieure 1991, see Heyen et al. 2024 in this anthology) in the 1970s and 80s. The opportunities and limits of technology assessment (TA) were reflected early on (Jochem 1975) with the impossibility of an "objective or neutral" TA (e.g. causal relationships are only partially known), methodological difficulties (e.g. subjective impact perceptions) and technocratic versus democratic management of technology (e.g. negligence of poorly organised groups). This calls for a participatory process approach. It is argued that (1) the integration of stakeholders benefits the identification of unintended and unforeseen side effects, (2) group-specific views of possible developments differ and (3) controversial steps in TA could be resolved through participation (Jochem 1975).

Accordingly, participatory Foresight processes are future-oriented activities that encourage the integrated, focused engagement of interdisciplinary experts, stakeholders and citizens at multiple points in the Foresight research process and recognise interactively created artefacts as an important mode of developing and communicating "bottom-up" imaginaries of the future and their inherent diverse aspirations. The participatory turn is similar to that in technology assessment (see Heyen et al. 2024 in this anthology). Different from TA studies, Foresight processes are creating these images. The plausible images of the future and the paths to them should be described in easy-to-understand narratives and in a way that is comprehensive, inspiring, evoking interest, provocative and nice to read. The science behind it involves the addressees in the creation of the images and narratives and combines it with data and information pieces that already exist or are assumed to be possibly based on current findings. Information could be gained from experts and stakeholders—and that is why they are often included in scenario processes or surveys (e.g. Delphi surveys).

Despite the identified shortcoming of a Foresight process that uses scenarios based on a few expert opinions only, i.e. to illustrate impacts of certain technologies, policies or actions at a systems level (Jochem 1975), participatory approaches were not at the centre of methodological improvements in the 1970s and 80s. During the formation years of the Innovation Systems approach in the mid-1980s (Irvine and Martin 1984), the quantitative analysis of the technological performance of national or regional economies was a main interest in "prospective analysis" (Grupp et al. 1987; Irvine and Martin 1984; Schmoch 1988). Consequently, the heuristic innovation system model attributes a key role in technological progress to actors from science and industry, and policy actors set the framework conditions. Other groups of actors are only considered as stakeholders, consumers or technology users (Kuhlmann and Arnold 2001).

One merit of the systems approach was that the need for interdisciplinary knowledge and for stakeholder involvement in Foresight was slowly increasing. It reflected the understanding that different actors and their roles are key for the development, diffusion and use of innovation (Dosi et al. 1988; Edquist 1997). Therefore, expert surveys like large Delphi surveys, for example, the Delphi 1993, 1995 and Delphi '98, spread not only in Germany (BMFT 1993; Bundesministerium für Forschung und Technologie 1993; Cuhls et al. 1996, 1998), but also in Hungary, France and the UK (Georghiou et al. 2008)). Alternatively, the so-called Key Technology Lists with national priorities were created, e.g. in Germany, the Czech Republic or France (Grupp 1994; Klusacek 2002; Ministère de l'Économie 2006; Wagner and Popper 2003), including international comparisons (Cuhls et al. 2002). Delphi surveys were already performed in the 1960s in the USA as large communicative and participative surveys. Since 1970 every 5 years surveys have been carried out in Japan without knowing the notion of the "innovation system", but they have been regarded as a tool which has taken into account the opinions of different (if possible all) actor groups in the innovation system.

Interviews with stakeholder representatives like in the INTERDIS Project in the 1990s were conducted to gain deeper insights and involve a broader audience—as the participants in surveys and interviews were also the multipliers of the processes (Schmoch et al. 1996). With time, the notion "expert" broadened, and more and more citizen involvement was asked for by the European Commission or the national ministries. In the 1990s, participatory Foresight gained momentum, led to some participatory frameworks (Inayatullah 2000; Rosa et al. 2018) and was even discussed in high-level circles in the European Commission (Brussels talks on opening up Foresight processes: Cuhls 2002). Since the beginning of this century, societies have increasingly faced complex, interrelated, grand challenges with high uncertainty. The realisation spread that more actors than knowledge providers need to be involved in foresight (Cuhls 2000, 2003; Martin and Johnston 1999) and that led to a new German Foresight approach: The first FUTUR activity tried to involve stakeholders "from bottom-up" in a workshop-based process combining "open space" and "focus group" activities with heterogeneous actors. The FUTUR conference on participation in other countries' Foresight processes (Cuhls and Jaspers 2004) demonstrated the huge interest in experiments with participative Foresight and citizen involvement in countries like Sweden or the Netherlands. From then on, more and more actors with a broad and general, interdisciplinary view were involved in Foresight processes to discuss and find solutions for the broad societal challenges, mainly via conceptualised workshops or surveys.

