eman ta zabal zazu

Universidad del País Vasco
Euskal Herriko Unibertsitatea

Faculty of Education, Anthropology, and Philosophy

Department of Philosophy

Anticipation and Responsible Innovation

Opening-up Futures through Plausibility Negotiations

Doctoral Dissertation

Philosophy, Science and Values

Author:

Sergio Urueña López

Supervisors:

Prof. Dr. Andoni Ibarra

Prof. Dr. Hannot Rodríguez

Donostia-San Sebastián

May 2022

Declaration of authorship

I hereby declare that this dissertation, entitled "Anticipation and Responsible Innovation: Opening-Up Futures through Plausibility Negotiations" and written under the supervision of Prof. Dr. Andoni Ibarra and Prof. Dr. Hannot Rodríguez, is the result of my own original research. To the best of my knowledge and belief, it contains no material previously published or written by another person, except where it is explicitly acknowledged in the text. No part of this thesis has been submitted for a degree at any other university or institution.

Sergio Urueña López

A Lolo, Pilar, Felipe, Sara y Nonna por haber sido
y ser la condición de plausibilidad que habilita
todos mis escenarios futuros deseables

ABSTRACT

This dissertation aims to develop a more robust conceptualisation of anticipation as a methodological-interventive relevant tool to promote more socio-politically responsible science, technology, and innovation (STI) practices. This conceptualisation would arguably allow a better understanding of anticipation regarding both (i) its functional and heuristic heterogeneity, and (ii) its interpretative and context-dependent character (as a situated socio-epistemic practice subject to potentials and limitations). The thesis argues that anticipation is a semantically and methodologically heterogeneous tool, whose heuristic capacity is of a heterogeneous kind in terms of both type and radicality. Regarding type heterogeneity, it is argued that the diverse modes of anticipation considered valuable to recent normative-interventive frameworks (e.g. Anticipatory Governance, Responsible Research and Innovation, Responsible Innovation) can be subsumed under three general types: strategic, exploratory, and critical-hermeneutic. Regarding radicality heterogeneity, it is shown that this fundamentally depends on two aspects. First and foremost, it depends on (a) which spaces of problematisation are formally enabled by the frameworks through which anticipation is instrumentally interpreted and adopted. Secondly, this formal radicality will be empirically settled depending on (b) how the (im)plausibility negotiation processes of the sociotechnical futures at stake deal with the openness/closure dynamics that prevail in the sociotechnical system in which anticipatory exercises operate.

ACKNOWLEDGEMENTS

I would like to thank my supervisors, Andoni Ibarra and Hannot Rodríguez, for their constant support during the development of this doctoral dissertation and for the trust they have placed in me throughout the project. It is mainly thanks to their continuous support and commitment that this work has been made possible.

I would also like to thank all the past and present, formal and informal, members of the PRAXIS research group with whom I have shared seminars and workspaces. I would like to explicitly mention and thank Hugo Rubio, Sandra Malagón, Javier Belastegui, César Alcazar, Ainhoa Fernández, Maite Arraiza and Maite Pelacho. The seminars, meetings, and informal discussions at Carlos Santamaría were an endless source of learning, motivation, and inspiration.

This thesis has also been made possible thanks to the financial support received from public funds. It was indeed produced thanks to an FPI pre-doctoral fellowship (BES-2016-079192, 2017–2021) awarded by the Spanish Ministry of Economy and Competitiveness and the European Regional Development Fund. The grant was associated with the research project "Representación y anticipación: Modelización interventiva RRI en las ciencias y técnicas emergentes" (MINECO-FEDER, FFI2015-69792-R, 2016–2019). This fellowship enabled me to conduct a research stay at the University of Twente (Enschede, The Netherlands) which was particularly relevant in the gestation of some of the ideas proposed in the thesis. I would like to thank Yashar Saghai for his willingness and eagerness to host me as a visiting pre-doctoral researcher.

I would also like to thank the Centre for Technology and Society (CTS-NTNU) at the Norwegian University of Science and Technology for awarding me a Visiting Research Grant (funded by the Norwegian Research Council). In this regard, I would like to thank the CTS-NTNU and the Department of Interdisciplinary Cultural Studies (KULT-NTNU) for their warm welcome and for making me feel "*koselig*" during my three months in Trondheim, Norway. I especially thank Knut H. Sørensen for his supervision, constant encouragement, and feedback during the stay.

I would like to address my last but most heartfelt words of thanks to those with whom I grew up and experienced my day-to-day life more closely along the way. In this context, I would like to thank Ana de Sosa, for making her house mine as well. I owe everything to my family, who have given me unconditional and invaluable support. I thank them for all their work and effort. Without them, my formation would not have been possible. Thank you too, Nonna: thank you for accompanying me, for sharing with me, for giving me hope when thinking about tomorrow.

TABLE OF CONTENTS

Abbreviations

AC	Alternating Current
AG	Anticipatory Governance
CNS-ASU	Center for Nanotechnology in Society at Arizona State University
CTA	Constructive Technology Assessment
DC	Direct Current
EC	European Commission
ELSA/ELSI	Ethical, Legal and Societal Aspects/Implications
FS	Future Scenario
NEST	New and Emerging Science and Technology
PCTI	Plan de Ciencia, Tecnología e Innovación
pTA	Participatory Technology Assessment
RC	Research Challenge
RI	Responsible Innovation
RRI	Responsible Research and Innovation
RTTA	Real-Time Technology Assessment
SPRU	Science Policy Research Unit
STI	Science, Technology and Innovation
STM	Sociotechnical *Momentum*
STS	Science and Technology Studies
SWAFS	Science with and for Society
TA	Technology Assessment
TRACES	Technology in Retrospect And Critical Events in Science project

List of Figures and Tables

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

0.1. General introduction

Scientific, technological, and innovation (STI) activities are inherent co-constituents of the human condition and life. The development of certain techniques, technological artefacts and sociotechnical systems has enabled us as a species to adapt to contexts that might a priori appear unsuitable to support the relatively comfortable conditions we currently enjoy. Scientific-technological developments have enabled us to feed and clothe ourselves more efficiently. It is also thanks to the development of certain sociotechnical systems that we can travel great distances in a short time and communicate instantly with people on the other side of the planet. However, technical creativity and scientific-technological research and innovation also (and simultaneously) enable and perpetuate the co-production of sociotechnical systems that systematically eliminate or hinder certain beings' existence, contaminate ecological habitats, and alter ecosystems (Almazán, 2021).

Yet, the constitutive roles of STI are not pre-given; they do not emerge *ex nihilo*. STI is instead the result of a constellation of dynamic-relational processes that co-evolve and are resolved—not without tensions and socio-political struggles—throughout space and time. STI mediate our experiences and actions in the world (Verbeek, 2012a, 2012b, 2015). But these mediations are themselves in turn enabled, mediated, conditioned, constrained, and guided by an array of sociotechnical, or socio-material, constellations of relationships and factors (Bijker, 2001; Bijker et al., 1987; Latour, 2005; Pinch and Bijker, 1984). STI development is shaped by an innumerable series of factors and influences, among which human agency could be only contextually and relationally located.

This introductory chapter presents the main and guiding research objectives and hypotheses that structure the thesis. It also situates the objectives and hypotheses within the general lines of the academic fields in which the dissertation is involved and to which it aims to respond or contribute. In particular, this introductory chapter briefly outlines that STS—broadly defined—has progressively expanded both the scope and the factors involved in describing, understanding, critiquing, and intervening in the dynamics that shape the governance of STI. The principal proposition argued here concerns the existence of a growing interest in temporality within STS—an interest in temporality that is specially bent towards "the future". This temporal expansion points to the need to consider future temporality as a constitutive element that modulates STI co-production dynamics in our sociotechnical milieus.

0.2. A temporal expansion in STS: Anticipation in the governance of STI

Science and Technology Studies (STS) aims to describe, critique, and modulate research processes in science and technology (and more recently innovation activities) and to examine the mutual coevolutions and co-constitutive interrelationships that these processes enact within the sociotechnical context in which these activities take place and which they simultaneously constitute.

There is not a broad consensus on the historical roots of STS, but they are generally located in the science movements of the 1960s and 1970s which focused on environmental issues (Cozzens, 1993). Since then, the approaches and foci of interest subsumed under the "STS" label have been very heterogeneous, both in terms of their most immediate goals and in terms of the methodological approaches and tools used to address those goals (see Cutcliffe and Mitcham, 2001; Fuglsang, 2001; Irwin, 2008; Sovacool and Hess, 2017). This heterogeneity of approaches and dispositions has understandably created—and at the same time is an expression of—certain tensions in the approaches to STI. Some of these tensions can be observed between a more activist-interventionist engagement and a more analytical engagement with STI (e.g. Pinch and Bijker, 1984).[1]

In the Third Edition of *The Handbook of Science and Technology Studies* (Hackett et al., 2008), Irwin (2008) provided a brief and illuminating discussion of the advances in the field of STS in terms of understanding the concept of governance. These advances were argued to be highly relevant to understanding the complexity of network dynamics conceptualised as "boundary work" (e.g. Gieryn, 1983, 1999; Guston, 2001; Jasanoff, 1990), "sociotechnical co-production" (e.g. Jasanoff, 2004), or the formation of "sociotechnical networks" (e.g. Moss, 2009; Wetmore, 2004). In relation to the concept of governance, Irwin noted the following:

> "Governance" can be taken to imply that the *development* and *control* of science and technology is not simply a matter for government or "the state" (…). Instead, it is necessary to include the activities of a much wider range of actors—including industry, scientific organizations, public and pressure groups, consumers, and the market. "Governance" encompasses the range of organizational mechanisms, operational assumptions, modes of thought, and consequential activities involved in governing a particular area of social action—in this case, relating to the *development* and *control* of science and technology (Irwin, 2008, p. 584; emphasis added).

[1] For an early diagnosis of this divide between analytical and activist dispositions, see Bijker (1993).

The emphasis added in the above quote underlines the double meaning of governance applied in STS, which mirrors the aforementioned activist-interventive and analytical divide:[2]

(i) The descriptive-analytical sense aims to trace the heterogeneous networks of actions, inter-actor relations, and power assemblages that de facto co-constitute sociotechnical realities (see Konrad et al., 2016).

(ii) The normative-interventive sense refers to those normative and interventive frameworks or approaches that seek «to coordinate or otherwise influence the actions and interactions of multiple actors» (Fisher, 2019, p. 1141). Grounded in a more or less articulated and explicit set of values, the normative-interventional approach intentionally interferes in sociotechnical systems.

Both the question of how STI de facto develop and the question of what dynamics should be encouraged to drive STI development are based on prior approaches or conceptions (which may be more or less explicit/implicit or sophisticated/naïve) of what the STI phenomenon de facto is and what its relations and entanglements with society are. Answering both the descriptive and normative questions of the STI phenomenon requires the prior definition of a position or approach to what STI is and its constitutive relations with the socio-material space in which it emerges, unfolds, and co-constitutes.

A cursory look at the development of STS shows that the approach to STI has been expanded (Table 1). The elements considered in describing and modulating the dynamics of sociotechnical co-production and coevolution have been extensively and intensively expanded. Today, there is a much more complex picture of STI coevolution and the different and overlapping roles of different social actors in the co-production of sociotechnical orders. The simplistic view of the linear model expressed in science policy in terms of "technology push" or "market pull" has been complexified by the inclusion of the constellation of elements that complexly and continuously interact with each other in real time to shape STI outcomes and pathways through contingent processes (e.g. Godin, 2016; Godin and Vinck, 2017; Kline and Rosenberg, 1986; Pfotenhauer and Juhl, 2017).

[2] Kuhlmann et al. (2019) have recently distinguished between two modes of governance (applicable to both the de facto and the inventive-normative facets): "tentative" and "definitive" models. This distinction is based on the degree of openness/closure and reflexivity/rigidity with which the processes of STI governance are de facto developed or are intended to be developed (in the interventive-normative facet). Governance would be considered tentative «when it is designed, practiced, exercised or evolves as a dynamic process to manage interdependencies and contingencies in a non-finalizing[, prudential, and preliminary] way» (Kuhlmann et al., 2019, p. 1093). Governance would be considered "definitive" when there are «attempts by key actors (such as governmental agencies) to "steer" sociotechnical developments towards certain desired aims by specified and stable means» (Kuhlmann et al., 2019, p. 1093) (i.e. when governance is designed, practiced, exercised, or evolves as a dynamic process to manage interdependencies and contingencies in a finalizing, target-oriented, and predetermined way). In this sense, tentative models would seek to maintain flexible spaces of open opportunities and possibilities for action, while definitive models would seek to achieve the goals pre-defined by a framework. In other words, tentative models are directed towards openness, definitive models towards closure.

Table 1. Three competing approaches on the relations of STI-society within STS.

	STI shapes society	**Society shapes STI**	**Interactive (coevolution/co-production) approach**
Time of prevalence	1950s-60s	1970s-80s	1990s-present
Definition of technology	Cause	Consequence	Cause and consequence
Independent variable	Technology	Society	Sociotechnical relational constellations
Relation of actor to technology	Beneficiaries or victims	Negotiate interests	Seamless web
Role of policy	Protect or reject science and technology	Empower actors, create networks	Democratise
Power structure	Technological regime	Negotiation	Frames, discourses
Method	Study impact of technology	Follow the artefact	Follow the actors

Source: Fuglsang (2001, p. 42).

Our current understanding of STI indicates that STI activities acquire meaning and are performed within sociotechnical relational assemblages, that is, within architectures in which the social and the technical are in mutual symbiosis and together form entities of a hybrid nature (Broncano, 2009; Haraway, 2006; Jasanoff, 2004, 2016; Latour, 1993) (Table 1). These sociotechnical entities and the systems they constitute are simultaneously (i) the enabling, co-creating or preserving milieu of STI activities and (ii) the subject-patient of STI performative power. The co-produced processes and products of STI activities shape and (de)stabilise the relational networks from which they emerge and in which they simultaneously operate, and thus co-constitute the maintenance or destruction of the worlds we inhabit. The outcomes, processes, and purposes of STI are simultaneously co-created by, and co-creators of, the *socio-material conditions of production* which define and (dis)enable heterogenous modes and places of existence and their corresponding (im)possibilities for action. Hence the high normative and political component involved in the development of STI (Blok, 2017; Broncano, 2009; Feenberg, 1991, 1999; Harbers, 2005).

Sociotechnical systems are typically described as socio-material systems composed by «heterogeneous ensembles of people, artifacts, infrastructures, research, cultural categories, norms and laws, and natural resources» (Hess and Sovacool, 2020, p. 3). This definition of sociotechnical systems includes technological artefacts among the heterogeneity of elements that, in a heterogeneously ensembled manner, conform the socio-material settings in which our lives are configured and unfold. Under this conception, STI would be conceived as an activity whose conditions of production are simultaneously enabled and constrained (e.g. in terms of processes and purposes to be pursued) by the prevalent architectures and dynamics of the sociotechnical assemblages where they unfold. The unfolding of STI activities within this sociotechnical fabric would in turn find among its main outputs the production of heterogeneous relational dynamics. These STI world-making dynamics might acquire diverse types of relationships with the system from which they emerged and in which they operate. For example, STI can establish relationships of destruction (e.g. consuming resources, invalidating previous findings or technologies, prioritising certain lines of research, disabling the possibility of certain relations), perpetuation (e.g. reproducing certain

modes of operating and research, and disabling the possibility of certain relations), and/or of innovative generation (e.g. generating new knowledge, new technologies or services). The world-making character of STI lies at the heart of the concept of co-production: «[T]he ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it» (Jasanoff, 2004, p. 2).

The recognition that the co-production and coevolution of STI is context-dependent and acquires unity and meaning in relation to the sociotechnical framework in which it is co-constituted and which it co-constitutes has the implication, among others, that in understanding and attempting to enrich or modulate STI, a multitude of (f)actors and their mutual interrelationships need to be considered. The social sciences and humanities have progressively expanded, complexified, and nuanced the heterogeneous and multidimensional linkages and dynamics of co-constitution considered in explaining and understanding the mutual interplay between STI and society. This general expansion is evident in the areas in which co-production was supposed to take place (and thus in the actors involved in it). This expansion can be seen, for example, in the moves made from the study of theory building to the study of laboratory practices (Doubleday, 2007; Fisher, 2007). This expansion can also be seen in the movement from the study of the laboratory to the inclusion of public controversies in STI, or the public politics of STI. Likewise, the focus on controversies and on the spaces of "regulatory science" (Weinberg, 1972) or "post-normal science" (Funtowicz and Ravetz, 1990, 1996) are expanded by the attention to the co-production dynamics (see Jasanoff, 1996). This expansion has ultimately amplified the actors that are considered in the governance of STI processes. It underlines the distributed nature of STI governance: «[G]overnance is a capacity that is lodged throughout society» (Karinen and Guston, 2009, p. 221). In this sense, «[g]overnance commonly refers to the move away from a strictly governmental approach to one in which a variety of regulatory activity by numerous and differently placed actors becomes possible» (Karinen and Guston, 2009, p. 219).

The distributed character of governance led the Actor-Network Theory to the notion of "following the actors" (Latour, 1987). But given this distributed character, one might ask "what actors?". The regimes of temporality are among the actors that are simultaneously components and products of our sociotechnical systems (see Emirbayer and Mische, 1998; Mische, 2009). Temporality, or representations appealing to pasts, presents, and futures are seen as a modulating actant/element of factual governance, as well as an instrument that can be used to support interventive governance exercises (see Bechtold, Fuchs, et al., 2017; Schwarz-Plaschg, 2018a, 2018b).

As part of the growing importance/recognition of temporality, representations appealing to futures have become a matter of increasing concern. Representations of the future, or sociotechnical futures, have been identified as key modulators of STI. This is because they shape and enact present action, forming the substratum of what Anticipation and Futures Studies refer to as "anticipations" (Poli, 2017, 2019a; Poli and Valerio, 2019). The "anticipatory" dynamics that co-constitute STI have become both objects worthy of

analytical attention and instruments for promoting better STI (Lösch, Grunwald, et al., 2019). Thus, it could be said that anticipation has been shown to be a functional activity within the two general conceptions of "governance" of STI previously discussed: descriptive or de facto governance as well as the "normative-interventive" governance (see Konrad et al., 2016).

On the one hand, from (i) the empirical-descriptive dimension, some STS scholars have concentrated their efforts on investigating how anticipations (i.e. actions based on future-oriented representations) arise, co-evolve, and/or influence the dynamics occurring within sociotechnical systems. The empirical-descriptive dimension focuses on describing how the future representations which are co-created and organically embedded as constituents of sociotechnical systems prompt their constellations of actors to enact a series of heterogeneous actions (e.g. Anderson, 2007; Konrad and Böhle, 2019; Selin, 2008). Expectations (e.g. Anderson, 2007; Selin, 2007; van Lente and Rip, 1998a), visions (Grunwald, 2018; Lösch, 2006; Simakova and Coenen, 2013), and sociotechnical imaginaries (Ballo, 2015; Jasanoff and Kim, 2015; Low, 2017) ongoingly shape the constitutive dynamics of sociotechnical systems. If the classic STS formula when describing co-production processes was "to follow the actors" (Latour, 1987) and, more recently, "to follow the narratives and imaginaries" (see Chakrabarti, 2004; Sekhsaria, 2016), STS scholars focusing on the performative role of futures (whether in the form of visions, expectations or sociotechnical imaginaries) apply the formula "follow the *future* narratives and imaginaries" (Jasanoff, 2015; McNeil et al., 2017). Indeed, the co-creation, mobilisation, and contestation of futures representations are nowadays seen as mechanisms influencing (in aggregation with many others) the politics of future-making (Jasanoff, 2020).

On the other hand, and operating in (ii) the instrumental-prescriptive dimension, some STS and science policy scholars have proposed to use instruments engaging with future representations to proactively and intentionally modulate or enhance reflexivity within the co-production processes of STI dynamics (e.g. Barben et al., 2008; Berne, 2008; Guston, 2014; Guston and Sarewitz, 2002; Karinen and Guston, 2009; Lösch, 2006; UNESCO, 2006). The aim here is not to observe how future representations help to create realities but rather to use futures' performative potential as a methodological resource to proactively generate the opening-up dynamics (on the basis of more or less articulated normative assumptions).

The temporal expansion has thus been particularly fruitful in both providing empirical evidence of how temporality actually permeates coevolutionary processes (descriptive dimension) and highlighting the possibility of fostering more robust STI governance dynamics by implementing methods capable of supporting more robust engagement with future representations (interventive-methodological dimension). However, this expansion still demands a number of further theoretical, conceptual, and methodological developments in both of these dimensions. It is in the context of this "temporal expansion" and the need to theoretically and conceptually strengthen the role that anticipations (could) play in STI

governance (whether de facto or interventive) that this dissertation is contextualised and attains academic meaning, significance, and relevance.

0.3. Concepts and practices of anticipation: Main research challenges

The previous section has briefly outlined how the STS field has expanded its focus of descriptive and normative analysis of STI practices both extensively and intensively. One of the aspects that deserves special attention in this context is the increasing emphasis on temporality, with a particular focus on future temporality. Representative practices involving various kinds of socio-epistemic engagements with sociotechnical futures (e.g. visions, expectations, imaginaries) have emerged as another (albeit highly relevant) actor in the (political) life of STI. As a result, they have also increasingly become the object of active modulation—an interventive modulation that is in turn often supported by using methods that mobilise representations about futures (e.g. foresight and visioneering practices).

However, this process of making temporality in general and future temporality in particular the subject of study and practice (Alvial-Palavicino, 2015) is relatively new and still developing. This means that there are still several theoretical and practical challenges that need to be addressed. In the following, I present five of these research challenges that can currently be found in the literature (STS, philosophy of technology) and that this dissertation will address. These research challenges (RC) are the following:

RC#1. Theorising the power mechanisms underlying the processes of creating and mobilising futures that constitute STI dynamics.

RC#2. Clarifying the characterisations of anticipation as a procedural interventive dimension to promote a more socio-politically robust STI.

RC#3. Elaborating further on the role "plausibility" plays in the context of anticipatory interventive practices.

RC#4. De-substantiating anticipatory heuristics by recognising their contingency and socio-epistemic situatedness.

RC#5. Problematising the operationalisation methods and processes of interventive anticipations.

These five research challenges span the whole spectrum from theoretical-conceptual to practical-operational and reveal interconnections and interrelationships between them. For example, the need to make explicit and account for how futures perform the governance of STI and are instrumental to the mobilisation of power (i.e. RC#1) has consequences for interpreting and making sense of anticipation as an intervening tool: Anticipation aims to develop its heuristics by mobilising futures within contexts shaped by politics with and through futures (thereby modulating the politics of anticipation). Similarly, the lack of conceptual elaboration of anticipation (i.e. RC#2) has implications for its sense-making

processes. The lack of such elaboration promotes the operationalisation of anticipation to acquire different meanings and degrees of problematising radicality (i.e. RC#5).

0.3.1. Conceptual-theoretical research challenges

From a more theoretical-conceptual perspective, it should first be noted that (RC#1) there is limited recognition and theorisation concerning the power mechanisms underlying the processes of creating and mobilising futures that ongoingly constitute anticipatory STI dynamics. The general and prevailing academic tenor of STS to rely on a strong case study methodology (see Law, 2008) also reverberates in the concrete study of the performativity of sociotechnical futures. There is a wealth of case studies that illuminate how futures perform under different degrees of radicality and in different spheres of sociotechnical life in STI practices (e.g. Brown et al., 2000; Jasanoff and Kim, 2013; Schneider et al., 2022; Selin, 2006a). Futures have proven to be pervasive and relevant elements that provide meaning, direction, and legitimisation to certain STI fields, especially those that are at an early stage of development (e.g. nanotechnologies, biotechnology, artificial intelligence). However, the theoretical foundations from which we can understand and comprehend these empirical practices and their respective conditions of production still need to be deepened. The antecedents for theorising futures within STS (including philosophy of technology) are relatively sparse in this regard.

Some exceptions in this respect are the works of van Lente (1993), Konrad and Alvial Palavicino (2017); Konrad et al. (2016), Alvial-Palavicino (2015), Grunwald (2014, 2016, 2017). Among these works, however, the contribution by Alvial-Palavicino (2015) is the only one that assumes the character of a general theoretical-conceptual framework. Alvial-Palavicino (2015) frames the future as a space that is practised, shared, shaped, and contested, constituting anticipatory assemblages that perform STI practices. This dissertation aims to move in this direction (i) by highlighting the mobilisation of power that underlies and reproduces these anticipatory assemblages shaped by practices of the future, and (ii) by including within this general assembly the dynamics and uses of the future that STS scholars themselves mobilise through their normative frameworks and interventive operationalisations. The dissertation thus recognises and explicitly addresses the politics of anticipation generated, mobilised, and contested by the various forms of "practising the future".

By emphasising the mobilisation of power with and through futures, I aim to explicitly highlight the eminently political character of these practices. By including the mobilisations of STS scholars in this landscape of practices of futures, I seek to extend the meanings that anticipation acquires precisely as an intervening tool, as well as to diagnose and evaluate how STS scholars participate in and engage with these futures (i.e. to what extent they disrupt the arrangements of power that simultaneously underlie, constitute, and confront the practices involving futures). The dialectical articulation and interrelation between anticipatory practices made on the basis of visions, expectations, sociotechnical imaginaries,

and interventive practices based on futures—i.e. «to integrate analysis and practice» (Borup et al., 2006, p. 296)—is one of the pressing research challenges identified by Borup et al. (2006, p. 296). The recent book by Lösch, Grunwald, et al. (2019) also proposes to explore the interrelationships between the practices of describing and analysing the performative power of futures (i.e. "analysis") and the experiments of engagement with futures that are intentionally mobilised by STS scholars (i.e. "practice"). The need to make this connection is more specifically emphasised within this volume in the discussion paper on the role of Technology Assessment within these landscapes of futures (Lösch, Böhle, et al., 2019).

The second major research challenge, which is also theoretical-conceptual in nature, relates to **(RC#2)** ***the need to elucidate the main features of anticipation as a procedural dimension or intervention tool for promoting a more socio-politically robust STI***. There is a lack of clarification and elaboration regarding (i) the meaning, (ii) the key heuristics, and (iii) the challenges associated with anticipation when postulating it as a highly disruptive tool to promote a more socio-politically responsible STI.

Several recent frameworks explicitly include anticipation as a constitutive procedural dimension to promote more socio-politically robust forms of research and innovation (i.e. with a focus on including a broader range of voices and concerns during the co-production process). Examples include the frameworks of Anticipatory Governance (AG), Responsible Research and Innovation (RRI), Responsible Innovation (RI), and newer forms of Technology Assessment (TA). Robustness is understood here in terms of bringing into productive and inclusive tension the different values, interests, knowledges, and concerns that exist about the STI in question from early stages of development and throughout the whole development process. However, the definitions of what anticipation means in these frameworks are extremely brief, nebulous, and somewhat vague in terms of the kind of engagements with futures they are intended to stimulate. It is therefore necessary to clarify what sense, meaning, and heuristic scope anticipation acquires in order to promote enriched forms of problematising how we construct sociotechnical worlds through STI.

This lack of concreteness is already evident in the characterisations offered for anticipation within the AG, RRI, RI, and TA literatures. The literatures of these normative frameworks offer both positive (specifying the features of what is defined) and negative characterisations (focusing on which features of what is defined should be discarded) of anticipation. On the one hand, the negative definitions emphasise that anticipation is not used to articulate actions in the present based on predictive models. On the other hand, the positive definitions focus on the generation of reflexivity within STI practices. However, there is a high degree of non-specificity in terms of the challenges that this reflexivity is intended to address, the degrees of radicality that it is intended to assume, the techniques through which it might be implemented, and in what sense all of this can be subsumed under the term "anticipation". As one of the architects of Anticipatory Governance recognises:

> [Anticipation] is perhaps the most crucial and problematic dimension [of responsible innovation] to deal with. This is not to say that reflection, deliberation, and responsiveness are uncontroversial. But, whereas there are

> relatively clear intuitions and broad literatures around reflection, deliberation, and responsiveness; there is less conceptual development around anticipation, and even poorer intuitions (Guston, 2013, p. 110).

This lack of elaboration and intuition is at the root of several misunderstandings in academic debates that attempt to critically assess the value of anticipation for promoting a more socio-politically responsible STI (see Chapter 4). The philosopher of science and technology Alfred Nordmann, for example, has been quite sceptical about the value of anticipation for promoting the kind of responsible innovation that characterises the above frameworks (i.e. for a more socio-politically robust responsibility). Specifically, Nordmann (2014) assumes that (i) anticipation consists in «acquir[ing] a kind of knowledge that is short of prediction but still provides a sense of reasonable possibility or plausibility» (Nordmann, 2014, p. 88), and that (ii) acquiring knowledge about the future is neither possible nor always desirable. The conclusion he reaches is that anticipation is not necessary (or might even be counterproductive) to promote Responsible Innovation or Anticipatory Governance. These assumptions and conclusions are also shared by other sceptics of anticipation such as van de Poel (2016) and Fuller (2018a, 2018b).

The first reactions to this conclusion from authors defending anticipation were directed against the notion of anticipation underlying Nordmann's critique. For example, Selin (2014) lamented Nordmann's lack of engagement with and understanding of the literature and epistemological traditions of Futures Studies, which in its recent history has largely distanced itself from the predictivist pretensions of generating knowledge about the future (Son, 2015). Similarly, Boenink (2013) discussed how the co-creation of plausible future scenarios (one of the central tools used to operationalise anticipation) can be shielded from Nordmann's critique, even if the critique served to point out some caveats that need to be considered when operationalising anticipation. While both responses emphasised the need to put Nordmann's characterisation of anticipation into perspective—which could be defined as the mainstream, admittedly narrow, understanding of anticipation—the task of developing a richer and deeper account of anticipation remains unresolved. This leaves us in a context where both critics and opponents fail to offer a defence or attack based on a robust characterisation of anticipation and its relevance to responsible STI. All of this reinforces and underscores Guston's diagnosis above and the need to make progress in this regard.

This lack of conceptual understanding of anticipation as an interventive tool to promote more socio-politically responsible research and innovation practices is particularly evident in **(RC#3)** ***the conceptualisation and understanding of "plausibility" as a key criterion in the implementation of the anticipatory practices that the above normative frameworks seek to promote*** (see Owen and Pansera, 2019, p. 31; Selin, 2011; Stilgoe et al., 2013, p. 1573).

The understanding of anticipation reflected in Nordmann's critique of anticipation rests on an understanding of "plausibility" as a criterion that (de)limits or pretends to accommodate futures that are considered «feasible and can be imagined with some facility» (Nordmann, 2013a, p. 127). However, by linking anticipation to a form of knowledge that

relates to the future, the role of plausibility is turned into a criterion that attempts to distinguish the trustworthy from the untrustworthy. In contrast, Selin and Guimarães Pereira (2013) and others (e.g. Fischer and Dannenberg, 2021; Ramírez and Selin, 2014; Wiek et al., 2013) go beyond this role—without denying it (e.g. Selin, 2006b)—and use plausibility as an inferential register that can incorporate and model information in a much broader way than would typically be done through the register of probability, thereby opening-up the voices involved, and subsequently the concerns and futures considered.

The first way of addressing plausibility emphasises the epistemic robustness of considered futures and focuses on *closing-down* considered futures in promoting a more responsible STI than those that do not start from extremely speculative visions (see also Lucivero, 2016a; Lucivero et al., 2011; Nordmann, 2007). The second way of facing plausibility is more concerned with *opening-up* the imagination of socio-political spaces of possibilities and capacities to deal with the open, contingent, and uncertain character of the future (see Barben et al., 2008; Berne, 2008; Lehoux et al., 2020; Nelson et al., 2022; Selin, 2011; Selin and Guimarães Pereira, 2013; Selin et al., 2017). Apart from this reading, which situates the plausibility debate within a (meta-)framework of openness and closure dynamics (Stirling, 2008), the identification of these roles, the ways in which plausibility affects them, and their respective epistemic and socio-political significance have been only tentatively explored and rarely problematised, especially within the STS field in general (in the broadest sense) and by scholars focusing on the architectural design and practical promotion of frameworks such as AG, RRI, RI, and TA in particular.

At this point, it could be suggested that this lack of deepening and problematisation within STS of anticipation as a phenomenon that constitutes our future-making practices and the roles that plausibility plays in them could be partially alleviated by drawing on the advances made by the so-called "Anticipation and Futures Studies". Anticipation and Futures Studies are focused on how representations of the future are, could or should be used to trigger action in the present and promote a particular outcome. Indeed, as mentioned above in connection with the appreciation of the value of anticipation, Selin (2014) denounced Nordmann's lack of engagement with the practical and theoretical journeys of Futures Studies.

While engaging with the literature of Anticipation and Futures Studies is necessary, it is also true that most of its contributors, with a few key exceptions (see e.g. Bell, 2003; Inayatullah, 1990, 1998; Marien, 2002; Masini, 2006; Miller and Poli, 2010; Miller et al., 2018; Milojević and Inayatullah, 2015; Slaughter, 1998), do not engage with their own theoretical-conceptual foundations (e.g. in terms of their underlying ontologies and epistemologies). And those who do address them are not free from some fragmentations and divergences of major theoretical and practical significance (Samet, 2010; Sardar, 2010; Son, 2015). The recent bibliographic review by Fergnani (2019) places these fragmented approaches into clusters and makes clear that one of the major clusters has its *raison d'être* in an extremely practical area: Corporate Foresight (i.e. a cluster that focuses on the

development of practices that support corporate survival; it is less concerned with the development and theoretical-conceptual legitimisation of the field).[3]

Two facts that speak to the existing need to deepen the foundations of anticipation and the importance and role of plausibility in intervention measures can be found in the recent request for the creation of a discipline of Anticipation Studies and in a 2018 call for papers that appeared in *Futures* (a central journal of the field). On the first point, Poli argues that «[i]f futures studies aims to become someday an autonomous field of research and application, it must prove that it contributes knowledge, methods, and viewpoints different from those distinctive of other already established fields» (Poli, 2018, p. 1). Hence, his intention to offer a robust concept and his call for a systematic study of futures-oriented methodologies (Poli, 2019b), which is intended to set «the agenda for the field» (Poli, 2019a) (see also Miller, 2018; Miller et al., 2013, 2018). On the second point, the *Futures* call for papers invited contributors to problematise the meaning and significance of plausibility in the processes of operationalising anticipation—it is precisely in this last special issue that the findings presented in Chapter 5 are framed.

All of the above indicates not only that there are studies that have diagnosed this lack of conceptual depth, but also that some progress has been made in this regard—albeit outside the STS field.

In relation to the problem of plausibility, for example, the recent work by Schmidt-Scheele (2020a) starts precisely from the recognition that there has been a lack of concreteness and theorisation around the meaning of plausibility, and makes a valuable contribution in its theoretical and empirical exploration of how plausibility is perceived from the perspective of users engaging in scenario-building practices, especially in terms of (cognitive) closure. Indeed, it would be very interesting to apply this study within the STI domain. Beyond the limiting role, the functional roles of epistemic-political openness remain largely unacknowledged, unexplored, and under-theorised.

In relation to the concept of "anticipation", Poli, for example, provides a basic concept of anticipation as an activity consisting of the translation of a future into action, and from there he proposes the pervasiveness of the phenomenon, as different systems (social, biological, technical) can be conceived as "anticipatory". While this definition is extremely useful as a starting point, it may not be sufficient to illuminate the meaning of anticipation for AG, RRI, RI, and TA (see Chapters 2 and 3). This is not to say that the definition is

[3] The field of Futures Studies is highly heterogeneous in terms of the disciplinary and professional backgrounds of its main actors. There are, for example, actors who come from the professional field of business (and who work with strategic planning methods), sociology, history, etc. The existing fragmentation in terms of underlying theories, ontologies, and epistemologies and the lack of explicitness, systematisation, and problematisation of these are among the multiple and complex factors that have kept Futures Studies excluded from academic circles. Hence, the call championed by Roberto Poli and Riel Miller to conceptually and operationally strengthen the systematic study of anticipation, starting with its ontological (Poli, 2011, 2014) and epistemic foundations (Miller, 2015; Miller and Poli, 2010), is linked to or involves the formalisation of a robust theory or concept of anticipation (Miller, 2018; Miller et al., 2013, 2018). Some limits and potentialities of this robust theory will be problematised in Chapter 3.

flawed. Rather, it implies that it is inadequate in descriptive terms (and, in relation to AG, RRI, RI, and TA, in normative terms too). Moreover, Poli's conceptual developments, while largely robust and necessary, often fail to incorporate a critical and sensitive perspective to the conditions of co-production of anticipatory processes—as this thesis seeks to emphasise. The conceptual reinforcement Poli and Miller have provided to Anticipation and Futures Studies is precisely what is missing from the STS literature on anticipation (both the descriptive and normative-interventive literature), and the lenses that STS could provide, in terms of analysing and accounting for the conditions of production of (the politics of) anticipation and its underlying power relations, are what Poli is missing when it comes to constructing and justifying his concept of anticipation and its associated methods of operationalisation.

However, the challenge of constructing a concept of anticipation that is sensitive to the conditions of production and power dynamics should not be understood as a task of merely translating STS findings with the insights of Anticipation and Futures Studies. The process reveals several conceptual issues and tensions that require further development and refinement on both sides. It is precisely for this reason, as noted in RC#1, that it is necessary to look more closely at the power dynamics in which anticipation is contextualised (and instrumentalised) as an intervening tool, and at the same time to clarify its meaning and heuristic value in relation to these contexts (RC#2)—especially regarding the roles that plausibility plays therein (RC#3).

Some relevant recent proposals have been put forward, for example, in the fields of anthropology (Bryant and Knight, 2019), psychology (Buckner et al., 2008; Oettingen et al., 2018), cognitive and behavioural sciences (Suddendorf and Redshaw, 2017), political economy (Beckert, 2011, 2016, 2018; Beckert and Bronk, 2018), history (Hölscher, 2016, 2018), and sociology (Adam, 1990; Adam and Groves, 2007; Emirbayer and Mische, 1998; Mische, 2009, 2014). Yet these proposals remain preliminary or semi-programmatic in character, in terms of delineating future research agendas, which signals the need to further advance research on the roles of temporality in general and future temporality in particular within all manner of human (and non-human) behaviour.

0.3.2. Practical-operational research challenges

The lack of theoretical-conceptual problematisation of anticipation and the role of plausibility within the AG, RRI, RI, and TA literature noted in the previous section has consequences for its operationalisation towards supporting a more socio-politically robust STI. The deficiency of comprehensive and detailed characterisations, as well as the open (or not definitely closed) nature of (some of) these frameworks (Owen and Pansera, 2019), has implications for the meaning and subsequent operationalisation of each of the dimensions that constitute these frameworks (see Pansera and Owen, 2020), including anticipation. The mobilisation of sociotechnical futures undertaken to activate more socio-politically responsible practices adopts different meanings, is directed towards different challenges, and

prescribes different ways of engaging with representations of the future. In the absence of a clear meaning of the term "anticipation", different ways of using and approaching the future coexist, some of which are more successful than others in enabling the problematisation of certain aspects of STI (e.g. processes, outcomes, purposes) (Chapters 2, 4, and 7). In other words, the different approaches to anticipation imply that the domains of plausibility of the different sociotechnical futures that are the subject of "negotiation" (Selin, 2011) vary, as does the scope of responsibility.

The existence of this plurality of meanings in the context of anticipation is not negative per se. Rather, it is an expression of the plurality and the heuristic richness that anticipation can achieve as an interventive tool. However, this heuristic richness always becomes effective in relation to certain aspects (and not others). The heuristic diversity of anticipation is useful in relation to addressing specific challenges that can subsequently be problematised with varying degrees of radicality and depth. Certain modes of anticipation allow for certain engagements with futures (while excluding others), opening-up certain spaces of future possibilities (while closing-down others).

This diversity of uses (and misuses) of the future invites us to consider something that has not been sufficiently emphasised in the literature: The need to pay attention to the practical-operative methods and dynamics that continuously constitute interventive anticipatory exercises. It is worth attending to how anticipatory practices develop in practice, and how they deal with the closure dynamics that characterise their context of application. Clearly, this vigilant, monitoring, or caring stance of responsibilisation practices is not only about the anticipatory dimension but can and must also consider how the different dimensions that constitute each of the normative frameworks (which often involve reflexivity and the inclusion of different considerations and actors) are interwoven and co-configured. Despite the importance of the socio-epistemic dynamics involved in operationalising anticipation (e.g. through foresight exercises), these have not been the subject of attention and reflexivity.

On the one hand, the heuristic character of anticipation is often taken for granted. The various anticipation exercises that are practised are ascribed the power to activate heuristics of different kinds, such as emancipating actors (e.g. Withycombe Keeler et al., 2019), and fostering more whole human beings (e.g. Ramos, 2006). However, **(RC#4)** ***it becomes necessary to consider and de-substantiate the anticipatory exercises and their associated heuristics.*** This de-substantiation of anticipation goes hand in hand with the recognition that both the foresight processes on which anticipation is based and its resulting heuristics are dependent on socio-epistemic processes, and must be situated and contextualised in space and time. In other words, it is necessary to recognise that anticipatory processes are co-constituted *in action* (van Asselt and van 't Klooster, 2010), and that their heuristic enactment ultimately depends on the epistemic and political dynamics that relationally underlie and dynamically constitute them (see Dufva and Ahlqvist, 2015b).

Bridging this research challenge does not necessarily mean denying the importance and the possibility of the existence of these heuristics (i.e. it does not mean denying the heuristic

value of anticipation). Rather, it is a matter of placing these heuristics in perspective and situation. It is a matter of conceiving these heuristics as the product (and operational engine) of a sociotechnical landscape that tends to modulate its constitutive dynamics and thus its disruptive scope. The point is to pay attention to the production conditions of these heuristics and to monitor the dynamics of closure and openness of plausibility spaces that are (not) considered. The works by van Asselt and van 't Klooster (2010) and Dufva and Ahlqvist (2015b) suggest attending to how foresight is constituted in action and how this action in turn rests and develops on relational dynamics. In this sense, they represent a step forward in relation to the substantivist or promising views on foresight or anticipation (both those that take the positive heuristic possibilities of anticipation/foresight for granted and those that assume their shortcomings). However, it is necessary to go further and examine how configurations of anticipatory interventions are embedded in socio-material constellations and exercise various forms of power by reifying certain futures (to the detriment of others) or protecting them from problematisation.

On the other hand, and related to the above, **(RC#5)** ***there is a need within the AG, RRI, RI, and TA literature to elaborate on the methods and related concrete processes that can be used and followed to operationalise anticipation***. This means not only that the foundational texts of these frameworks are somewhat superficial in terms of the methods they seek to activate through anticipation, but also that more meta-methodological debates are needed that address the performativity of anticipatory techniques and problematise how they are conceived and deployed and for what reasons. What is missing, in short, is a problematisation of how the techniques employed shape the sociotechnical futures we consider (i.e. how they modulate the plausibility spaces).

Some exceptions that confirm the pattern are the recent contributions of Arnaldi (2018) and Macnaghten (2017, 2021).[4] Arnaldi (2018) argues for the need to re-formulate the anticipatory technique of techno-moral scenarios by encouraging explicit reflection on how different regimes of responsibility would enable different aspects (and ways of dealing with) a controversy. The methodology includes important nuances that enrich traditional ways of operationalising techno-moral scenarios (see Boenink et al., 2010; Stemerding, 2015; Stemerding et al., 2019; Swierstra et al., 2009). However, (i) the methodological approach is limited to reflection on the positive/negative outcomes of the scientific-technological line or artefact in question (and thus closes the debate on its broader sociotechnical or socio-political processes and purposes), and (ii) the anticipatory exercise is framed in terms of the opening and closing of "controversies", and not so much in terms of co-production (see

[4] Outside the realm of AG, RRI, RI, and TA, Philip Brey (2000, 2012, 2017) is a prominent author who has pointed to the need to pay particular attention to the methods by which we seek to promote more ethical and responsible innovation practices (in this case technological innovations). He led the SIENNA project (Horizon 2020 of the European Union, 2017–2021), and Deliverable 6.3. of this project indeed focuses on revising and creating new methodologies that enable the ethical development and use of new technologies. The proposed methodologies are intended to be inclusive and reflexive, incorporating a multi-stakeholder perspective (Brey et al., 2021). For a comprehensive overview of methods in the field of ethics, see Reijers et al. (2018).

Jasanoff, 1996). As a result, the debate focuses on specific points of conflict rather than on how STI constitutes our sociotechnical fabric. Both "(i)" and "(ii)" ultimately suggest that while the proposed technique has great theoretical/conceptual value and can enrich the way an artefact or technological innovation can be developed, it can also serve as a mechanism for an uncritical (i.e. unquestioned) reification of the research agenda around the artefact under study. The problematisation focuses on the outcomes; and scenarios are omitted where even the development of the artefact in question is seen as neither plausible nor desirable. As I will show in Chapter 7, the uncritical reification problem affects several exercises that have attempted to operationalise anticipation/foresight to serve AG, RRI, RI, and TA (see Table 14).

By addressing the interrelationships between the politics of anticipation and methodology, Macnaghten (2017, 2021) delves into the use of focus groups as an anticipatory tool. The research focuses particularly on «exploring whether a deliberative form of research (…) could lead to better representation of the potential social and ethical implications of the technology, at a stage early enough to guide (or even restrict) their further development» (Macnaghten, 2017, p. 344):

> [F]ocus groups are presented as offering potential in opening up social imaginaries (Taylor, 2004) of the different kinds of futures enabled by (advanced) science and technology, including their societal and ethical dimensions, as a means of injecting social agency in technological appraisal (Macnaghten, 2017, pp. 358–359).

The realisation of this inquiry is raised in Macnaghten (2017, 2021) in terms of attending to aspects of design, context, framing, moderation, sampling and analysis, and interpretation of the interventional exercises. The aim is to enable forms of engagement that facilitate an open critique, including deliberation on the "right impacts" (von Schomberg, 2014). His invitation is to foster «*a new kind of conversation* that is partially about the politics of anticipation and partially about methodology, with open questions concerning the quality, usability, robustness, cultural contingency and context dependencies of the approaches adopted» (Macnaghten, 2021, p. 16; emphasis added). As yet, this invitation, which points to the need to address the methods and processes of operationalising anticipation (and how these constrain the politics of anticipation), has remained underdeveloped and unaddressed. The "novel" character of the conversation only underlines the need to move forward in this regard and to pay attention to the political performativity of methods (i.e. to monitor the spaces of plausibility that the methods and techniques used allow to be imagined and enacted).

In conclusion, this section has thus shown a general academic and operational landscape where anticipation (i.e. the use of the future to inform action in the present) is only hesitantly attended to and theorised. The deficit of attention and theorisation around anticipation is noticeable in relation to several aspects, including: (i) The role of anticipation in the constitution of STI dynamics (RC#1), (ii) the importance of anticipation as an interventive

tool to promote more socio-politically robust STI (RC#2), and (iii) the role of plausibility and its negotiation processes in such interventions (RC#3).

This, in turn, has implications for the conceptual underpinnings of frameworks that explicitly incorporate anticipation, such as AG, RRI, RI, and TA. Similarly, there are areas of research where progress is needed on the practices of anticipation as an instrument of intervention. For example, there is a need for (i) a much more spatio-temporally situated look at anticipation practices and their heuristics (RC#4) and (ii) a deeper focus on how the politics of anticipation is methodologically conditioned in intervening practices (RC#5).

These five research challenges identified here do not capture (and do not intend to cover) all the research challenges or lines of research that could and should be explored (neither extensively nor intensively). Nonetheless, they provide a mapping of various open problems that give us a first approximation of the theoretical-conceptual challenges and their operational implications with which this dissertation is concerned and to which it modestly aims to contribute.

0.4. Objectives and hypothesis

Against the background outlined in the previous section, the research **objective** of this dissertation is ***to develop a more robust conceptualisation of anticipation as a heuristically relevant tool to promote a more socio-politically responsible STI.*** This conceptualisation aims in turn to enable a better understanding of anticipation regarding (i) its functional and heuristic heterogeneity, and (ii) its interpretative and context-dependent character (as a situated socio-epistemic practice subject to potentials and limitations). Special attention will be paid to the role that plausibility co-negotiations play in anticipatory processes.

The present dissertation will defend the **hypothesis** that anticipation ***is a semantically and methodologically heterogeneous instrument for promoting a more socio-politically responsible STI, exhibiting heuristics of heterogenous*** **types *and* radicalities of openness**. This hypothesis is made more precise in relation to the aspects of heterogeneity and the degree of radicality of anticipation as follows:

- Regarding anticipation heterogeneity, I will argue that the diverse modes of anticipation considered valuable for promoting this socio-politically robust conception of responsibility can be subsumed under three general types: strategic, exploratory (based either on representations of the future or future-building processes, whether normative or evocative), and critical-hermeneutic. Each of these modes of anticipation takes on a different operational meaning, each being associated with different types of challenges in promoting better STI governance.
- Concerning the degree of radicality of anticipation, I will argue that it mainly depends on two aspects. First and foremost, the radicality of anticipation depends on (i) which spaces of problematisation are *formally* opened up by the frameworks by

which anticipation is instrumentally interpreted and adopted. Ultimately, this formal radicality will be *empirically* settled depending on (ii) how the (im)plausibility negotiation processes of the sociotechnical futures at stake deal with the openness/closure (anticipation) dynamics that prevail in the sociotechnical system in which anticipatory exercises de facto operate.[5] Plausibility becomes a criterion and inferential register of epistemic and political relevance for the construction and assessment of the futures at stake—hence the need emphasised in this dissertation to monitor the socio-material (pre)conditions that shape the co-production of plausibility. Such monitoring is important to identify and critically evaluate which futures are (not) being considered, whose futures these are, and why these and not others. Plausibility will be shown to be at the heart of the politics of anticipation.

The ultimate purpose of the theoretical-conceptual exercise developed here is to expand the semantic and operational meaning of what is or could be typically understood by "anticipation" in recent frameworks such as AG, RRI, RI, and TA. Although this pursuit is mainly addressed in theoretical terms, it finds its most immediate operational purpose in enabling more socio-political and inclusive anticipatory practices. The better understanding of anticipation and the role plausibility co-creation processes play therein invites analysis and evaluation of the futures of STI that are currently opened/closed. Because (i) methodologies formally channel the spaces of STI that are the object of problematisation, and (ii) these methodologies emerge in contexts characterised by socio-material constraints that are prone to closure, the analysis and problematisation of anticipation requires consideration of the methodological designs and contexts of the production of plausibility allocations.

To fulfil the research objective and defend the hypothesis, I will seek to meet the following five specific objectives. Each specific objective corresponds to one of the research challenges previously identified:

O1. Develop an explanatory model for making sense of anticipatory dynamics (de facto, critical-normative, and methodological-interventive) as active elements in the political life of opening-up/closing-down the *momentum* of sociotechnical systems through the modulation of the future spaces deemed "(im)plausible" (i.e. through the exercise of "modal power").

O2. Elucidate the characteristics of anticipation as an interventive tool for promoting more socio-politically robust forms of STI governance by considering (i) the multiple forms of engagement with the future that anticipation de facto encompasses (especially in

[5] The most immediate consequence of this heterogeneity and contingency of the anticipatory heuristics is that the epistemic and political significance and operative scope of anticipation for promoting a more socio-politically robust governance of STI (e.g. through the operationalisation of frameworks such as AG, RRI, RI, and TA) must be appraised in relation to landscapes in which various representational artefacts that appeal to the future attempt to modulate the *momentum* of sociotechnical systems by colonising what actors deem as "(im)plausible" (i.e. by mobilising and executing modal power) and "(un)desirable".

AG, RRI, RI, and newer forms of TA), (ii) the different formal radicalities of STI problematisation that anticipation can take, and (iii) the different challenges associated with each form of engagement with the future.

O3. Clarify the socio-epistemic and political significance and value of plausibility as a criterion and inferential register by identifying its methodological-limiting and anticipatory-enabling role in operationalising anticipation.

O4. Recognise that the disruptive reach of anticipatory-interventive practices and their associated heuristics for promoting more responsible STI are context-dependent and contingent, depending on how their *ex-ante*, *ex-dure*, and *ex-post* dynamics deal with the contextual factors in which they operate and which they seek to transform. Anticipatory practices must therefore be recognised simultaneously as (i) instruments *for* promoting responsibility and (ii) subjects to care for (i.e. subjects *of* responsibilisation).

O5. Problematise the methods recently adopted in operationalising anticipation in frameworks such as AG, RRI, RI, and TA by (i) assessing the spaces of plausibility they open/close and (ii) proposing alternative methodological structures to minimise some of the main weaknesses these methods present.

0.5. Structure of the dissertation

The dissertation is divided into the following seven chapters to achieve the above objectives and to support the hypothesis.

Chapter 1 focuses on anticipation as a phenomenon that de facto permeates sociotechnical systems and constitutes STI's future-making politics and power dynamics. Against the limited theorisation concerning the power mechanisms underlying the processes of creating and mobilising futures (RC#1), Chapter 1 presents a general framework to understand and address the anticipatory dynamics and politics that constitute STI (O1). The framework situates the dynamics of mobilising futures in a landscape where futures, through the mobilisation and exercise of modal power (i.e. the modulation of what actors consider "(im)plausible"), are instrumental in opening-up/closing-down the directions and speeds (i.e. the *momentum*) of our sociotechnical systems. Therefore, the first chapter focuses on characterising the dynamics *of* and *with* futures (e.g. those processes rendered by visions, expectations, promises, and imaginaries) as part of the politics of anticipation that constitute STI. Moreover, Chapter 1 confronts these de facto dynamics with recent demands by STS scholars for intervening anticipations. It argues that both the processes promoted by innovation actors and those from the social sciences and humanities that seek to problematise STI are embedded in the dynamics of shaping STI governance through the creation, mobilisation, and contestation of modal power through futures. Anticipation as a methodological-interventive tool for AG, RRI, RI, and TA gains importance within this context. It gains importance as an interventive tool with ambitions for openness. However,

such openness can take on different conceptual meanings and thereby inform the problematisation of STI with varying degrees of depth in practice. The chapter therefore highlights the need to examine how interventive anticipations are *understood* and *put into practice*, thus substantiating the importance of the following elaborations.

Chapters 2, 3, and 4 are precisely aimed at providing a better understanding of the characteristics of anticipation as an interventive tool (and its conceptual limits and possibilities) for promoting more socio-politically robust forms of STI governance (RC#2, O2). This advance in the characterisation of anticipation takes place through three argumentative movements, each of which is developed in one of the following three chapters.

Chapter 2 takes the first argumentative step towards this clarification of what we can understand by "anticipating". It argues that if we start from the basic definition of anticipation offered by Anticipation and Futures Studies (where anticipation is defined as the use of representations of the future to guide present action), then we can safely assume that anticipation has been a common tool in the service of various normative/interventive frameworks—even if it has not always been understood by that name and has taken on different meanings and functionalities. Indeed, anticipation can be seen as an essential and necessary feature of all normative and interventive proposals that take an *ex-ante* approach to responsibility or STI governance. Examples of heterogeneous interventive approaches or frameworks that have an underlying *ex-ante* and anticipatory-interventive mood towards STI governance are technology foresight, the ELSA/ELSI program, recent forms of TA, AG, RRI, and RI.

However, the fact that anticipation has long been present in our normative and interventive approaches or frameworks should not cause us to overlook at least two aspects. The first is that each *ex-ante* framework or approach presents different gradients of radicality of STI problematisation (i.e. each framework/proposal aims at opening-up STI with different gradients of depth), thereby modulating the meaning and functionality that anticipation acquires for them. The conceptual nature of anticipation and the scope of its heuristic disruptiveness as an interventive tool are primarily delimited from a formal point of view by the normative constraints imposed by the interventive framework from which it is interpreted.[6] The second is that there is a lack of specificity in stipulating the types of engagements with the future that are required to activate the recent, more radical conceptualisation of responsible STI (including clarifying the respective challenges to which each type of engagement with the future seeks to respond).

[6] To these formal constraints related to the concepts and interpretations of responsible STI and anticipation, one could subsequently add the socio-material constraints that further limit the disruptive character of the operationalisation of anticipation (see Chapter 6). Normative frameworks of responsible STI first define the formal scope of the problematisation of STI that they seek to serve (and anticipation is constrained by this formal scope). But this formal scope is in turn limited in its operationalisation or implementation by the socio-material constraints that define the context in which frameworks operate.

The lack of precision regarding anticipation in recent frameworks is partly due to a lack of specificity on the part of their founding architects—founding texts tend to be brief in their presentations of anticipation/foresight. But the basic concept of anticipation used by Anticipation and Futures Studies does not help either: It is not sufficiently fine-grained to illuminate (and thus differentiate) the various ways of engaging with the future that can inform anticipation, and thereby to differentiate what kinds of engagements with the future are seen as conducive to promoting more socio-politically robust STI governance.

The second argumentative step is to extend the notion of anticipation used by Anticipation and Futures Studies. **Chapter 3** carries out this task. Starting with a brief genesis and relevance of the basic concept of anticipation used in Anticipation Studies, it is shown that the concept is simultaneously too broad (or vague) and too narrow when it comes to offering analytical resources to explain and account for the various socio-epistemic steps, or practices, that constitute (human) anticipations. Confronting the narrow nature of the concept, an expanded characterisation of anticipation is proposed.

The third and final argumentative step concerning the conceptual elucidation of anticipation is presented in **Chapter 4** and involves the application of the concept of anticipation developed in the previous chapter. The application of this concept serves two purposes simultaneously. First, it demonstrates the heterogeneity of the engagements with the future (and thus the diverse modes of anticipation) that recent frameworks encouraging more radical forms of responsibility seek to promote, as well as the challenges associated with each of these engagements with the future/modes of anticipation. Second, it puts Nordmann's critique of the "future talk" into perspective. The discussion of Nordmann's critique on "future talk" highlights two important points. The first is that each mode of anticipation is susceptible to the critiques under different gradients and that in many cases the degree of affectedness is decided in practice (it is therefore necessary to pay attention to practice, especially to the processes of determining the (im)plausibility of the futures in question). The second point is that the critical-hermeneutic approach to futures is the least affected by these criticisms.

The next three chapters (i.e. Chapters 5, 6, and 7) are less concerned with the meanings/concepts of anticipation, as these have already been discussed in the previous chapters. In contrast, the focus in these chapters is on diverse aspects concerned with the implementation of anticipation. Specifically, they will deal with the roles and importance of plausibility, the contingent and situational nature of anticipatory heuristics, and the need to be sensitive to the methodological designs of anticipation, respectively.

Chapter 5 is devoted to clarifying the importance and dual role of plausibility in anticipation exercises (RC#3), focusing on scenario-based exercises. Specifically, differentiating plausibility from other registers such as "possibility" and "probability", I argue that it is both a methodological-limiting criterion and an abductive inferential register that enables the opening of alternatives (i.e. an "anticipatory-enabling" socio-epistemic and political device) (O3). Plausibility thus plays a particularly relevant role in anticipatory processes, as it simultaneously closes down and opens up the futures under consideration.

Plausibility negotiation processes are presented as being at the core of the politics of anticipation due to their role in disrupting modal power.

Chapter 6 emphasises that this opening and closing of plausibility not only occurs during the exact negotiating plausibility process (i.e. in the *ex-dure* phase). Instead, it is settled throughout the whole operationalisation process of foresight/anticipatory exercises. Moreover, the chapter reveals that the various anticipatory heuristics that may emerge during operationalising foresight are not given but are constituted throughout the process. The heuristics of foresight emerge during its whole *ex-ante*, *ex-dure*, and *ex-post* phases. It is argued that the degree of openness of futures or disruptiveness of anticipatory heuristics is highly dependent on how anticipatory practices deal with a series of socio-material constraints, or hampering (f)actors, that shape the sociotechnical system in which they are implemented and which they seek to enrich. These constraints narrow down the "plausibilisation" of the futures being considered. The relevance of the whole process of operationalising foresight/participation and dealing with the constraints of the context pushes one to understand foresight not only as an instrument *for* responsibilisation, but also as a subject *of* responsibility (RC#4, O4).

Chapter 7 addresses the challenge of making anticipation and foresight the subject of responsibility by problematising how anticipation exercises have been structured in practice. In other words, it reflects on the operational and methodological foundations of anticipation (RC#5, O5). Specifically, this chapter analyses 17 case studies in which anticipation was operationalised in the service of AG, RRI, RI, and TA. The analysis focuses on the methodological structure underlying the interventions, the challenges addressed, and the respective general points of closure/openness (e.g. in terms of actors considered or futures reified). The research shows that the key challenges of anticipation are addressed in practice in fragmented ways and under dynamics of closure, supported by methodological structures that are not comprehensive. For this reason, a methodological structure of anticipation based on the development of four workshops is proposed that compensates the deficit of fragmentation in dealing with the challenges of AG, RRI, RI, and TA, while simultaneously minimising the problem of uncritical reification of futures.

The thesis closes with a final section: **Conclusion**. This last section reconstructs the main findings of the dissertation and presents a brief (self-)reflection on their respective scope and limits. It also identifies some lines of enquiry that have remained open during the research process and that warrant attention in the future. The conclusion also underlines the relevance of the results obtained both for the academic field (e.g. for advancing existing academic debates) and for the political-institutional field (e.g. for designing STI policies and implementing anticipation tools therein).

The following table provides an overview of the research objectives, challenges, and tasks addressed in each chapter/section of this dissertation.

Table 2. Correlations between research objectives, challenges, tasks, and chapters/sections.

<table>
<tr><th colspan="2">Research objective</th><th colspan="2">Hypothesis</th></tr>
<tr><td colspan="2">To develop a more robust conceptualisation of anticipation as a heuristically relevant tool to promote a more socio-politically responsible STI. This conceptualisation aims in turn to enable a better understanding of anticipation regarding:
(i). Its functional and heuristic heterogeneity; and
(ii). Its interpretative and context-dependent character</td><td colspan="2">Anticipation is a semantically and methodologically heterogeneous instrument for promoting a more socio-politically responsible STI, exhibiting heuristics of heterogeneous (i) types and (ii) radicalities.
(i). The heterogeneity of anticipation heuristics can be subsumed under three general types: strategic, exploratory, and critical-hermeneutic
(ii). The radicality of anticipatory heuristics fundamentally depends on two aspects. First and foremost, it depends on (a) which spaces of problematisation are formally enabled by the frameworks from which anticipation is instrumentally interpreted and adopted. Ultimately, this formal radicality will be empirically settled depending on (b) how the (im)plausibility negotiation processes of the sociotechnical futures at stake deal with the openness/closure dynamics that prevail in the sociotechnical system in which anticipatory exercises de facto operate</td></tr>
<tr><th>Specific research objectives</th><th>Research challenges</th><th>Research tasks</th><th>Chapters / Sections</th></tr>
<tr><td>O1</td><td>RC#1: Theorising the power mechanisms underlying the processes of creating and mobilising futures that constitute STI dynamics</td><td>To build a model of sociotechnical coevolution where the futures at stake anticipatorily shape the momentum of sociotechnical systems through the mobilisation of modal power</td><td>1</td></tr>
<tr><td rowspan="3">O2</td><td rowspan="3">RC#2: Clarifying the characterisations of anticipation as a procedural interventive dimension to promote a more socio-politically robust STI (e.g. AG, RRI, RI, and TA)</td><td>To analyse how some normative frameworks that seek to promote an ex-ante type of responsibility have typically understood anticipation, considering the heterogeneous functionalities and degrees of ethical-political radicality that anticipation theoretically assumes in them</td><td>2</td></tr>
<tr><td>To identify the limitations and possibilities of the basic concept of anticipation used by Anticipation and Futures Studies
To generate an expanded concept of anticipation to analyse and account for the multiplicity of engagements with the future that human interventive anticipations might encompass</td><td>3</td></tr>
<tr><td>To elucidate the challenges associated with anticipation in recent normative-interventive frameworks
To apply the concept of anticipation previously developed to clarify the different ways of engaging with the future that recent frameworks intend to activate
To heuristically assess the critical potential of some of the criticisms levelled against “future talk” when applied to the modes of anticipation previously identified</td><td>4</td></tr>
<tr><td rowspan="3">O3</td><td rowspan="3">RC#3: Elaborating further on the roles that “plausibility” plays in the context of anticipatory interventive practices</td><td rowspan="3">To conceptualise plausibility as a methodological criterion and as an inferential register in the practices of generating future scenarios
To elucidate the socio-epistemic and political roles that plausibility co-negotiation processes play in anticipatory processes</td><td>1.4</td></tr>
<tr><td>4.5</td></tr>
<tr><td>5</td></tr>
</table>

O4	RC#4: De-substantiating anticipatory heuristics by recognising their contingency and socio-epistemic situatedness	To conceptualise the anticipatory heuristics of foresight exercises as contingent outcomes dependent on the processes constructing the exercises To identify some important hampering (f)actors that can modulate plausibility negotiation processes leading to the closure of the futures under consideration and the anticipatory capacities activated To support the assessment of foresight not only as a tool to promote more responsible STI, but also and simultaneously as an object of responsibility	6
O5	RC#5: Problematising the operationalisation methods and processes of interventive anticipations	To identify and assess the plausibility spaces opened/closed by the design and operationalisation of the anticipatory practices of AG, RRI, RI, and TA To construct an anticipatory methodological structure as a first step towards enabling more open-by-design forms of anticipatory practices (without denying the situated and contingent nature of the resulting heuristics in practice, as proposed in "O4.")	7

In addressing all these research challenges and pursuing these research objectives, my focus is not on providing absolute solutions. Rather, my intention is to conceptually and operationally enrich our understanding and functioning of anticipation and from there to complexify many of the existing discussions in the literature, particularly in AG, RRI, RI, and TA circles. If this dissertation contributes anything, it is to show the relevance, heterogeneity, and complexity that anticipatory practices acquire to foster practices in contexts where futures play a relevant performative role, and to note some limitations that anticipatory-interventive tools have in relation to such practices. It is expected that this overview and conceptual explanation will be relevant to the interventive frameworks mentioned above.

CHAPTER 1

The constitution of STI through futures: Modal power in the opening-up and closing-down of sociotechnical systems' *momentum*

Abstract The last three decades have been particularly fruitful in identifying and theorising how representations that integrate assumptions about potential and (un)desirable futures function in the co-production and coevolution of sociotechnical realities. Within STS literature, there are three internally heterogeneous approaches to the creation and mobilisation of futures: descriptive, critical-normative, and methodological-interventive. Visions, expectations, and imaginaries are currently recognised as de facto anticipatory artefacts that close down the *momentum* of sociotechnical systems and, as such, they are also normatively considered as objects of critical scrutiny. At the same time, interventive techniques engaging with future representations (such as foresight) are considered by recent normative frameworks as useful anticipatory instruments for opening-up the range of envisaged alternative futures. This chapter reviews STS advancements on the performativity of both de facto and interventive anticipatory practices in shaping the *momentum* of sociotechnical systems in light of the phenomenon of modal power (i.e. the modulation dynamics of what actors deem to be "(im)plausible" and/or "(un)desirable"). In the process, the chapter theoretically argues that the diverse attempts of STS scholars and practitioners to understand, critique, and interventively engage with the politics of opening-up and closing-down the *momentum* of sociotechnical systems through future representations requires engaging with the creation, mobilisation, and execution of modal power. The heuristics presented in this chapter are intended to be useful in framing and recognising the political-epistemic radicality that the creation and mobilisation of sociotechnical futures holds in the constitution of our sociotechnical orders, as well as the role that the attribution of (im)plausibility or (un)desirability plays in such processes.

1.1. Introduction

Over the last three decades, Science and Technology Studies (STS) has shown a growing interest in how sociotechnical futures shape the ongoing co-production and coevolution of science and technology with society. Material and discursive sociotechnical entities that contain implicit or explicit assumptions about the future—such as expectations, visions, and sociotechnical imaginaries—have become an important analytical focus of scholarly work. These entities constitute an important part of the ongoing dynamics that orient scientific-technological activities (Borup et al., 2006; Jasanoff and Kim, 2015; Konrad and Böhle, 2019; Lösch, Grunwald, et al., 2019).

Anticipatory dynamics—those guided (consciously or unconsciously, intentionally or unintentionally) by future representations (Miller, 2018; Poli, 2017; Poli and Valerio, 2019)—are currently addressed within STS from three ideal-typical and internally heterogeneous approaches:

(i) *Descriptive approaches* aim to elucidate the diverse performative roles and impacts of future representations (whether in the form of scripts, visions, sociotechnical imaginaries, or expectations). The focus here is typically on describing how futures shape heterogeneous sociotechnical assemblages.

(ii) *Critical-normative approaches* emphasise the duty to open up futures' performative dynamics by subjecting them to critical analysis and reflexive governance. STS research conducted under a critical-normative approach criticises hegemonic futures and suggests the promotion of alternative, more desirable ones.

(iii) *Methodological-interventive approaches* use techniques that engage futures representations (e.g. foresight, visioning, or futuring practices) in order to proactively open up the de facto anticipatory dynamics. Here anticipation is typically used as a heuristic resource to proactively support (more or less tentative and explicit) normative STS commitments.

Anticipation thus simultaneously appears within STS as an *object of research*, an *object of critical analysis*, and a *means for intervention* (Bechtold, Fuchs, et al., 2017; Konrad et al., 2016). STS scholars are observers, producers, modellers, and users of future representations. They are thereby involved in multiple forms in the anticipatory dynamics of opening-up/closing-down the potentialities of sociotechnical pathways (Stirling, 2008).

This chapter reviews existing STS research and interventions concerned with the politics of futures. In the process, it heuristically situates this STS research as simultaneously confronted with, embedded in, and contributing to, the broad opening-up/closing-down anticipatory dynamics co-shaping the *momentum* of sociotechnical systems in the present. More specifically, the chapter argues that these anticipatory dynamics of openness/closure are constituted, motivated, and conditioned by a politics of creation, exercise, and mobilisation of what Steve Fuller (2018b, pp. 139–149) calls "modal power" (i.e. by the

modulation of what actors cognitively and affectively deem to be "(im)plausible" and/or "(un)desirable"). Diverse STS engagements with the anticipatory politics of opening-up/closing-down the *momentum* of sociotechnical systems can be understood as attempts to trace, assess, and co-shape how the (im)plausible and the (un)desirable—which encode the directionality of our present actions—is fixed by futures.

The argument builds on three key concepts: "sociotechnical *momentum*" (Hughes, 1969, 1994), the opening-up and closing-down of sociotechnical possibilities (e.g. Stirling, 2008), and "modal power" (Fuller, 2018b, pp. 139–149). It aims to facilitate the understanding of the limits, challenges, and potential political-epistemic radicality of STS work that engages with sociotechnical futures. STS scholars are often driven by the commendable motivation of opening-up or democratising futures. However, through their participation in modal power allocation processes, STS scholars are no strangers to contributing to stabilisation and closure dynamics which reify sociotechnical futures and solidify ongoing sociotechnical commitments.

The argument unfolds as follows. After this introductory section, I present how anticipations shape the *momentum* (i.e. the direction and speed) of sociotechnical systems' paths, as well as how STS scholars have engaged with this phenomenon (Section 1.2). The chapter then delves into the political opening-up/closing-down processes in which these anticipatory dynamics participate. Concretely, I conceptualise how anticipation is an instrument for, and simultaneously a product of, the mobilisation and exercise of modal power. This implies recognising that the function of anticipatory exercises is the mobilisation and modulation of what actors consider "(im)plausible" and "(un)desirable". It is by virtue of this modulation that the performativity of anticipatory artefacts such as predictivist regimes, scripts, expectations, visions, and imaginaries becomes socio-politically significant (Section 1.3). The next section draws on the above findings to argue that when STS scholars attempt to open up, expand, and/or enrich the futures under consideration through foresight or futuring practices, these interventions are primarily aimed at redistributing modal power. More specifically, I emphasise that these STS interventive practices engaging with futures can only democratise current anticipatory choices by proposing genuinely alternative futures if they disrupt the socio-material mechanisms that underlie and sustain current patterns of modal power allocations (Section 1.4). The chapter ends with a series of concluding remarks (Section 1.5).

1.2. "The future" in the co-production of sociotechnical worlds: Constituting *momentums* through anticipatory artefacts

Sociotechnical configurations shape our physical, affective, moral, and legal environments in which life comes into being and ongoingly develops. They channel the relationships we establish with others (both humans and non-humans) and thereby «enable and constrain basic human possibilities» (Jasanoff, 2016, p. 9). Sociotechnical assemblages co-constitute the scene and integrate the organisation and rules *in* and *through* which our existence (and

its meanings) takes root and flourishes. Sociotechnical systems are playgrounds of (and for) power.

The consideration that sociotechnical systems enable and constrain a series of possibilities raises numerous questions, both descriptive and normative in nature: How did the possibilities that today constitute our sociotechnical *factum* become established, and why? By what mechanisms were alternative forms of development closed down? How is it possible to currently identify and open up the space of possibilities to make the co-productive dynamics of science, technology, and innovation more reflexive, responsive, and equitable?

These questions, though crucial, are certainly not easy to answer. The heterogeneous constellations and choreographies of actors (both human and non-human) that come into play in the complex, messy, and unruly sociotechnical fabric makes it difficult for any description or attempt at modulation to be exhaustive. The enormous, intricate, and contingent interrelationships established by the various actors at different scales (global and local) and levels (macro, meso, and micro) not only complicate the traceability of the factual governance dynamics, but also temper the potential scope of any normative-interventive proposal.

The purpose here is not to give a substantive answer to these questions, but instead to emphasise that any response to them must focus on a central element that operates transversally in multiple spheres of social life in general and of the co-production and coevolution of our sociotechnical systems in particular: anticipatory dynamics. The dynamics of anticipation are those activated by means of social future-oriented artefacts such as scripts, imaginaries, visions, and expectations. They co-shape sociotechnical systems, playing an important role in opening-up/closing-down sociotechnical systems' *momentum* (i.e. their speed and directionality of development). STS scholars have addressed these anticipatory dynamics—even if not always named and identified as such—under a variety of approaches. However, this attention is currently taking on increasing significance in the field.

1.2.1. The *momentum* of sociotechnical systems: Mass, direction, and speed of development

Sociotechnical *momentum* refers to the intertwining of, and reciprocal relationships between, technology and society that unfold over time and ongoingly constitute the coevolutionary patterns of sociotechnical systems. The concept of technological *momentum* has been used as a heuristic resource to explain the historical coevolution of different social and technical phenomena (e.g. Boslaugh, 2011; Nye, 2006; Povlock, 2016; Wang and Burton Swanson, 2008). Thomas P. Hughes introduced this metaphor in 1969 with the aim of analysing and explaining the dynamic forces that fuel the development of large technological systems (e.g. the airline industry, electrical systems) (Hughes, 1969, 1983). Hughes recognised that in such technological systems both technical and social components reciprocally interact and

mutually constitute each other, and hence his technological systems can be understood as sociotechnical systems (Hughes, 1994, pp. 101, 105).

The metaphor draws inspiration from Newtonian mechanics, where the concept of *momentum* describes a mass *in motion*. Any object that is moving has a vectorial force that constitutes its *momentum*. As such, *momentum* describes both magnitude (how much force defines the mass movement) and direction (the mass's heading path). When momentum is applied as a heuristic concept to complex and non-deterministic systems, such as sociotechnical ones, it serves to emphasise that sociotechnical systems are not static entities, but rather that they are co-constituted *in motion*, through their ongoing processes of coevolution. It is precisely the characteristics and meanings of these dynamic processes of coevolution that are at stake socio-politically.

In this sense, the concept of sociotechnical *momentum* (hereafter "STM") involves considering the interactions between three abstract elements that co-constitute sociotechnical systems through time (Hughes, 1987, p. 76):

- *Mass*: The series of assembled components—human and non-human actors—that constitute the sociotechnical system;
- *Direction*: The more or less defined orientation towards which the dynamic system seems to coevolve;
- *Velocity*: Its rate of expansion or growth.

STM can therefore be characterised as the invigorating force generated by the heterogeneous, messy, unruly, and historically contingent constellation of dynamics that constitute, with certain characteristics and in a more or less discernible direction, the ongoing coevolution of sociotechnical systems.

The concept of STM was proposed by Hughes to explain the Collingridge dilemma (Collingridge, 1980): Why do successful sociotechnical systems tend over time "to resist changes in the direction of [their] development"? (Hughes, 1983, p. 140). Sociotechnical systems tend to be more flexible and open (i.e. more susceptible to modulation of their features and directions) in their early stages of co-production and coevolution, and they become successively more stable and firm (i.e. less susceptible to modulation) as they grow and consolidate. Growth and consolidation are understood in terms of the expansion of actors, interconnections, and complexity defining the sociotechnical system in question. For Hughes, it is the high degree of *momentum* that certain sociotechnical systems gradually acquire over time (by growing, competing with alternatives, and consolidating) that provides their stability and firmness. STM thus hinders the possibilities of re-shaping the attributes and orientation of sociotechnical systems' development.