With the emerging concept of "Responsible Research and Innovation (RRI)" (see Bührer et al. 2024 in this anthology) and its guiding principles of inclusiveness, anticipation, reflexivity and responsiveness, more actors in the system, namely science and society, were supposed to work intensively together to develop responses to the grand societal challenges and to identify new challenges. The idea of harnessing the wisdom of the crowd, in the sense of "many people know more", even if they are not specialists (Surowiecki 2005) like in the large Delphi surveys (Belton et al. 2021), was gaining momentum, not only in open innovation activities in industry (Baldwin and von Hippel 2011) but also in innovation systems research, in particular for energy and sustainability transitions. As a consequence, the understanding of actor constellations and their specific roles in innovation systems was revised (Warnke et al. 2016) and led to the concept of *open organisational Foresight* (Wiener 2018). In Germany, the BMBF Foresight cycles I and II mobilised different actors, new types of experts and citizens for emerging trends, and initiated dialogues between them (Warnke and Schirrmeister 2016), for example in "strategic dialogues" (BMBF Foresight Process I) and different co-creative workshop formats to support mission-oriented (innovation) policy.

The development illustrates that it is not only crucial to use a wide range of sources to search for signals of continuity or change in Foresight, but also to include a variety of perspectives and knowledge from different backgrounds, key actors and affected stakeholder groups in developing visions, analysing alternative futures and developing the necessary actions. Opening up Foresight to more participants and to involve stakeholder representatives and citizens as experts of everyday life has two objectives: first, to provide a more valid knowledge base for strategic decision-making by harnessing the cognitive diversity and varying perspectives of different actors; and second, to broaden the engagement of different actors in agenda-setting, prioritisation of action needs, development of ideas for solutions, and in the implementation of measures (Rosa et al. 2021; Nikolova 2014). In addition to the benefits of a more valid information base, despite uncertainties, there is also a societal function of participatory Foresight. It can support pluralistic information and communication about emerging societal challenges, "which builds political coherence and trust, increases commitment to joint action and reduces resistance to change (...), and highlights tensions in society in a constructive way" (Committee for the Future 2020). Specifically the societal function of participatory Foresight nowadays receives increased attention, in particular in the context of resilience in times of crises (Kononenko 2021).

The key to participatory Foresight that builds upon citizen engagement is the strengthening of people's capacity to recognise and embrace uncertainty while collectively shaping a preferable vision of the future. Engaging with citizens in

Foresight requires specific methods suitable for the different phases of a Foresight process, for the development of joint visions, for dialogues to share perspectives and priorities and for scenario generation and analysis to identify challenges or develop ideas for actions (Rosa et al. 2021). Visioning methods can support diverse groups of actors, including citizens, to develop a shared vision of their preferred future as a community, often shaped by normative principles, e.g., well-being or sustainability (Rosa et al. 2018). Futures dialogue methods enable discussions with a strict future-orientation on complex issues like bioeconomy or sustainable consumption (Kimpeler et al. 2022; Zweck et al. 2015b). Co-created storylines for consistent scenarios about possible futures in everyday life of the people are more comprehensible than expert reports. They serve as narrations in the communication about possible futures (Kimpeler et al. 2021). Examples like the storyboards on the application of Artificial Intelligence in new environments (see, e.g., https://www.uba-ki-storyboard.de) or the bioeconomy scenario stories "How do we want to live in the future?" can evoke discussions to negotiate desirable futures, be it in workshops with young people, in museum exhibitions, or other arenas (Kimpeler et al. 2021). These different forms of engagement can be considered at multiple scales of governance, from local communities or regions, to national, European or global levels (Rosa et al. 2021).