Hughes proposed the *momentum* metaphor as a «more complex, flexible, time-dependent, and persuasive» (Hughes, 1994, p. 102) explanatory theory of technological change than those offered by social and technological determinism (in which the explanans for sociotechnical phenomena is reduced to the agency of social or technical actors,

respectively). For Hughes (1994, p. 102), both social and technological determinism «suffer from a failure to encompass the complexity of technological change»; a complexity in which the social and technological agencies inherently hybridise and mutually co-constitute each other. Sociotechnical change shapes and is simultaneously shaped by a constellation of socio-cultural, economic, and technical factors.

The degree of influence of each of the abstract poles is, however, asymmetrical over time. In Hughes's words, «as they grow larger and more complex, systems tend to be more shaping of society and less shaped by it» (Hughes, 1994, p. 112). The degree of influence of the "social component", so to speak, is conceived as inversely proportional to the degree of *momentum*. In the initial phases of development, social agency predominates, while in advanced phases the technological agency becomes more prominent. Sociotechnical systems tend to gain *momentum* as they grow in size and maturity, *diminishing* (without totally abolishing) the capacity of societal actors to change their characteristics and orientation (Hughes, 1987, p. 54). Highly mature, deep-rooted, and large sociotechnical systems are more difficult to shape because they tend to force new and existing innovations to be designed and co-produced in adaptation to their requirements (i.e. they tend to hinder the generation and setting of alternatives that contradict or threaten their own persistence). The phenomena of STM is thus related to STS concepts such as "closure" (Bijker et al., 1987; Misa, 1992), "stabilisation" or "flexibility" (Hanseth et al., 1996; Misa, 1994), as well as "irreversibility" (Callon, 1990).

A brief historical case may illustrate the idea of STM. As David E. Nye (2006, pp. 54–56) notes, various societal actors had to choose between using two ranges of supply voltage—100-127v versus 200-240v—and transmission systems—direct current (DC) versus alternating current (AC)—during a protracted historical process. These decisions were influenced by a variety of variables, such as the power and status of the actors pushing each alternative (e.g. Edison's companies), financial commitments, the existence of patents, the infrastructure available at the time (e.g. wiring infrastructure, facilities for installing power plants), the level of energy demand, or the availability of other artefacts (e.g. transformers). The complex arrangement of contingent and spatiotemporally situated choices gradually configured the characteristics and directions of different sociotechnical systems in different geographical areas. In North and Central America, the 100-127v voltage range and DC transmission systems (i.e. Edison's mode) were established very early, while in the rest of the world (especially in Europe) the 200-240v single-phase voltage range and the use of AC transmission systems (i.e. Tesla's mode) were the norm from the outset. Although AC was eventually adopted as the standard form of power transmission, the voltage range in North America, Central America, and some South American countries remains at 100-127v—notwithstanding that in some areas of these countries, homes, buildings, and utilities also accommodate two-line systems at 120+120v. Once the electricity grids were set to 100-127v and the production of technology (e.g. lamps and some household appliances) and wiring systems were adapted to this voltage in certain geographical areas, the possibility of modifying the prevailing sociotechnical voltage regime was considered extremely costly, both logistically and economically (apart from the safety arguments in

favour of remaining in the lower voltage range). The 100-127v standard materially set the basic sociotechnical conditions of possibility from which all further developments were framed. In North, Central, and some parts of South America, the use of 100-127v was initially a matter of choice, but once it gained *momentum* and became standardised, it influenced the range of alternative directions of development that were seen as plausible and feasible by later generations. It is in this sense that Hughes argues that sociotechnical systems with high *momentum* «exert a soft determinism» (Hughes, 1987, pp. 54–55).

This soft determinism, however, does imply a fatalistic *autonomy* of sociotechnical systems. *Pace* Vermaas et al. (2011, p. 89), Hughes' STM theory does not assume that «systems go their own way, and in those situations, society seems to have no alternative but to adapt to that path». STM is instead conceived as contingently and ongoingly co-constituted and perpetuated. STM is dependent on how the interlocking mechanisms and intertwined constituent actors of the sociotechnical systems in question coevolve (e.g. institutions, physical and bureaucratic infrastructures, technologies, cultural and economic orders, norms and laws, institutions, etc.). In this sense, STM «is not irresistible» and «can be made to change direction if a variety of its components are subjected to the forces of change» (Hughes, 1994, pp. 112–113). The ensembles in which co-production processes are situated channel, modulate, and enable/constrain (with varying degrees of intensity and explicitness) the *potential* direction of their further dynamics. The possibility for changing these ensembles exists, but STM makes it an arduous and costly undertaking. The "soft determinism" that STM exerts thus rather resides in its function of constraining the *possibilities* considered potentially realisable (i.e. possible, plausible, and feasible). For instance, the high STM of the internet and our hyperconnected societies hinders the possibility of shaping *nowadays* the co-construction of *future* sociotechnical worlds not permeated by this condition and technology. Many of the technological devices being developed today converge with (and at the same time perpetuate) its existence (e.g. the "internet of things" programme). It is not that the internet acquires its own autonomy, but that its ongoing sociotechnical coevolution and *momentum* have progressively shaped the feasibility of potentially (un)navigable future world paths. In a nutshell, STM stresses that proposing and pursuing highly disruptive directions finds its most immediate constraint or limit in the socio-material and organisational characteristics of sociotechnical systems and their tendency to self-preservation and self-perpetuation.

The STM metaphor provides a diachronic and dialectical approach in which processes of sociotechnical co-production and coevolution are subject to (and at the same time producers of) hybrid socio-cultural and technical forces and political motivations throughout the whole set of processes. This approach allows us to move away from the illusory and dangerous image that reduces the roots of technological development and change to technological autonomy. It leaves enough room for politics and decision-making (navigating somewhere between the illusion of total control and the complete absence of control) while recognising technologies as simultaneously co-creations and instruments for world-making; as vehicles and objects of the ongoing and dynamic constitution of politics (Winner, 1980). Sociotechnical orders established in the course of historical processes matter, but there is

always room for active human agency, and thus the total rigidity of technological lock-ins and prefixed paths assumed in some discourses is relativised (yet without neglecting the roles that technologies have in configuring our realities) (Jasanoff, 2016, p. 2).

1.2.2. Anticipation and the formation of sociotechnical *momentum*

Anticipatory practices are a crucial component of the constellation of practices that shape (and are shaped by) STM. Anticipation, understood as an activity or action that is informed (consciously or unconsciously) by representations or images of potential futures (Miller, 2018; Poli, 2017; Poli and Valerio, 2019), is simultaneously *constitutive of* and *constituted by* the dynamics of sociotechnical systems (in terms of both growth rate and directionality).

To claim that anticipation is among the many activities and factors that shape STM entails attending to not only how sociotechnical systems develop and unfold over *time*, but also how such historical development is embedded in, and modulated by, heterogeneous regimes or orders of *temporality* (see Selin, 2006a). As Emirbayer and Mische (1998, p. 963) argue, the agentic dimension of social action can only be captured in its full complexity if it is analytically situated within the flow of temporality. Sociotechnical coevolution processes occur within contingent and evolving *régimes d'historicité* (Hartog, 2003; Koselleck, 2004). These *régimes d'historicité* express ways of being in time (i.e. experiencing and ordering temporality). Although the past, present, and future are inextricably interwoven in our individual and social experimentation with reality (Buckner et al., 2008; Doll et al., 2015; Seligman et al., 2016), these are not symmetrically articulated in guiding the directionality of our actions. The three dimensions always resonate. They co-jointly conform to what Emirbayer and Mische (1998, pp. 970–974) call «the chordal triad of agency». However, they take on different intensities and tonalities depending on the situation and context.

Understanding how anticipation connects to STM requires an understanding of how the heterogeneous (and often conflicting) modes of inhabiting the not-yet—in terms of both modality (i.e. the modes and genres of approaching and living the future) and content (i.e. the depicted images of the future)—enact the individual and social life *in the present* (e.g. Bryant and Knight, 2019). Anticipatory dynamics modulate sociotechnical co-production and coevolution activities from multiple dimensions and angles, steering them towards certain projects and away from others (Alvial-Palavicino, 2015; Jasanoff, 2015). The trajectory of nanotechnology is exemplary in this regard: Futures were central to stimulating the *momentum* of nano development by supporting its legitimacy and socially anchoring it as a key "enabling" technology (Anderson, 2007; Berube, 2004; Hanson, 2011; Lösch, 2006; Parandian et al., 2012; Selin, 2006a, 2007).

The recognition of the agential or performative dimension of anticipatory dynamics constituting STM prompts us to expand the theoretical and empirical apparatuses through which social sciences and humanities have typically analysed, understood, and modulated reality. It calls for amplifying the areas of theoretical and practical concern by focusing on the performative role of "living futures" as well as the mechanisms by which those "futures"

are created, silenced/amplified, and sustained/altered (Adam and Groves, 2007, p. 198; Poli, 2014). Anticipation underlines the role of projective grammars (in its different modes, genres, contents, etc.) in sustaining current social practices and artefacts (e.g. forecasting methods, hopes, promises, visions, planning, imaginaries). As such, anticipation points to the role of future projections in shaping the dynamics of social perpetuation, stabilisation, and transformation (Mische, 2009; 2014, pp. 451–457).

STS scholars and practitioners have long been interested in *intentional* and highly *formal* uses of the future. For instance, classic works in the field have asked how forecasting and expert-based future modelling methods are simultaneously a product and a constructive element of efforts to "depoliticise" the future (e.g. Jasanoff, 2003; Nowotny et al., 2001). Predictive approaches to the future and modes of orienting action on the basis of forecast models have proved to be instrumentally valuable to technocratic approaches, in which political-technical issues are reduced to their technical aspects and wrongly conceived as neutralised by appealing exclusively to the latter. These techniques often serve to justify controversial decisions in political decision-making arenas as well as to establish the relevance of specific present events (see Mallard and Lakoff, 2011; Sarewitz et al., 2000).

STS has also been a central locus for the study of *informal* uses of the future that are not always intentional, conscious, and controlled.[7] Although this literature does not always use the term "anticipation", it is also concerned with the future-oriented character of science and technology and the role that these projections play in enabling and constraining alternative possibilities. For instance, the Social Construction of Technology (SCOT) programme identified that futures representations are a constitutive element in the construction of technologies. SCOT considered that artefacts project into the future their socially constructed features (Bijker et al., 1987; Bijker and Law, 1992). These future projections have been considered both in SCOT and other frameworks (e.g. Actor-Network Theory) as being embedded in the so-called "scripts" ascribed to technological artefacts during the design processes. Scripts are conceived as guiding the experiences and behaviours of future users of the technology in question. As Latour (1992, p. 244) illustrates, embedded in speed bumps is the script: «[S]low down your vehicle (or else break the suspension)!». Similarly, password strength indicators compel us to adopt (increasingly) complex and safer passwords, emphasising the value of privacy. The scripts are thus conceived as guiding the experiences, uses, and behaviours with respect to the technology in question. Although scripts are not considered to fully determine experiences and actions, their role is to limit the future *possibilities of use* and *experience* by *prescribing* the performance of some actions instead of others (see Akrich, 1992; Latour, 1992). In this sense, the scripts operate as

[7] As Borup et al. (2006, p. 286) note, one of the factors underlying this nascent interest in expectations and other anticipatory drivers is the gradual increase and intensity that these have acquired in the shaping of our modern societies. The relationships between the "strategic turn" in scientific-technological practices and anticipation must be read in a context marked by the modes of temporal organisation characteristic of modern and capitalist societies, in which future temporality is exploited as a central resource. For more on how the prevailing *régimes d'historicité* in modernity and our capitalist societies are skewed towards the future, see Beckert (2016); Beckert and Bronk (2018); Hölscher (2018); Ogle (2019).

anticipatory elements that aim to constrain the sphere of *potential* meanings attributed to a technological artefact and the *potential* pragmatic fields of actions that could be realised through such an artefact.[8]

The late 1990s and early 2000s were particularly fruitful in terms of identifying and recognising that «[c]o-production processes include anticipation» and that «[t]echnical change is driven partly by the historical experience of actors, their views of the future, and their perception of the promise or threat of impacts which will change over time» (Schot and Rip, 1997, p. 257). The growing interest in the Sociology of Expectations at that time undoubtedly played an important role in this identification and recognition (see Borup et al., 2006). The Sociology of Expectations literature emphasised that in addition to scripts, promises and expectations are important anticipatory elements that dynamically shape science, technology, and innovation practices. Evidence from a number of empirical case studies illustrates how promise-based rhetoric and expectation dynamics are instrumental in fuelling the material realisation of scientific-technological projects (e.g. Alvial-Palavicino and Konrad, 2019; Brown and Michael, 2003; Brown et al., 2000; Parandian et al., 2012; Pollock and Williams, 2010; van Lente and Rip, 1998a; van Lente et al., 2013). For instance, van Lente and Rip (1998b) expose how the mobilisation of promises and the subsequent conformation of "shared expectations" constituted the backbone for the development of mutual positionings around membrane technology and its establishment as a strategic research field.

Heterogeneous coexisting theories of sociotechnical development and change (see Sovacool and Hess, 2017) currently focus on the roles that these and other related prospective elements perform in sociotechnical dynamics. For instance, several authors stress the importance of the mobilisation of *leitbilder* or guiding sociotechnical visions. *Leitbilder* are considered «schemata that represent future objectives and express the means by which these objectives will be realised» (Berkhout, 2006, p. 302). Mainstream futures representations constituting the development of in-vitro meat clearly reflect this definition: They present the future goal of solving the problems of overproduction and overconsumption of meat while meeting sustainability and animal ethics standards, and position in-vitro meat as the better means by which these goals can (and should) be achieved (Ferrari and Lösch, 2017). Once alignment exists with the future goal embodied in the vision, the vision unfolds its normative power by establishing a technology as the best or necessary solution to achieve that goal, thereby directing and guiding action towards its fulfilment (see also Dierkes et al., 1992; Hellige, 1996; Lösch, 2006; Schneider and Lösch, 2019).

"Sociotechnical imaginaries" is another prominent concept in STS that is tightly connected to the aforementioned ones. Sociotechnical imaginaries are «visions of desirable futures, animated by shared understandings of forms of social life and social order attainable

[8] The range of potential possibilities constrained by scripts are in turn defined as being based on a series of preconfigured representations of technologies' *potential future users*—users who are often idealised and/or subjected to biases during the testing process (Akrich, 1992). For a critique of the idea of script see Verbeek (2005).

through, and supportive of, advances in science and technology» (Jasanoff, 2015, p. 4). Like *leitbilder*, sociotechnical imaginaries connect social and technological orders while encoding a normative force: They subtly prescribe «how life ought, or ought not, to be lived» (Jasanoff, 2015, p. 4). Jasanoff and Kim (2009, 2013), for example, have documented how sociotechnical imaginaries on nuclear energy in the United States and South Korea played a crucial role in framing the future benefits and risks of nuclear energy. Sociotechnical imaginaries were instrumental *in reinforcing their respective hegemonic ideals of collective life and socio-political orderings* (see also Ballo, 2015; Jasanoff and Kim, 2015).[9]

Promises, expectations, visions, and imaginaries are collectively held and co-produced representations about the future that function as STM modulators, nudging sociotechnical systems towards certain paths (see Brown and Michael, 2003, p. 3; Konrad, 2006, p. 430). They are simultaneously evolving products and performative producers of sociotechnical realities. These sociotechnical futures colonise belief and value systems as well as the horizons that configure individual and social agency, thereby legitimising programmes of action and mobilising human and material resources and legitimising programmes of action (Anderson, 2007; Jasanoff and Kim, 2009, p. 123; Konrad and Böhle, 2019). Despite being fictitious in character, futures re-arrange "the mass" of sociotechnical systems (i.e. the series of assembled socio-material actors) and provide it with directionality. They enable/constrain (i.e. open up/close down) the orientation and speed of development of scientific-technological activities by gearing them towards satisfying particular research and development agendas and social orders (to the detriment of others) (Michael, 2000).

Because these anticipatory constituents orchestrate the direction of the ongoing construction of sociotechnical realities, they can be understood as mechanisms of power fabrication, mobilisation, and enactment. These anticipatory forces at play are socio-spatially situated, variable, plural, and produce evolving dialectics of contestation, neutrality, and/or mutual nourishment at different degrees and levels between them. Futures representations are machineries that anticipatorily shape (while simultaneously expressing) the politics of future-making and are therefore never free of socio-political tensions and struggles (Jasanoff, 2020). Thus, key questions relate to what, whose, how, and why certain futures emerge/disappear, coevolve and/or succeed/fail to shape reality.

The diagnosis of the performativity and political significance of anticipation has led to normative STS proposals to attend to anticipation as an object of critique and interventive modulation (e.g. Konrad and Alvial Palavicino, 2017; Lösch, Grunwald, et al., 2019; Lösch et al., 2017). Proposals such as Constructive Technology Assessment (Schot and Rip, 1997), Vision Assessment (Grin and Grunwald, 2000; Grunwald, 2009b), and Hermeneutic Technology Assessment (Grunwald, 2020) are exemplary here. The first proposal strives «to broaden the design of new technologies (and the redesign of old technologies)» (Schot and Rip, 1997, p. 252) by expanding the concerns and actors considered; that is, it aims to

[9] For more case studies in sociotechnical imaginaries, see Volume 50, Issue 4 (2020) of *Social Studies of Science*.

problematise the scripts attached to technologies in design processes. The other two proposals aim to critically assess the sociotechnical meanings that visions and futures convey.[10]

In some instances, these assessment and modulation activities not only have the future as their focus, but are themselves enacted through activities that use representations of the future as a methodological-interventive resource. Following a "*similia et similibus curantur*" rationale (literally, "like cures like"), several STS methodological-interventive initiatives nowadays promote foresight, visioning, or futuring techniques as a means to open up the futures that shape STM. In contrast to technocratic uses of futures, the operationalisation of these anticipatory techniques seeks to broaden the concerns considered by nurturing critical reflective capabilities (e.g. Arnaldi, 2018; Betten et al., 2018; Rip and te Kulve, 2008; Swierstra et al., 2009). For instance, Selin (2011) operationalises futures scenarios to explore alternative impacts of nanotechnologies, Lehoux et al. (2020) to stimulate moral imagination in health technology, and Withycombe Keeler et al. (2019) to promote "emancipatory" capabilities and sustainable presents.

Examples of recent influential normative proposals that explicitly operationalise anticipation as a non-predictivist and non-technocratic methodological-interventive tool are Anticipatory Governance (AG) (Barben et al., 2008; Guston, 2014),[11] Responsible Research and Innovation (RRI) (European Commission, 2013a; von Schomberg, 2013), Responsible Innovation (RI) (Stilgoe et al., 2013), Anticipatory Ethics (Brey, 2012), and recent formulations of Technology Assessment (TA) (Grunwald, 2019b; Nazarko, 2017). Regardless of the respective normative foundations or visions that define and distinguish them, their common operational idea is to open up the sociotechnical systems' STM by making the multiple sites of closure that exist in the name of the future amenable to interventive modulation (see Chapter 2).

Anticipation thus appears in STS as: (i) One element of the manifold phenomena that articulate and modulate the co-production and coevolution dynamics constituting STM; (ii) a phenomenon that should be subject to critical-reflexive consideration; and (iii) a set of future-oriented interventive methods to modulate the prospective structures of contemporary sociotechnical systems and thereby re-shape their STM.

[10] For an empirical case study where Constructive Technology Assessment and Vision Assessment are integrated, see Roelofsen et al. (2008).

[11] Muiderman et al. (2020), without limiting their review analysis to the field of STS, show how different proposals that promote an "anticipatory" governance (i.e. a governance that involves the methodological-interventive use of futures) coexist. The concepts and forms of engagement with futures that these various "anticipatory" governance proposals promote are variable. Acknowledging this heterogeneity (see Chapter 2), the use of the term "anticipatory governance" in this chapter is limited to denote the normative STS proposal/framework presented by Barben et al. (2008).

1.3. Modal power and the politics of (un)certain futures

Although anticipation is addressed in STS from the three ideal-typical approaches mentioned above (descriptive, critical-normative, and methodological-interventive), these overlap in practice. For example, descriptions that expose how images of the future anticipatorily perform reality could be understood as interventions if they enrich existing understandings of science, technology, and innovation dynamics and thereby aid critique and reflection. Moreover, engagements with futures performed by STS scholars are usually driven by more or less implicit/explicit normative commitments: They are motivated to realize more desirable futures where co-production processes articulate—and are simultaneously articulated by—more self-aware, transparent, and democratic orders (e.g. Guston, 2014; Jasanoff, 2020; Stilgoe et al., 2013). In this sense, STS scholars not only treat anticipation as an object of description, critique or as a means for interventive modulation, but *are themselves embedded in, and contributing to, anticipatory dynamics*.

Both the anticipatory dynamics that STS scholars describe, critically assess, and aim to modulate, as well as those that STS scholars mobilise through their visions and normative commitments, are involved in the general dialectics of opening-up/closing-down the present *patterns* and *directions* of STM governance (Fisher, 2019; Stirling, 2008).

The political dynamics of opening-up/closing-down the space of conceived possibilities and the anticipatory role of future representations can be framed within a model in which the course of history is reconstructed as a space full of possibilities that could have been realised, but few of which finally materialised in what we reconstruct (not without difficulties, tensions, and struggles) as "the past". Past pathways could have taken alternative directions and history can thus be conceived of as a space filled with unrealised opportunities. The present is a contingent outcome of an incalculable and highly complex constellation of events and decisions (conscious and unconscious); an outcome that simultaneously enables and constrains (by virtue of its socio-material characteristics) "open future possibilities".

However, how various actors navigate these "presently open possibilities" (i.e. what futures these actors identify, engage, and exploit) varies, and this navigation is anticipatorily mediated by artefacts such as predictions, scripts, visions, expectations, and sociotechnical imaginaries. The co-creation, mobilisation, and transformation of futures are part of the major political games that seek to promote certain modes and directions of governance. Anticipations constitute a significant component of the dialectics of opening-up/closing-down the present in terms of modulating the set of conceivable normative and pragmatic possibilities on the basis of which the diverse actors direct (and give meaning to) their present actions. Anticipatory dynamics steer STM towards different sociotechnical and political orders, disrupting or sustaining with varying degrees of radicality "business-as-usual" co-production and coevolution patterns. As blinkers, the performative relevance of these anticipatory artefacts lies in their ability to limit the envisioning of certain spaces of possibility towards which future-making practices could be directed. The representations of the future that coexist in each present act as anticipatory artefacts constraining the

imagination to a concrete subset of possibilities out of the vast ocean afforded by the present condition (Figure 1).

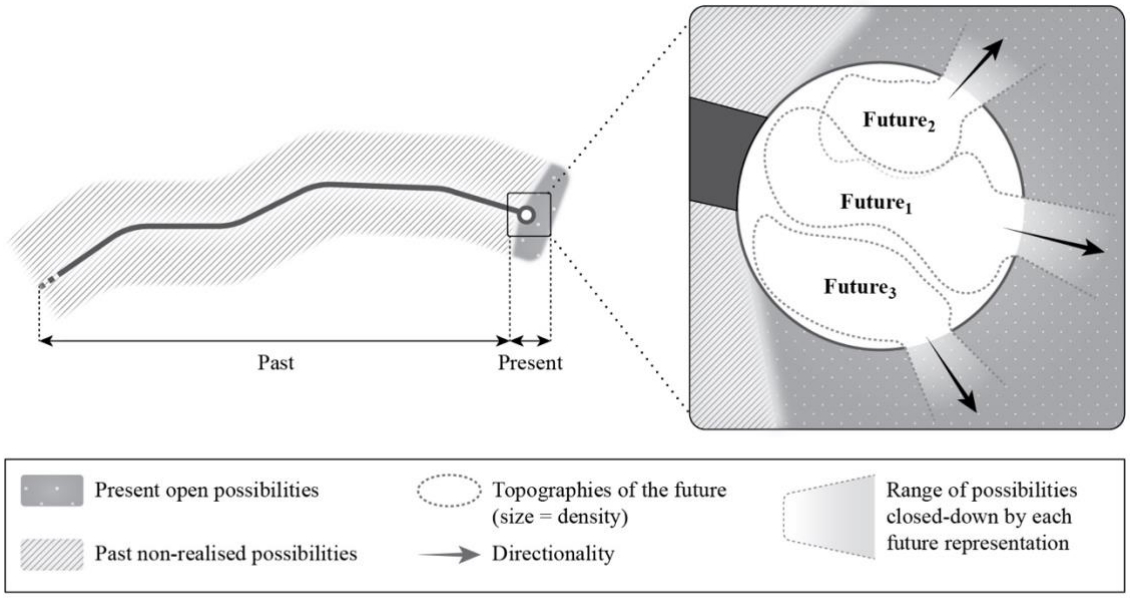

Figure 1. Topographies of futures anticipatorily providing directionality to the coevolution of sociotechnical systems.

The anticipatory power and relevance of sociotechnical futures and predictivist regimes therefore lies in the functions they perform within the politics of opening-up/closing-down future-making practices in the present: They constrain the focus and scope of the projections that constitute the complex and heterogeneous agential choreographies through which STM is ongoingly co-constructed (Emirbayer and Mische, 1998; Mische, 2009). Recalling the empirical cases previously mentioned: The promises and expectations on membrane technology, mainstream sustainable visions on in-vitro meat, or the sociotechnical imaginaries on nuclear energy are considered relevant because they encode empirical and normative stances that fix (or close down) how each technology should be socially and technically framed and valued, as well as the sociotechnical orders that could/should be pursued through such technology. In the same vein, predictivist apparatuses often *close down* the scope and depth of the issues potentially considered in technology assessment processes (e.g. by focusing on risks and obscuring the required political debate about the purposes and means of technological development). Predictivist modes of framing the futures constrain agents' imagination both in terms of considering unpredictable impacts and problematising the processes, purposes, and directions of research and development.

Within this landscape, STS scholars often consider their research and interventions relevant insofar as they confront this obscuring of alternatives that visions and predictive

apparatuses provoke. Motivated by visions of openness, STS researchers tentatively seek to open up the closure dynamics by proposing alternative directions and modes of governance (e.g. Jasanoff, 2020; Kuhlmann et al., 2019; Lösch, Grunwald, et al., 2019). STS scholars typically emphasise the existence of opportunities for manoeuvre by recognising the indeterminate nature of the future and the limited capabilities of human agency to shape—albeit not totally control—the directions and forms of sociotechnical co-production (Guston, 2014).

Research and interventive STS practices are thus embedded within and confront and engage with the politics of opening-up/closing-down the STM directionality through futures. They are part of a broad landscape in which co-existing or living futures jointly configure futures topographies, each defined by their respective prescriptive and descriptive assumptions. As Michael (2017) suggests, this landscape of polyphonic topographies of futures is variable. Futures emerge, expand, and decay in a geographically and temporally localised manner, and these mutate over time in accordance with the sociotechnical co-production dynamics that simultaneously sustain and shape their ongoing development. In this process, the heterogeneous futures' topographies acquire distinct social densities according to (i) the ability of each future to attract/convince and mobilise different actors (e.g. institutions, individuals, organisations) and (ii) the positioning of these "future holders" within their network. The density of future representations at any given moment determines the predominant—but not unique—mode of orientation of actions at that moment and thus constitutes the dominant directionality of the STM. In the struggle for effective STM influence, the different topographies of futures maintain interactions and relations of different kinds and depths between them (e.g. total or partial confrontation, domination, mutual nourishment, neutrality).

The varying choreographies of futures' topographies configure anticipatory dynamics that shape—both in form (how the future is approached) and content (which prescriptive and normative assumptions we attribute to the future)—how future temporality is/should be experienced and lived. If power is fundamentally understood as the capacity of an agent (human or non-human; individual, collective, or institutional) to actively or passively influence the ways and directions in which reality is constituted and unfolds, then anticipation can be considered as a subtle mechanism for the fabrication, mobilisation, and execution of power.

This mechanism of power finds its basic *modus operandi* in fixing hypothetical assumptions concerning what is (or should be) considered "(im)plausible" and "(un)desirable" regarding the future, thereby restricting the imagination about practical alternative possibilities towards which action could be oriented in the present. Future representations channel the range of possibilities that animate the direction of ongoing activities and actions that constitute STM, hampering the contemplation of alternatives to guide future-making practices. This capability to fix the domain of what is conceivable as a space of possibilities has been specifically labelled by Steve Fuller (2018b, pp. 139–149) as "modal power". The heterogeneous future representations widely distributed in the social

space form choreographies of anticipatory topological dynamics that engage, fabricate, modulate, and exercise modal power.

The exercise of modal power through anticipatory practices is at the heart of the political life of opening-up/closing-down STM. Hughes subtly alluded to how sociotechnical design practices—identified in the previous section as being mediated by anticipatory practices—involve the exercise of what is here framed as "modal power":

> One of the primary characteristics of a system builder is the ability to construct or to force unity from diversity, centralization in the face of pluralism, and coherence from chaos. *This construction often involves the destruction of alternative systems* (Hughes, 1987, p. 52; emphasis added).

The mobilisation of visions, expectations, and imaginaries as well as the confinement of governance articulations to predictivist schemas involve the destruction of alternatives by subtle fixations on what can be considered certain or uncertain, what is imaginable and what is not. They inevitably lead to the destruction of alternatives that might nevertheless have been legitimately considered.

The concept of "modal power" offers a tentative account of the mechanisms by which sociotechnical futures and predictive machineries enable/constrain possibilities (i.e. modal spaces) and acquire the performativity and socio-political significance to which STS scholars often allude. It draws attention to the socio-epistemic and socio-material conditions of (un)certainty co-production that sustains, underlies, and enables the performative power of sociotechnical futures. To illuminate the mechanisms that, through representations of the future, mobilise and exercise modal power involves grappling with the politics that underlie the anticipatory fabrication of empirical and normative (un)certainty. Representations of the future that are co-generated and mobilised across social practices generate and conceal, under specific modalities, the spaces of (un)certainty that are detectable and recognisable as such.

Spaces of (un)certainty are established in terms of what is deemed known/unknown, necessary/contingent, desirable/undesirable, etc. By looking to the modes of production and mobilisation of modal power, the focus is not so much (or not only) on how the existence of epistemic ambiguity and uncertainty in contexts of political cleavage raises the possibility of politicisation (e.g. Funtowicz and Ravetz, 1990). Rather, the focus is principally on how certainty is co-constructed and used as a mechanism to depoliticise the possibilities of sociotechnical co-construction open in the present. It is not only a matter of seeing politics in spaces of uncertainty, but also (and primarily) in the very mechanisms of establishing certainty in political arenas—especially when this establishment applies to events that are (relatively) open to (in)occurrence, such as future ones (Rubino, 2000). Restricting the aperture to scrutinising only those spaces that are considered uncertain implies shielding from scrutiny those spaces that are typically considered certain on the basis of purely scientific and technical criteria, as if the production of certainty were completely detached from political values and concerns. Refusing to problematise the politics underlying the

mechanisms of fixing certainty entails blindly accepting that the production and fixation of a large part of the assumptions and facts about the future are settled and normative-free.

The co-production of certainty regarding the future has indeed been considered instrumental for domesticating "feral futures", i.e. as a way of neglecting that sociotechnical coevolution can/might take unexpected and different directions (Ramírez and Ravetz, 2011). The mechanisms of the co-production of certainty involve the exercise of modal power insofar as they imply the removal from consideration of "uncomfortable" paths that might challenge the choices (and/or the assumptions on which those choices are based) of those in power. The call to open up modal power, however, is not (and should not be) about entering into a dynamic where "anything goes" (or where everything is considered equally valid). Rather, it is about taking seriously the mechanisms for determining the realms of the "(im)plausible" and the "(un)desirable" by exposing them to discussion and transparency. Key questions in this regard are: Who determines the realm of the "(im)plausible" and/or "(un)desirable"? By what means and on what justificatory grounds? In relation to what problems and purposes? Whose values are considered, and why those ones rather than others? The call to open up modal power entails following up and problematising the heterogeneous *contents* and *modes* with which we imagine and approach sociotechnical futures by considering how these are inseparable from our personal and socio-political projects and ambitions; from how we orient our life in the present.[12] It means paying close attention to how anticipatory elements such as expectations, visions, and imaginaries, as well as predictivist regimes engender both "substantive" and "formal" bias (Feenberg, 2017) by embodying preferences and meanings about the worlds that *should* (not) be inhabited.

1.4. The negotiation of "(im)plausibility" and "(un)desirability" as a disturbance of modal power

The recent STS critical-reflexive engagement with prospective elements such as expectations, visions, and imaginaries can be read as an attempt to make visible and disrupt the modes of modal power distribution that these anticipatory representations contain. It may be read, in other words, as an attempt to widen the scope of the anticipatory blinkers through which we experience, imagine, know, and perform the present reality. On the one hand, STS descriptive studies on the co-creation and mobilisation of representations of the future such as visions, expectations, and imaginaries trace the anticipatory channels and contents through which modal power is generated, distributed, and executed. On the other hand, STS normative proposals typically point to the need to amplify the space of the "(im)plausible"

[12] The problematisation of futures in terms of *content* refers to the critical engagement with normative and descriptive assumptions underlying future representations. In contrast, problematising the *modes* refers to assessing what kind of engagements with the futures are promoted throughout the mobilisation of these prospective elements: "Do they promote a predictivist relation to the future (i.e. an epistemic approach)?", "Is the future presented as a prefixed space in which human action plays a passive role (i.e. a deterministic approach) or is it presented as an open space to be cared for proactively, not free of struggles and tensions (i.e. a constructive-political approach)?"

or "(un)desirable" fixed by such representations through the consideration of alternatives for action and the visibilisation of issues or values that are not contemplated. Both description and normative critique involve intervention to some extent. However, it is the STS methodological-interventive proposals that explicitly consider anticipatory instruments (e.g. foresight, visioning or futuring practices) as means to enhance reflexivity and support the modulation of modal power.

Consider, for example, AG, which uses "foresight" (along with "engagement" and "integration") to «collectively imagine, critique, and thereby shape the issues presented by emerging technologies before they become reified» (see Barben et al., 2008, p. 992)—in other words, to intervene in sociotechnical systems before STM renders their modulation more difficult. In contrast to technocratic and predictivist approaches to the future, foresight is conceived here as a technique which «aims to enrich futures-in-the-making by encouraging and developing reflexivity in the system» (Barben et al., 2008, p. 986).

RRI is another normative framework championed by the European Commission (EC) that relies on «the introduction of a broader foresight» (von Schomberg, 2013, p. 51). RRI «anticipates and assesses potential implications and societal expectations with regard research and innovation, with the aim to foster the design of inclusive and sustainable research and innovation» (European Commission, 2013a). In the same vein, the RI framework defines anticipation as a central dimension (alongside inclusivity, reflexivity, and responsiveness) aimed at «consider[ing] contingency, what is known, what is likely, what is plausible and what is possible» (Stilgoe et al., 2013, p. 1570). Similarly, TA advocates have also recently recognised the importance of «enhancing reflexivity *over time*» through anticipation (Grunwald, 2019b, p. 703) to democratise technology co-production processes.

These STS-related normative frameworks understand anticipation as an interventive practice that is not primarily focused on looking *into* the future (i.e. generating future presents), but as a socio-epistemic activity that could be framed here as aimed at disrupting modal power (at opening-up the mode and content through which we look *to* the future). Far from generating knowledge about what is yet to come, anticipation is used as a tool to make the sociotechnical futures presently considered "(im)plausible" and "(un)desirable" (and the underlying reasons behind these considerations) the subject of inclusive discussion, thereby opening-up alternative courses of action that may be more responsive to a broader range of social actors and concerns (Chapters 2 and 5). Making visible the assumptions about the future is intended not only to enable a (more or less explicit) critical assessment of expectations, visions, and imaginaries, but also to bring to the table aspects of how we create sociotechnical worlds through scientific and technological innovation that would otherwise remain invisible. By anticipatorily using futures representations, foresight aims to "emancipate" (Withycombe Keeler et al., 2019) «the still, small voices less often heard in the innovation process» (Guston, 2014, p. 229) in the present. Anticipation is understood in this context as an interventive tool that assists in «taking care of the future through collective stewardship of science and innovation in the present» (Stilgoe et al., 2013, p. 1570). Anticipation and foresight exercises aim to open up various processes that continuously

constitute and close down the STM of sociotechnical systems by setting spaces of (un)certainty. Thus, within the frame provided in this chapter, anticipation/foresight can be interpreted as a tool for disrupting the modal power allocations which shape and sustain the *momentum* of sociotechnical coevolution processes.

This understanding of anticipation and foresight as tools for the disruption of modal power aligns with recent developments in Anticipation and Futures Studies regarding scenario development and the promotion of capabilities such as futures literacy (see Miller et al., 2018; Miller and Sandford, 2019; Poli, 2021; Rhisiart et al., 2015). For instance, scenario work seeks «to extend the peer community by seriously considering that which had hitherto been unwelcome, politically incorrect, destabilising, and radical, along with that which questions established categories, labels, connotations, roles, sources of legitimacy, and power relations» (Ramírez and Ravetz, 2011, p. 482). Furthermore, futures literacy proposals aim to (i) identify and/or make visible underlying anticipatory assumptions (including an awareness of the past and present) and (ii) deconstruct or challenge the dominant anticipatory assumptions in order to raise new questions, ways of framing, and paths of action in the present (Miller, 2018; Miller and Sandford, 2019).

All these STS methodological-interventive proposals emphasise the need to disrupt and distribute the modal power that is mobilised and executed on the basis of representations of the future. It should be emphasised, however, that this disruption can entail different degrees of radicality. The blinkers can be widened to different scopes and in relation to different aspects.

The level of radicality could be defined in terms of (i) the domains of research and innovation that are problematised (e.g. impacts/outcomes, processes and/or purposes), (ii) the timing of this problematisation (whether *ex-ante* to the development of the innovation, *ex-dure*, and/or *ex-post*), (iii) the actors and concerns involved in this process, and (iv) the degree of embeddedness of this problematisation in STI practices. For example, only opening-up the debate on the outcomes of an innovation at advanced stages of development may be considered less disruptive or radical than opening-up the debate on its outcomes, processes, and purposes at earlier stages of development. This implies that STS scholars using anticipation as a disruptive tool could benefit from considering what type and degree of disruption they seek to realise and which actors or futures will be left out or included (and why) (see Section 2.4.1 and Chapter 7).

For instance, Withycombe Keeler et al. (2019) argue that foresight exercises can provide "emancipatory" heuristics for disrupting status-quo imaginaries. However, the scenarios-building practice through which that potential is illustrated takes for granted futures where the problematised technology already exist. Similarly, Selin (2011) attempts to promote mechanisms of "negotiating plausibility" in the field of nanotechnology—which can be read, in the context of this chapter, as an attempt to disrupt modal power—and sets up a series of scenarios where what is problematised is not the political meaning and/or desirability of nanotechnology itself, but rather its concrete applications (i.e. the scenarios subtly assume and reproduce the promises of disruptive development of nanotechnology). When the

political dynamics of opening-up/closing-down the present through futures is at stake, the question of which futures are (or should be) considered and in relation to which aspects they are problematised becomes central.