In addition, a gradual expansion of expert assumptions and advice towards more co-generation of knowledge about possible futures and collaboration in the development of ideas for action to tackle the challenges can be observed. This has taken a long time to become acknowledged and is aligned with the engagement of more people in the co-creation of the urgently needed societal transitions to meet the UN Sustainable Development Goals. One example is the participation process for the co-creation of ideas for action in the context of mission-oriented innovation policies for the German High-Tech Strategy (Trénel et al. 2020).

For this kind of co-thinking and co-creation of futures, a thorough stakeholder analysis that identifies not only dominant but also affected and "silent" system stakeholders (Haegeman et al. 2012; Schmidt et al. 2020) is crucial. It should be the first step of any participatory Foresight process. A particular emphasis is on recognising potential future stakeholders who may emerge along with the change of the system (dormant or latent stakeholders, Clausen et al. 2020), stakeholders with a particular role in transformations (Lyon et al. 2020) and long-term stakeholders such as future generations. Also, as we are dealing with complex emergent and transforming systems, a continuous critical reflection of system boundaries and subsequent revision of stakeholder mapping is crucial (Achterkamp and Vos 2007).

Due to the urgency of change in society as a whole, there is a demand for participatory approaches in Foresight that go beyond describing trends or exploring the space of possibilities and opportunities. Approaches in the 2020s try to support the various actors and experts in critically reflecting on their expectations for the future, and learning from each other to be able to shape transformations together. Participatory Foresight is asked for to include citizens in critical thinking about futures and the co-creation of goals, priorities and actions for mission-oriented policies. This is essential for bridging citizen needs and policy requirements to finally increase the reflexivity of innovation systems.

2.4 Towards Conscious Integration of Machine-Learning Based Approaches

In the 1980s and 90s, literature and patent data were the most important data publicly available to analyse innovation activity (Blind et al. 1999, 2001; Cuhls 1998; Cuhls et al. 2002; Grupp 1997; Schmoch 1990). Technology Foresight was closely interlinked with these activities and extensively used scientometrics methods along with expert interviews and surveys. In addition to the Delphi surveys for the BMBF or the EU (Bundesministerium für Forschung und Technologie 1993; Cuhls et al. 1996, 1998; Dreher et al. 2005; Grupp 1995), the production innovation survey, later on the European Manufacturing Surveys (EMS), can be mentioned as extensive primary surveys connected to Foresight (see Lerch and Jäger 2024 in this anthology).

Since the 1990s and even more so the beginning of the 2000s, researchers have explored the mining of more diverse but structured and clearly defined databases for environmental scanning and Horizon Scanning, for example in Cuhls et al. (1995). Bibliometric analyses offer the possibility to broaden the perspective and to include scientific developments outside the patent realm such as social sciences. At the same time, the use of new data sources became possible with much less effort than the collection of primary data, allowing the definition of keywords for further searches even in different languages (Cuhls et al. 1995, 2009a, b). To enlarge the diversity of sources even further, Foresight researchers combine qualitative and quantitative sources and pay closer attention to the biases at play. As an example, in the second BMBF Foresight process, the Fraunhofer ISI team developed a sophisticated approach for working with fringe sources to identify seeds of change across fields of human needs (Warnke and Schirrmeister 2016).

At the same time, the very notion of objectively "observing" signals of change is challenged. Especially in Finland, a lively discourse emerged to advance capacities for identifying and assessing "weak signals" (Hiltunen 2010; Ilmola and Kuusi 2006 based on the early work of Igor Ansoff (1975)). Others investigated the role of rare and unexpected high-impact events under labels such as "wildcards" or "black swans" (Taleb 2007).

Another group of Futurists and Foresighters emphasised challenging of anticipatory assumptions in order to recognise "change in the conditions of change" (Miller 2007). Foresight researchers increasingly adopt a constructivist approach towards futures thinking (Rossel 2012) and subsequently focus on the cognitive framings determining the way futures are perceived (Schirrmeister et al. 2019, 2020) and build on seminal work in cognitive science (Gigerenzer and Gaissmaier 2011;

Tversky and Kahneman 1974). Human perception can be distorted by such biases at the individual, group or organisational level.