The "negotiation of plausibility" here thus takes on an ambivalent or tension-laden character. On the one hand, the use of plausibility as a methodological criterion and as an epistemic and inferential register enables the futures under consideration to be opened up beyond those that could be identified by standard probabilistic criteria (i.e. plausibility enables broader explorations and sense-making beyond probabilistic projections) (see Chapter 5) (see Fischer and Dannenberg, 2021; Ramírez and Selin, 2014; Schmidt-Scheele, 2020a). On the other hand, limiting the scope of discussion to nanotechnology applications requires assuming in advance that nanotechnology is a plausible and desirable general technological project. This second aspect implies closing-down the scope of the "plausibility negotiation" process from a more fundamental debate about the plausibility (and desirability) of nanotechnology itself. Although made in a spirit of openness, these anticipatory interventions may end up reproducing assumptions about the "(im)plausible" and the "(un)desirable". These anticipatory interventions were «not designed to manufacture support (…), but rather to critically reflect on how the technology could develop in unexpected ways» (Withycombe Keeler et al., 2019, p. 277). However, insofar as these practices take for granted the desirability and plausibility of the emerging technologies under their respective critique and study, they indirectly stabilise the modal power dynamics that seek to benefit and pave the way for their development. Such assumptions restrict the scope for imagining alternatives and thus reify (even if unintentionally) development paths that could otherwise be problematised.

In addition to examining the scope and depth of the opening created in practice, it is also relevant to ask to what extent the disruption is actually effective. The factors that constitute the STM of sociotechnical systems will also hinder the potential of these methodological-inventive anticipatory practices. Like any form of power, modal power is embedded in and reproduced through complex social fabrics with deep socio-material roots. Institutions, traditions, and sociotechnical forms of organisation will perpetuate and privilege actors who reproduce and ensure their survival.

This implies that anticipation, understood as an interventive methodology aimed at the co-construction of more reflexive, inclusive, and perhaps fairer sociotechnical futures, must itself be located within the sociotechnical context from which it simultaneously emerges and in which it intends to operate. The constitutive dynamics of this context will tend to privilege certain actors and render others invisible. Heterogeneous actors compete to impose their range of considerations regarding the "(im)plausibility" and "(un)desirability" of futures (i.e. to exercise modal power and impose their anticipatory criteria). Only by recognising these socio-material constraints and encouraging their disruption during the operationalisation of intervention can anticipation become an effective and realistic tool for democratising the politics of future-making.

1.5. Conclusions

The future is a battlefield that is continuously settled in the present. But this settlement in the present is in turn influenced by futures images and modes of inhabiting future temporality. STS scholars have devoted particular attention to this phenomenon over the last three decades. STS research has made significant progress in identifying how heterogeneous future-oriented elements shape the direction and speed of science, technology, and innovation co-production dynamics.

Anticipation has been understood in STS as one element of the sociotechnical fabric that shapes (and is simultaneously shaped by) the complex assemblages in which these elements come into play. Whether in the form of predictive-technocratic machineries and scripts embedded in technologies, or as expectations, visions or sociotechnical imaginaries, futures representations modulate the directions and speed of sociotechnical coevolutionary patterns. Following Hughes' terminology: Futures constitute heterogeneous anticipatory dynamics that shape the *momentum* of sociotechnical systems.

The cohabiting topographies of futures (e.g. scripts, expectations, visions, sociotechnical imaginaries) and temporal regimes (e.g. prediction-based modes of governance) co-configure (and simultaneously are an expression of) the existing politics of and with futures. These futures and temporal orderings function as blinkers which open up/close down horizons of futures possibilities by modulating what counts as "(im)plausible" or "(un)desirable" at present. In other words, futures play an important role in the political games of opening-up/closing-down the directionality of sociotechnical development by means of exercising modal power (i.e. by means of settling the registers of epistemic and normative (un)certainty).

As this chapter has emphasised, STS scholars are not outsiders to these opening-up/closing-down anticipatory dynamics. They are embedded within, account for, contribute to, and aim to re-shape these dynamics; usually guided by aperturist motivations (i.e. aiming to point to alternative directions and modes of sociotechnical co-production and coevolution). Indeed, this chapter has argued that STS attempts to open up (i.e. expand and/or enrich) the existing anticipatory dynamics through their empirical analysis, critical assessments or methodological-interventive anticipatory practices (e.g. foresight, visioning, futuring) are primarily involved and confronted with the description, assessment, and redistribution of modal power. The laudable impetus to democratise future-making practices is operationalized through attempts to open up what is presently considered "(im)plausible" and "(un)desirable". Once again, but in the sphere of futures, STS scholars are concerned with the politics of (un)certainty.

However, commendable attempts to open up futures always problematise certain aspects and protect others, and therefore can subtly contribute to the stabilisation of certain hegemonic futures. This is the case, for instance, when the socio-political legitimacy of sociotechnical agendas is tacitly shielded from problematisation (e.g. by focusing on impacts while overlooking the debate on their political meanings and the often unresolved issues of

social justice). Anticipation can only be a disruptive interventive tool capable of democratising and proposing genuinely alternative futures (i.e. capable of widening the blinkers' scope through which we understand and perform our realities) if it is able to disrupt the socio-material mechanisms that sustain current patterns of (un)certainty fixations through modal power allocations. In this sense, the present chapter has underscored the need to pay further attention to the conditions and modalities under which these openings occur. Relevant questions in this regard include: Which futures are disrupted, and which stabilised? Whose futures are these? Why these futures and not others?

CHAPTER 2

Revisiting conceptions of interventive anticipations: Gradients of openness radicality and conceptual challenges

Abstract This chapter presents the first argumentative move in strengthening and making sense of anticipation as an interventive tool for the promotion of a more socio-politically responsible STI. Specifically, it shows that anticipation as an interventive tool can be considered *sensu stricto* as a widespread phenomenon. Indeed, the use of representations of the future to guide present action is a necessary condition for all those normative approaches and frameworks that strive to promote a proactive and *ex-ante* conception of the responsibility or governance of STI. Various normative frameworks and approaches have in fact relied on anticipation or foresight tools in their attempts to promote their respective normative conceptions of STI governance. Approaches reviewed here that exemplify this are Future-Oriented Technology Analysis, diverse modes of TA, ELSA/ELSI, AG, RRI, and RI. Nevertheless, the conduct of this review of conceptions of interventive anticipations diagnoses two central issues that need to be acknowledged, addressed, and problematised. The first is that (i) the ways in which these forms of anticipation are put into practice are heterogeneous, in terms of both the objectives pursued and the types of uses and engagements with future representations, with varying degrees of radical problematisation of STI. The second is that (ii) recent frameworks advocating a more socio-politically radical responsibility are not sufficiently informative or explicit in specifying the kinds of engagements with the future that they seek to promote through anticipation (e.g. which challenges are intended to be addressed, how this is to be done, etc.). This lack of specificity hinders the processes of sense-making and operationalisation of anticipation to promote the co-production of a more socio-politically robust STI.

2.1. Introduction

In the last two decades, various normative frameworks for the governance of STI have emerged, pointing to the possibility and necessity of promoting more inclusive and socially desirable research practices (Eizagirre et al., 2017; Grinbaum and Christopher, 2013; Nielsen, 2016). This process is not only taking place in academic spheres, but also resonates in institutional circles, as in the case of the European Commission (EC) (European Commission, 2013a). Particularly prominent examples in this regard, already mentioned in earlier chapters, are Anticipatory Governance (AG) (Barben et al., 2008; Karinen and Guston, 2009), Responsible Innovation (RI) (Owen et al., 2013; Stilgoe et al., 2013), Responsible Research and Innovation (RRI) (European Commission, 2013b; von

Schomberg and Blok, 2021; von Schomberg, 2013), and newer forms of Technology Assessment (TA) (Grunwald, 2019a, 2019b; Guston and Sarewitz, 2002).

These frameworks have both overlaps and important differences in terms of their normative assumptions and central domains of action, and historically they have maintained relationships of mutual influence and co-constitution. One of the common elements connecting them is the explicit inclusion of anticipation/foresight[13] as a constitutive dimension. Anticipation is seen as a tool and dimension with great heuristic potential to promote a more robust alignment of STI with societal needs and expectations (i.e. a more socio-politically responsible STI). Although crucial, this aspect of anticipation is rarely explored in depth and problematised, especially regarding the links between different conceptions of anticipation and understandings of responsibility.

In the previous chapter, this recent call for the use and mobilisation of futures was understood as an attempt to engage with the dynamics of modal power. It was pointed out that STS scholars often engage in the opening-up/closing-down dynamics of modal power, aiming for openness. However, it was also noted that these dynamics can take on different gradations of radical problematisation: They can open up futures in relation to particular issues (and not others), involving particular actors, concerns, and knowledges (and excluding others), and within particular time periods. The different gradations of openness that anticipation can assume as an interventive instrument invites us to focus on the conditions of sense-making and production of anticipatory interventions (i.e. how anticipation is understood and de facto put into practice).

This chapter represents the first argumentative step in the quest to conceptually strengthen and give meaning to anticipation as a tool for promoting a more socio-politically responsible STI and to highlight its de facto heterogeneous character. The first step is to acknowledge that anticipation, if we understand it in terms of Anticipation and Futures Studies—i.e. as an action informed by a model of the future—is a ubiquitous phenomenon. It is present in a variety of approaches and frameworks.

Indeed, building on the basic concept of anticipation in Anticipation and Futures Studies, the chapter shows how the use of representations of the future to guide present action is a necessary condition for all those approaches and normative frameworks that seek to pursue proactive and *ex-ante* conceptions of responsibility or governance of STI (Section 2.2). Different normative frameworks and approaches have in fact made use of anticipation or foresight tools in their attempts to promote their respective practices of interventive STI

[13] Poli (2017, 2021) distinguishes between foresight and anticipation. Foresight involves various forms of creating and engaging with future representations, while anticipation extends foresight by including the translation of those representations into action (i.e. anticipation involves foresight plus action). The distinction holds and has theoretical significance (i.e. there could be foresight processes that prima facie are not action-oriented, or translated into action). However, since in the context of STI governance foresight focuses on enabling capabilities and enhancing orientation and decision-making in the present (i.e. it is always action-oriented), the terms "foresight" and "anticipation" are employed interchangeably in this dissertation.

governance. The approaches reviewed here that exemplify these various uses of foresight are Future-Oriented Technology Analysis, diverse modes of TA, ELSA/ELSI, AG, RRI, and RI (Section 2.3).[14] The review of conceptions of interventive anticipation/foresight, however, diagnoses two central issues that need to be acknowledged, addressed, and problematised. The first is that (i) the ways in which these forms of anticipation are put into practice are heterogeneous in terms of both the objectives pursued and the types of uses and engagements with future representations, acquiring disparate formal gradients of problematisation of STI. These gradations of radicalisation or openness of STI are in fact subordinated to the conception of responsibility that underlies each of the frameworks in question. Second, (ii) the more recent frameworks that advocate a more socio-politically radical responsibility are not sufficiently informative or explicit when it comes to specifying the kinds of engagements with the future they seek to promote through anticipation (e.g. what challenges are targeted, how they are to be addressed, etc.) (Section 2.4).

2.2. Anticipation as a constitutive element of *ex-ante*, or proactive, responsibility approaches

The previous chapter has shown that representations that appeal to the future simultaneously (i) perform STI governance, (ii) become the object of assessment and critique, (iii) as well as being a methodological-interventive tool for modulating existing dynamics. Indeed, frameworks such as AG, RRI, RI, and newer forms of TA explicitly invoke anticipation as a constitutive dimension. Anticipation becomes a processual dimension, which is typically transformed into an interventive tool and operationalised through foresight exercises.

If we depart from the basic concept of "anticipation" offered by Anticipation and Futures Studies—where anticipation denotes any action consciously or unconsciously undertaken on the basis of representations of futures (Poli, 2017, 2021)—then we can conclude that various activities that constitute governance (both factual and those aimed at more desirable ways of promoting STI practices) have long acquired an anticipatory mood (i.e. they have typically been articulated by future representations) (e.g. Coates, 1971; Ported, 1995).

At the methodological-interventive level, the articulation of responsibility on techniques and methods that rely on future representations can be understood in the light of the various

[14] There are some other frameworks and proposals that could be added to this list of analysed frameworks. Examples are Anticipatory Ethics (Brey, 2012), Mediation Theory (Verbeek, 2015, p. 31) or Future-Oriented Technology Assessment (Nazarko, 2017). These frameworks were omitted due to space and time constraints. The chosen frameworks were deemed sufficient to achieve the more direct instrumental objective of the analysis. The aim is not comprehensiveness or exhaustiveness, but to show that (i) anticipation can be considered a ubiquitous tool for interventive frameworks, and that (ii) the ways of conceptualising anticipation are nonetheless heterogeneous, with different gradations and extensionalities of problematisation—a problematisation that is in turn subordinated to the conception of responsibility/governance that defines the framework at stake. The inclusion of the above-mentioned approaches—and possibly other ones not mentioned here—would only reinforce these two aspects.

attempts to overcome the limitations of consequentialist, reactive, and retrospective conceptions of responsibility. An example of these conceptions of responsibility can be found in the accountability models of responsibility. Models of accountability are based on the attribution of responsibility after the event in question has occurred. A subject or group of subjects *S* is held responsible (i.e. accountable) for the event *E* if and only if it is proven that *S* played a role in causing *E*. This notion of responsibility is passive (responsibility is assigned), retrospective (it relates to representations of events that have already occurred), and compensatory (responsibility means that *S* justifies its role in *E* and/or attempts to remedy the harm caused by *E*).

All anticipatory conceptions of responsibility aim to overcome this *ex-post* conception of responsibility (even predictivist ones). The inclusion of the future enables the possibility of assuming responsibility in advance, insofar as it is articulated on future projections of what might (not) be the case (i.e. it is articulated on potential *E*s). This is the idea that typically articulates, for example, the prevailing risk management and assessment discourses, just as this is the idea that articulated the initial TA proposals (see Section 2.3.2). Mainstream modes of risk assessment and management are articulated in representations of futures that depict potential STI "negative" impacts, which are sought to be *ex-ante*, or proactively, minimised (through the application of cost-benefit balancing formulae). More specifically, risk assessment processes are articulated around forecasting processes (typically probabilistic-based forms of exploring the future), where the objective is to minimise as far as possible the uncertainty about the future on the basis of probabilistic projections (i.e. on the basis of probable futures).

The framing of responsible STI on the basis of probabilistic projections that represent negative future impacts is indeed a step forward in the process of promoting more radical responsible practices. In contrast to retrospective models, a forward-looking formulation of responsibility allows action to be taken proactively before certain impacts occur (either to prevent or mitigate them). However, restricting this future-oriented stance to probabilistic projections can be subject to numerous limitations (both in theory and in practice). Examples of these limitations, which also contain many interrelations, include the following:

1) A purely predictive approach to responsibility narrows down the range of impacts and issues to be problematised to those that are susceptible to treatment through the scientific-technical techniques of projection and modulation of futures. For example, it implies leaving out the problematisation of the potential techno-moral coevolutions (Kudina, 2019) that could occur with the emergence of the technology or innovation in question.

2) There is a tendency to concentrate scenarios exclusively on negative and so-called "hard" impacts. This leaves out questions about the positive impacts that STI could promote and the people who could (not) benefit from it (von Schomberg, 2014) as well as problematising this in relation to the so-called "soft" impacts (Swierstra and te Molder, 2012; van der Burg, 2009b). This means that, for example, issues related to equity in the distribution of costs and benefits are excluded from the discussion.

3) Formulating responsibility on the basis of purely predictive scenarios often masks a false normative neutrality. Not only are predictions loaded with assumptions about what the world should look like in the future, but any future scenario, when translated into anticipatory action, must take a set of normative/political assumptions for granted.

4) The elaboration of predictive future projections requires both (i) knowledge about the technology in question, and (ii) the making of assumptions regarding the maintenance of present states and trends (i.e. they are based on *ceteris paribus* clauses). The former limits the application of this proactive-predictivist approach from earlier stages of development, when there is less knowledge and yet more flexibility to influence scientific-technological development (Collingridge, 1980). This case is further aggravated in the case of technologies whose technical characteristics make them extremely difficult to assess, thereby becoming a niche of intrinsic uncertainty (e.g. nanotechnologies). The latter reifies or protects the problematisation of the present worlds that are depicted in the *ceteris paribus* clauses.

These limitations restrict the spaces of STI opened up for problematisation and thus the radicality of the disruption of modal distributions potentiated by anticipatory practices. The limitations of articulating responsibility on predictive methods/representations of the future, together with the need to maintain some form of *ex-ante* responsibility (i.e. problematisation of STI occurs in the early stages of development), have led to various normative-interventive approaches and frameworks for the governance of STI to rely on other types of non-predictive methods.

The precautionary principle, whether in its strong or weak version[15], could be considered an example of an anticipatory principle of responsibility that aims to deal with the weak knowledge that we might have of potential STI impacts in the early stages of development (i.e. with the type of knowledge recently referred in "4-(i)"). The precautionary principle advises to take preventive, or cautionary, action (understood in terms of promoting environmental and health safety) when our representations of future impacts are weak or insufficiently conclusive (or even when we lack the necessary epistemic resources to assess its weakness/robustness). In other words, it prescribes that if an STI product or activity has *a suspected* risk of causing harm, protective action should be supported (Veflen Olsen and Motarjemi, 2014). The precautionary principle raises the point that the absence or a weak

[15] The difference between a weak and a strong conception of the precautionary principle lies in the way uncertainty is dealt with, the emphasis on the need for formal regulation, and who bears the burden of proof. The strong version emphasises that regulation is necessary whenever harm to health or the environment is possible (even if the evidence to support this claim is not well developed and the expected socio-economic benefits would be high). In the strong version, the burden of proof is placed on those claiming the safety of STI. The weak version emphasises the need for caution (without the requirement of, but also without resistance to, formal regulation) whenever the existence of some kind of harm is plausible. In the weak version, the burden of proof is placed on those claiming the plausibility of harm or risk (Government of New Zealand, 2006; Sunstein, 2003).

amount of evidence on futures of STI does not relieve us of the duty to take care of its potential negative impacts.

While the precautionary principle allows for an extension of responsibility beyond evidence-based forms of risk assessment, this principle is passive in the face of the other problems mentioned above. In this sense, the precautionary principle comes up against several limits in its potential to radicalise responsibility. The precautionary principle remains limited to the effects of STI (and in particular to the negative impacts, or risks), and its scope is narrowed to cases where there is no (strong) conclusive evidence of STI risks. The immediate question we might ask is: "What about responsible STI in cases where there is some degree of "conclusive evidence'"?", "What about problematising the positive impacts, processes, and purposes that guide STI?". The precautionary principle remains mute on these questions. This muteness makes this principle of responsible STI not only inadequate, but even counterproductive. The precautionary principle narrows the potential spaces of STI problematisation to those spaces in which the existence of "uncertainty" is presupposed, as if (un)certainty itself (or "evidence") could not be co-constituted and made amenable to scrutiny (see Funtowicz and Ravetz, 1990; Jasanoff, 2003; Rubino, 2000). While the precautionary principle has been criticised as a paralysing principle for STI and socio-economic progress (Harris and Holm, 2002; Holm and Harris, 1999; Stirling, 2017; Sunstein, 2003)[16], it is paradoxically also a kind of deterrent against the realisation of a deeper problematisation of STI.

These limitations of the precautionary principle—in addition to the tendency of European institutions to instrumentalise it in order to facilitate a smooth absorption and implementation of technology and innovation (Bogner and Torgersen, 2018, p. 3)—may explain recent moves since the 2000s in both academic and institutional circles to promote more robust and deeper forms of responsibility, which deal with uncertainty and constitutively accompany the development of STI (Dupuy, 2007; Dupuy and Grinbaum, 2004). For instance, in the institutional domain, the EC has recently modified its mission-oriented character[17] by orienting STI towards addressing societal pressing problems (the so-

[16] Note that this critique of the precautionary principle assumes that innovation is an essential driving principle for socio-economic progress. This reasoning, which is often accompanied by a linear notion of STI progress, is widely held in innovation policy, although it has been shown to be susceptible to nuance and complexity (see Godin, 2006; Godin and Vinck, 2017; Pfotenhauer and Juhl, 2017).

[17] After World War II, with the development of so-called "Big Science", a mission-oriented relationship between science and government began to develop (see Bush, 1945). The term "Big Science" is intended to encompass large-scale research and development projects, typically with the financial and bureaucratic support of national governments, governmental associations, or bodies with a strong international presence. Paradigmatic examples of these modes of promotion and implementation of research and development can be found in the Manhattan Project (United States of America), the Uranium Club (Germany), the Japanese nuclear weapon programme, or the Human Genome Project (United States of America). Governmental support for nanotechnological development at the international level can be seen as part of this trend (see Galison and Hevly, 1992). A relevant aspect of "Big Science" that remains to this day is that STI is understood as a driver of socio-economic progress. STI, understood under an enlightened view of it as a solution to all problems and challenges of humanity, became an object of public support and a priority for investment: «Governments

called "Grand Challenges"). The focus of responsibility here is not so much on eliminating risks or applying a precautionary principle, but rather on aligning STI with society's values and expectations. This alignment, however, has co-existed with (and been subordinated to) STI policies that are largely committed to fostering economic competitiveness. The orientation of STI towards profitable forms thus co-exists, under a harmonious ideal, with the imperative of guiding STI towards goals and processes in line with societal expectations and desires (e.g. sustainability, climate change).[18]

The development of AG, RRI, RI, and recent forms of TA are clear examples of normative approaches or frameworks that support and encourage this attempt to promote more robust forms of STI. Indeed, AG and RRI emerged as responses to institutional calls for promoting broader public engagement and responsibility in nanotechnology development. AG materialised in 2005 at the Center for Nanotechnology in Society at Arizona State University thanks to funds provided by the National Science Foundation and the National Nanotechnology Initiative (Guston, 2014),[19] whereas RRI was fuelled by the EC (European Commission, 2013b; von Schomberg, 2013). AG, RRI, RI, and TA have maintained profound influences and tensions and converge in their claim to go beyond traditional and narrow ways of addressing responsibility, precaution, and relating to "(un)certainty" (beyond the precautionary principle), while simultaneously dealing with STI in socially and epistemically inclusive ways.

As the central idea is to maintain an *ex-ante* conception of responsibility and STI governance while promoting richer forms of responsibilisation and problematisation of STI, the anticipatory aspect (i.e. the use of representations that appeal to the future to illuminate present action or promote certain capabilities) nevertheless remains indispensable. However, this form of anticipation is intended to be explicitly distinguished from prediction:

> An anticipatory disposition is not about seeing into the future (prudence) or saying what the future is going to be (prediction) or estimating the chances of a certain outcome (probabilistic forecasting), all of which prescribe a "knowledge first" approach to action (Foley et al., 2018, p. 228).

The key point is to determine what conceptions of non-predictivist uses of the future are proposed, what dynamics constitute them (i.e. what are the characteristics of these uses of the future), and what challenges these "non-predictivist" uses are intended to address or are aimed at activating in STI governance processes. The following section aims at advancing

---

have made of technological innovation an instrument of industrial competitiveness, world leadership, and national wealth» (Godin, 2016, p. 548).

[18] It is not casual in this respect that many of the initiatives aimed at promoting STIs more aligned with societal values, expectations, and desires have become ambivalent in these contexts. Indeed, processes of alignment with societal desires can easily be instrumentalised to improve the market receptiveness of the STI in question (as was the case with the precautionary principle).

[19] The University of California Santa Barbara also hosted another Center for Nanotechnology in Society.

the debate in this regard by reviewing the conceptions of anticipation that have been presented in various normative frameworks and approaches to STI governance.

2.3. The role of interventive futures in STI governance: Some methodological examples

This section briefly approximates how the future has been conceptualised in terms of STI interventive governance through several normative and methodological-interventive proposals. Specifically, the analysis will cover six proposals: Future-Oriented Technology Analysis, ELSA/ELSI, various forms of TA, AG, RRI, and RI. To this end, the founding texts of each of these proposals will be examined.

Before proceeding with the analysis, two preliminary comments are in order. First, the analysis does not claim to be exhaustive. It merely aims to show that the futures and normativities at stake are heterogeneous and that each of them—at least on the narrative or formal level—aspires to open/close different spaces of problematisation regarding STI. Since the focus here is on the meanings of non-predictivist anticipations in relation to each frame, attention will be particularly directed to the predominant ways in which each frame has approached the future, as well as to their respective formal radicalities or narratives of STI problematisation (what kinds of modal redistribution of power does each frame seek to enable through anticipation?). On the other hand, it is important to bear in mind that the proposals or frameworks presented here are not closed but open and living entities. They are entities that are constantly being revised, reconfigured, and refined over time. The refinement of these frameworks sometimes responded to ongoing academic developments and institutional trends (e.g. in response to changing institutional requirements or in critical dialogue with other emerging proposals). The exploration of these coevolutions is left out of the analysis for reasons of research constraints. The information provided here will suffice for an initial approximation of (i) the diversities of anticipations, and to recognise that (ii) the formal scope of anticipation in the problematisation of STI is dependent on the formal scope of the framework through which it is interpreted and operationalised.

2.3.1. Future-Oriented Technology Analysis

One of the approaches to be considered, given its impact and close relationship with institutions promoting STI, are the main derivations of Analysis and Strategic Management of STI (a field particularly populated by actors linked to management, economic, and business studies). More specifically, the emergence of technology analysis studies can be traced back to the 1980s in the context of the Science Policy Research Unit (SPRU) at the University of Sussex (Falmer, United Kingdom). The SPRU was founded in 1966 by Chris Freeman (1921–2010), an eminent economist and pioneer in terms of research in what was

then still a very early stage of Innovation Studies.[20] The unit was particularly pioneering in terms of combining innovation studies policy and management with Futures Studies (especially through the introduction of exercises that today are called "technology foresight") (Miles et al., 2016, pp. 9–10).

A paradigmatic and early example of the interest in the use of the future to guide present action within the context of Technology Analysis and the SPRU is the work of John Irvine and Ben R. Martin (Irvine and Martin, 1984, 1989). These authors are deeply concerned with the analysis and development of prospective techniques aimed at generating and managing information to improve or assist in decision-making in relation to STI (especially in assisting in the management of the so-called "Big Science"). This forward-looking approach was specifically reflected in what would become known in 1983 as the "Foresight Project", funded by the Advisory Council for Applied Research and Development—an advisory body reporting to the United Kingdom Cabinet Office (a department of the Government of the United Kingdom responsible for supporting the Prime Minister and the senior decision-making body).

This project contrasted with the retrospective thinking that prevailed at the time, which was based on identifying the key past scientific and technological milestones that enabled the existence of innovations considered important in the present (e.g. in the Hindsight project or the TRACES [Technology in Retrospect And Critical Events in Science] project). The Foresight Project proposed to turn this approach on its head: The aim was to explore what technologies might be profitable in the future, and from that to determine what current and future actions might help shape the realisation of those technologies (Martin, 2010, pp. 1439–1440). The exploratory activity in the Foresight project moved temporally and cognitively not from the past to the present (as the Hindsight and TRACES projects did), but from the future to the present.

A pioneering work on the systematic, methodologically mediated use of foresight that was produced as part of the Foresight Project (and thus reflects or summarises its orientation) is *Foresight in Science: Picking the Winners* (1984) (Irvine and Martin, 1984). The idea behind this work, as the subtitle suggests, is to present one of the first reviews of the then existing non-predictive foresight methods for enriching decision-making in order to pick (i.e. invest in) the winners of tomorrow's lines of research (those that would yield the greatest benefits in economic and social terms). Specifically, the study included 100 interviews on foresight methods used in research and development organisations, agencies, companies, and institutions (both public and private) in four countries: France, Germany, Japan, and the United States of America. Among the conclusions of the work was that foresight exercises were used as a tool to promote the following benefits in STI governance dynamics (whether

[20] See, for example, their work on the economics of technical change (Freeman, 1994), on the economics of industrial innovation (Freeman, 1982; Freeman and Soete, 1997), and innovation-driven growth (Freeman, 1990, 1995a). These approaches to innovation would later differ in their approach to innovation from what is now known as "Critical Studies of Innovation" (see Godin and Vinck, 2017), which is closer to the scope and critical spirit of STS.

combined or individually): (i) Fostering communication between diverse authors (industrialists, academics, policy-makers, analysts, etc.); (ii) enhancing long-/mid-term attention; (iii) enabling plan coordination; (iv) arriving at consensus; (v) creating a commitment to shared goals; (vi) fostering co-production; and (vii) generating co-ownership (Irvine and Martin, 1984, p. 144).

The aim of the study of practical experiences in all these countries was in fact driven by the desire of the United Kingdom's research and innovation regulatory and management institutions not to be left behind in the race for economic competitiveness. The aim was to emulate other leading global players, particularly Japan.[21] However, the interest in using the future to improve STI decision-making was not limited to United Kingdom institutions. Indeed, the call of the Advisory Council for Applied Research and Development should be interpreted within a European context that is largely dominated by techno-industrial development thinking. It must be placed in a European context where the development and consolidation of national innovation systems and European industrial policies were flourishing (see Sharif, 2006). These systems and policies were guided by the old, persistent, and mistaken notions that (i) innovation and socio-economic development are causally linked in a simple and linear way, that (ii) there is the possibility of potentially unlimited growth,[22] and that (iii) the development of technology and innovation is the main driver of socio-economic progress (Godin, 2006; Godin and Vinck, 2017).

[21] The interest in studying Japan's national innovation system is particularly relevant in this context. In the 1980s and 1990s, Japan was seen as a model of an emerging economy based on an STI system that was considered highly efficient. Despite the difficulties that had plagued Japan (e.g. World War II, the Hiroshima and Nagasaki disasters), the country showed great recovery and strength in growth and was one of the major exporters of high-tech products (although it later experienced a strong economic bubble known as the *baburu keiki*). Japan was therefore seen simultaneously as a potential competitor to the rest of the world's economies, as well as an example to learn from: «[T]he idea was to respond to the threat from Japan by being more *like* Japan» (Sharif, 2006, p. 761; emphasis in the original). Freeman (1987), the founder of the SPRU, was one of the authors interested in the functioning of the Japanese model, among others (see Giraud and Godet, 1987; Johnson, 1982; Vogel, 1979). He paid particular attention to the organisational architecture of the Japanese research system and the tools that supported the optimisation of resources and decisions. Particularly relevant in this context were the uses of the future made to articulate this organisation and optimisation (see Freeman et al., 1988). The Japanese Science and Technology Agency, which sets Japan's basic science and technology plans, has conducted a futures research programme every five years since the 1960s. In the early days, this programme was called "Technology Forecasting". However, since it operated under non-predictive parameters, it was soon renamed as "Technology Foresight" after the introduction of the term "Foresight". The aim of the programme since then has been to identify trends in research and innovation and to set priorities according to the country's social and economic needs at a given time. This programme has been strongly promoted by independent institutions in Japan (e.g. Think Tanks) such as the Institute for Future Technology or the Institute for Future Engineering.

[22] It is no coincidence that various SPRU actors participated in the debates that took place at the time in connection with the report *The Limits to Growth* (1972) (see Meadows et al., 1972). The debate centred on the report's basic assumptions about the demographic future of the planet and its technological capabilities and developments. According to several critics, including SPRU actors, the report was extremely pessimistic and underestimated the role of technological progress in solving problems such as pollution or food shortages (see Cole et al., 1973; Freeman, 1984; Passell et al., 1972). Criticism of the report spread across space and time (see Atkisson, 2011), and the team that produced it did not hesitate to respond to SPRU's criticism in an article in *Futures*. In this article, based on an analysis of the assumptions on which the SPRU authors based their critique, they accuse them of inaccuracy: «The Sussex authors have not put forward an alternate theory of growth to support their views, nor have they described in precise terms the processes of social change and technological advance that they believe will accommodate current growth processes» (Meadows et al., 1973, p. 135). The

Set in this context, the optimisation of decision-making towards "picking the winners" that seemed to characterise foresight exercises was seen by various institutions in different countries as a possible remedy to boost their socio-economic development (see Gavigan and Scapolo, 1999; Grupp, 1999). The underlying rationale was the early, or *ex-ante*, identification of the lines of research that (it was believed) would in the future prove most relevant to support the economic growth of the country in question and their subsequent early support would optimise management processes and resource allocation which in turn would result in important gains. The intervening use of anticipation methods is targeted at increasing the success of research efforts, i.e. to bet on the "winning horse" of new technologies and thus contribute to the struggle to increase economic and social prosperity amid international competition. Responsibility in this context means nothing other than ensuring that national innovation systems are focused on the strategic areas of scientific and technological innovation (what has more recently been referred to as Key Enabling Technologies in the context of the EC).

Backed by funding from institutions beyond the United Kingdom,[23] John Irvine and Ben R. Martin moved forward with their study on foresight for governing STI. Their next book *Research Foresight: Priority-setting in Science* (1989) included not only a larger sample size (e.g. New Zealand, Canada, Norway, Sweden, Germany, France), but also a greater interest in what "foresight" or "anticipate" meant. There are three central aspects of foresight practices that are highlighted there.

The first aspect of foresight practices is (i) their distinctly non-predictive nature. This distinguishes and distances foresight exercises from others that focus on identifying what will (probably) happen (i.e. probabilistic "forecasting"):[24]

> [T]he failure to predict the 1973 "oil-shock" led to considerable scepticism concerning the validity and utility of forecasting. (…) Anticipation or foresight involves an explicit recognition that the choices made today can shape or create the future, and that there is little point in making deterministic predictions in spheres (including science and technology) where social and political processes

successive critiques and responses in this debate reveal a struggle between different visions rooted in values and normative assumptions about the future (e.g. certain positions regarding the ideology of techno-economic progress can be discerned among the report's supporters and opponents). Similarly, the struggle is also one between descriptive assumptions. It is about what each actor considers (im)plausible and (un)desirable in relation to the future, and what kinds of world-making practices are thereby reified.

[23] Examples are the Dutch Ministry of Education and Science (1987) (see Irvine and Martin, 1989) and the Organisation for Economic Co-operation and Development (1994) (see Martin, 1994). As a result of the broadening of the institutions providing the funding, there was also a broadening of the frame of benefits. For example, the Dutch Ministry was particularly interested in knowing not only the economic benefits of STI, but also the social benefits.

[24] It is interesting in this respect to note the statements of Ian Miles (SPRU member and now a member of the Futures Studies community) regarding the use of the word "foresight" in this early period of the 1980s: «At this stage of preparing the [Project Foresight] proposal (in Spring 1983), we had not carried out more than a bare minimum of literature review on previous forecasting or futures work, and we certainly had no idea whether or not the term 'foresight' had been used by others in connection with forecasting or futures studies. That would only come later» (Martin, 2010, p. 1440).

> exercise a major influence. There has consequently been a move away from forecasting and prediction towards activities variously labelled as "outlook", "foresight", "issues management" and "la prospective" (Irvine and Martin, 1989, p. 4).

The second characteristic aspect of "foresight", already mentioned in the previous quote, is that it is (ii) based on an open ontology of the future. This way of conceptualising foresight was largely influenced by "*la prospective*" approaches developed in Futures Studies at the time.[25] In fact, it is precisely the consideration of the open character of the future that allows for the possibility of an economic rationalisation of present action. Precisely because there are different possible futures, some of which are more desirable than others, it is possible to rationalise action in order to take the path that we believe will orient us towards the most desirable of these futures (see Martin, 1995, p. 140).

Finally, the third aspect attributed to "foresight" is (iii) its distinctly processual character. Foresight was conceived primarily in terms of process and not in terms of the future models presented or envisaged. The focus was intended to be on knowledge sharing between different actors in the quest for identifying potential profitable STIs. The procedural heuristic of futures research provided certain resources and feedback of an advisory nature «to select the most promising research and emerging technologies on which to target resources and, hence, drive the greatest benefits» (Martin, 1995, p. 139). Indeed, "technology foresight" was defined by Martin (1995, p. 140) as follows:

> 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 generic technologies likely to yield the greatest economic and social benefits.

The institutional uptake of foresight as a key tool for the management and governance of STI has varied over time and according to geographical scope, with phases of expansion and decline.[26] Both the level of adoption and implementation of foresight and the specific techniques and modes of operationalisation varied and were adapted and redeveloped according to the institutional needs of the time and of the geographical area.

For example, the United Kingdom and Dutch foresight programmes in the mid-1990s were particularly participatory. Foresight exercises were not limited to expert-based Delphi studies, but expanded the range of foresight techniques used for promoting mutual learning, including collaborative panels and meetings aimed at strengthening connection, discussion, and knowledge sharing between different actors (see Martin, 1995, p. 149). One of the

[25] Examples of advances in this respect can be found in Berger (1967), Flechtheim (1970), and de Jouvenel (1967). The school of "*la prospective*" emphasised that the future must be thought of in plural and not singular terms (i.e. as "*les futuribles*" and not as "the future"), as well as the need for a cognitive shift from prediction to conjecture (i.e. from inductive-probabilistic to abductive-plausibilistic inferences).

[26] For instance, see Burgelman et al. (2014) regarding the fluctuations of support for foresight programmes within the EC.

reasons for this expansion was the institutions' preoccupation with public concern about technologies and their impact on the environment and health (e.g. nuclear energy, the agri-food industry, nanotechnologies). The inclusion of different actors and the commitment to co-production mechanisms was seen, especially at the European level, as a way of ensuring future-proof policies: «Governments operate more successfully when they jointly produce policy with other stakeholders, creating shared visions of the future that can, to a considerable extent, become self-fulfilling prophecies» (Martin, 1995, p. 149).

The production of alternatives that foresight presumes is typically applied here in terms of the envisioning of different future pathways for the attainment of desired and prefixed futures (i.e. deliberation and knowledge co-production occurs within modal spaces protected from scrutiny).[27] This form of foresight acquires a clear strategic tonality (hence it is sometimes also called "strategic foresight") (see European Commission, 2022a, 2022b).

2.3.2. Technology Assessment

"Technology Assessment" (TA) today encompasses a wide range of practices and approaches that attempt to assess the impacts and coevolutions that a technology might have once it is introduced, expanded, and/or changed (see Coates, 1971). This broad range of practices and approaches has evolved over time, so that today a variety of forms of TA co-exist. Each has its own labels, specific fields of action, traditions, and research groups. What they all have in common, however, is the need to promote better technology.