In addition, data artefacts that root in signal thresholds or decision rules coded into the algorithms can be misleading when judged by humans. The deliberate explication of such biases and distortions has become a focus of Foresight researchers within the last 10 years (Day and Schoemaker 2004).

The availability of new, unstructured data in different sources and the possibility of using this data via machine-learning algorithms have developed very dynamically in the last 5 years. Algorithms to analyse patterns in unstructured data sources such as natural language processing (NLP), topic-modelling such as Latent Dirichlet Allocation (LDA) and deep learning methods based on artificial neural networks are increasingly available (Daas and van der Doef 2020; LeCun et al. 2015; Muhlroth and Grottke 2022; Porter 2019). These new possibilities are incorporated mainly at the beginning of the Foresight process. One example is the "hybrid AI-expert foresight framework" (Geurts et al. 2021), which serves to support the questioning of anticipatory assumptions by feeding a wider range of (emerging) aspects into users' conceptualisations of the future. In current and recently completed projects, researchers extensively analyse unstructured data (especially news sites) without a predefined search realm and use the results as a starting point and reflection opportunity for future dialogues with experts. However, in most cases, the outcomes require substantial human sense-making activities. In addition, the development of quality criteria for AI-based approaches to deliver futures insights is still under way.

In the future, the development and choice of suitable algorithms will be a key challenge for generating meaningful insights for Foresight processes in machine-based approaches. The composition of sources for the search with sufficient diversity and quality is similarly important. It will be key to generate results in a format that lends itself to sense-making and assessment by humans in participatory futures dialogues. Examples are projects like the Radical Innovation Breakthrough Inquirer (Warnke et al. 2018) or Fraunhofer Foresight (Ganz and Schirrmeister 2019) where future technologies and other potential innovations were identified semi-automatically by algorithms and then assessed in dialogues by human beings. In these "sense-making processes" humans excel with their abilities to identify relationships across concepts and generating novel ideas. The cognitive biases of human perception can partly be counter-acted by the machine-based input. But AI algorithms and the underlying databases are also subject to biases on several levels (Friedman and Nissenbaum 1996), and sole reliance on algorithms in Foresight might even lead to self-fulfilling data prophecies (Gransche 2016).

To sum up, there is no such thing as an unbiased assessment of "signals of change", yet it is possible to soften the shortcomings of both the human and machine side by combining the two approaches reflexively, and thereby broaden our perspectives when constructing possible futures. In short, we are inclined towards cautious optimism when it comes to data-driven anticipatory methods if complemented by human sense-making.

2.5 Towards New Combinations of Quantitative and Qualitative Methods

Quantitative forecasting methods are helpful within Foresight, when themes are identified and investigated in more detail (Cuhls 2003). They can be relatively precise in the short term, but cannot adequately capture qualitative factors such as political, social, ecological and technological future developments. Moreover, it is often challenging to take the structural discontinuities into account, since mathematical-statistical models assume that patterns observed in the past will continue to be valid in the future (Helm and Satzinger 1999). An important feature of qualitative Foresight and forecasting methods is the collection of non-quantifiable expert knowledge about science, technology or innovation issues, including subjective opinions, in expert-based approaches. The focus is less on "explaining" a certain issue (causally) and more on "understanding" its meaning (Dilthey 1968). However, purely qualitative statements about the future are often difficult to communicate as a basis for decision-making.

Over time, the collaboration between more quantitatively oriented research and more qualitatively oriented Foresight has differed substantially. In the 1970s and 80s, both approaches existed alongside and first attempts were made to bring issues about science and technology, changes in technology directions or emerging technologies into the frameworks of economic—often input-output—models. Later in the 1980s and 90s, qualitative approaches and quantitative simulations were often used independently of each other, because both have their advantages depending on the specific research question (Alcamo 2008; Lamnek and Krell 1993). There was an increasing distinction between the two research directions (even in one single institute), differing scientific communities (Foresight versus forecasting) and controversial discussions about their respective performance and possible applications (Kardorff v. 1995). However, it soon became obvious that there are many overlaps and shared concepts between the methodological approaches (Moschner and Anschütz 2010; Stummer et al. 2021), especially when single methods are combined in a larger process.