The fact that TA is an approach that has evolved over time makes it difficult to provide an exhaustive history or do justice to the approach. Indeed, recent historical overviews of the approach are rare (e.g. Grunwald, 2009a). This is not so much because it is not an interesting topic (quite the contrary). The lack of a recent comprehensive history of TA must be attributed to the difficulty of making visible the multiple connections between the great variety of sub-lines that have emerged and co-evolved.

For the present purposes (i.e. to show how there were different ways of using the future that articulated different approaches to TA over time), it will in any case suffice to show how different forms of TA subsequently maintained different relationships and predominant ways of using the future. Different forms of TA articulate themselves in different forms of anticipation.

In this respect, it is necessary to mention how in the early days of TA (e.g. in the 1970s) this framework embraced a vision largely linked to the application of an anticipation of a

[27] Andersson (2018) has noted an ambivalence within Futures Studies that is worth highlighting here. She argues that foresight has always played an ambivalent role between reifying institutional goals and reproducing a technocratic ethos, on the one hand, and promoting forms of openness, on the other. The use of foresight has been in the service of both openness and closure. Foresight practices become evident within future-oriented technology analysis, as presented here, primarily as a tool in favour of foreclosure.

predictivist nature (see Coates et al., 2001). The "classical conception of TA"[28] was as an institutional practice[29] specially focused on reporting on the most direct future consequences that technologies could have, with special emphasis on the so-called "unintended consequences", or "side-effects",[30] and on carrying out cost-benefit analyses. TA was supported by various methodologies such as quantitative and qualitative scenarios, Delphi, growth models, relevance trees, etc. (see Coates et al., 1994). These reports served as a starting point in parliamentary decision-making processes. As such, the traditional dominant (but not the only) form of TA was first and foremost a scientific tool focused on conducting technical analyses and providing technical solutions that would later assist in decision-making. In this process, forecasting techniques played an important role.

However, the use of predictive methodologies also co-existed from the beginning in the classic TA with non-predictive anticipatory interventions. In fact, "technology foresight"—as described in the previous section—was also one of the tools and approaches used to identify those technologies that were considered to be of special interest (in terms of their social desirability and profitability).

Regardless of whether TA was rendered on predictivist exercises or on other types of explorations, what is relevant is that in its beginnings it operated under different types of rhetoric akin to technocracy. TA followed the technical problem-solution instrumental rationality. Indeed, Grunwald (2009a, pp. 1114–1115) identifies at least six elements that would characterise this classical conceptualisation of TA: positivism, statism, comprehensiveness of future effects, quantification, prognosticism, and orientation towards experts.

---

[28] As Grunwald (2009a, p. 1114) argues, «[t]he classical concept of TA is an ex post facto construct. It does, in fact, incorporate aspects of the way in which TA was practised during its "classical" phase in the 1970s». However, as he points out, it is also useful to «to recall the elements of this classical concept».

[29] For instance, the Office of Technology Assessment (United States of America, 1974), the Office Parliamentaire d'Evaluate des Choix Scientifiques et Technologiques (France, 1983), the Nederlandse Organisatie voor Technologisch Aspectenonderzoek (actually named "Rathenau Institute") (The Netherlands, 1986), the Science and Technology Options Assessment (European Parliament, 1987), the Parliamentary Office of Science and Technology (Britain, 1987), or the Büro für Technikfolgen - Abschätzung beim Deutschen Bundestag (Germany, 1990).

[30] The effects that are not envisaged in technological design processes are typically referred to as unintended "consequences", "impacts", or "risks" (e.g. European Commission, 2004; Kinsner-Ovaskainen et al., 2014; Reyns et al., 2013). Jasanoff (2016, pp. 21–26) includes the idea of "unintended consequences" among the three widely held but flawed beliefs about the relationship between technology and society (alongside the idea of technological determinism and the myth of technocracy). Her critique centres on pointing out that the term "unintended" delegates technological impacts (specifically negative ones) to "chance". Thereby, the expression "unintended consequences" obscures the possibility of raising the question of how design and co-creation processes were conducted, and whether they could have been improved by enabling more inclusive co-creation processes in relation to a broader set of impacts, concerns, and actors. Moreover, the term "unintended" locates us in a static context where the intentionality of technological effects is fixed in design processes, thus it disregards the relationships between science, technology, and innovation and society as fluid and contextualised. In the same vein, and building on feminist technoscience analysis, Parvin and Pollock (2020) revisit the notion of "unintended consequences", arguing that it dismisses important ethical and political concerns during the co-production of technologies and innovation practices.

Precisely because the anticipatory practices of TA carried this kind of instrumental rationality, and thus served as protective mechanisms for the broader problematisation of STI, these practices were subject to various criticisms by actors from the STS (e.g. Tribe, 1973; Wynne, 1975). These criticisms should also be situated within a historical-cultural context in which technical and instrumental rationality, expertocracy, and the positions that linked science and technology to progress were also questioned by influential normative proposals coming from the fields of deliberative democracy or discourse ethics (e.g. Barber, 1984; Habermas, 1985). The ineffectiveness of predictivist methods in promoting a broader problematisation of STI and dealing with the problems underlying STI was becoming visible:

> [P]roblems of forecasting the future consequences of such complex technologies as nuclear power also became more and more obvious. Conflicts of opinion between well-informed experts were by no means exceptional and the limitations of a purely economic-based assessment of social and environmental problems became clear.
>
> It was in these circumstances that techniques of 'Technology Assessment' began to be used in an attempt to overcome the short-comings and limitations of cost-benefit analysis and to extend its range beyond the individual project to technologies affecting many products and processes (Freeman, 1995b, pp. viii-ix).

The question of the legitimacy of decisions has been on the table since the beginnings of TA (Grunwald, 2019b). However, it was not until the emergence of the concept of "participatory TA" (pTA) that the need to include the voices of different publics in STI decision-making processes was emphasised and expanded. Participatory exercises were seen as a prerequisite for strengthening decision-making (by multiplying the voices considered and their respective values) (see Joss and Bellucci, 2002; Kaplan et al., 2021). The operationalisation of techniques such as consensus conferences, citizen juries and assemblies, round tables, foresight and scenario workshops (see Andersen and Jæger, 1999; Joss, 2002) were techniques in the service of pTA to promote the required extended peer review (Funtowicz and Ravetz, 1996) in situations of uncertainty (Hennen, 1999). Anticipatory techniques with a participatory nature—akin to early participatory foresight proposals (e.g. Faucheux and Hue, 2001; Tijink, 1996)—have been positioned as useful tools for enhancing the legitimacy and socio-political robustness of TA-supported decisions. In the light of developments in STS and critical understandings of science, the aim of pTA was to open up TA to the public sphere (Durant, 1999).

Certainly, pTA is a further step in the opening-up of STI practices. However, the opening-up character of pTA processes should not prevent us from pointing out some of their limitations. This openness may prove to be insufficient or limited in certain aspects. In fact, one of the relevant points of closure is that these participatory processes only took place in constrained decision-making processes that were very limited in space and time (typically once the technology or product in question was already developed and in the stages prior to its launch on the market). In this sense, the binding character of the decisions and the ways

in which public participation was encouraged sometimes acquired a poor quality, having little effect on the coevolution and constructive process of STI co-production. In addition, the pTA exercises must deal with problems related to public engagement and participation that have not yet been solved: What actors are included, how are they included, what is the relational quality of the inclusion, and how to deal with contradictory visions of the future in decision-making processes. Moreover, interactions were often limited to improving public understanding, thus creating forms of participation of a unidirectional nature.

These limitations were the basis for the proposal of the Constructive TA (CTA) approach in the mid-1990s (Rip et al., 1995; Rip and Robinson, 2013). CTA was envisioned to overcome the limitations encountered by participatory and classic TA approaches: The framework of "conflict resolution" through the punctual promotion of two-track directionality communications between diverse actors is amplified by the promotion of continuous "social learning" processes during the coevolution and co-production of STI. Moreover, the problems problematised in CTA focus not only on STI post hoc impacts, but also on what values, assumptions, commitments, etc., the technologies reproduce. The focus on the co-production of technological activities goes beyond effects and specific important points of decision-making and concentrates on the "enculturation" of STI across a multiplicity of constructive and ongoing processes. The main idea is that STI construction processes are not reduced to decision-making points, but are constituted through a large constellation of decisions and processes in a spatially and temporally distributed manner.[31]

> [The concept of CTA] marks specially the recognition that TA cannot be a one-off type of appraisal but must involve a continuous process, just as R&D project evaluation within the individual firm has to be a process. Secondly, CTA marks the recognition that TA must be in the nature of a continuous dialogue between potential or actual users of new products and processes, those who are affected by them and those who design, develop and promote them. Finally, it marks the recognition that in the end it is only a 'kritikfäige Öffentlichkeit' (a public opinion capable of informed critique of new technological developments) that can sustain democratic government (Freeman, 1995b, p. xi).

"Anticipation", together with "Social Learning" and "Reflexivity", co-forms one of the key features of CTA (see Schot, 2001; Schot and Rip, 1997). Anticipation is one of the CTA devices through which reflexivity and social learning is introduced during the constructive processes of the technology (and vice versa). Anticipation is not so much about predicting, but about exploring the «potential technological interactions and adverse side-effects» (Schot, 2001, p. 40). More recently, Grunwald continues to hold up anticipation as one of the three conceptual dimensions he identifies as constitutive of TA, in conjunction with

[31] It should be noted that this distributed character does not mean denying the importance that certain actors and certain decisions may have in coevolutionary processes. Rather, it is about introducing complexity and situatedness into the processes that ongoingly constitute the development of STI. It is important to focus on some specific points, but it is expected that follow-up and intervention throughout the process will offer a deeper problematisation of STI, intertwined with STI processes.

"inclusion" (in terms of the perspectives involved) and "complexity". Anticipation «addresses the dimension of time when facing an open future: enhancing reflexivity *over time*» (Grunwald, 2019b, p. 2).

The operationalisation of anticipation takes place in CTA through scenarios of future worlds realised in interactive workshops. In these workshops, actors explore and discuss possible problems, visions, and alternatives that might emerge from the coevolution of a technology within our sociotechnical systems. For example, Remmenn (1995) presents scenario-building processes as mechanisms for social learning. Similarly, future scenario building is often conceptualised as assisting in the identification of potential "endogenous futures" that could be co-produced through an STI development (e.g. Parandian, 2012; Rip and te Kulve, 2008; te Kulve and Rip, 2011).

Although the emphasis of anticipation is mainly on the *effects* or the "endogenous futures" of technologies in their coevolution with society, there are some nuances in CTA that make anticipation an interesting aspect.

> Co-production processes include anticipation. Technical change is driven partly by the historical experience of actors, their views of the future, and their perceptions of the promise or threat of impacts which will change over time. In turn, technical change generates new impacts when applied to new social settings. These dynamic, multi-actor, and decentralized co-production processes are shot through with assessments. Thus, the situation is not one where TA has to introduce assessment. Assessment occurs all the time, and it is a modulation of ongoing processes of assessment (and feedback) which is in order. This, we claim, is the thrust of CTA (Schot and Rip, 1997, p. 257)

The quote introduced above represents, to my knowledge, one of the first recognitions within a normative-interventive framework that the governance of STI and its co-production is de facto permeated by anticipations (i.e. factual uses of the future). The works of van Lente (1993) and van Lente and Rip (1998a, 1998b) and the emergence of the sociology of expectations (see Borup et al., 2006; Brown and Michael, 2003) have certainly helped to emphasise this. The recognition that anticipation is a constitutive element of STI co-production (as conceptualised in Chapter 1) puts a new face on anticipation: It is about fostering mechanisms of social learning and reflexivity in relation to the implications of these factual anticipation processes.

Indeed, the work of Akrich (1992, 1995) shows how design and innovation processes are built on anticipations regarding potential users. These anticipations mediate the design processes and materialise in so-called "scripts". These representations are often idealisations that emerge without mere interaction with potential users. The task of CTA would be to mobilise (i.e. de- and re-construct) these anticipations, including processes of reflexivity and social learning about them (see Rip et al., 1995, pp. 138–139).

The performative capacity of anticipation in co-production dynamics has indeed led to the emergence of a set of tools associated with TA in general and CTA in particular. These tools aim to enhance reflexivity in relation to the performativity that futures entail (i.e. they

aim to engage with the modal power dynamics engendered by and through the mobilisations of futures). This is the case, for instance, of Vision Assessment (see Grin and Grunwald, 2000) or Hermeneutic Technology Assessment (see Grunwald, 2020). Vision Assessment focused at its beginning especially on *ex-post* tracing of *leitbilder* (guiding visions) production and effects (Grunwald, 2009a, p. 1118), but soon it was interpreted as an active element *of* and *for* responsibilisation (Lösch, Böhle, et al., 2019; Lösch et al., 2017). Similarly, hermeneutic approaches to TA emphasise the need not only to scrutinise and dissect the sociotechnical meanings that futures mobilise, but to turn them into objects of responsibilisation (Grunwald, 2014, 2016, 2019a, 2020). Given the often speculative character of the visions and these meanings, TA has been qualified as a myth-busting tool (Torgersen and Fuchs, 2017). Anticipation as an interventive tool is nowadays related to the ambition of generating reflection on visions and sociotechnical meanings attached to emerging technologies, thus on generating a transformative vision assessment through anticipations (see Schneider et al., 2021; Schneider et al., 2022). Therefore, I would further append that anticipation is a dimension of TA to enhance reflexivity not only *over time* (Grunwald, 2019b, p. 2), but also and especially *over temporality* (i.e. about how modes of inhabiting time provide guidance for action) (Chapter 1).

Precisely in a context where highly speculative visions of nanotechnology were emerging and where various institutional calls had been made for nano-responsibilisation, Guston and Sarewitz (2002) proposed a step beyond CTA and presented in 2002 what they called a "new technology assessment" approach: "Real-Time-Technology Assessment" (RTTA). While CTA is about fostering constructive assessment in continuous dialogue with different actors, RTTA can be understood as a research programme that *embeds* assessment in STI research and co-production dynamics from the outset. Assessment is not an external (though continuous) element of STI (as in other forms of TA), but becomes ingrained in the very dynamics of STI co-production through the whole process. Specifically, the assessment that RTTA proposes is based on the idea of "sociotechnical integration" (see Fisher, 2019; Fisher et al., 2006; Mitcham and Muñoz, 2010): «This integration means that the R&D process must be reconceptualized to encompass scientists and technologists, social scientists, and a range of potential stakeholders interacting on various levels» (Guston and Sarewitz, 2002, p. 101). The aim of real-time sociotechnical integration is to generate dynamics of reflexivity that will serve as «an explicit mechanism for observing, critiquing, and influencing social values as they become embedded in innovations» (Guston and Sarewitz, 2002, p. 93) (i.e. a form of observing, criticising, and influencing in real time). Ultimately, RTTA is about «rendering explicit and self-aware the currently implicit and unconscious process of co-production» (Guston and Sarewitz, 2002, p. 101).

Guston and Sarewitz (2002, p. 98; emphasis added) differentiate their RTTA proposal from CTA as follows:

> First, although it follows CTA in engaging in socio-technical mapping and dialogue between producers and consumers, it does not engage in experimentation with new technologies *because it is embedded in the knowledge creation process itself*. It makes use of more reflexive measures such as public

> opinion polling, focus groups, and *scenario development* to elicit values and *explore alternative potential outcomes*. Second, it uses content analysis, social judgment research, and survey research to investigate how knowledge, perceptions, and values are evolving over time, to enhance communication, and to identify emerging problems. Third, it integrates socio-technical mapping and dialogue with retrospective (historical) as well as *prospective (scenario) analysis*, attempting to situate the innovation of concern in a historical context that will render it more amenable to understanding and, if necessary, to modification.

Like other TA approaches, RTTA relies on a range of foresight techniques to promote sociotechnical integration. In addition to analogous case studies, RTTA relies on foresight exercises to develop research programme mappings ("who is researching what?"), to improve communication and early warning between researchers and other societal actors ("what public concerns and aspirations are at stake?"), and, specially, to participatorily inform and open up technological choice. Anticipation, or foresight, operationalised through future scenarios development and analysis, thus becomes an important tool in this approach as well. As with the other forms of TA mentioned and briefly discussed above, anticipation in RTTA is not predictive in nature. Instead, it is conceptualised as a form of decision-making that mediates between prediction (impossible on the one hand) and inaction (futile and with devastating consequences). Anticipation is understood as a tool for promoting insights that foster «incremental action based on synchronous reflection and adjustment» (Guston and Sarewitz, 2002, p. 100). This synchronous reflection and adjustment is in turn expected to «stimulate efforts to enhance desirable impacts and mitigate undesirable ones» (Guston and Sarewitz, 2002, p. 106).

RTTA is heavily influenced by the ELSA/ELSI programmes, even if it aims to overcome their inadequacies (Section 2.3.3), and could be seen as a guiding principle of what will later be formulated as "Anticipatory Governance" (Section 2.3.4).

2.3.3. The ELSA/ELSI programmes

The emergence of the Human Genome Project led to the emergence of various concerns about genetic manipulation and genomics—first in the United States, and then spreading to other geographic and STI areas such as Canada (see López and Lunau, 2012), Europe (see Hullmann, 2008), and East Asia (e.g. Yoshizawa et al., 2014). The Ethical, Legal, Social Aspects or Implications programmes emerged as a reaction to this concern and as an attempt to develop an STI informed by socio-ethical and legal research. The acronym ELSA (in Europe) or ELSI (in the United States) represents the idea of promoting an STI that examines the potential implications of the STI in question as it develops, thereby helping to identify potential areas of concern and subsequently formulate interventions to address the issues. ELSA/ELSI programmes involved «the *integration* of societal research in large-scale techno-science programme» (Zwart and Nelis, 2009, p. 540; emphasis added).

Ultimately, ELSA/ELSI are programmes that calls for the use of the knowledge and skills of experts from the social sciences and humanities to promote an STI that conforms to certain ethical and legal criteria from the outset and through the upstream movements of STI. While Zwart and Nelis (2009, p. 543) accept the existence of multiple meanings of ELSA/ELSI and different ways of putting them into practice (thus acknowledging the existence of formal and operational heterogeneity), they argue that they have the following four key features:

- *Proximity*: Promotes embeddedness in scientific programmes.[32]
- *Early anticipation*: Focuses on societal issues and mapping of potential controversies.
- *Interactivity*: Encourages stakeholders and publics to take an active part in STI agenda-building.
- *Interdisciplinarity*: Links different disciplines and fields of knowledge, such as the scientific-technical with that created by STS.

Although all these features or dimensions need to be considered as a whole when assessing the scope and significance of ELSA/ELSI approaches, it is worth focusing here on the issue of early intervention through anticipation: How it is conceptualised and what aspects it is conceived to address.

In principle, and as in the frameworks analysed previously, anticipation is conceived to adopt a proactive stance towards the problems and controversies that may arise from the development of STI:

> Such concerns have prompted a widespread desire to anticipate, rather than react to, problems that could result from genetic technology. This proactive goal presents policymakers with the difficult challenge of determining, in advance, how genetic technology might be misused and how to prevent such misuse from occurring (Yesley, 2008, p. 1).

In this way, the use of anticipation within ELSA/ELSI takes on a strongly preventive character, which is implemented in a proactive manner. In contrast to the precautionary principle, however, this preventive stance is postulated as independent on the existence of (un)certainty: The point is to examine the risks and implications of the innovation in a sociotechnically informed way. This preventive approach has basically two nuances concerning its meaning.

On the one hand, it moves away from predictivist aspects and tries to activate through explorations and the application of foresight techniques: «Through interactive techniques

[32] This implies that «ELSA research addresses the relationship between the new and emerging techno-sciences and society, a relationship that is understood in terms of co-production (Jasanoff, 2005) or reflexive coevolution (Rip, 2005b)» (Zwart and Nelis, 2009, p. 540).

such as focus groups or scenario workshops, the future societal risks and benefits are fleshed out in the form of collective foresight explorations» (Zwart and Nelis, 2009, p. 542).

On the other hand, it takes on different internal modalities and is activated in narrative terms by different agents of change. Thus, for example, ELSA/ELSI finds experts (albeit from different disciplines) as the main actors of the assessment, sometimes including "interactions"[33] with audiences beyond academia. Likewise, these non-predictivist explorations find their ultimate *raison d'être*—as they do in recent versions of TA—in the generation of critique and reflexivity:

> In recent years, various strands of foresight research have been developed. ELSA genomics clearly has some of its roots in technology assessment (TA), which deals with the assessment of the future impact of technology on society. Often, this means that researchers investigate as-yet unknown futures and deal with what has become known as the 'Collingridge dilemma' (…). Early anticipation not only helps to define both unwanted and desirable solutions for the future, but also asks for critical and reflexive anticipation (Zwart and Nelis, 2009, p. 542).

However, this anticipatory reflexivity that was timidly visible in the ELSA/ELSI literature acquired several formal and operational limitations. In particular, Williams (2008, pp. 273–275) points to three main problems associated with "ELSI-fication": (i) The promotion of simplification in STI problematisation, (ii) the framing of STI problematisation (what is problematised and how), and (iii) the low capacity to influence STI dynamics (the perception of STS scholars is that the capacity of ELSA/ELSI scholars to influence STI was undermined).

These three problems suggest that although there has been a tendency in institutional policies to support research projects under a modality of increasing sociotechnical integration (Rodríguez et al., 2013), the way in which these programmes are conceptualised and implemented limits the scope and depth of a more radical problematisation of STI. The way in which ELSA/ELSI research was conceived and implemented served as a mechanism of resistance to the opening-up of certain spaces and spheres of scientific and technological activity to problematisation. The following are some aspects of ELSA/ELSI that have limited the potential scope of this programme:

- *Strong formal and practical fixation on future outcomes*: Anticipation in ELSA/ELSI is fixed in terms of the treatment of products or outcomes (and, more specifically, their impacts, mostly understood in terms of "risks"). This simplifies the future spaces that are the subject of STI problematisation. The narrow focus on outcomes obscures the problematisation of the purposes and processes of STI. The problematisation of the STI agenda within ELSA/ELSI takes place within pre-given

[33] It is interesting to note that the term "interaction" is somewhat ambiguous in relation to the binding nature of the relationships between actors. The presence of "interaction" indicates the presence of some kind of dialogue, but it does not qualify the orientation of these dialogues and how the voices of actors beyond academia are expected to be welcomed and to what extent those voices have influence in guiding the research agendas.

spaces of STI possibilities: The problematisation of STI was aimed at improving the realisation of STI, not at criticising its significance, necessity, or socio-political meaning.[34] As such, it could be argued that ELSA/ELSI functioned as an "artefact" that served to reify, or legitimise, certain STI future research lines by mobilising "modal power" allocations and closing-down the futures under consideration.

- The problem of formal fixation on future outcomes is exacerbated by the poor way they have been identified and assessed in certain academic circles (especially in theoretical ethics). This poor approach is effective in relation to at least three aspects: (i) The speculative nature of some ethical assessments, (ii) the linear nature of some ethical reasonings, and (iii) the tendency to reduce the debate to whether the STI in question meets certain pre-set ethical standards:

  (i) Several critics emphasised that the socio-epistemic and argumentative foundations from which the future implications of emerging STIs were derived and assessed in ethical debates were unsatisfactory (e.g. Lucivero, 2016a; Lucivero et al., 2011; Nordmann, 2007; Swierstra and Rip, 2007). In particular, there was some concern and criticism that studies on social and ethical concerns were becoming too linear and speculative. Linearity and speculation not only oversimplify the complexity and multifactorial nature of STI development, but also, in some cases, entrench and reinforce the promises and visions that legitimise emerging STIs.

  (ii) Williams (2008, p. 274) argues that «the emphasis on ethical assessment of research and development activities takes us back to an essentialist understanding of the relationship between social values and innovation outcomes that have long been rejected by STS». This is not to suggest that all ELSA/ELSI scholars take a substantivist approach to STI. Rather, the central point is that ELSA/ELSI approaches promote a linear approach to STI. The linear view emerges insofar as ELSA/ELSI assumes that an *ex-ante* treatment of the ethical, legal and social implications of the STI in question can

[34] This excessive focus of ELSA/ELSI on impact has been widely criticised. Critics pointed out that this excessive focus on impact distracts STS scientists from the critical-constructive spirit they saw as characteristic of the field. For example, Rip (2005a) argues that the ELSA/ELSI treatment of STI was involving a loss of critical distance towards STI. Rather than contributing to the goal of increasing reflexivity in the coevolution of STS and society in constant feedback with the public (see Rip et al., 1995), the ELSA/ELSI programme instrumentally promoted the legitimisation of the technologies in question. This critique was essentially intended to show that the STS field was growing, but at the cost of serving the predetermined institutional and techno-industrial purposes. The presence of STS scientists as intermediaries in the co-production of STI became mainstream. However, in the process, STS lost many of the motivations that had permeated their more activist wing. In fact, the Workshop "Does STS mean business too?" (Said Business School, Oxford) held in June 2005 diagnoses this concern in the profession about its ways of engaging with business and management studies and practical contexts (see also Woolgar et al., 2009). This concern would also materialise in later criticisms of the interventive and normative side of STS—including forms that sought to go beyond ELSA/ELSI such as Anticipatory Governance (Barben et al., 2008). For example, Fuller (2009; 2018b, p. 183) accused AG of moving from "following the actors" to "following the money".

influence the development and governance of this STI itself and as a result avoid the occurrence of these implications.[35]

(iii) Ethical anticipatory debates often take on a structure that does not allow for the politics embedded in STI to be addressed. Indeed, ethical assessments of future STI are often limited to questioning whether (and how) a future STI might violate some taken-for-granted values (e.g. security, privacy, welfare, freedom). This drastically narrows the scope of the debates and leaves aside the broader and politically charged question of the future sociotechnical worlds we enable through STI.[36]

- *Delimitation of the actors involved and of their respective spheres of action*: Wynne (2001) pointed out and denounced how debates on STI ethics tend to be divided between "hard" and "soft" effects (see also Swierstra and te Molder, 2012). This artificial dichotomy between "hard"/"soft" effects is in turn often accompanied by an association about which actors have epistemological and political legitimacy to argue about them (see Mitcham, 1997). While questions about the "hard" effects are left to scientists and technicians (and the participation of other actors is only possible in relation to certain aspects and in a controlled and guided way), questions about the "soft" aspects (e.g. ethical, social, and legal aspects) are left to the humanities and social scientists (or the publics). This moral division of labour is a simplification that does not account for and capture the heterogeneously constituted nature of risks (see Rodríguez, 2016).

- *Poor embedding in research*: Although the ELSA/ELSI programmes were intended to be embedded in the "upstream" scientific-technical STI practices themselves, ELSA/ELSI practices were often promoted *in parallel* with STI research, exerting an unknown and untested influence on it (Yesley, 2008). Even in those practices that attempted to promote ethical problematisation of STI from an upstream or bottom-

[35] In the context of the emergence of nanotechnology and biotechnology, various metaethical debates focused on discussing the values and pitfalls of engaging with speculative futures in ethical appraisals (see Brownsword, 2009; Racine et al., 2014; Roache, 2008). For instance, in the specific field of nanotechnology, some criticised the futuristic and speculative aspect of "nanoethics" (e.g. Nordmann, 2007; Nordmann and Rip, 2009; Rip, 2006). In contrast, others defended the relevance and necessity of futures as the basis for a kind of "exploratory" philosophy or ethics of nanotechnology (see Grunwald, 2010) only under the condition that these futures were "informed" or generated by an "educated imagination" (e.g. Roache, 2008; van der Burg, 2010).

[36] Broncano (2009) notes that ethical debates (despite their necessity) are insufficient when it comes to radically problematising and taking responsibility for STI. In relation to biotechnologies and the field of bioethics, Broncano (2009, p. 23) states the following: «[M]e parece que el debate ético está dejando oscurecer el mucho más urgente debate político» («*It seems to me that the ethical debate is obscuring the much more urgent political debate*»). The fact that the author prioritises the need for a political debate over the ethical debate shows that he proceeds from an eminently political concept of responsibility aimed at the democratisation of STI. According to this author, this democratisation should not be limited to the results, but should also include the question of the "ends" or purposes of STI. Many of the criticisms of "ELSI-fication" have led to politically radical normative proposals that call for a democratisation of outcomes, processes, and purposes (e.g. Owen et al., 2012; Owen et al., 2013; Stilgoe et al., 2013; von Schomberg, 2013).

up approach, the ways in which ethical issues were approached, framed, and discussed were found to produce subtle mechanisms of closure (see Felt et al., 2009).

The articulation of STI governance based on ELSA/ELSI is certainly an advance over technocratic models that lack socio-ethical reflection (e.g. Bush, 1945). However, the way ELSA/ELSI are conceptualised and de facto mobilise sociotechnical futures pushes us to point out the limitations of these programmes and their possible role in obstructing a more radical problematisation of STI.

2.3.4. Anticipatory Governance

The emergence of the "Anticipatory Governance" (AG) framework—as well as that of RRI (Section 2.3.6) and RRI (Section 2.3.5)—must be understood within a context marked by the emergence of nanotechnology and the existence of a certain "nanophobia-phobia" (Rip, 2006) on the part of both policymakers and institutions promoting STI. The emergence of these frameworks must be understood also in relation to past experiences of regulation and public controversy in STI matters (e.g. HIV tainted blood, "mad cow" disease, GMOs) and the possibility that the dystopian scenarios disseminated in popular culture around nano (e.g. Joy, 2000) could hinder the development of a technology that was presented as a major driver of socio-economic progress and competitiveness.

To avoid repeating these experiences and to promote more robust forms of STI co-production, institutions have from the outset promoted and supported more proactive approaches to addressing the social and ethical aspects of STI (e.g. Commission of the European Communities, 2004; National Science and Technology Council, 2004). These promotion and sponsorship practices appear to have been driven by both instrumental (e.g. securing market acceptance by avoiding controversy) and substantive (e.g. genuinely promoting more responsible and socially responsive practices) motives. This demand for sociotechnical integration, both in terms of public integration and social science research, has been increasingly embedded in policy in both the United States and Europe (see Fisher and Mahajan, 2006; Rodríguez et al., 2013). The main question was not only to address the risks of nanotechnologies but also questions related to their desirability (Bennett and Sarewitz, 2006). It is this growing concern for a comprehensive discussion on the desirability of STI that has led Eizagirre et al. (2017) to point to the existence of a politicisation of the concept of responsibility.

It is in this context of inviting STS participation in STI research programmes that the development of AG is located.[37] This normative-interventive approach acquired institutional

[37] The emergence of nanotechnology was understood from a normative standpoint as an opportunity to develop, operationalise, test, and/or enrich the existing science, technology, and innovation governance approaches. The use of the term "opportunity" is not casual. For instance, regarding the descriptive dimension, Cyrus Mody (2004, p. 101) explicitly stated that:

materiality in the Center for Nanotechnology in Society at Arizona State University, funded by the National Science Foundation in 2005 and directed by David H. Guston. The grant was awarded with the aim «to support research and education on nanotechnology and social change, as well as educational and public outreach activities and international collaborations» (CNS-ASU, 2005).

In the beginning AG found as a basic operating principle the modus operandi of RTTA (Section 2.3.2), where the concept of "anticipation" was just mentioned (and not defined). In this sense, the aim of AG is to promote a form of sociotechnical integration (in terms of social actors and knowledge) that accompanies the co-production processes themselves and redirects them in the process (Conley, 2013). However, the concept was further developed shortly thereafter. For instance, Karinen and Guston (2009, pp. 225–228) point to the «somewhat mysterious» genealogy of the concept. Specifically, they show how the concept of anticipation finds its close genealogy in environmental studies rather than in public administration and management studies. In the former, the term is not associated with prediction and has a more favourable connotation (see Gupta, 2001). Indeed, there anticipation is understood as a capacity-building exercise through futures (e.g. Konrad et al., 2021). Following this capability-based approach, David H. Guston defined AG as «a broad-based capacity extending through society that can help individuals and institutions act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible» (Guston, 2008, p. vi).

Understood in this way, it is clear that AG «was of course born with frustration over the Collingridge (1980) dilemma» (Guston, 2014, p. 226). However, the way to address (not overcome) the Collingridge dilemma is not to try to know more about the future, but to build governance-related capabilities with the future in mind. It is not so much about looking *into* the future, but about looking *at* the future:

> Anticipatory governance implies that effective action is based on more than sound analytical capacities and relevant empirical knowledge: It also emerges out of a distributed collection of social epistemological capacities, including collective self-criticism, imagination, and the disposition to learn from trial and error (…). [A]s the concept of "anticipation" is meant to indicate, the co-evolution of science and society is distinct from the notion of predictive certainty. In addition, the anticipatory approach is distinct from the more reactionary and

---

> [S]cholars of science and technology have a tremendous opportunity. Nano represents a scientific and technological movement in the making (or, perhaps, unmaking). Nano should be viewed as an exquisite field site for testing our ideas about how people generate knowledge and artifacts; how they integrate new technologies into their practices and organize themselves around new kinds of artifacts; and, indeed, how they use emerging technologies to push the limits of human instrumentality.

In the same vein, but regarding the normative-interventive dimension on nanotechnology, Davies et al. (2009, p. 10) expressed that «[t]he move towards 'responsible development' of nanotechnology, then, offers a key opportunity to develop a science that is truly in step with society».

> retrospective activities that follow the production of knowledge-based innovations – rather than emerge with them (Barben et al., 2008, pp. 991–992).

The major focus is therefore not on "assessment", but on the exercise and development of reflective capacities[38] to influence—within our limited capacities for agency—the trajectory of STI governance and thereby «contribute to bending the long arc of technoscience more toward humane ends» (Guston, 2014, p. 234). The exercise of anticipation capabilities, grounded within the framework provided in Chapter 1, would serve in AG as an element of self-awareness and deliberation on the directionality of STI governance.

AG seeks to capacitate the actors that shape STI governance in a distributed manner through the "ensemble-isation" of foresight, public engagement, and sociotechnical integration research exercises. Barben et al. (2008, pp. 984–989) characterise as follows these key elements of AG:

- *Foresight*: It «aims to enrich futures-in-the-making by encouraging and developing reflexivity» (Barben et al., 2008, p. 986). This reflexivity is achieved through participatory scenario-based exercises (e.g. Selin, 2011) or vision assessment processes. "Plausibility" is considered a relevant criterion in AG for opening-up the alternatives considered (Ramírez and Selin, 2014; Selin, 2014). In contrast to forecast exercises, often supported by probabilistic judgements, foresight in AG aims to emphasise the multiplicity of futures at stake as well as to embrace uncertainty.
- *Public engagement*: This engagement is intended to go beyond opinion polls and exercises that focus on public knowledge/ignorance and perceptions. They aim to create a more engaging and substantive dynamic with STI. The forms of public engagement can be diverse, including participatory experiments to promote *integration*.
- *Integration*: Both foresight and public engagement «are meant to be taken up into ongoing sociotechnical processes to shape their eventual outcomes» (Barben et al., 2008, p. 988). Integration prompts researchers from the natural and social sciences to work together, and in concert with other actors (e.g. NGOs, private sector, citizens).

As with CTA and RTTA, foresight is seen in AG as a tool for creating reflexivity. However, reflexivity here is not focused solely on outcomes (as in ELSA/ELSI, CTA) or technology

[38] The following passage illustrates this idea:

> An analogy for anticipation, properly conceived, is that of exercise. When you go to the gym to work out – performing your curls and your presses and your pulls – you are not doing those specific maneuvers because you believe that at some point in the future you will need to press a heavy beam off your chest in order to survive. You exercise that way because you believe you are building in your body a capacity to face any physical or emotional challenge life might throw at you. Anticipation thus admits contemporaneous activities like exercise, practice, and rehearsal, oriented in a non-predictive way toward an undefined future (Guston, 2013, p. 111).

design processes (as is the central focus of CTA). Rather, reflexivity takes on a broader sense, referring to all processes and decision-making that continuously render the governance of STI (in different spheres and arenas of co-production). For instance, Lehoux et al. (2020) have recently shown how foresight exercises such as scenario building are a heuristically valuable resource for the generation of cross-cutting capacities in STI that work throughout the process such as "moral imagination". As STI governance is conceived as a distributed phenomenon, the anticipatory capacities to be activated through continuous processes of mutual social learning (echoing CTA) are manifold.

Although AG had some influence on the later development of frameworks such as "Responsible Research and Innovation" (Section 2.3.5) and "Research and Innovation" (Section 2.3.6), it has been subject to criticisms. An important critique refers to the tendency of AG exercises to serve as a reification mechanism of the nano project (Nordmann, 2014). By taking the imaginaries of nanotechnology as plausible, and emphasising more the openness of how nanotechnology was realised, AG fuelled and operated within the spaces of modal power that the nano-advocates were interested in promoting and maintaining (see Guston, 2014). The search for alternatives thus acquired a certain ambivalence: While it opened up certain modal spaces, these openings took place under the umbrella of the space of possibilities marked out by the nano project—indeed, AG «was developed *to facilitate* nanotechnology funding policies in the US» (Kuhlmann et al., 2019, p. 1094; emphasis added). It is in this sense, and regardless this was not the intention of AG scholars, that their anticipatory interventive exercises often reproduced and reified the visions and imaginaries of nano.[39]

Another criticism of AG is that, as with earlier forms of TA and ELSA/ELSI, it is not clear what the meaning and direction of the forms of public engagement sought and encouraged by AG are. AG aims «at amplifying the still, small voices less often heard in the innovation process» (Guston, 2014, p. 229). But the types of engagement undertaken to this end, and the depth and impact on STI governance they gain, are not made explicit. How are the different voices actually amplified, heard, and integrated during the co-production process? Whose voices are they? Similarly, foresight in AG takes on an extremely important anticipatory dimension. However, it is not made explicit which concrete analytical engagements with the future are to be developed through foresight. It is clear what engagements with the future are not currently encouraged (prediction, determinism, closure of the future), yet it is not clear what engagements are deemed appropriate to encourage the kind of reflexivity AG aims to support. What specific goals are being pursued beyond the

[39] Steve Fuller (2009, 2018a, 2018b) criticised AG as an industry within STS dedicated to discouraging criticism of nanotechnology practices, thereby serving the motives of the institutions that created it. He described AG as:

> [A] strategy to facilitate the acceptance of new technosciences by inviting people to voice their hopes and concerns in focus groups, science cafés, and computer-based interactive spaces before the innovations are actually implemented. To the cynic, anticipatory governance looks like public relations. The challenge facing the next edition of the handbook will be to prove the cynic wrong—that STS is not reducible to the formula "Follow the money." (Fuller, 2009, p. 209).

general goal of solving the Collingridge dilemma? If AG aims to become a truly disruptive framework, it must further conceptualise and clarify its constitutive dimensions and the ways in which it engages with the various sociotechnical actors, as well as enable forms of deconstruction of the imaginaries, visions, and expectations at stake. In other words, AG must attend to the forms of openness it promotes (see Chapter 1; see also Chapters 6 and 7).

2.3.5. Responsible Research and Innovation

The emergence of AG finds some commonalities and influences with the framework that will be briefly discussed here: "Responsible Research and Innovation" (RRI). On the one hand, both the emergence of RRI and AG is the result of a long process that incorporates several of the advances made in terms of promoting responsible innovation (e.g. research integrity, ELSA/ELSI, public engagement, sociotechnical integration, issues of social acceptability)—whilst encountering also innovation and interesting aspects of originality (e.g. real-time and collective problematisation of STI). On the other hand, both AG and RRI emerge as a response to a demand from STI institutions. Specifically, RRI was born as a response to the EC's demand to define a more comprehensive, pervasive, and inclusive concept of responsibility for the then upcoming 8th Framework Programme "Horizon 2020" (2014–2020). Owen et al. (2012, pp. 751–754) report that Octavi Quintana, the then Director of the European Research Area, made the following call at a workshop held at the Directorate-General Research in Brussels in May 2011. The workshop was attended by a number of experts drawn from academia and policy:

> We need your help to define responsible research and innovation. After several years of research on the relation between science and society, we evidenced that we need to involve civil society very upstream to avoid misunderstanding and difficulties afterwards… We cannot guarantee the social acceptability for anything but the more we have dialogue the easier it is to understand the potential obstacles and to work on them (…). Your advice is important to help us build a policy for the years to come, notably for the Common Strategic Framework that will begin its life in 2014 and for the European Research Area (Octavi Quintana; quoted by Owen et al., 2012, p. 752).

This quote captures at least three aspects of RRI's genealogy that deserve attention. The first is the emphasis on strengthening the general evolution that had been taking place in the prevailing ways of setting science-society relations within European policies and their associated governance styles (see European Science Foundation, 2013; Sutcliffe, 2011). Following in the wake of the shift from a promotion of a "Science and Society" (2001–2006, 6th Framework Programme) to a "Science in Society" (2007–2013, 7th Framework Programme), it was now a matter of promoting more radical and upstream forms of social involvement. The new RRI approach would be known in "Horizon 2020" (2014–2020, 8th Framework Programme) as "Science with and for Society" (see Table 3).

Table 3. From "Science – Society" to "Science *with* and *for* Society" in European STI Policies.

<table>
<tr><th colspan="2">Dominant conceptions of "Science-society" relations</th><th>European Framework Programmes</th><th colspan="2">Prevalent assumptions</th></tr>
<tr><td colspan="2">Division</td><td>ca.1970s</td><td colspan="2">Clear division of actors and roles
Linear concept: +STI = +socio-economic progress = +welfare
Focus on knowledge generation
STI "autonomy" (moral and functional)
STI triumphalism
Raising awareness of STI (science outreach and the deficit model)</td></tr>
<tr><td rowspan="3">Confluence</td><td>Science and society</td><td>6th (2001–2006)</td><td>Promoting scientific culture
"ELSA": Responsibility at the core of STI
Dialogue, participation and governance: Bringing STI closer to citizens</td><td rowspan="3">Linear concept: +STI = +socio-economic progress = +welfare
Diversity of interacting actors (science in context)
Structural complexity of STI systems
Science as an instrument to be governed: Economic competitiveness and societal challenges
Challenge-oriented: "Grand Challenges"</td></tr>
<tr><td>Science in Society</td><td>7th (2007–2013)</td><td>Fostering reflection on STI and the relationships it establishes with the whole socio-cultural spectrum</td></tr>
<tr><td>Science with and for society</td><td>8th (2014–2020)</td><td>Promoting deeper, more systematic and horizontal collaboration between a wide range of actors
Co-production throughout the whole process
Inclusivity of all societal actors
Problematisation of outcomes and processes</td></tr>
</table>

Sources: (European Commission, 2002, 2007, 2010, 2013b, 2017).

The second aspect of the genealogy of RRI that merits attention from the above quotation concerns *the motivations behind this strengthening of science-society relations*. Although it is not possible to make a definitive statement about the motivations, the previous quote gives us some clues in this regard. The first rationale for this strengthening is instrumental: «to avoid misunderstanding and difficulties afterwards» (Octavi Quintana; quoted by Owen et al., 2012, p. 752). These difficulties and misunderstandings of course should be understood in the context of the controversies that arose in Europe in previous years (e.g. GMOs, "mad cow" disease). The "misunderstandings" refer to the controversies that might arise in the face of the emergence of key technologies (e.g. nanotechnology, biotechnology). These "difficulties", one might surmise, relate to the potential obstacles that these controversies could cause in the development of STI as well as in their adoption. This conjecture makes more sense when interpreting the complaint that «we cannot guarantee the social acceptability for anything but the more we have dialogue the easier it is to understand the potential obstacles and to work on them» (Octavi Quintana; quoted by Owen et al., 2012, p. 752). These instrumental motivations that underpinned the call for a new definition of responsibility were subsequently maintained in the understanding and application of RRI

(always co-existing, however, with other, more normatively grounded motivations for openness).

The third and final point that deserves further attention for the purposes of this chapter concerns the call for the development of a new concept of responsibility concerning research and innovation. In this context, René von Schomberg (EC, Directorate General for Research) is particularly important. In the meeting that gave rise to the above-mentioned call, von Schomberg circulated a draft of "*Prospects for technology assessment in a framework of responsible research and innovation*" (von Schomberg, 2012). There, he formulates the need to promote innovation practices with a consideration of the issue of "right impacts". This expands the classic focus on negative impacts (whether expected or not) to include aspects related to defining problems addressed by STI. These considerations of "right impacts" took on a distinctly inclusive, participatory, and deliberative tone, in line with new developments in the field of STS and the new normative approaches mentioned above. As a result, von Schomberg arrived at the following widely known and quoted definition of RRI:

> Responsible research and innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society) (von Schomberg, 2012, p. 50).

According to this definition, STI are responsibly developed when (i) STI processes and outcomes are problematised in interaction and mutual responsibility between STI actors and other actors, and when (ii) this interaction and co-responsibility is rooted in the normative anchor points of the European Treaty (more specifically, those set out in Article 2).[40] In a nutshell, STI is considered responsible when this is directed at, and undertaken towards, socially desirable and acceptable ends (which are deliberatively discussed in accordance with the normative anchor points of Article 2 of the European Treaty).

This definition and conceptualisation of responsible STI was later adopted by the EC and became the transversal axis of the 8th Framework Programme "Horizon 2020" (2014–2020), and more specifically of the Work Programme "Science with and for Society" (or "SwafS"). RRI/SwafS is defined as follows:

> It [RRI/SwafS] allows all societal actors (researchers, citizens, policy makers, business, third sector organisations etc.) to work together during the whole research and innovation process in order to better align both the process and its

[40] Article 2 of the European Treaty calls for the sustainable development of the European Union in balance or in harmony with scientific and technological development and social progress. Furthermore, the European Union is committed to employment, a high level of competitiveness in the market, the fight against social exclusion and discrimination, and the promotion of social justice. Understood in this way, Article 2 is based on an ideal of harmony between sustainability, economic growth, and social justice, which is being challenged by various movements—e.g. the "degrowth/postgrowth" movement (see Pansera and Fressoli, 2021; Pansera and Owen, 2018).

> outcomes with the values, needs and expectations of European society (European Commission, 2013b, p. 4).

In addition to embracing the key points of von Schomberg's (2012, p. 50) previous definition, this one stresses the continuous character of the interaction. A relevant aspect is that this definition does not refer to public *engagement* with actors "outside" STI (as was the case with AG), but speaks of "working together"—hence, pointing to a more genuine *inclusive* co-production process.

Once again, and similarly to AG, one of the instruments considered interesting for the design of these socio-politically more robust forms of co-production is "foresight":

> Foresight projects can make a contribution towards the possibility that alternative developments might remain in sight for possible public policy responses and towards enabling democratic choices at early stages of technological development. The use of foresight projects can help us to overcome the often too narrowly conceived problem definition scientists implicitly work with (von Schomberg, 2012, p. 46).

Following Future-Oriented Technology Analysis, foresight is positioned as a strategic tool to rationalise trial and error, while at the same time, and echoing CTA, foresight is appraised as a process focused on fostering "social learning". Foresight is situated as a powerful heuristic tool to make the aspirations of RRI operational:

> Technology Assessment and Technology Foresight can reduce the human cost of trial and error and take advantage of a societal learning process involving stakeholders and technical innovators. It creates a possibility for anticipatory governance (…). This should ultimately lead to products which are (more) societally-robust (von Schomberg, 2013, p. 65).

Despite the disruptive scope that may a priori be attributed to RRI in narrative terms, several aspects have limited both its interpretation and its implementation. Among these limiting aspects is the structuring (and reduction) of RRI to five/six policy keys, or pillars: social engagement, gender equity, open access, science education, ethics and, in some documents, governance.[41] The division of RRI into five/six pillars can be seen as a limitation of this framework, as these pillars reduce the topics covered to those that reflect the issues they encompass (often without addressing the interconnections between them or issues that go

[41] These five/six policy keys of RRI have their historical roots in the "Science in Society" programme (2007–2013, 7th Framework Programme). The retention of these pillars from the 7th Framework Programme and their role in constraining RRI interpretations illustrates what I discussed in Chapter 1. It shows how the *momentum* that our artefacts (in this case a programme) acquire through their anchoring in institutional practices can constrain potential future arrangements. Past configurations constrain present and future re-configurations and mediate the space of possibilities. The maintenance of these political keys, or pillars, hinders the expansion of a more radical interpretations of RRI.

beyond them).[42] As Owen and Pansera (2019, p. 27) note, «the EC policy keys represent isolated themes rather than a coherent discourse».

Moreover, another aspect that ambivalently enables and constrains this framework is its strong fixation on the "Grand Challenges". On the one hand, the "Grand Challenges" are an enabling element of RRI in that they reflect its intention to guide STI towards socially desirable futures. RRI's fixation on the "Grand Challenges" derives from the commitment of "Horizon 2020" to the Lund Declaration, which stated that STI «must focus on the grand challenges of our time moving beyond current rigid thematic approaches» (Lund Declaration, 2009, p. 40).[43] On the other hand, the "Grand Challenges" are a constraining factor as they set the goals of STI. Although it is established that the «[s]etting of research *priorities* and their anticipated impacts needs to be subject to a societal review» (von Schomberg, 2013, p. 65; emphasis added), the goals are prefixed with "Grand Challenges", which are also somewhat non-specific in terms of the type of sociotechnical worlds that are promoted to address them. The lack of socio-political specificity of the Grand Challenges, combined with their shielding from problematisation (i.e. their prefixed status), makes them an instrument for reifying futures and maintaining the status quo.[44] In this respect, it is interesting to note that both the definition of RRI and the "features" of RRI refer only to the product and process dimension (von Schomberg, 2013, pp. 63–65). The lack of emphasis on meaningful openness of STI purposes could limit the formal disruptive scope of RRI.

2.3.6. Responsible Innovation

The literature on RRI has often been treated indifferently—or even interchangeably—with the literature on Responsible Innovation (RI) (e.g. Burget et al., 2017). This interchangeable treatment of RRI and RI may have some valid reasons, given the mutual influences in their genealogy and their parallel emergence. However, recent analyses suggest a number of reasons to distinguish them (see Owen and Pansera, 2019; Timmermans and Blok, 2021). Although both normative frameworks question STI governance practices and aim to open them up to problematisation, there are some differences between these discourses that deserve a separate treatment.

---

[42] That is not to claim, of course, that ethics are not important or that gender should not be relevant to RRI. Rather, it means that co-responsibility encompasses these and many other variables (variables that cannot be fully predetermined, but often depend on the context and situation). Moreover, it is important to bear in mind that the operationalisation of these pillars is often reduced to the fulfilment of simplistic requirements such as numerical gender parity or ethical tick-boxing. These requirements against which RRI operates and is evaluated represent an extreme narrowing of the more radical concept of RRI, which aims to enable forms of STI co-production that are more aligned with shared values and expectations.

[43] Foresight becomes a central tool in this respect: «[P]rocesses need to become more responsive and adaptive to these grand challenges. This implies, among others, the introduction of broader foresight» (von Schomberg, 2013, p. 51).

[44] In fact, and again, this approach to the Grand Challenges is based on both normative and instrumental motivations: «[M]eeting the grand challenges will be a prerequisite for continued economic growth and for improved changes to tackle key issues» (Lund Declaration, 2009, p. 41).

Possibly the first and most direct difference between RRI and RI is that RI comes from a more academic setting, whereas RRI is a policy-driven concept, as shown earlier. The RI proposal is offered as an umbrella framework that combines a large number of advances from different fields: STS, science policy, public participation, environmental studies, to name a few.

The second major difference may be that while RI builds on the advances of RRI and reflects its spirit, RI is much less restrictive in terms of the values on which it is based and in terms of the limitations in problematising the purposes of STI. RI emerges in dialogue with RRI, but RI aims to «offer a broader definition» (Stilgoe et al., 2013, p. 1570). This broader character is supported by the reliance on a conception of responsibility of highly procedural character (see Pellé, 2016), not a priori limited in scope by a set of predefined values and purposes. On the contrary, these values and goals are conceived as elements to be inclusively established during the RI processes themselves. The absence of a normative closure within RI renders this normative framework as a framework that «remains unresolved in terms of its political, institutional and normative imaginaries and practices» (Owen and Pansera, 2019, p. 27). This unresolved character is what gives RI a certain interpretative openness that allows it to be operationalised in different geographical and temporal contexts (Pansera and Owen, 2020).

This guiding principle of responsibility in STI is in fact defined as follows: «Responsible innovation means taking care of the future through collective stewardship of science and innovation in the present» (Stilgoe et al., 2013, p. 1570). This definition takes on a more concrete operational and procedural sense in enabling the problematisation of STI in terms of its products, processes, and outcomes. The problematisation of STI during its co-production would become responsible if it were performed in real time in accordance with the following four procedural dimensions in combination:

- *Anticipation*: Following in the tradition previously noted in relation to other frameworks, RI calls for improved anticipation in STI governance. Anticipation is conceived in RI as a procedural element that, through the use of the future, urges reflexivity. Anticipation involves posing "What if…?" questions and it «involves systematic thinking aimed at increasing resilience, while revealing new opportunities for innovation and the shaping of agendas for socially-robust risk research» (Stilgoe et al., 2013, p. 1570).

- *Reflexivity*: RI calls for both institutional and individual reflexivity in governance. This implies «holding a mirror up to one's own activities, commitments and assumptions, being aware of the limits of knowledge and being mindful that a particular framing of an issue may not be universally held» (Stilgoe et al., 2013, p. 1571). This notion of reflexivity requires both first- and second-order reflexivity (González Esteban, 2019; Owen and Pansera, 2019, p. 31).

- *Inclusion*: The inclusive dimension refers to the idea that co-production processes should be undertaken by involving the widest possible diversity of societal positions

and actors at the negotiation table. In order to promote inclusion, a key requirement is to promote exercises that are open to the participation of societal actors.

- *Responsiveness*: Refers to the capacities of STI systems to adjust the courses of action that shape STI directionality (processes and purposes) in response to various values and changing circumstances.

An STI practice is held to be more or less responsible depending on how its purposes, processes, and outcomes are problematised in accordance with these dimensions during the co-production processes. These classical dimensions of responsibility in RI have been the subject of various discussions and extensions. For example, Ruggiu (2020) and Burget et al. (2017) point to the need to explicitly include care as a fundamental normative procedural element in addition to the four listed above. Similarly, Owen and Pansera (2019, p. 31) point to the inclusion of the "openness" dimension, partly as an adaptive response to the recent call in STI public policy for the promotion of "open access".

2.4. The pervasiveness and conceptual limitations of anticipation

The previous section shows how anticipation has been a pervasive element of various normative frameworks that seek to interventively modulate the governance of STI. However, the way anticipation is conceptualised in each of them has proven to be different, even if there is some common element in all of them: a move away from prediction and, in most cases, a linkage of anticipation with the generation of reflexivity.

The fact that there are different normative frameworks with different scopes and understandings of responsibility including a non-predictivist anticipation as a dimension shows that what is relevant is not so much whether the promoted form of governance is "anticipatory" and "non-predictivist", but the ways in which this non-predictivist form(s) of anticipation acquires meaning and, subsequently, materiality. In other words, *what is important is not so much whether futures are used in a non-predictivist manner, but the kinds of engagements with modal power that are (intended to be) produced through them*.

In the light of this reality, this section will assist in revealing two principal points. The first is that although we have always been anticipatory (i.e. we have always used the future), the forms this use has taken have varied. This variation acquires different meanings and formal gradients of radical problematisation of STI depending on the radicality of the framework through which anticipation is interpreted and implemented (Section 2.4.1). Second, a more detailed description of the ways of engaging with the future and the concrete challenges that anticipation can take on is needed to promote the alignment of STI with societal desires and expectations (as AG, RRI, RI, and newer forms of TA intend) (Section 2.4.2).

2.4.1. Gradients of radicality of responsibility and their impact on the anticipatory dimension

The previous sections demonstrated that interventive governance has typically taken on an anticipatory character. What has varied, however, is the sense and scope that governance normative frameworks have taken on and, correspondingly, the kind of engagements with representations of the future that are promoted. As might be expected, different ways of conceiving governance and its articulation based on the use of methodologies engaging with futures have co-existed in each historical moment and continue to co-exist.

The heterogeneity of ways of understanding and anticipatorily triggering the governance of STI only reflects the different interests and political visions at work. In the light of what was discussed in Chapter 1, the different ways of approaching STI governance (dis)enable the problematisation and opening-up of certain modal spaces, thereby acquiring different openness gradients of radicality.

The analysis conducted earlier serves to identify something that has not received much attention so far—namely, how certain governance frameworks that emphasise the desire for openness in their narratives narrow their scope of action to a subset of the potentially considerable STI issues/domains. In this way, even frameworks that tend to be perceived as disruptive from a socio-political and critically reflective perspective can act as subtle narrowing mechanisms in the face of broader or radically open responsibility. All normative frameworks tend in some way towards openness. The question is what kind of openness they promote and what uses of the future they seek to operationalise for that purpose.

The following tentative variables could be simultaneously considered in assessing what gradients of openness the different frameworks formally promote (see Table 4):

(i) *Temporal variable*: When does the problematisation start and how far does it extend? The analysis shows that all normative frameworks take an *ex-ante* perspective. In the more recent frameworks (e.g. CTA, RTTA, AG, RRI, and RI), the problematisation extends to the whole process: *ex-ante*, *ex-dure*, and *ex-post*.

(ii) *Inclusive variable*: Which actors are included in the problematisation? The analysis shows how the different frameworks have deepened their openness in relation to this variable—from including only experts (e.g. classic TA) to including stakeholders (e.g. pTA, CTA, RTTA). Furthermore, we have recently moved on to include "diverse" or "all" societal actors (e.g. AG, RRI, RI). There has been a tendency towards radicalising responsibility in political terms: Responsibility has been gradually and prevalently recognised as a function of developing a governance of STI in which STI dynamics should incorporate during the whole co-production processes the voices, values, and interests of diverse actors.

(iii) *Objectual variable*: Which area or aspect of STI is being problematised? The areas of STI that can be problematised have changed. We have moved from problematisation that focuses on negative impacts to a progressive focus on positive impacts and processes. More radical forms of problematisation, such as RI, explicitly include purposes as a central area of problematisation (thus showing a high degree of openness).

(iv) *Operational variable*: How are the above domains problematised? We have seen how we have gradually progressed from frameworks that put an external evaluation (e.g. classic TA), to frameworks that promoted a parallel evaluation (e.g. ELSA/ELSI, CTA). Going a step further, RTTA, AG, AG, RRI, and RI promote an evaluation "from within", ingrained in STI co-production.

Table 4. Tentative variables representing openness gradients of radicality.

	Variables			
Radicality	*Temporal*	*Inclusive*	*Objectual*	*Operational*
Less radical ↓ More radical	*Ex-post*	Experts ▪ STI / STEM ▪ Social and human sciences ▪ Sociotechnical integration	Outcomes/Impacts: ▪ Negative impacts ▪ Right impacts	External assessment (e.g. classic TA)
	Ex-dure	Stakeholders	Processes	Parallel assessment processes (e.g. ELSA/ELSI)
	Ex-ante	All societal actors	Purposes ▪ Technical-functional ▪ Socio-political	Sociotechnical integration (ingrained in co-production)

Normative frameworks open up STI to a greater or lesser degree depending on how they position themselves in relation to each of these variables. While there are different normative radicalities in terms of the ways in which the hegemonic orders of STI co-production can be disrupted, the analysis suggests that the more recent frameworks exhibit a high degree of radical openness. RI stands out in particular insofar as it is the only one with arguably the highest degree of radicality in the objectual variable: It explicitly includes the problematisation of outcomes, processes, *and purposes*.

Apart from these minor nuances, it is interesting to note that the descriptions of the anticipatory variable remain virtually constant, with little variation between frames (i.e. anticipation appears to be effective regardless of the gradients of openness formally acquired by the frames that anticipation is intended to serve). The goals pursued by anticipation and the ways in which the future is used seem to vary according to the frame in which it is interpreted. Anticipation inherits the formal radicality of the framework in which it is interpreted and deployed. However, the definitions offered for anticipation remain constant (e.g. by invoking "reflexivity"). What qualities does anticipation take on in one framework that are more radical than in another? What makes it different? What kind of engagement

with the future does anticipation foster in relation to each framework in order to support their respective gradients of radicality?

The following subsection points precisely to the need to advance the conceptualisation of anticipation in order to promote more radical forms of responsible STI.

***Excursus:* On contingency, ambivalence, and the radicalisation of responsibility—"Open Science" as a lesson**

The above findings invite us to consider the radicalisation of responsibility in terms of its politicisation (i.e. in terms of promoting more inclusive STI governance in relation to knowledge and considered actors) (Eizagirre et al., 2017). Recent developments in relation to AG, RRI, RI, and new forms of TA position different societal actors as agents of sociotechnical change.

This radicalisation, which has occurred at least in narrative terms, has to be considered as historically contingent. Indeed, different forms of responsibilisation have co-existed, each of which acquires different gradients of radicality. And they have done so in contexts marked by ambivalent dynamics. This ambivalence is evident in both the instrumental and substantive motivations (Fiorino, 1990) that have guided the adoption and implementation of these recent frameworks (Rodríguez and Urueña, 2020). This ambivalence needs to be contextualised, moreover, in sociotechnical systems tending to enframe STI as drivers of socio-economic progress (Godin, 2006; Godin and Vinck, 2017; Pfotenhauer and Juhl, 2017). In this context, the narratives that were originally perceived as disruptive were re-interpreted as forms of "public relations" to enable a smooth STI domestication (see Rodríguez et al., 2019; Rodríguez et al., 2020).

Acknowledging and accommodating the contingency, tensions, and ambivalences pervading these more radical frameworks is important in order not to fall into the error of constructing a "Whig history"—namely, a history that necessarily moves towards a better present. A vivid example of these fluctuations and of the need to avoid establishing a historiography in the sense of a "Whig history" can be found in the context of the current Framework Programme "Horizon Europe" (2021–2027). In this programme, RRI is removed as a cross-cutting theme and replaced by the promotion of "Open Science". RRI is now deflated as an operational objective in the specific programme (Article 2.2c) which consists of «promoting responsible research and innovation, taking into account the precautionary principle» (European Parliament, 2019, p. 5).

It is important to note that the pillar "Open Science" is not only interpreted in terms of opening-up research results according to the principles of shareability, transparency, and publicity. It also contains references to the need to promote active engagement in society. However, this engagement finds an unspecific radicality in formal or narrative

terms. Horizon 2020 clearly established that RRI engagements were intended to be unambiguously participatory and deliberative. Engagements in RRI are clearly headed towards aligning STI with the interests, expectations, and values of (European) society. However, the scope and objectives of the "participatory" commitment are much less specific in Open Science to date. Providing that RRI, a more specific framework, was denounced by its low degree of disruptiveness and by great interpretative diversity (both theoretical and practical) (see Klaassen et al., 2019; Pansera and Owen, 2020), it is reasonable to expect that the practices derived from Open Science will become even more diffuse and less disruptive.

This concern about the fluctuations, the minor role of RRI, and the unspecific nature of the radicality and objectives to be promoted within the Open Science programme have led several RRI scholars to denounce this situation at an early stage and to call for the return of greater importance of RRI in "Horizon Europe". For instance, the recent Position Paper written by RRI in Horizon Europe (2020) and the Pathways Declaration signed by NUCLEUS et al. (2019) (i.e. various projects and associations involved in the promotion of RRI in "Horizon Europe") call on the European Union to take immediate action to make RRI more visible in "Horizon Europe". This Declaration was subsequently published in the *Journal of Responsible Innovation* (Gerber et al., 2020). Specifically, the Position Paper demands that:

> RRI should be specifically outlined as a requirement of research and innovation in each programme line of Horizon Europe and should be funded as a research and innovation action on its own terms in Reforming and Enhancing the European R&I system (RRI in Horizon Europe, 2020).

On the other hand, the Pathways Declaration calls for making RRI an essential and living element of "Horizon Europe", as follows:

> Europe should strengthen its efforts to focus on responsible and sustainable modes of research and innovation. We therefore call on European Institutions, EU Member States and their R&I Funding and Performing Organisations, business and civil society to continue to make Responsible Research and Innovation a central objective, with appropriate budgets, across all relevant policies and activities (NUCLEUS et al., 2019, p. 1).

This call for the continuation of RRI implementation is simultaneously based on both instrumental motivations (i.e. aimed at securing funding so that the actors supporting these initiatives can continue in the RRI wave and safely pursue their research agendas) and substantive motivations (i.e. aimed at validating a proposal that, under its normative criteria, is valuable as a promoter of a democratic process that is considered valuable and necessary).

2.4.2. Furthering the elucidation of anticipation

Section 2.3 briefly showed how this move towards a more open, or radical, conception of responsibility includes anticipation, or foresight, among its various procedural dimensions. However, despite the importance of anticipation as a procedural element to these normative frameworks, it is surprising that the literature on these frameworks lacks an in-depth discussion of anticipation. As noted in the Introduction (Section 0.3), one of the architects of AG, David Guston (2013), lamented the poor intuitions surrounding the concept—indeed, as we shall see, these poor intuitions underlie some of the criticisms levelled at anticipation (Chapter 4). This raises the need for a more detailed analysis and elaboration of what is meant by "anticipation" in the newer frameworks that advocate a more socio-politically robust form of responsibility (e.g. AG, RRI, RI, and newer forms of TA).

A closer look at the foundational texts of AG, RRI, RI, and more recent forms of TA can reveal the different characterisations of anticipation they offer. Table 5 catalogues some of the most revealing characterisations that each of these normative frameworks or approaches posits when discussing their corresponding dimension of anticipation/foresight. At this point, it is important to remember that anticipation does not appear as the only dimension in any of the frameworks mentioned, but always functions in symbiosis or mutual reinforcement with other dimensions. The interplay of the different procedural dimensions given by each approach/framework circumscribes the forms of responsibility (or the principle of responsibility) that each framework or approach seeks to promote.

Table 5. Anticipation in AG, RRI, RI, and recent approaches to TA. Definitions, objectives, and associated techniques.

Normative framework	Definitions of the framework	Other dimensions assembled with anticipation	Objectives and characteristics of foresight/anticipation	Techniques and activities linked to anticipation
Anticipatory Governance (AG)	AG «comprises the ability of a variety of lay and expert stakeholders, both individually and through an array of feedback mechanisms, to collectively imagine, critique, and thereby shape the issues presented by emerging technologies before they become reified in particular way» (Barben et al., 2008, p. 993) AG «is about building a capacity (which shares the root, *capere*, to take) in a way that is prior (*ante*-) in either time (e.g. antebellum) or position or order (e.g. antechamber)» (Guston, 2013, p. 111) AG is «a broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible» (Guston, 2014, p. 219)	Engagement Sociotechnical integration	Non-predictivist (does not strive for certainty, or to reduce complexity) Public engagement exercises aimed «to help frame debates about the societal implications of new technologies» (Barben et al., 2008, p. 986) «[S]eek to integrate reflection with everyday decision making» (Barben et al., 2008, p. 986)[45] «[T]o characterize the outcomes of [STI researchers] knowledge production» (Barben et al., 2008, p. 991) «[N]ot only formal methodologies but also more generalized abilities to bridge the cognitive gap between present and future» (Barben et al., 2008, p. 991)	Future scenarios co-constructed in a large-scale through multiple wiki sites Scenario development or visioning workshops (Selin, 2011) Life cycle assessment Delphi studies Cross-impact assessment Future-oriented bibliometrics Science fiction prototyping (Miller and Bennett, 2008)

[45] As Guston (2014, p. 219) explains, «[r]eflection here quite simply means awareness of one's own position as participant, with a specific set of roles and responsibilities, in a field of other actors».

Normative framework	Definitions of the framework	Other dimensions assembled with anticipation	Objectives and characteristics of foresight/anticipation	Techniques and activities linked to anticipation
Responsible Research and Innovation (RRI)	RRI is «a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)» (von Schomberg, 2012, p. 50) RRI «allows all societal actors (researchers, citizens, policy makers, business, third sector organisations, etc.) to work together during the whole research and innovation process in order to better align both the process and its outcomes with the values, needs and expectations of European society» (European Commission, 2013b, p. 4)	EC – Pillars / Themes: societal engagement, gender, open access/data, science education, ethics, and governance The European Treaty as normative anchor point	«[T]he use of foresight projects can help us to overcome the often too narrowly conceived problem definition scientists implicitly work with» (von Schomberg, 2012, p. 46) «[T]echnology assessment and technology foresight can reduce the human cost of trial and error and make advantage of a societal learning process of stakeholders and technical innovators. (…) This will ultimately lead to products which are (more) societal robust» (von Schomberg, 2012, p. 52) RRI «processes need to become more responsive and adaptive to these grand challenges. This implies, among others, the introduction of broader foresight» (von Schomberg, 2013, p. 51)	Technology foresight Technology Assessment Impact assessment

Normative framework	Definitions of the framework	Other dimensions assembled with anticipation	Objectives and characteristics of foresight/anticipation	Techniques and activities linked to anticipation
Responsible Innovation (RI)	RI «means taking care of the future through collective stewardship of science and innovation in the present» (Stilgoe et al., 2013, p. 1570) RI «is a collective commitment of care for the future through responsive stewardship of science and innovation in the present» (Owen et al., 2013, p. 36) RI implies «to ask what futures do we collectively want science and innovation to bring about, and on what values are these based» (Owen et al., 2013, p. 37)	Inclusive deliberation Reflexivity Responsiveness * Openness	«Anticipation is here distinguished from prediction in its explicit recognition of the complexities and uncertainties of science and society's co-evolution» (Stilgoe et al., 2013, p. 1571) «Anticipation prompts researchers and organisations to ask 'what if. . .?' questions (…), to consider contingency, what is known, what is likely, what is plausible and what is possible. Anticipation involves systematic thinking aimed at increasing resilience, while revealing new opportunities for innovation and the shaping of agendas for socially-robust risk research» (Stilgoe et al., 2013, p. 1570) «[D]escribing and analyzing those intended and potentially unintended impacts that might arise, be these economic, social, environmental, or otherwise» (Owen et al., 2013, p. 38) Anticipatory methodologies «are useful as a space to surface issues and explore possible impacts and implications that may otherwise remain uncovered and little discussed. They serve as a useful entry point for reflection on the purposes, promises, and possible impacts of innovation» (Owen et al., 2013, p. 38) «Searching for alternative scenarios and options» (Owen and Pansera, 2019)	Foresight (Constructive) Technology Assessment Scenario development Horizon scanning Vision assessment Socio-literary futures-thinking

Normative framework	Definitions of the framework	Other dimensions assembled with anticipation	Objectives and characteristics of foresight/anticipation	Techniques and activities linked to anticipation
Technology Assessment (TA) (recent approaches)	«TA is an interdisciplinary field of scientific research and advice, which aims to provide knowledge and orientation for better-informed and well-reflected decisions concerning new technologies and their consequences» (Grunwald, 2019b, pp. 1–2)	Inclusion Complexity	TA entails «providing and assessing prospective knowledge (anticipation)» (Grunwald, 2019b, p. 2) «[*A*]*nticipation* addresses the dimension of time when facing an open future: enhancing reflexivity *over time*» (Grunwald, 2019b, p. 2) Anticipation as a specific indicator on «[w]hether and how participants take longer term effects into account. Relevant trends and expected future changes are used in the present when assessing technological opportunities» (van Merkerk and Smits, 2008, p. 323) Anticipation aims to stimulate actors to productively imagine options for desirable technological futures (Decker et al., 2017) «[F]oresight in TA is increasingly oriented towards processes of knowledge co-generation between different actor groups» (Sotoudeh and Gudowsky, 2018, p. 53)	Foresight Scenario development (e.g. Bechtold, Capari, et al., 2017; Rip and te Kulve, 2008; Tran and Daim, 2008) Vision Assessment Hermeneutic Technology Assessment

* Dimensions added by Owen and Pansera (2019).

Sources analysed: AG: Barben et al. (2008), Guston (2013, 2014); RRI: von Schomberg (2012, 2013, 2014, 2019), European Commission (2013b, 2017, 2020b); RI: Stilgoe et al. (2013), Owen et al. (2013), Owen and Pansera (2019); TA: Grunwald (2019b), Rip (2018), van Merkerk and Smits (2008), Decker et al. (2017), Sotoudeh and Gudowsky (2018).

Table 5 shows how AG, RRI, RI, and TA offer both negative and positive characterisations of anticipation. While negative definitions emphasise the absence of features of anticipation, positive definitions provide information on anticipation. In this sense, the latter characterisations are much more informative than the former.

On the one hand, the negative characterisations of anticipation generally exclude in this context those interventive actions informed by predictive engagements with futures. The predictive way of approaching the future is considered insufficient and counterproductive to promote the politicised notion of responsibility at stake. Prediction-based forms of governance (often operating in the register of "probable futures") are regarded as social machineries that are instrumental in the reification of futures and thereby the preservation of the status quo (see Derbyshire, 2017; Miles, 1975; Ramírez and Selin, 2014; Selin, 2011; Selin and Guimarães Pereira, 2013). This negative consideration finds its basis in the inability of predictive techniques to recognise and address the contingent, open-ended, and plural character of futures (see Bell and Olick, 1989; Gjefsen, 2013; Miles, 1975; York and Clark, 2007), as well as—as previously argued in Section 2.2—to problematise in a comprehensive and integral way the socio-political and normative aspects related to the governance of STI (Sarewitz et al., 2000). This is not to deny the potential value of predictive anticipation methods when dealing with some very limited aspects in stable systems (see Poli, 2019b). Rather, the point is to highlight the limitations of using predictive models in promoting negotiation or deliberation mechanisms that help to open up alternative forms of STI co-production. The rendering of STI governance on predictive forms of anticipation encounters serious limitations for serving as mechanisms for combating the reification of futures and for raising awareness and contesting the mobilisation of what has been understood here as "modal power" (Chapter 1).

The common denominator of the positive characterisations of anticipation, on the other hand, emphasises the functions of foresight/anticipation for the development of reflexive heuristics and capabilities. It is interesting to note in this context that most characterisations of anticipation in AG, RRI, RI, and recent TA approaches focus mainly on the heuristic-reflexive potential of anticipation in relation to STI impacts. However, the methods briefly mentioned in the conceptual foundations of AG, RRI, RI, and recent forms of TA (Table 5)—as well as the developments around radicality outlined in the previous subsection—suggest that anticipation is not, or should not be, exclusively focused on impacts. The allusion to methods such as scenario planning or vision assessment broadens the consideration of STI impacts and opens it up to the question of STI processes and the creation of reflexivity in relation to futures that set STI purposes or agendas. The recent frameworks are not sufficiently informative or explicit about the kind of engagement with the future that they seek to promote through anticipation, the challenges they seek to address in doing so, how this should be done, etc.

As a first step towards promoting a more explicit and robust characterisation of anticipation, we can interpret that in AG, RRI, RI, and recent forms of TA, anticipation is understood as a means for enhancing the reflective capital concerning STI orientation

throughout their co-production process and at the early stages of development, before the uncritical closure of sociotechnical coevolutionary pathways. Anticipation/Foresight is a dimension oriented towards the collective problematisation of sociotechnical futures that we enable through STI. Anticipation is primarily a tool for addressing—which does not mean solving—the general challenge posed by the Collingridge dilemma (Collingridge, 1980).

Anticipation and Futures Studies define anticipatory systems as follows:

> An anticipatory system is a system containing a predictive model of itself and/or its environment which allows the system to change state at one instant in accord with the model's predictions pertaining to a later instant (Poli, 2017, p. 2).

Based on this definition of anticipation, and considering the normative anchoring values of the recent frameworks discussed above, I propose to reformulate it as follows:

> *An STI system can be described as AG/RRI/RI/TA-anticipatory when the collective, or inclusive, early, and ongoing problematisation of its plausible and desirable (present, past, and) future states enable its actors' capabilities to envision existing alternative courses of action and to intervene intentionally and reflexively in its present co-production.*

This definition simultaneously captures the following practices: (i) Early stage and in real time problematising STI (i.e. promoting *ex-ante*, *ex-dure*, and *ex-post* forms of responsibility) (e.g. Guston and Sarewitz, 2002); (ii) conducting inclusive or collective problematisation (e.g. Stilgoe et al., 2013); (iii) enabling reflective capacities (e.g. Barben et al., 2008; Guston, 2014; Rip, 2018, Chapter 2; Selin et al., 2017); and (iv) intentionally intervening through futures (e.g. Konrad et al., 2016). In accordance with AG, RRI, RI, and TA, the purpose of this problematisation of future states would be to promote the deeper alignment of STI with social desires, values, and expectations.

But even this definition, although more comprehensive and informative, does not give any indication of the engagements with futures and what this problematisation might comprise: How it is activated and in relation to what challenges. If we want to be more precise in this regard, it would be necessary to expand, or enrich, the socio-epistemic steps considered within the definition. This applies both to the definition we have taken as a starting point (i.e. the canonical definition from Anticipation and Futures Studies) and to the definition derived from it. This extension is not only necessary to identify the internal socio-systemic mechanisms that are necessary when it comes to translating futures into practice. The basic definition does not allow to delineate the types of engagement themselves, in what sense they are translated into practice, and in relation to which challenges.

The following chapter is dedicated to refining this basic concept of anticipation (Chapter 3). This extension will be an important prerequisite for later identifying the heuristic and functional heterogeneity of anticipation for AG, RRI, RI, and TA (Chapter 4).