Thus, the combination of the two approaches with qualitative Foresight as the open view into the future and quantitative data from the past and present simulated into the future by different models was increasingly discussed as reasonable. It was tested in different projects because problems can be described more comprehensively and the disadvantages of each type of approach can be overcome (Smolenaars et al. 2021). For the identification of new topics (from problem fields to thematic research areas), quantitative approaches are mainly used in bibliometrics (mapping) or later in semi-automated Horizon Scanning approaches—as phases of broader Foresight activities (see previous section).

Different types of combinations for qualitative and quantitative approaches are used nowadays: Firstly, narratives containing qualitative statements are created with the involvement of experts and then transformed into quantitative parameters or model variables or input values for simulation models (Mallampalli et al. 2016;

Shaaban et al. 2022; Voglhuber-Slavinsky et al. 2022; Erdmann and Priebe 2022). And secondly, quantitative results from modelling are placed in context by developing narratives to explain the model and the results of the modelling (Rogge et al. 2020).

An example for a combination is the project Time Rebound, Time Prosperity and Sustainable Consumption (ReZeitKon), where a combined scenario narrative and systems dynamics modelling approach was used. Scenarios were framed through guideline-based interviews challenging peoples' mindsets and by identifying influencing factors from Foresight or futures studies. The initial causal loop diagrams of the system under study served to develop scenario storylines, from which implications on future parameter values were estimated in focus groups and led to the refinement of the model structure. In addition, a representative survey was used to calibrate the system dynamics model with empirical data (Erdmann and Priebe 2022). Another example is the creation of scenarios for the maritime industry's pathway to a greener future, which are mainly available as stories. They also contain quantitative statements, and they are subsequently transferred into model parameters of the MATISSE-SHIP simulation model (MAN Energy Solutions 2020). The scenarios were discussed in a workshop with international experts, verified with stakeholders and updated. In a further round, the experts' feedback for the final results was incorporated.

The future will see more combinations of scenario stories or single assumptions about futures with quantitative models or backed up by surveys, because they have the advantage of linking subjective judgement and rational analysis, which is meaningful only to a certain degree. Mathematical models are able to contribute to the interpretation of qualitative statements and allow quantitative conclusions about possible social, ecological or political effects and conditions in the future. In addition, the usually static representation at the selected point (of time) in the future gains analytical depth in dynamics through the combination with simulation models. In the combination of qualitative scenarios and quantitative modelling, there are many new opportunities, which require researchers to collaborate intensively.

2.6 *Foresight and Innovation Systems: From Wiring Up to Rewiring*

From the mid-1970s onwards, in the context of "evolutionary economics", systems approaches have gained considerable importance in innovation research along with a new recognition of the complexity and non-linearity of innovation processes (c.f. Dosi 1982; Dosi et al. 1988; Nelson and Winter 1977). This resulted in the central notion of the "national innovation system" that was supposed to comprise "... all important economic, social, political, organisational, institutional, and other factors that influence the development, diffusion, and use of innovation" (Edquist 2005). It implies that in order to foster competitiveness, national governments should strengthen not only the technological infrastructures but also the interlinkages between system elements, in particular between research and industry actors.

This concept has been further expanded to include regional, sectoral and even technological innovation systems. The image developed by Kuhlmann and Arnold (2001) in the context of the evaluation of the Norwegian Research Council has become one of the most cited elements in innovation research, and different teams have developed countless variants for specific policy arenas and tested them in projects. The emergence of the innovation system framework is also a defining element of the rise of Foresight in the innovation policy discourse. Foresight became one of the "systemic" instruments (Smits et al. 2010; Smits and Kuhlmann 2004) with the core function of "wiring up" innovation systems (Martin and Johnston 1999) to better evolve in phase with changing framework conditions, aligning actors behind shared priorities and creating "distributed anticipatory intelligence".

This understanding remained dominant for almost two decades and fuelled several large Foresight exercises in countries around the globe. The framework began to evolve again along with changes both in the understanding of innovation processes and in the innovation policy framework. The crucial role of actors beyond research and industry became increasingly obvious and the "triple helix" of university, industry and government (Etzkowitz and Leydesdorff 2000) broadened to include societal actors (Knappe et al. 2019) and even ecosystems actors in a "quintuple helix" approach (Galvao et al. 2019). In parallel, in the 1990s, the notion of "social shaping" of technology gradually diffused from its origin in "Science and Technology Studies (STS)" into the innovation research community. The result was that closer attention was paid to societal actors and downstream phases of innovation trajectories (Warnke and Heimeriks 2008). Subsequently, concepts like user innovation, collaborative innovation, social innovation as well as social and relational capital became important also in the innovation systems framework. An internal research project involving researchers from all competence centres at Fraunhofer ISI about opening up the innovation system framework resulted in a new graphical representation of the innovation system (Warnke et al. 2016). At the same time, in the innovation policy arena, the "Lund declaration" in 2009 marked the beginning of the orientation towards addressing "grand challenges", while internal Fraunhofer Foresight processes were also carried out (Cuhls 2012). This shift later resulted in the "mission orientation" (Mazzucato 2021) of the European and EU member states' research and innovation policy (cf. Lindner et al. 2024). This again has major implications for the "systemic instruments" and especially for Foresight (Daimer et al. 2012).

Since 2010, it has no longer been enough to "wire up" the existing structures but essential to form new ones, that are better suited to accomplish "missions" in the sense of "desirable futures". This "rewiring" includes also actively challenging or breaking up existing non-sustainable innovation trajectories (Kivimaa and Kern 2016). The increasingly broadening notion of innovation systems enables innovation policy-oriented Foresight processes to expand their long-established practice of expert and stakeholder involvement.

While this aspect of opening up is well addressed in Foresight theory and practice (Nikolova 2014), the “mission orientation” is still posing challenges. Foresight is increasingly requested to generate “transformative pathways” or “normative scenarios” for defining targets or achieving predefined goals. Even though first approaches have been developed (Brunori et al. 2020; Erdmann et al. 2013; Schirrmeister and Warnke 2013; van den Ende et al. 2021; Warnke and Schirrmeister 2018) some tensions between open and oriented scenario building remain. Predefined normative orientations do not go hand in hand with key notions of the openness of the future. A bridging concept may be the notion of “resilience” which has long been an important pillar of Foresight thinking. Resilience entails both the ability of systems to react to unexpected futures (coping/ adaptive capacity) and the capacity to transform and develop new narratives that reach beyond dominant frameworks (Brunori et al. 2020; Lorenz 2013; Roth et al. 2021). A focus on such a transformative capacity in reflexive resilient innovation systems may become the next interface between Foresight and innovation system thinking. It can lead to the incorporation of Foresight into governance structures or an institutionalisation of Foresight (Warnke et al. 2021).

2.7 From Loose Networks to International Collaboration and Networking

During the 1980s and 90s, an international innovation policy network existed and futures research discussions already took place with an exchange of knowledge on methods and approaches organised in irregular workshops and conferences (e.g. in Kyôto in 1992). The regular monitoring of science and technology as an official network started with the European Science and Technology Observatory (ESTO), the first project of the European Commission’s Joint Research Centre’s Institute for Prospective Technological Studies based in Seville, Spain. It was set up to attempt to “create a platform of experts engaged in monitoring and analysing scientific and technological developments and their relation and interaction with society”. ESTO developed into two new networks: the ERAWATCH Network, a web-based service that presented information on national research policies, actors, organisations and programmes, and the ETEPS Network (European Techno Economic Policy Support Network), a network which supports Foresight of European organisations. ETEPS managed projects in all 27 EU Member States, covering policy subjects such as agriculture, consumer protection, energy, environment, enterprise, health, information society, innovation, research and transport and their respective futures. Through these networks, the European Commission financed several projects to foster Foresight and observations and laid the ground for further developments.

From 2001 on, under the heading of “Future-oriented Technology Analysis (FTA)” a series of conferences in Seville and Brussels were organised by JRC, and many papers concerning Foresight and FTA were published by authors from very different backgrounds. The last of these conferences took place in Brussels in 2018. They were the major meeting place for Foresight experts from all over the world.