2.5. Conclusions

This chapter has provided the first argumentative step towards strengthening and giving meaning to anticipation as an interventive tool in the service of frameworks such as AG, RRI, RI, or recent TA approaches to promote a more socio-politically responsible STI.

The chapter began by emphasising that anticipation as an intervening tool is a necessary element of any normative approach that seeks a proactive, or *ex-ante*, conceptualisation of responsibility. In other words, anticipation is a necessary tool for any normative interventive approach aiming to promote responsibility at the early stages of STI development—i.e. anticipation is important for all normative or interventive approaches that aim to move beyond *ex-post* conceptions of responsibility (e.g. "accountability" or "liability" conceptions). However, the possible usages and approaches to future representations that may be made to trigger the *ex-ante* form of responsibility and governance are very diverse. *Ex-ante* or anticipatory forms of interventive governance may adopt different modalities and different degrees of radicality in the problematisation of STI.

One of the most common ways of conceiving of *ex-ante* responsibility for STI is to formulate it by means of forecast models. However, this way of promoting *ex-ante* responsibility has been widely criticised. Among other criticisms, these tools are found to be unable to problematise aspects related to the desirability of STI (e.g. the goals and processes of STI) and to promote technocratic forms of governance. In this respect, it is not surprising that normative frameworks that seek to promote more socio-politically robust or inclusive forms of governance of STI refer to the need to formulate forms of governance based on "non-predictive" anticipations. This is for instance the case with AG, RRI, RI, and newer forms of TA.

However, various normative and interventive frameworks have long been proposing "non-predictive" forms of anticipation to operationalise their respective notions of an *ex-ante* STI governance. Approaches discussed here that illustrate this include Future-Oriented Technology Analysis, ELSA/ELSI, AG, RRI, RI, and various forms of TA. Some of these approaches rely on the use of future scenarios aimed at generating reflexivity in technology development processes (e.g. CTA through the use of sociotechnical scenarios). The use of "non-predictive" and reflection-oriented anticipations, as proposed in recent normative and interventive frameworks, is therefore not a completely new phenomenon.

Consequently, if we want to deepen the conceptual meaning and operative significance of anticipation for recent frameworks that support more socio-politically robust, or open, forms of STI co-production (e.g. AG, RRI, RI, and recent forms of TA), we need to not only ask whether they incorporate anticipation as a procedural intervening tool of a "non-predictivist" nature, but also consider what formal and material modalities this incorporation assumes. The key question is what forms of non-predictivist uses of the future are proposed, what dynamics constitute them (i.e. what are the characteristics of these uses of the future), and what forms of responsibility these non-predictivist uses are intended to serve, or activate, in the governance of STI. What is important, therefore, is not so much whether the future is

used, but what kinds of uses of the future are envisioned and adopted, and how these uses encourage engaging with modal power allocations.

The brief overview of conceptions of anticipation as an intervening instrument undertaken here has helped to diagnose two central aspects:

The *first aspect* is that (i) the ways in which these forms of anticipation are conceived are heterogeneous, both in terms of the goals pursued and how they are intended to be used and engage with future representations, creating different gradations of problematisation of STI. Indeed, the *formal* radicality of anticipation has been shown to be subordinate to the *formal* radicality of conceptualising the responsibility and governance of STI that underpins each framework that anticipation is intended to support.

This argued formal radicality, or openness, can be identified and assessed in terms of different variables. It was established that some of the tentative variables that could be considered simultaneously when assessing the radicality of normative frameworks and anticipation are the temporal (when is STI problematised?), the objectual (what aspects of STI are considered?), the inclusive (what actors, concerns, knowledge, and interests are included during the problematisation process?), and the operative (how are the above domains problematised?).

In view of these tentative variables, it can be observed that AG, RRI, RI, and recent approaches of TA claim to embrace a very radical conception of responsibility at the narrative level (particularly in the case of RI). This narrative, or *formal*, radicality can nevertheless subsequently acquire various *socio-material* de facto radicalities when it becomes operational and deals with the socio-material reality that is the object of its intervention. The greater radicality of these recent normative frameworks/approaches is supported by positioning their narratives in relation to the above variables as follows:

- They are committed to conducting an *ex-ante* problematisation, before the pathways of STI become locked-in or reified;
- They strive to encompass the problematisation of the processes, the outcomes, and—in the case of RI—the purposes of STI;
- They aim to perform this problematisation by including the interests, values, and knowledge of diverse societal actors;
- They attempt to promote these problematisation exercises throughout, and within, the whole STI research and development process.

The *second aspect* is that (ii) recent frameworks that advocate the promotion of a more socio-politically radical responsibility are not informative enough in specifying the kinds of engagements with the future that they seek to promote through anticipation. Indeed, a brief review of some of the characterisations provided by highly representative frameworks in this regard such as AG, RRI, RI, and recent forms of TA shows how their respective characterisations of anticipation are exceptionally brief (Table 5), and little developed or

attended to in the literature. Specifically, it was shown how the aforementioned frameworks include both negative and positive characterisations of anticipation. While negative characterisations usually exclude anticipations based on forecast exercises, positive characterisations emphasise that anticipatory heuristics are oriented towards generating reflexivity in STI processes. Specifically, I have characterised an anticipatory STI system as follows:

> *An STI system can be described as AG/RRI/RI/TA-anticipatory when the collective, or inclusive, early, and ongoing problematisation of its plausible and desirable (present, past, and) future states enable its actors' capabilities to envision existing alternative courses of action and to intervene intentionally and reflexively in its present co-production.*

The characterisation of anticipation presented in this chapter marks a small step towards understanding anticipation as a key dimension in promoting a socio-politically responsible STI. However, it remains somewhat unspecific. Like the definitions of anticipation/foresight put forward by AG, RRI, RI, and more recent forms of TA, this definition is still somewhat lacking in specificity in the following regards: How should anticipation be activated? What types of engagement with the future should be promoted? What heuristic benefits and what challenges should it consider or address? This lack of specificity in the context of semantic, interpretative, and operational diversity (Pansera and Owen, 2020) hampers the sense-making processes of anticipation and could consequently undermine its operational reception and scope for promoting a more socio-politically robust co-production of STI.

In order to answer the questions posed above, it is necessary to expand the basic characterisation of anticipation from which I have started in this chapter. Both the normatively charged characterisation of anticipation I have elaborated here and the primordial one stemming from Anticipation and Futures Studies need to be extended. The characterisations of anticipation require the expansion of the constitutive socio-epistemic steps beyond the two mentioned in the definitions: (i) "using the future" and "translating it into action" (Anticipation and Futures Studies), and (ii) "using the future" and "opening-up alternative courses of action and turning them into action" (presented here). The extension is necessary to explain or account for the various socio-systemic activities and engagements that might be de facto mobilised to fulfil anticipatory practices, and the various challenges for which these engagements or uses of the future may be of heuristic value for the responsibilisation of STI. The following chapter problematises and elaborates on the ideal-typical socio-epistemic steps considered in the characterisation of anticipation (Chapter 3). Extending this characterisation through the amplification of these socio-epistemic steps will help to clarify the heterogeneity and heuristic value that anticipation acquires, and the different challenges that may be associated with it in these more radical frameworks (e.g. AG, RRI, RI, and newer forms of TA) (Chapter 4).

CHAPTER 3

Amplifying anticipation: Socio-epistemic remarks on an emerging field of knowledge

Abstract The Discipline of Anticipation is an emerging field of knowledge that deals with actions that are shaped by ideas about the future. As the discipline is in an early stage of development, there is a growing motivation to strengthen and consolidate its underlying theoretical foundations. The main goal of this chapter is to critically review the foundational concept of anticipation that is addressed in the discipline. By scrutinizing the socio-epistemic processes considered in the definition, the chapter argues that this notion, when applied to human behavioural systems, presents certain ambivalences regarding its denotative or binding character. On the one hand, the definition is narrow as it does not account for many socio-epistemic and cognitive processes that shape anticipatory actions (thus depriving them of analytical-critical consideration). On the other hand, the definition is too loose, as almost any kind of human behaviour could trivially be defined as anticipatory, leading to problems regarding the ubiquity of anticipation and the specificity of the discipline. Confronted with the problematic narrowness of the definition, the chapter expands the socio-epistemic processes it includes, and thus the socio-political and epistemic aspects considered analytically relevant in describing and critically reflecting on anticipatory phenomena. The purpose of this conceptual clarification is to develop a concept of anticipation that allows for a more analytically robust approach to the ways in which recent normative frameworks such as AG, RI, RRI, and TA embody anticipation—which, as shown in the previous chapter, lack specificity when it comes to accounting for the role of anticipation and the specific challenges it aims to address.

3.1. Introduction

The emergence, legitimization, and consolidation of a new field of knowledge in the complex web of academic disciplines is a lengthy process influenced by socio-political and socio-epistemic struggles.[46] On the one hand, these processes require, among many other milestones, the production of a specific theoretical and methodological corpus, the formation

[46] Definitions and demarcations of disciplines and fields of knowledge are permeated by interests and power relations, like any other activities that involve drawing and maintaining boundaries. Definitions characterize, classify, organize and embody the "infrastructures of science" (Lenoir, 1997) and, thus, mark norms of inclusion/exclusion that favor or harm certain social actors and research directions over others. For instance, the definitions of a scientific field determine which research projects might be included or excluded a priori from certain domain-specific competitive funding calls. The strong connections between power and the demarcation of disciplinary domains is clearly reflected in concrete contexts, such as the struggles between faculties and disciplines as well as between areas of knowledge belonging to the same discipline (see Bourdieu, 1984).

of an academic community that supports and develops this corpus (e.g. professional associations, journals, faculties, departments), the establishment of college degrees (e.g. bachelor's, master's, PhD programs), and the regular holding of collective academic events (e.g. conferences and annual meetings). Similarly, supporting a labour market capable of generating and attracting material and human resources is essential for the continued promotion and development of the lines of research associated with the knowledge area or discipline in question (i.e. ensuring the survival of the field over time). However, the above milestones are only possible if they are all considered to be sufficiently justified or supported (conceptually and/or empirically) by a more or less precise and robust characterization of the specific research *loci* of the field (Krishnan, 2009). The successful development of a discipline presupposes, as a necessary but not sufficient condition, that the phenomenon of study that constitutes its identity is adequately delimited. The delimitation of the object of study is a *sine qua non* for a discipline to fulfil some of its main tasks: to build credibility and to make a community of arguers possible (Bridges, 2006).

One field of knowledge that has attempted to gain some identity, depth, and scientific-academic legitimacy over the past five years is the Discipline of Anticipation (Miller et al., 2013, 2018), or Anticipation Studies (see Poli, 2014, 2017, 2019a; Poli and Valerio, 2019). One of the major challenges in legitimizing and establishing «anticipation of the future as a legitimate topic of research» (Poli, 2017, p. ii) has been to establish a basic definition of "anticipation" and demand that the discipline's central theoretical foundations (i.e. its ontological, epistemological, or axiological foundations) be anchored and underpinned. Specifically, Anticipation Studies are claimed to encompass «natural, formal, and social systems that intentionally or unintentionally use ideas of a future to act in the present» (Poli, 2017, p. ii). Anticipation would therefore denote any action (whether individual or collective) that has been motivated by the use (whether consciously or unconsciously) of a representation appealing to a future (Poli, 2019a).

The main goal of this chapter is to critically review this basic definition of anticipatory phenomena. This chapter argues that this canonical and basic definition of anticipation, when applied to human anticipatory behavioural systems in general and to the socio-epistemic activities that shape the anticipatory governance of sociotechnical systems in particular (whether implicit or explicit anticipation), suffers from ambivalences with respect to its bounding power, or boundedness. On the one hand, it seems too restrictive, or narrow, in terms of the socio-epistemic or cognitive processes it explicitly identifies as constitutive of an action to be considered "anticipatory". On the other hand, the definition seems to be too loose, or non-restrictive, since many human actions could trivially be considered "anticipatory". While the bounding narrowness prevents a deeper problematization of the socio-epistemic processes of knowledge generation, transmission, and validation that constitute human anticipatory practices, the bounding looseness may lead to problems regarding the ubiquity of anticipation and the triviality of Anticipation Studies' specificity. Confronted with the problem of narrowness, the chapter suggests an expansion of the socio-epistemic and cognitive processes considered in anticipatory processes.

The analysis offered in this chapter thus points to the normative power of the concept of anticipation that underlies Anticipation Studies: What makes it (in)visible, and where does it demand that the focus of analysis be placed? The relevance of the proposed extension is not only theoretical (e.g. in terms of strengthening the concept itself) but also practical (e.g. in terms of a more sophisticated socio-epistemic analysis and evaluation of anticipatory dynamics).

One of the most immediate consequences of the clarification of the concept of anticipation undertaken here will be to enable a more detailed analysis of the heterogeneous ways of engaging with the future that are considered relevant to AG, RRI, RI, and TA. In doing so, this clarification will also be important for understanding the relationships between each of these ways of engaging with the future and the STI governance challenges that these frameworks seek to address. The analysis will therefore be crucial for developing the findings presented in Chapters 4 and 7 (which address the theoretical heterogeneity of anticipation in theoretical and practical terms respectively).

The structure of the chapter is as follows. Section 3.2 introduces some milestones in the emergence of Anticipation Studies. The focus is on the development of the term "anticipation" used to identify the discipline. Section 3.3 shows that the concept of anticipation suffers from the ambivalence mentioned above regarding its restrictive power and diagnoses the need to problematize, nuance, and expand the socio-epistemic and cognitive elements and processes under consideration when considering anticipatory practices. Against this background, Section 3.4 presents an extended concept of anticipation. Finally, Section 3.5 summarizes the content of the chapter and offers some conclusions regarding the socio-political implications of the extension proposed.

3.2. The emergence of Anticipation Studies: Conceptualising anticipation

As the leading proponents of Anticipation Studies openly admit, academic interest in the question of how the future is used to guide present action is not a new phenomenon (Miller, 2018; Poli, 2010, 2019b). Although not always under the term "anticipation", various scholars and theories have addressed the phenomenon of using the future to guide action in the present, with examples from physics, biology, psychology, anthropology, economics, political science, and philosophy (see Poli, 2017).

Anticipation Studies emerged in the second decade of this century, and its main proponents justified its existence by the need to systematize the treatment of ideas about the future and their use. It arose from the commitment to study monographically and systematically how different entities use the future (consciously or unconsciously and with varying degrees of complexity) during the development of their vital and/or functional activities in the present. While maintaining «a broad focus on humans, institutions, and human-designed systems» (Poli, 2017, p. ii), Anticipation Studies strictly aligns with a non-

anthropocentric perspective by recognizing the presence of anticipatory behaviours in non-human beings, such as plants, animals, or even in technical systems (e.g. robotic systems) (Poli, 2010, p. 8).

This interest in the way the future is understood and used in the present keeps the Anticipation Studies in close contact—not without certain tensions and overlaps—with one of the academic circles that have an academic and practical interest in the future: the internally heterogeneous field of Futures Studies, which is no less difficult to delimit.[47] Indeed, one could say that many of the concerns with which Anticipation Studies are currently engaged have emerged from a diagnosis of the need to strengthen and extend the theoretical and conceptual foundations of Futures Studies (e.g. Miller and Poli, 2010; Poli, 2011, 2014, 2015).

One of the leading figures in carrying out the task «to centralize the study of anticipation and to define the Discipline of Anticipation as a cohesive body of knowledge» (UNESCO, 2021) is the philosopher, sociologist, and UNESCO Chair in Anticipatory Systems Roberto Poli. In attempting to conceptualize and theorize anticipation, Poli acknowledges the influence of the mathematical biologist Robert Rosen (1934–1998). It is the work of Rosen (1985, 1991) that serves as the starting point for a more explicit and robust characterization of anticipation. Specifically, Rosen (1985, p. 339) defines anticipatory systems as those systems that contain a predictive model of itself and/or its environment, which allows it to change state at an instant following the model's predictions about a later instant. Against the background of Rosen's work and considering the early diagnosis that «currently no general theory of anticipation is available» (Poli, 2010, p. 770), Poli proposed a first tentative characterization of anticipation: «Generally speaking, anticipation concerns the capacity exhibited by some systems to tune their behaviour according to a model of the future evolution of the environment in which they are embedded» (Poli, 2010, p. 770). Picking up an umbrella before going to work and after having watched a weather forecast that announces rain would be an example of anticipatory behaviours.

However, there are subtle but important differences between Rosen's concept and Poli's earlier concept. On the one hand, Rosen emphasizes the need for the action-guiding model to be predictive (i.e. a model that in some sense reveals the future properties of the system in question), whereas Poli subtly expands the models to include not only predictive models

[47] Anticipation and Futures Studies interrelate at multiples levels. Futures Studies encounter a historically evolving community of actors (see Son, 2015) with non-homogeneous practical and/or academic concerns (Samet, 2010; Sardar, 2010). Within this heterogeneity, Anticipation Studies would resonate with those Futures Studies that not only seek to pluralize (Bell, 2003; Dator, 2019) or critique (e.g. Inayatullah, 1990) futures and anticipatorily use them in practice, but rather with those that aim to examine how (and under what assumptions) this engagement with futures and their respective realizations «into strategy and action» (Poli, 2021, p. 3) occurs. In this sense, Anticipation Studies emphasize a second-order reflexivity. Its systematic field of inquiry is not the future per se, but how forecast/foresight practices *anticipatorily* shape or guide present action. The *momentum* that the study of anticipation is currently experiencing has led one of the central journals that has been the foundation of Futures Studies since 1968 to change its name: From "*Futures: The Journal of Policy, Planning and Futures Studies*" to "*Futures: For the Interdisciplinary Study of Futures, Anticipation and Foresight*".

but also a range of other models or representations that appeal to the future (e.g. expectations, visions, hopes) (Poli, 2016). On the other hand, Rosen argues that action-relevant futures can refer to future states of the system itself as well as to its environment, whereas Poli (2010), in this early approach, considers only futures that refer to potential states of the system's environment (see Table 6).

Table 6. Differences between Rosen's and Poli's concepts of anticipation.

	Rosen	**Poli**
Anticipation definition	An anticipatory system is «a system containing a predictive model of itself and/or its environment, which allows it to change state at an instant in accord with the model's predictions pertaining to a later instant» (Rosen, 1985, p. 339)	«[A]nticipation concerns the capacity exhibited by some systems to tune their behaviour according to a model of the future evolution of the environment in which they are embedded» (Poli, 2010, p. 770) «Anticipation as here understood includes two mandatory components: a forward-looking attitude, and the use of the former's result for action» (Poli, 2017, p. 1)
The heuristic source that informs current action	A predictive model	A model evoking a future
Understanding of "model"	«[A] model is a relation between a natural system *S* and some suitable formal system *M*» (Rosen, 1985, p. 339). «The robustness of this relation lies in the conjugacy between the properties of S, and the properties of M» (Rosen, 1985, p. 339)	«The concept of model that I adopt is very broad. (…) For me a model [of the future] is any activity that looks forward, to what might happen. According to this meaning, even hopes and fears are models» (Poli, 2019b, p. 10)

Working with a broader notion of "model" allows Poli to include as anticipatory behaviours those that are based on assumptions about the future but that do not have an indicative or denotative function or mood (i.e. representations that do not claim to say anything about what will be the case per se). This is the case, for example, with actions and behaviours that are motivated, articulated, or informed by normative (i.e. how the future should be) or volitional (i.e. how the future is desired) models. Thus, an activity such as recycling might be considered an anticipatory activity if, and only if, it is motivated or articulated by a desirable vision of a more sustainable future (i.e. by a normative and/or volitional model of the future that is considered positive for the system performing the action). Applied to the case of human behaviour and action, anticipation emphasizes that our actions are conditioned and articulated not only by models of the past and present but also by models of the future.

This broad concept of "model" is maintained in subsequent refinements of the concept of anticipation. However, the initial limitation regarding the orientation of the model by appealing to the future of the environment of the system in question is no longer present in more recent work. Anticipation is nowadays defined much more simply as any action or behaviour performed based on beliefs or ideas about the future (Poli, 2017, p. 1): «Anticipation consists of two elements: a [future] model and its translation into action» (Poli, 2019b, p. 14).

This definition of anticipation as an activity based on a model that includes (descriptive, normative, volitional) assumptions about the future is considered fundamental; it is the starting point «for developing more inclusive forward-looking perspectives» (Poli, 2017, p. 7). Indeed, it is recognized that anticipation can take many forms (i.e. that the future can be used in different ways). For example, it has been pointed out that the use of future models can be at either the individual level (i.e. by a single system) or the collective level (i.e. by a system composed of multiple subsystems). It was also noted that anticipation can be explicit or implicit, depending on whether the system is aware of the use of future models (Miller et al., 2013, p. 4; Poli, 2010, pp. 12–13).

Defined in this way, Anticipation Studies encompasses a wide range of events, behaviors, and actions that, although they have been addressed by other, more established academic disciplines (e.g. philosophy, psychology, sociology, anthropology, management, political science), have not received specific and systematic attention. For example, the study of anticipation phenomena would involve describing and explaining natural biological mechanisms by which certain plants and animals respond adaptively (individually or collectively) to a variety of signals regarding the future of their environment (e.g. Novoplansky, 2016; van den Bos, 2019).[48]

This includes clarifying how social actors (either individually or collectively) epistemically, sensitively, and/or volitionally experience and engage with futures and use them (consciously or unconsciously) to orient themselves and make sense of their actions (Baumeister et al., 2016; Oettingen et al., 2018; Seligman et al., 2016). In this sense, questions about how we have historically experienced and made sense of future temporality (Hölscher, 2018; Uprichard, 2011; Wells, 1913), how imagining of the future and our hopes are part of our anthropological and cultural conditions (Appadurai, 2013; Bryant and Knight, 2019), how these forms of articulating temporality intertwine with socio-economic orders (Beckert, 2016; Ogle, 2019), and how we should plan for the future and orient ourselves accordingly (Hopkins, 2019) would be at the heart of the study of anticipation. Indeed, the recent findings from Science and Technology Studies about the way representations of the future perform knowledge co-production dynamics (see Konrad et al., 2016; Lösch, Grunwald, et al., 2019)—be it in the form of promises and expectations (Borup et al., 2006; van Lente, 1993), visions (Ferrari and Lösch, 2017; Schneider and Lösch, 2019) or sociotechnical imaginaries (Jasanoff, 2020; Jasanoff and Kim, 2015)—would be recognized as anticipatory activities by Anticipation and Future Studies (Chapter 1). Similarly, the various ways in which science, technology, and innovation are intentionally managed, regulated, directed, and/or shaped based on prospective methods and models of the future (e.g. risks and market-cost-opportunity analyses) would be considered as formally directed

[48] Miller et al. (2013, p. 3) and Poli (2015, p. 110) for instance suggest that 'a tree that loses its leaves in the Autumn' would be an anticipatory behavior. Non-human animals can also exhibit anticipatory behaviors with varying degrees of cognitive complexity. For example, dogs often adapt their direction and speed when hunting by anticipating the movements, positions, and possible paths of their prey (i.e. they act on the basis of representations about the future position of their target). This idea of the future may be more or less self-consciously generated, vivid, refined, and/or accurate.

and deliberate forms of anticipation. In this sense, Anticipation and Futures Studies would not only involve the analysis of how the future is used and translated into actions, but it would also include the clarification of the various relevant models, procedures, and issues that come into play when the future is used to influence actions in the present (see Miller et al., 2013, p. 7).

3.3. Anticipation and its "intensional boundedness" ambivalence

The basic definition of "anticipation" as any activity that is informed by future ideas or models seems to constrain, necessarily and sufficiently, the phenomenon that is the subject of the field. However, this section argues that this basic definition may be subject to "intensional boundedness" ambivalence when applied to anticipation (whether individual or collective, explicit, or implicit anticipation) performed by humans.

A concept is formed from the alignment of three components: (i) A term intended to denote (ii) an event or phenomenon (the extension or definiendum), through (iii) the assignment of a set of attributes to the phenomenon (the intension, definiens, or definition) (see Gerring, 1999; Ogden and Richards, 1923). This assignment of attributes may be more or less precise and exhaustive, marking the intensional richness of a concept.

The claim that the basic and currently used definition of anticipation has an "intensional bounding ambivalence" implies that it has two opposing values with respect to its restrictive-denotative power (i.e. it has two opposing values when it comes to delimiting the definiendum by a definiens). On the one hand, it is too loose, since any social and/or human activity could trivially fit the definition offered. On the other hand, it is too narrow, since it does not consider all the socio-epistemic and cognitive processes at play in anticipatory activities (i.e. its intension is not rich enough).

Before explaining the rationale for the ambivalence hypothesis, we must first emphasize something that is not often found in the literature on anticipation: Human anticipation is a socio-epistemic activity and practice. This means that it emerges and is embedded in a relational structure of actors and actions, where it acquires meaning and significance. Anticipation occurs in concrete social and epistemic networks and situations. Paraphrasing Jasanoff (2004, p. 2), the way we create and use models that contain assumptions about the future (i.e. the way we anticipate) is inextricably linked to how we coordinate and enact social orders. Anticipatory actions, like any other type of action, cannot be considered in isolation and therefore must be evaluated and analysed in relation to the frameworks and contexts in which they occur.

Even the exemplary scenario in which a subject anticipatorily picks up an umbrella after watching the weather forecast confronts us with the socio-epistemic dimension of this reality, thus raising some questions that have classically been addressed by social epistemologists. The fact that the subject trusts a weather forecast and considers it as a reliable resource for decision-making appeals to phenomena such as epistemic division of

labour, attribution of expertise, and trust in a community of subjects (e.g. in the group of communicators who disseminate the main meteorological conclusions, in the weather forecasting models, in the abilities of some scientists and technicians to operationalize these models, or in the instruments for measuring the variables involved in modelling and forecasting the future). The reliability that the subject performing the anticipatory action ascribes to the weather forecasting model must therefore be contextually considered, analysed, and evaluated within the specific socio-epistemic environment where it occurs. For example, it must be understood within a socio-epistemic setting where scientific-technical techniques for modelling the future are typically accorded a special epistemic, empirical, and predictive status—even though the legitimacy for these models is often opaque, especially to those who do not belong to the scientific community in question.

One of the purposes for which Poli often uses the example of the subject picking up the umbrella is to intuitively dispel the common misunderstanding that future models (in this case, weather forecasting) can be considered "anticipations" (Poli, 2017, p. 2; Poli and Valerio, 2019, pp. 2–3). *Sensu stricto*, if we apply the basic definition of anticipation, a model cannot be considered anticipation since anticipations denote only certain kinds of actions. However, if we apply a contextualized and relational analysis, we can understand certain hypothetical situations in which the weather forecast model becomes a product of anticipatory actions itself. For example, we might assume that the group of scientists created this model with certain hopes and/or expectations. Indeed, they may have chosen to create the weather forecast with the expectation that people might benefit from it, or simply to take paid work that would allow them to realize their visions and (non-professional) life projects. In the example of the subject picking up an umbrella as a consequence of observing a weather forecast, the action that turns picking up the umbrella anticipatorily (i.e. paying attention to the weather forecast) could itself be considered anticipatory, since it could be performed in the light of a vision of the future representation in which the actor wishes to avoid any meteorological misfortunes.

These examples and hypothetical situations suggest that in defining an action as anticipatory, it is necessary to define a context of reference that points to the not apparent and easily discernible intentions and motivations underlining it. In particular, it must be established that the action in question is based in some way on assumptions, motivations, or intentions that relate to the future (i.e. projections of the future).

However, it is not trivial that any human action (whether individual or social) satisfies this requirement. Indeed, various studies indicate that humans inhabit present, past, and future temporality simultaneously, albeit not in an equally distributed manner. Past, present, and future receive different weights depending on the situation, context, and other historical (Hartog, 2003; Hölscher, 2018; Koselleck, 2004), anthropological (Bryant and Knight, 2019) and psycho-social (Buckner et al., 2008; Doll et al., 2015; Seligman et al., 2016) factors. This means that our way of experiencing the world is always permeated by future temporality. There are always more or less implicit assumptions about how the future will/could/should be (Oettingen et al., 2018). The very fact that we expect and trust that the

supermarket or college we regularly visit will be open again the next day, or even that the sun will be on the horizon again, and we act accordingly, puts us in a scenario where the use of models about the future is ubiquitous. Human action (both at the individual and societal level) is linked to the ability to project and imagine alternative paths. As Emirbayer and Mische (1998) suggest, social agency can only be understood in depth if it is situated in temporal flow, always in relation to the coral triad of past, present, and future (see also Mische, 2009, 2014).

Against this background, the definition of human anticipation as any action based on a future model seems too loose since it can practically denote the totality of human actions. Assuming that a minimal projective assumption can always be trivially included, any action can trivially be explained as anticipatory. Anticipation could encompass every human action. This first side of ambivalence has some Janus-faced consequences. On the one hand, it may lead one to think of the nonspecific nature of a theory of anticipation *vis-à-vis* a general theory of action and decision-making. This can be a source of scepticism about the genuineness and specificity of anticipation as a phenomenon and, thus, about Anticipation Studies' identity and necessity. On the other hand, the ubiquity of the phenomenon makes it more urgent than ever to explore how we engage with the future and use it to guide our actions (whether in our individual or socio-political lives). Because models of the future are important, though not the only, factors in explaining behaviours, action, and agency, it is critical to pay attention to what models or representations of the future we engage with and on what socio-epistemic basis. It is precisely this ubiquity and omnipresence of anticipation (widely and explicitly acknowledged by theorists of Anticipation and Futures Studies) that explains the depth, complexity, and relevance that the study of anticipation might acquire.

While this first side of the ambivalence of anticipation's definiens (i.e. relative to the loose value of the concept) is probably still somewhat salvageable and acceptable, the second side (relative to the narrow value of the concept) could pose more problems. The second side of ambivalence would allude to the fact that the definiens of anticipation is too narrow, as it does not make explicit or specify all the properties or attributes that could de facto define an anticipatory activity, especially when we are talking about human anticipations. By properties or attributes, I refer specifically to the cognitive and socio-epistemic activities that are explicitly signalled by the anticipation definition or definiens.

Adam and Groves (2007, pp. 17–19) argue that the question of the future and the way it colonizes social spaces and shapes action raises several far-reaching ethical and epistemic-political questions. In this vein, Adam (2008, p. 112) argues the following:

> These relate to ownership (who is thought to own the future), to origin (where and when the future originates, its source), to expertise (who are deemed to be experts in the future), and to methods (what methods and knowledge tools are considered legitimate).

While the dimensions of ownership, origin, expertise, and methods are not—and are not intended to be—exhaustive, they can serve as a starting point (i) to illustrate the narrow nature of the concept and (ii) to expand it.

The narrow character of the definition of anticipation stems in particular from the fact that it explicitly includes only a subset of those socio-epistemic and cognitive activities that constitute anticipatory actions. As we have already seen, Poli notes that all anticipatory behaviours consist of two components: (a) A forward-looking model/attitude and (b) the translation of that model into action (see Table 6). While this definition is basic and correct, it does not illuminate all the possible socio-epistemic steps that may be present when "anticipating" (and thus indirectly shields us from a broader analysis and problematization of these practices). The example of the subject anticipatively picking up an umbrella is, as I have already mentioned, much more complex than simply translating a future into action. It depends on and implies cognitive and socio-epistemic processes that go beyond the two steps mentioned in the basic definition of anticipation.

Human anticipation is a highly complex socio-epistemic practice composed of many other components. The analysis of anticipation could therefore address more questions than the basic definition suggests (i.e. anticipation could be problematized beyond the question of how and under what conditions actors adopt a model of the future and translate it into action). Consistent with what was mentioned in the context of the previous characterization of anticipation as a socio-epistemic practice and the epistemic-political questions highlighted by Adam and Groves (2007, pp. 17–19), it is worth asking who created these futures and how (problems related to the origins and methods of creation), what modal spaces (do not) allow us to imagine these futures and who they favour (problems related to ownership), why they are considered relevant, and under what conditions (epistemic, normative, and/or volitional) (problems related to expertise and legitimacy), what information is gleaned from them, and how they are translated into action. Moreover, all these problems should always be considered as embedded in contexts characterized by power dynamics in which the envision of certain futures (to the detriment of others who that are silenced and hidden) is part of the game of enabling or preventing the socio-material emergence of certain realities.

3.4. Amplifying human anticipation: The use of "the future" as a socio-epistemic practice

The fact that the intension, or definition, of the term "anticipation" is, in some sense, narrow when extended to human behaviour has the most immediate heuristic consequence of limiting the analytical and descriptive richness of the phenomenon. In other words, the extension (definition) and intensionality (how we capture the phenomena) of the term "anticipation" are intertwined; thus, narrow intensionality reveals less of the phenomenon it is meant to denote. Moreover, the intensional narrowness of the concept obscures the critical identification, analysis, and evaluation of some of the socio-epistemic mechanisms that come into play in anticipatory practices.

Given the problem of the narrowness of anticipation's definition, the purpose of this section is to elaborate the need to problematize, nuance, and expand the properties that are considered constitutive of anticipatory practices to expand the socio-epistemic and cognitive

elements and processes that are considered in characterizing anticipatory acts. To facilitate the problematisation of the key issues pointed by Adam and Groves (2007, pp. 17–19) and discussed in the previous section, this extension proposes to consider the basis of anticipatory practices in four rather than two socio-epistemic steps (Figure 2 represents a simplified scheme).

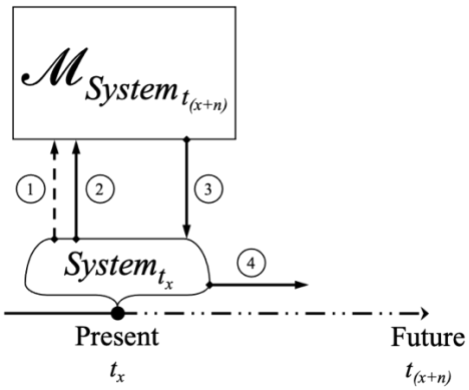

Figure 2. Scheme of anticipatory actions based on four socio-epistemic steps.

The *first component* or step of anticipatory actions is (1) the (co-)construction of the future model or scenarios ($\mathscr{M}$, or FS, as of "Futures Scenarios", from now on). For a model of the future to be used, it must first exist. Models or representations of the future must be created by specific actors (either locally or socially distributed, either by the same actors who will perform the anticipatory action or by others). For example, the creation of predictive models can be relatively easily attributed to a particular community of scientists. The origin of models such as sociotechnical imaginaries, visions, or expectations is more difficult to trace, as they tend to co-evolve dynamically and are collectively held. In any case, identifying the process of creation is crucial to determine which actors are reflected in these future models and what methods and procedures were used in their creation. They are identified to explain the presence of certain assumptions and values and clarify which aspects were considered (and why these and not others). In the umbrella example, this would entail recognizing and paying attention to the processes of creating the weather forecast.

The *second step* of anticipatory actions is (2) a mode of approach or engagement with the future model. Once the model is created, an actor or group of actors may engage with it. This engagement can take various forms. These forms are usually related to the character of the model in question (e.g. the denotative ambitions of the model, its normative or volitional force). For example, models of the future that are approached as scientific forecasts are often considered as if they actually are saying something about the future. In contrast, models approached as visions that point to a desirable future represent hypothetical goals toward which we should move (i.e. the future models act as a target for orienting action). The different modalities that engagements with the future take constitute different typologies of anticipation. In this step, it is important to address both the socio-epistemic mechanisms of trust and knowledge attribution underlying the engagements with the future model and the

kinds of commitments made towards it (e.g. what makes a future model to be deemed (im)probable, (im)plausible, and/or (un)desirable).

The *third step* of anticipatory actions is (3) the heuristic extraction of information from the future model. The extraction of information from a future model is not a straightforward and epistemically neutral process. It requires certain skills, such as focusing on certain pieces of information while discarding others. Moreover, this extraction may require the acceptance of certain assumptions that might otherwise be problematized. In the case of the umbrella example, the conclusion that the person should carry the umbrella stands only if the normative and volitional assumption that one should or wants to avoid rain (or get wet) is added to the information in the weather forecast announcing rain. Although this assumption may seem unproblematic in this context, these assumptions are of great importance in policy domains.

Finally, the *fourth step* of anticipatory actions consists in (4) translating the heuristics obtained from the future model into action. The possibility of implementing and executing an action can be enhanced or constrained by the context in which the action is embedded. Among the aspects that would require special attention here would be the gradients of effective success achieved by each anticipatory action. Which futures are most likely to be realized and why? Whose futures are these? A smooth and unhindered translation of a future into action within a sociotechnical system can be taken as an indicator of the hegemonic futures that symbolically and materially colonize that sociotechnical system.

These four abstract steps do not claim to be exhaustive or definitive. They are a simplification, and they maintain iterative dynamics in practice. The components and steps of anticipation outlined here can (and perhaps should) be problematized, nuanced, and expanded, both extensively (in terms of number) and intensively (in terms of the issues that should be considered in each of them). The extension presented here finds its most important consequence in extending the cognitive aspects and epistemological-political questions that can be considered when analysing and making the phenomenon of anticipation the object of study. By explicitly incorporating (1)–(4) into the definiens of the concept of anticipation, the chapter aims precisely to point to the need and relevance of considering issues of provenance, ownership, expertise, legitimacy, and socio-epistemic robustness when analysing anticipatory practices. This only points to the great fruitfulness of the phenomenon of anticipation and the great opportunity for social epistemology to critically contribute to the further development of Anticipation and Futures Studies.

3.5. Conclusions

Anticipation is a fundamental activity that permeates a wide range of actions by various entities, including those undertaken by humans. Our ways of planning ahead, our hopes for the future, and our ways of grounding decision-making on expert-based models of the future are forms of anticipation that shape our ways of living in the world. The production and

governance of scientific and technological knowledge and innovative practices, as forms of human social activity, are not alien to the phenomenon of anticipation. They are also imbued with the temporality of the future and, therefore, with the use of future representations. The proposal of Anticipation and Futures Studies is to focus analytical attention on how futures shape action, and the analytical tools proposed for this purpose can, indeed, complement and support recent proposals from Science and Technology Studies that point to the need to analyse, criticize, and modulate the performativity of sociotechnical futures (e.g. visions, imaginaries, expectations, and/or interventive exercises, such as future scenarios).

However, for the heuristic function that Anticipation and Futures Studies could potentially provide to be as socio-politically rich as possible, it would first be necessary to reconsider and expand the socio-epistemic practices that are considered when looking at human anticipatory behaviours. In this chapter, the basic concept of anticipation used by Anticipation Studies was closely reviewed. It was argued that the concept of anticipation suffers from an ambivalence regarding its binding power when applied to systems of human behaviour.