The unification of Foresight in science and technology but also towards making use of “strategic intelligence” on a European level gained momentum with the project TSER-ASTPP as a European Network that defined terminology and raised questions about making use of actor networks and their strategic intelligence (Kuhlmann et al. 1999). The ForLearn Foresight Learning Platform (https://knowledge4policy.ec.europa.eu/foresight/topic/forlearn-online-foresight-guide_en) has been built up since 2005 to foster a shared understanding of Foresight, teach newcomers and facilitate mutual learning among practitioners. The platform was followed by the European Foresight Monitoring Network and funded by the European Commission. It formed the basis for a platform to collect Foresight studies and processes from all over the world. The network described Foresight projects in “briefs” to give a short overview of different approaches and their implementations and developed a sandbox for retrieval. The European Foresight Platform was its successor (http://www.foresight-platform.eu/community/forlearn/what-is-foresight/). The European network FOREN for mutual Foresight learning in the Regions (Gavigan et al. 2001) served to bring Foresight to the regions.

In Germany, the Federal Ministry of Education and Research (BMBF) was one of the drivers of Foresight starting in 1992 with larger activities to connect Foresight colleagues internationally. Several of the single projects in the different ministries could be labelled with “Foresight”, but there was no co-ordination or coherent understanding of what Foresight could mean for ministries and agencies. The external impetus came from the Stiftung Neue Verantwortung (Foundation New Responsibility, SNV) that tried to bring Foresight into different government agencies and ministries. This also initiated new conversations about futures and Strategic Foresight first on a rather informal level at the German Bundesakademie für Sicherheitspolitik (BAKS), later more formalised in the Federal Chancellery. More and more ministries or agencies now institutionalise Foresight in their departments (often as “Strategic Foresight”, see also Warnke et al. 2021). The SNV also started the first teaching programmes that were taken over by the BAKS, which developed towards a node connecting the ministerial network. The seminars on Foresight started as a trial—but in 2022, they are still on-going and always fully booked.

A German network for Futures Research has been already established since 2007 as a club (“Verein”; see https://netzwerk-zukunftsforschung.de/) with the aim of uniting the understanding of Futures Research in Germany, giving the researchers a joint “Leitbild” (kind of vision) and mutual exchange in working groups. The Foresight Europe Network (https://feneu.org/) tries to connect the Foresight community for a “better Europe”. The Millennium project (https://www.millennium-project.org/) can be located between a project and a network: It connects “futurists” around the world to improve global foresight, has so-called “nodes” in many countries and carries out global projects. National private activities like the D2030 (https://www.d2030.de) contribute to the picture.

Internationally, the OECD, very active in data gathering, quantitative analyses and reporting information to the member states started a Government Foresight Network (GFN) with a broadened perspective in Foresight. To bring together worldwide approaches in anticipatory monitoring for policy-makers and governments under the headline of "anticipatory innovation governance", the observatory OPSI intends to give new impetus to the strategic orientation of policy processes and is driving Strategic Foresight further within the respective organisations (OPSI 2020). The international collaboration and networking of Foresighters worked on joint book projects, International Advisory Boards of journals, the collaboration with the nodes of the Millennium Project and was present in institutions' Advisory Boards. Also expert groups of the European Commission like the European Forum of Forward-Looking Activities (EFFLA), the Strategic Foresight Group (SFRI) or the Research, innovation and science expert group (RISE) cooperate for independent scientific advice in Foresight. Major associations, in which the researchers organise themselves globally are the World Future Society (WFS), founded in 1966, and the World Futures Studies Federation (WFSF) which has existed since 1973.

The new possibilities of video meetings together with joint working tools like boards, fast surveys or games offer many new possibilities of international exchange, networking, collaboration on projects, training Foresight or fast information collection as well as project acquisition. Even though many researchers are looking forward to meeting physically again, there will be huge opportunities in offline, online and hybrid workshops of all kinds for connecting and conducting future Foresight. Researchers will go on working globally and in their respective networks. OECD and EU have the intention to broaden their networks further.

3 Reflection and Outlook

We have outlined key dimensions in the development of Foresight theory and practice within the last 50 years. This included institutional maturing such as the development towards an established academic field and the forming of a differentiated community with dedicated networks, organisations, conferences and journals. The evolution of innovation systems theory and related policy approaches also impacted Foresight. Its role evolved from informing to wiring up and transforming innovation systems. At the same time, the underlying epistemological basis of Foresight shifted from a predictive forecasting mode to an emphasis on better dealing with uncertainty and complexity by broadening present perceptions of the future through challenging dominant cognitive framings. In line with this, Foresight processes became increasingly participatory and included a wider range of diverse voices and perspectives. In parallel, the increasing availability of data, computing capacities and algorithms for their machine-based analysis led to a plethora of new approaches for identifying emerging changes under the umbrella term of "horizon scanning". This added up to an already on-going integration of quantitative modelling approaches into qualitative Foresight scenarios.

Across these dimensions of change, a few emerging issues can be highlighted:

As indicated in Sect. 2.6, Foresight will be increasingly requested to position itself vis-à-vis transformative mission-oriented agendas. One of the major contributions will certainly be the well-honed set of participatory deliberative Foresight approaches outlined in Sect. 2.3. Already now Foresight methods like visioning, backcasting or transformative scenario development increasingly underpin the deliberation of goals and transition pathways. Established Foresight approaches are adopted in many transformative policy arenas such as those fostering sustainability. Balancing this normative orientation with Foresight's insistence on the openness of the future and the inherent uncertainty of complex systems (Sect. 2.2) will most likely remain a highly dynamic and contested field of evolution in the coming years. Reflexivity and resilience may function as bridging concepts.

The second "game changer" under way is certainly the uptake of machine-based approaches and especially the analysis of unstructured data through natural language processing (NLP). As discussed in Sect. 2.4 this is opening up a whole range of new possibilities and brings in various perspectives. At the same time, the development of adequate sense-making activities is posing major challenges. There is a risk that the impressive possibilities create a false sense of certainty about future pathways. This could bring about a reversal of the focus on reflexive processes for challenging today's anticipatory assumptions and may lead to subsequent re-emergence of purely predictive and deterministic approaches.

Finally, as indicated especially in Sect. 2.2, Foresight is increasingly embedded into wider policy and strategy processes. In the European Commission and many countries around the world, Foresight units are being set up on high political level and also in corporate strategy departments. Driven by the increasing number of unexpected developments the need for futures literacy is becoming ever more obvious. This may open up new inroads to actual implementation of Foresight insights and strengthening of anticipatory culture in organisations. At the same time, it pushes Foresight to reflect more on the institutional framework required to fulfil its function of opening up arenas for reflections and deliberations that may well go beyond well-accepted paradigms and not lend themselves to immediate implementation. It poses a challenge to "institutionally embedded Foresighters" to carefully balance institutional power and scientific autonomy as well as the risks and opportunities of driving change from within versus reflecting on change unhindered from inside constraints.

Summing up one could say that all three key developments in Foresight bring major opportunities for strengthening outreach and impact of Foresight but also carry a tendency to draw Foresight back into the deterministic paradigms of the "planning decade". Foresight activities penetrate deeper into persisting and new power structures (again). Reaping these opportunities while avoiding the risks will most certainly be a major challenge for Foresight in the coming decade.

Addressing this challenge will require Foresight to further extend its co-operations and to continuously ask underlying epistemological questions. Existing networks and terminologies (Sects. 2.1 and 2.7) will most certainly evolve. A growing alignment with transformative R&I policy as well as transition-oriented networks, in particular with a sustainability focus, is already visible. On its way is also increased co-operation with researchers from public management and organisational innovation. The recent prominence of the notion of "anticipatory innovation governance" terminology in the OECD context could be seen as an indicator. Less developed yet but of at least the same urgency is to strengthen ties with research communities in artificial intelligence, big data analysis and natural language processing. This would need to include critical reflection on these approaches within the social sciences and humanities. Foresight was a fragile field but we, the authors, are convinced that it will continue to evolve and even expand—maybe under different headings and most certainly linked to an increasing number of diverse research fields.

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