In particular, it has been argued that the concept of anticipation is, on the one hand, too narrow, as it does not capture the diversity of cognitive and socio-epistemic processes involved in human anticipatory actions. By limiting anticipation to two basic socio-epistemic steps, the basic definition of anticipation passively restricts the practices that are considered the objects of analysis in the study of anticipatory behaviour and, thus, the scope of possible criticism. The narrow nature of the definition of anticipation is thus not conducive to unleashing the full heuristic potential, it might have to make visible the constitutive processes of the anticipatory activities under analysis. On the other hand, the notion of anticipation that underlies anticipation studies is too loose when it comes to describing its specificity. Since belief systems and desires about the past, present, and future are intertwined, and all human actions are directed toward the future, all human actions could be considered anticipatory. This assumption has consequences for anticipation research: While it underscores the ubiquity of anticipation (and thus the relevance of its consideration and study), it may also complicate the justification of the distinctiveness of anticipation (and thus the justification for making anticipation research a scientific discipline).

While the problem of the loose nature of the concept is left in the chapter as a challenge for the future, the problem of the narrow nature of the concept has been addressed by proposing an extension of the socio-epistemic processes considered in explicit human anticipations. This extension consists in articulating anticipation in four steps instead of two basic socio-epistemic steps. Anticipation is no longer considered as the use of future model and its translation into action but as an activity consisting of the following steps: (1) The creation of a representation that evokes future states of a system (whether or not it originates from the same subjects who subsequently use it); (2) some kind of cognitive engagement with that future; (3) the heuristic extraction of relevant information for decision-making; (4) the translation of the extracted information into action. Each of these socio-epistemic

activities can take on different modalities, which in practice complicates the cognitive mechanisms and aspects considered in each of these stages.

The goal of this extension is to bring nuance to the aspects explicitly considered by Anticipation Studies in defining and analysing anticipatory human behaviour. The extension of the concept makes visible the performativity and normative power of the basic concept of anticipation. In particular, the basic concept of anticipation forces us to ask two general questions, "What future conception/model is used?" and "How does it influence action in the present?". In contrast, the concept presented here extends these considerations by explicitly including questions such as "Who created these representations and under what socio-epistemic conditions/assumptions?"; "What aspects do these future models represent, what assumptions do they contain?"; "How do actors engage with these future models (i.e. what modalities do these engagements take, what are the epistemic, political and normative commitments towards this future models)?"; "What information did subjects focus on in relation to these future models, what heuristics were extracted, and how?"; and, "In what processes and according to what criteria was this information assessed, evaluated, extracted, and translated into action?". In other words, the expansion of the concept implies an expansion of the potentially problematic socio-epistemic milestones that constitute anticipatory behaviours and actions and, thereby, also implies an expansion of the socio-epistemic and political issues that can be considered by Anticipation and Futures Studies when analysing anticipation.

Apart from the consequences that the extension of the concept presented here may have for Anticipation and Futures Studies when analysing and evaluating anticipations, it is interesting to note that this extension also has great instrumental value for the purposes pursued in this second part of the dissertation: clarifying the concept of anticipation as an interventive tool for AG, RRI, RI, and TA. Specifically, the concept of anticipation developed here will be used in the following chapter to identify the different ways of engaging with the future that AG, RRI, RI, and TA seek to activate. This identification will also allow for a characterisation of the heterogeneous types of anticipation that are sought to be activated to promote more responsible STI, as well as their associated challenges. The recognition of heterogeneity, as we will see in Chapter 4 below, is also particularly important in addressing particular critiques of particular uses of the future. Moreover, the identification and mapping of forms of engagement with the future and its associated challenges, made possible by the expansion of the basic concept of anticipation undertaken in this chapter, will in turn be key to the analysis of the forms of operationalisation of anticipation presented in Chapter 7.

CHAPTER 4

Responsibility through anticipation? The "future talk" and the quest for plausibility in the governance of emerging technologies

This chapter is a slightly modified version of the article **Urueña, Sergio** (2021). "Responsibility through Anticipation? The 'Future Talk' and the Quest for Plausibility in the Governance of Emerging Technologies", *NanoEthics, 15*, 271–302. doi: 10.1007/s11569-021-00408-5. It has been reproduced here with the permission of the copyright holder.

Abstract In Anticipatory Governance (AG) and Responsible Innovation (RI), anticipation is a key theoretical and practical dimension for promoting a more responsible governance of new and emerging sciences and technologies. Yet, anticipation has been subjected to a range of criticisms, such that many now see it as unnecessary for AG and RI. According to Alfred Nordmann, practices engaging with "the future", when performed under certain conditions, may reify the future, diminish our ability to see what is happening, and/or reproduce the illusion of control over the future. Several authors have stressed that these critiques fail to capture the heterogeneous character of anticipatory practices, and yet the question of what particular kind of socio-epistemic engagements with "the future" AG and RI aim to enact through anticipation remain fragmentary and their underlying rationale under-theorised. This chapter aims to advance the theoretical characterisation and problematisation of anticipation as a key interventive tool for AG and RI. By distinguishing between four modes of anticipation and heuristically testing them against Nordmann's critiques, the chapter argues that despite his assessment failing to recognise the heterogeneity of anticipatory practices considered valuable for AG and RI, it reinforces the relevance of performing critical-hermeneutic modes of anticipations. Thus, anticipation continues to be a necessary heuristic dimension for AG and RI. More concretely, the chapter maintains that such anticipatory heuristics may find their radical constructive and critical-reflective character in the dynamics of inclusive scrutiny and negotiation about the (im)plausibility and (un)desirability of the envisioned or (co-)created futures.

4.1. Introduction

The future has always been used in the responsibilisation of technological development. However, we have recently seen a growing call for responsibilising through anticipation. Different normative frameworks and interventive proposals—each with their own distinctive (though sometimes overlapping) rationales—recognise "anticipation" as a useful interventive tool for promoting a more responsible development of New and Emerging Sciences and Technologies (NESTs) from early stages of development, when epistemic and normative uncertainty and ignorance challenge their assessment and governance (e.g. Boenink, 2013; Brey, 2012; Grunwald, 2019b; Guston and Sarewitz, 2002; Swierstra et al., 2009; von Schomberg et al., 2006).

Two recent umbrella frameworks that highlight the need of anticipation are Anticipatory Governance (AG) (Barben et al., 2008; Guston, 2014; Karinen and Guston, 2009) and Responsible Innovation (RI) (Owen et al., 2012; Owen and Pansera, 2019; Owen et al., 2013; Stilgoe et al., 2013). Through an inclusive engagement (in terms of knowledges and actors) with representations of "the future", AG and RI aim to enable a range of capacities to the constellation of social actors that constitute the innovation co-production network, and thereby facilitate more self-reflexive and responsive ongoing STI practices.

However, this incipient call for anticipation has not been accompanied by a specific and systematic conceptual treatment of this socio-epistemic practice within AG and RI literature. Presentations of "anticipation" usually contain brief and nebulous characterisations, allusions to heterogenous existing methodologies/techniques, and brief mentions of their miscellaneous and general expected functional heuristics (Chapter 2, Table 5). For instance, anticipatory exercises are expected, among other things, to facilitate public engagement, increase resilience, foster critical appraisal of visions and promissory statements, or enhance understanding of the contingent and indeterminate innovation pathways and their associated potential impacts (Barben et al., 2008, pp. 985–986; Owen and Pansera, 2019, p. 31). What all these heterogeneous practices have in common, such that they are referred to as "anticipatory", and what analytical prescriptions toward "the future" anticipatory exercises require to enact all these heuristics are issues that remain only sketched and under-theorised (Guston, 2013, p. 110) (Section 2.4.2).

Different prescriptions of what to do analytically with "the future" can articulate different paradigms of responsibility (Adam and Groves, 2007, 2011). In addition, intuitions about the concept of anticipation are in general poor (the mainstream way of approaching the future is as an arena awaiting to be epistemically conquered or strategically designed). In this light, it is crucial to move forward and elucidate the minimal features of anticipatory practices, the kind of socio-epistemic dynamics and heuristics that are possible to enact through these exercises, and which of these are desirable and worth pursuing (and how) for AG and RI. The results can also be extrapolated to other recent frameworks such as Responsible Research and Innovation (RRI) and Technology Assessment (TA).

This chapter aims to advance the theoretical characterisation and problematisation of anticipation as a legitimised heterogeneous interventive tool for encouraging a more inclusive and responsive development of NESTs. For this purpose, I will consider Alfred Nordmann's assessments of the possible shortcomings of certain practices engaging with "the future" as a valuable theoretical instrument for exploring the potential virtues and limits of certain anticipations. Because Nordmann's criticisms pose relevant questions for the very foundations and limits of anticipatory practices, a critical dialogue with his arguments can only help to assess the underlying legitimising rationale of anticipations.

Among other criticisms, Nordmann argues that practices engaging with "the future" (i.e. the "future talk"), *when performed under certain conditions*, may (i) reify certain future perspectives (e.g. propagating deterministic visions) (Nordmann, 2007), (ii) diminish our ability to see what is happening, and/or (iii) (re)produce the illusion of control over the future (Nordmann, 2013a, 2014). While the first critique was specifically directed towards the anticipatory *modus operandi* of speculative ethics—it was never directed towards AG and/or RI as such—the target of the latter two criticisms was anticipation as a tool for AG and RI. These last two criticisms served as premises for Nordmann to conclude that anticipation is not a necessary part of AG and RI (Nordmann, 2014, p. 87).

While I agree with Nordmann on many points of his critiques—and even more so with his underlying concern about the dangers of misusing "the future"—I do not support his conclusion. This is not to say that his arguments are invalid, but rather that his diagnosis of the value of anticipations for responsibilising the governance of innovation is constructed over a narrow concept of anticipation. His concept does not capture the socio-epistemic heterogeneity of these practices, and thus their functional diversity for AG and RI umbrella frameworks. In other words, I agree with Nordmann that anticipations, *as he conceives of these practices*—i.e. as «a kind of preparedness that is based on knowledge of what may come in the future» (Nordmann, 2014, p. 87)—can lead to the problems he identifies. However, the issue at stake is whether anticipation is (or should be) understood in that way within AG and RI.

In this respect, it is no coincidence that the brief and immediate reactions to Nordmann's critiques coming from AG and RI scholars were primarily focused on his expectations regarding anticipation. Specifically, the responses suggested that the heuristics they were seeking to achieve through foresight and anticipatory exercises were substantially different from those Nordmann assumed (Boenink, 2013; Guston, 2013; Selin, 2014; van der Burg, 2014). However, these responses did not explicitly provide a basic conceptualisation and theoretical categorisation of "modes of anticipation" and a discussion of the value of their respective possible accompanying heuristics for AG and RI, as is my intention here. For instance, Simone van der Burg (2010, 2014) stresses that instead of knowledge about the future, anticipation is used as a reflective, meaning-giving function to prevent decisions from being taken blindly. Marianne Boenink (2013) argues that anticipatory practices, such as sociotechnical or techno-moral scenarios, do not aim to predict but rather emphasise contingency (although, as she stresses, to achieve this, they should be carefully executed).

Cynthia Selin (2014) laments Nordmann's lack of background in Futures Studies when it comes to characterising anticipation (a discipline in which the various uses of the future are systematically investigated alongside interventive anticipatory methods with different rationales and goals).

Both Nordmann's narrow characterisation of anticipation and the lack of an explicit basic systematisation of what modes of anticipation exist point to an ongoing need to articulate, discuss, and/or reinforce how anticipation can (and/or should) be understood within AG and RI, and to adequately address the challenges arising from its theoretical characterisation and practical operationalisation. My argument is that it is precisely the deficiencies attributed by Nordmann to the "future talk" (and his underlying worries about misuses of "the future") that AG and RI seem intent on counteracting through the performance of certain types of anticipations. Therefore, his criticism, instead of showing that anticipation is unnecessary, reinforces the legitimacy of performing certain types of anticipatory exercises (while at the same time warning of the possible pitfalls of others). For instance, "anticipation" and "foresight" are broad enough to subsume exercises that Nordmann himself seems to consider valuable—without conceiving of them as "anticipations"—such as (non-speculative) "thought experiments" (Nordmann, 2014, p. 91) and "vision assessment" (Nordmann, 2013b).

The argument of the chapter unfolds as follows. After this introductory section, I briefly contextualise the emergence of AG and RI discourses and outline the different layers in which "the future" becomes an important element for them (Section 4.2). Next, I take some initial steps towards a more explicit conceptualisation of anticipation as an interventive tool and its socio-epistemic functionalities by distinguishing four approaches to our representations of the future, each of which articulates a different general mode of anticipation. These approaches are the predictivist, strategic, exploratory, and critical-hermeneutic (Section 4.3). Then, I revisit Nordmann's three critical arguments against the "future talk", examining to what extent each of these threaten the legitimacy of the modes of anticipation considered valuable for AG and RI. Concretely, I will show that despite Nordmann's assessments failing to recognise the heterogeneity of anticipatory practices considered valuable for AG and RI, a number of valuable lessons can be drawn from his criticisms. In particular, these criticisms help us to clarify why we need to focus on the constructive dynamics articulating anticipatory practices and to support critical-hermeneutic anticipations as a robust and key element in making discourses and practices that engage with futures a legitimate part of "responsibilisation" (Section 4.4). I then note how many of the worthwhile critical-hermeneutic anticipatory heuristics for AG and RI practices would find their radical and critical-constructive character in the dynamics of inclusive scrutiny and negotiation about the plausibility and desirability of futures (Section 4.5). The chapter ends with some concluding remarks (Section 4.6).

4.2. NESTs "responsibilisation" and the challenges of anticipation

The use of representations of the future to support more responsible technological development has been a constant feature of Technology Assessment (TA) approaches since their inception (Coates, 1971; Enzer, 1972; Rip et al., 1995). However, our understanding of what is considered "being responsible" in STI contexts and the approaches towards temporality in the attempt to cultivate this responsibility have been (and continue to be) refined (Arnaldi and Bianchi, 2016). Nowadays, different discourses of responsibility co-exist, each with their own (sometimes overlapping) ways of engaging with the past, the present and the future.

For instance, and summarising the results of Chapter 2, TA's initial attempts in the mid-1960s aimed to encourage responsible development of technologies on the basis of *external* and expert-based cost-benefit analysis supported by statements regarding the likely future ("hard") *impacts* of a technology (e.g. the US Office of Technology Assessment) (Van Eijndhoven, 1997). TA aimed to provide policy makers with "objective" and "value-free" information of the future likely impacts of technological developments, thus only indirectly intervening in decision-making processes. However, early on, this expertocratic, positivist, and predictivist conception of TA was called into question in response to a range of historical and intellectual changes and societal challenges (Grunwald, 2009a). On the one hand, the restriction of the assessment activity to experts was soon challenged when new forms of TA (e.g. participatory TA) stressed the need to involve stakeholders or citizens and to take into account their different perspectives and values. On the other hand, the Collingridge dilemma (1980)—which is widely mentioned and often wrongly conceived as a problem to be overcome (Nordmann, 2010)—stressed our epistemic precariousness when trying to influence technological change (given the recognition of its indeterminate and non-lineal character): It is precisely at the stage of development when we are most likely to influence STI in order to avoid technology's uncritical entrenchment, or lock-in (Arthur, 1989), that uncertainty and ignorance obstruct the possibility of illuminating the possible consequences and action horizons that might arise from them (Collingridge, 1980).

Recognition of this epistemically precarious state, together with the more nuanced and complex understandings of the messy and multidimensional constellation of processes constituting the de facto governance arrangements of science and technology presented by Science and Technology Studies (STS) (Fuglsang, 2001; Godin, 2006; Irwin, 2008; Jasanoff, 1996; Rip and Kemp, 1998), did not relieve subsequent TA approaches of their impetus to promote a responsible development of NESTs from early stages through representations of the future (i.e. through anticipatory practices).

A clear example is Constructive TA (CTA). CTA emerged in the mid-1980s in the Netherlands (the Netherlands Organisation of Technology Assessment) as a «new design practice» (Schot and Rip, 1997, p. 255) built on a "coevolutionary" conception of science-society relationships. Although CTA shifted the focus away from "likely future impacts", it adopted anticipation as an instrumental tool for participatively and proactively enhancing

reflexivity within the design, development and implementation processes (Rip et al., 1995). In this vein, CTA proposed to build «TA activities *into* the actual construction of technology», during the ongoing «coevolution» between science and society (Schot and Rip, 1997, p. 252). Sociotechnical scenarios are interventive anticipatory exercises considered favourably by CTA to promote social learning and reflexivity (te Kulve and Rip, 2011) and to expand "endogenous futures" (Rip and te Kulve, 2008).

Another noteworthy aspect of CTA is that it not only incorporated anticipation as a non-predictivist interventive methodology, but also considered anticipatory dynamics (e.g. expectations, visions, future imaginaries) as a constitutive guiding force in science and technology co-production processes:

> Co-production processes include anticipation. Technical change is driven partly by the historical experience of actors, their views of the future, and their perception of the promise or threat of impacts which will change over time (Schot and Rip, 1997, p. 257).

Early contributions in STS and the sociology of expectations helped to formulate and reinforce this diagnosis (Borup et al., 2006; van Lente, 1993; van Lente and Rip, 1998a, 1998b), and fuelled the need to amplify the repertoire of TA methods engaging with futures by including, for instance, vision assessment (Coenen and Simakova, 2013; Grin and Grunwald, 2000; Nordmann, 2013b). Thus, CTA already reflected the two interrelated dimensions under which anticipatory phenomena are understood today, i.e. as interventive tools and as anthropological and sociological phenomena that, among many other influences, shape the teleology of our actions (Bryant and Knight, 2019; Konrad et al., 2016).

In critical dialogue (and quite a lot of overlap) with CTA, David H. Guston and Daniel Sarewitz (Guston and Sarewitz, 2002) proposed in the early 2000s to develop Real-Time TA (RTTA). The main innovation of RTTA with respect to CTA—beyond some differences in their interventive techniques and operative methods, see (Guston and Sarewitz, 2002, pp. 100–106)—is that RTTA ambitiously and radically proposes to embed TA *within* the knowledge co-production processes themselves. More concretely, it aims to build up actors" capacities for action «on synchronous reflection and adjustment» (Guston and Sarewitz, 2002, p. 100) by integrating sociotechnical mapping and dialogue with retrospective (analogies) and prospective (foresight) analysis. RTTA aims to integrate scientific-technical research with social sciences and humanities from the outset, thus making inherent to STI practices the project that emerged in the 1990s of addressing their ethical, legal and social implications/aspects (ELSA/ELSI) (Zwart and Nelis, 2009).

The previously depicted—inevitably inexhaustive and simplified—trajectory of TA may serve to illustrate the radicalisation that had arguably taken place regarding what it is "to be responsible" within the normative and interventive frameworks of science, technology and innovation. This radicalisation refers to at least four issues: (i) What aspects of STI are the subject of analysis (e.g. from the impacts of technologies to the whole innovation process); (ii) when these aspects are problematised; (iii) which agents come into play when assessing and responsibilising STI (from experts to distributed co-production and

responsibilisation); and (iv) the position of TA with respect to STI enterprises (from a TA isolated from STI, or a TA whose experiments *feed into* STI, to a TA that aims to be systematically integrated *from within* the constellation of co-production processes themselves). In all these processes and discourses, the engagement with "the future" is in one way or another understood as an instrument of great heuristic value for orienting actions. In fact, TA approaches currently recognise anticipation as a key operational dimension for enhancing reflexivity (Grunwald, 2019b): "The future" is used as both a multi-directional method (Tran and Daim, 2008) and an object of investigation (Bechtold, Fuchs, et al., 2017).

AG (*ca*. 2008–) and RI (*ca*. 2011–) can be situated within this general trajectory of broadening the responsibilisation of STI governance while maintaining this future-oriented character. Both frameworks are rooted in previous TA approaches[49] and in other STS-related interdisciplinary fields concerned with public engagement and the increase in legitimacy of world-making processes (e.g. environmental studies, science policy). Moreover, they both emerged in response to a number of institutional needs[50] and scholarly and policy opportunities. For instance, the Center for Nanotechnology in Society at Arizona State University (CNS-ASU), whose strategic guiding vision was to foster the AG of nanotechnologies, was funded by the National Science Foundation «to facilitate nanotechnology funding policies in the US» (Kuhlmann et al., 2019, p. 1094). At the same time, it embodied the conviction within the STS community that the emergence of nanotechnology provided an *opportunity* to "test" the scope and limits of promoting a more inclusive or democratic governance of a NEST from the outset.

AG and RI are considered "umbrella frameworks" precisely because they attempt to ambitiously embrace and systematise a great diversity of existing approaches and techniques (Grunwald, 2011, pp. 16–17). They also strive to respond to a number of evolving challenges identified in various academic and institutional domains with regard to innovation governance. As noted in Chapter 2, one of the most basic challenges of AG and RI (and also of RRI and recent forms of TA) is to address the Collingridge dilemma by supporting *early and extended social intervention* (Genus and Stirling, 2018). In order to avoid uncritical sociotechnical entrenchment, early social intervention throughout the whole STI process is recommended. The early intervention has to be «well-timed so that they are early enough to be constructive but late enough to be meaningful» (Stilgoe et al., 2013, p. 1571). It conveys that future-making practices performed in the present should not be discounted or left to

[49] While the influences of RTTA and other approaches on AG are clear given the involvement of David H. Guston in the conception of both approaches (Barben et al., 2008; Guston, 2014; Karinen and Guston, 2009), in the case of RI the influence of CTA, RTTA (and even AG) is explicitly stated (Owen et al., 2012, pp. 751–754; Owen and Pansera, 2019, p. 28).

[50] The emergence of nanotechnology was fraught with uncertainties and institutional concerns about its public perception and acceptance. Considering earlier impasses with other NESTs (e.g. genomics), the demand for inclusive and responsible governance by institutions from the United States and Europe was instrumentally increased. As Arie Rip notes, "nanophobia-phobia" could be found in many discourses (Rip, 2006, p. 350).

chance, but rather collectively problematised and its possible alternatives kept open in order to facilitate the modulation of technology.

Arguably, AG and RI intend to respond comprehensively to the Collingridge dilemma by addressing the following three concrete and interrelated challenges—all of which contain a direct or indirect appeal to the future, and many of which overlap with those previously recognised for TA proposals, see Grunwald (2009a, p. 1103):

I. *Socially-robust risk research*: This alludes to the challenge of conducting risk assessment processes in a comprehensive manner. This comprehensiveness concerns both the outcomes—i.e. the consideration of possible so-called "hard" and "soft" (Swierstra and te Molder, 2012) as well as "positive"/"right" and "negative" (von Schomberg, 2014) impacts and aspects—and the procedures—i.e. the treatment of how those impacts and aspects are addressed in relation to normative concerns such as the purposes or motivations of research. This requires sociotechnical integration in STI processes. "The future" appeals to the different ways in which innovation could influence how sociotechnical and techno-moral systems co-evolve.

II. *Political radicalisation and upstream public engagement*: The goal here is to address STI *processes* and *purposes* through inclusive deliberation in order to align STI dynamics with the interests and values of societal actors. Here "the future" is understood as an arena pregnant with possibilities and projects of socio-political nature.

III. *Performativity of promises and hype on NESTs*: The not-yet-existing temporal character of NESTs situates them in a space that is deeply anchored in promises and imagined (speculative) futures (Brown et al., 2000, p. 1570; Jasanoff and Kim, 2015). AG and RI—following Vision Assessment approaches (Grunwald, 2009b)—propose to critically engage with existing promises, expectations, imaginaries and visions to prevent them from blindly and illegitimately influencing decision-making and the purposes, motivations and ends of innovation (e.g. by shaping the agenda and allocation of recourses). "The future" refers here to all those representations and discourses of the future that overwhelm the present and narrow the space for alternative actions (e.g. by creating a form of tunnel vision).

In addressing these challenges, both frameworks propose a series of elements or dimensions that function as *procedural norms*. Innovation processes or systems are considered more or less responsible depending on the degree to which they continually unfold by meeting these procedural norms. These elements or dimensions must be understood in an integrated or assembled way. Although all of these dimensions are necessary, none of them alone is sufficient; they all are co-dependent and they mutually reinforce each other (see Table 7).

Table 7. Elements of AG and dimensions of RI.

Anticipatory Governance		**Responsible Innovation**	
Element	*Description*	*Dimension*	*Description*
Foresight	It «aims to enrich futures-in-the-making by encouraging and developing reflexivity in the system» (Barben et al., 2008, p. 986)	Anticipation	It «involves systematic thinking aimed at increasing resilience, while revealing new opportunities for innovation and the shaping of agendas for socially-robust risk research» and «to consider contingency, what is known, what is likely, what is plausible and what is possible» (Stilgoe et al., 2013)
Integration	The objective is to connect engineers, natural scientists, social scientists and humanists in order to work "together in dialogue" during the ongoing innovation processes	Reflexivity	It means «holding a mirror up to one's own activities, commitments and assumptions, being aware of the limits of knowledge and being mindful that a particular framing of an issue may not be universally held» (Stilgoe et al., 2013, p. 1571)
Engagement	The aim is to enhance the interaction between different societal actors and expertise in order to raise awareness of others" activities and roles, promote knowledge exchange…	Inclusion	It implies the embracing of new voices in the governance of science and innovation practices. Inclusion processes aim to "open up" framing issues while considering questions of legitimacy and power
Ensemblisation	The objective is to combine all the previous elements in order to enhance the reflexive capabilities that defines AG	Responsiveness	It involves «a capacity to change shape or direction in response to stakeholder and public values and changing circumstances» (Stilgoe et al., 2013, p. 1572)

Source: (Barben et al., 2008; Foley et al., 2018) (AG), and (Stilgoe et al., 2013) (RI).

The previous four dimensions/elements co-configure a guiding principle for action. Echoing previous proposals (e.g. Dupuy and Grinbaum, 2004), AG and RI endorse a concept of responsibility that is considered "future-oriented" and normatively procedural in character (i.e. it is not based on substantive norms or values). The substantive values are expected to emerge from the very processes of ongoing inclusive experimentation and deliberation (in a bottom-up mode). Based on the constructivist consideration that innovation is a world-making force (Jasanoff, 2016), and that it shapes present and future possibilities, the idea of AG and RI is to proactively and collectively assume "the threads of innovation" (within our significantly restricted capacities and considering our available resources). For instance, RI is explicitly defined as «taking care of the future through collective stewardship of science and innovation in the present» (Stilgoe et al., 2013, p. 1570).

Therefore, the future is involved in AG and RI both in the challenges they seek to address and in their underlying concept of responsibility (through the anticipatory element). However, that concept of responsibility is recognised as being somewhat general and vague, and «unresolved in terms of its political, institutional and normative imaginaries and practices» (Owen and Pansera, 2019, p. 27). This vagueness and unresolved character affects (and at the same time is affected by faintly detailed characterisations of) anticipation: What kind of procedural socio-epistemic mechanisms are (not) considered when characterising anticipation in the foundational texts of these frameworks? What engagements with "the

future" do they seem to promote? The following section provides a more detailed (though still preliminary) answer to these questions, distinguishing between four different general modes of anticipation considered (un)favourable for AG and RI.

4.3. On four approaches to "the future" and four corresponding modes of anticipation

The founding texts of AG and RI contain both negative and positive characterisations of "anticipation" and "foresight". These characterisations are usually brief and place particular emphasis on the methods/techniques by which the anticipatory dimension could be operationalised and/or the heuristics intended to be achieved. These considered methods and heuristics are heterogeneous and, in some cases, have little in common (each embracing distinct rationales and prescriptions on how to approach and what to do with "the future").

In this section, and after departing from the concept of anticipation developed in Section 3.4, I will distinguish—without supposing any exhaustiveness and typological rigidity—four distinct analytical approaches to representations of the future, and four corresponding modes of anticipation that are implicitly considered (un)favourable within AG and RI's foundational texts. These are: The *predictivist* (4.3.1), *strategic* (4.3.2), *exploratory* (4.3.3), and *critical-hermeneutic* (4.3.4).

The purpose of this elucidation is twofold. On the one hand, I attempt to continue moving towards a more explicit characterisation of interventive anticipations. On the other hand, I want to emphasise that anticipatory practices are heterogeneous in nature. Recognition of this heterogeneity ought to be a starting point when assessing the virtues and/or limitations of interventive anticipatory practices in support of AG and RI.

"Anticipation" is considered within Futures and Anticipation Studies as an activity characterised by the use of a future representation, or a future scenario (*FS*), (consciously or not) in order to guide actions in the present (Miller, 2018; Poli, 2019a). Anticipatory exercises are typically characterised as consisting of «two elements: a model and its translation into action» (Poli, 2019b, p. 14).

Anticipation co-exists as both a sociological and/or anthropological de facto phenomenon (e.g. countless of our individual and social actions are based on visions, expectations, and other images of the future) and a tool for intervention (e.g. forecast and foresight practices) (Konrad et al., 2016). Through foresight and anticipation, AG and RI—as well as other STS scholars—aim to *intentionally* intervene and mobilise (e.g. study, criticise, enrich, complexify) the constellation of *FSs* at stake that constitute the de facto anticipatory dynamics of innovation.

The more than 35 methods currently existing within Anticipation and Futures Studies (Glenn and Gordon, 2009) illustrate that the "uses" of *FSs* are manifold. The different possible epistemic, normative, and/or ontological approaches to *FSs*, as well as the different

processes and ends that could be pursued through their use, could articulate different modes of interventive anticipation and produce different kind of anticipatory heuristics. These heuristics, in turn, can be functional in certain application contexts, but not in others.

The multifaceted nature of anticipation highlights the need to further elaborate the previous minimum definition based on "two elements". As argued in Chapter 3 (Figure 2), anticipatory practices require the execution of at least the following four basic socio-epistemic steps:

Step 1. *Construction of* FS: In order to "use" an *FS*, it must first be created (regardless of whether the *FS* is produced by the same agents that will translate it into action). The process of constructing *FSs* is influenced by a wide range of interrelated factors (e.g. the (quality of the) information considered, the methodology employed, the future timeframe chosen, the objective(s) pursued, the actors involved).

Step 2. *Interaction (approach and engagement) with* FS: The engagement with *FS* can be undertaken from several perspectives and adopt different modalities. The different possible affective, moral, and/or epistemic dispositions that might govern the interaction with *FS* configure different modalities of anticipation (each of which could have its specific role within specific STI phases, areas, and dynamics). For example, the *FSs* produced through scientific forecasting methods are typically approached as robust representations of what is likely to be the case, while the *FSs* produced by science-fiction writers tend to be interpreted as socio-cultural expressions.

Step 3. *Extraction of information/heuristics from* FS: The interaction with *FS* enables the subsequent "extraction" of information/heuristics considered relevant for guiding or directing action in the present.

Step 4. *Translation of information/heuristics into action*: Once information has been extracted, it is interpreted and translated into action (with more or less strength and success).

These four basic steps are interrelated in a complex and iterative way (e.g. the operationalisation context and the goal(s) pursued may *ex-ante* constrain how *FS* should be constructed, approached, and what information counts for illuminating action). An adequate coordination between all the steps is considered a necessary (but not sufficient) condition for effective interventive anticipatory practices.

In the following subsections, I will distinguish four general approaches to *FSs* that articulate different co-existing modes of performing anticipation: The *predictivist*, *strategic*, *exploratory*, and *critical-hermeneutic*. In doing so, I do not intend to be exhaustive. Indeed, there might be different overlaps and combinations of the identified modes of anticipation. To extend, develop, and refine this classification by considering these possible combinations and other important variables—e.g. actors involved, timeframes, purposes, iterative processes and feedbacks, etc.—would exceed the limits of this chapter.

The four approaches could be placed on a gradual scale, ranging from those "representational and projective", where the focus on *FSs* lies in their projective or representational force (i.e. in the causal chains or images of the future they depict), to those "meta-representational and reflective", where the focus on *FSs* lies in their underlying socio-political, ethical, and epistemic assumptions and/or its (co-)production processes. In this sense, "meta-representational" approaches to *FSs* introduce a second-order reflexivity into "representational and projective" anticipatory practices (Miller, 2015) (see Table 8).

Table 8. Four general modes of anticipation and their corresponding challenges for responsibilising STI.

	Modes of anticipation		Construction and approach to *FS*	Approach to uncertainty	Epistemic source	Examples of expected heuristics	Examples of practices where they are considered	Challenges
Representational – Projective	**Predictivist**		Constructed and/or approached as a representation aimed at depicting what the future state will (not) be or what it is (un)likely to be	Minimising uncertainty	*FS*	Information regarding the impacts that a technology will / is likely to produce When combined with strategic anticipations: precautionary, adaptive, and/or mitigation plans	Early versions of TA Mainstream risk assessment	--
	Strategic		Constructed and/or approached as future-target that *should* be achieved or avoided (proactive strategies) or that which we must adapt (reactive strategies)	Minimising uncertainty	Causal chains pointing to *FS*	Information regarding plausible and (un)desirable causal chains reaching target futures: goal- and process-oriented knowledge Identification of key sociotechnical drivers Action guidelines for matching short- and/or long-term innovation goals Optimisation of time and resources in STI Planning and strategic knowledge in STI agendas	Early versions of TA Mainstream risk management Strategic STI policy planning RI (e.g. scenario planning)	II
Meta-representational – Reflexive	**Exploratory**	**Product-based**	Constructed and/or approached as one of the multiple plausible and/or (un)desirable future states that might (not) be derivable from an initial scenario (ideally the present)	Embracing or extending uncertainty	Set of plausible and/or (un)desirable *FS*s Diverse causal chains pointing to diverse *FS*s	Identification and information of alternative sociotechnical or techno-moral development paths Enhancement of technical, moral, and political imagination	Constructive TA (e.g. sociotechnical scenarios) AG (e.g. prospective Life-Cycle Assessment) RI (e.g. sociotechnical and techno-moral scenarios)	I, II
		Processual			Processes of collectively constructing and/or assessing a set of plausible and/or (un)desirable *FS*s	Knowledge emerged from co-creating and/or co-negotiating a future's plausibility and (un)desirability Diagnosis of the diversity of existing sociotechnical visions and imaginaries Responsiveness to the different contemporary values, frames, motivations, socio-political projects, etc., that co-exist around NESTs Awareness of the openness and contingency of STI practices	Constructive TA (e.g. sociotechnical scenarios as a means for social learning) AG & RI (e.g. future scenarios as input for public engagement)	I, II
	Critical-hermeneutic		Approached and scrutinised as a socio-epistemic product that has been co-constructed by specific societal actors, through certain processes, on the basis of certain assumptions, etc.	Politicising uncertainty	Processes of deconstructing the underlying assumptions of *FSs* and/or of their co-constructions/co-assessment processes	Knowledge emerged from critically analysing and reflecting on (i) the political-epistemic assumptions underlying existing *FSs* and/or (ii) the dynamics of their use, (co-)construction, and (co-)assessment Diagnosis of the diversity of existing assumptions and values underlying visions and imaginaries of the future (*FS* could reveal what those actors (do not) know / think / desire / feel in the present) Reflexive and critical capacities regarding contemporary assumptions, and socio-political projects that co-exist around NESTs Critical sense-making of the ways we construct, use, and assess representations of the future ("Futures Literacy")	Constructive TA (Vision Assessment) Governance *of* and *by* expectations Hermeneutic TA (e.g. hermeneutic circle analysis) RI & AG (Vision Assessment)	III

4.3.1. Anticipation and robust epistemic models of the future: The predictivist approach

The customary way of understanding anticipation is as an activity consisting of providing orientation on the basis of prospects of the future (i.e. on the basis of an *FS* constructed and approached as a forecast or prognosis) [Steps 1 & 2]. The information represented in *FS* is then analysed [Step 3] and translated into action in order to either minimise, avoid, or accelerate/optimise the occurrence of the forecasted impacts [Step 4].

A common example of this mode of anticipatory action would be to pick up an umbrella after seeing in the weather forecast that it will most likely rain.[51] In the context of NESTs assessment, the predictive *FSs* are expected to provide accurate knowledge regarding the probable impacts that a technology could produce if implemented. This anticipatory *modus operandi* prevails in mainstream risk assessment practices and, as briefly mentioned in Chapter 2, it was considered functional within classic TA approaches (e.g. *FSs* are used as input information for supporting subsequent cost-benefit analysis and/or creating precautionary, adaptive, and/or mitigation strategies).

Despite the well-known benefits of forecast models for optimising decision-making, there are nevertheless some weaknesses when they are broadly applied for comprehensively governing innovation (Jasanoff, 2003, p. 238). On the one hand, there are concerns about the epistemic feasibility of forecasting. Forecasting and predictivist approaches require uncertainty to be managed and minimised as much as possible (instead of treating it as a constitutive feature of the target systems) (Sarewitz et al., 2000). The management of uncertainties regarding the development and coevolution of NESTs is frequently limited or impossible (e.g. the case of nanotechnology), and predictive practices usually cannot deliver their expected outcomes. This is especially the case when the focus shifts from the "hard" to the so-called "soft" impacts (Swierstra and te Molder, 2012) and more holistic issues are included into the equation (e.g. the relationship between humanity and technology), as these are impossible to predict (Dupuy, 2007; Dupuy and Grinbaum, 2004).

On the other hand, articulating the interventive governance of innovation on predictivist anticipations is politically problematic. For instance, these exercises *on their own* do not directly address the relative openness of the future and the socio-political constructive dimension of sociotechnical systems, often reproducing linear or deterministic conceptions of STI development. Decision-making practices based solely on scientific-technical prognosis often fail to account for the fact that innovation and technological development are themselves a socio-political matter of concern and not just a technical matter of fact

[51] Any predictive anticipation has to be combined with a strategic anticipatory practice and normative statements to meaningfully transfer the information extracted from the *FS* model into practice. To act in the way depicted by the example would require one to assume the normative stance that "a future in which one gets wet from the rain is not desirable and should therefore be avoided". This simple and trivial example shows the possible co-existence and complementarity that exist between different modes of anticipation. The sequence in which the modes of anticipation are integrated in practice makes a big difference to the heuristic outcome of the exercises.

(Feenberg, 2002). Moreover, the forecasted *FSs* that serve as the anticipatory substrate of anticipatory predictivist actions are formulated on the basis of assumptions about the maintenance of certain socio-political trends and structures (*ceteris paribus* clauses) that are not explicitly the object of critical scrutiny when projecting the future and illuminating action. If predictions are not critically considered, they could subtly function as safeguards of the *status quo* (Callon, 2007; Voß and Freeman, 2016, pp. 23–25).

These and other limitations make it difficult for predictive anticipations to be regarded as a legitimate or favourable instrument for AG and RI. In fact, AG and RI scholars explicitly exclude this mode of interventive anticipations as tools for responsibilisation: «Forecasting *can be set* apart (…) in its orientation toward accurate predictions and allegiance to technological determinism» (Barben et al., 2008, p. 985; emphasis added). «Anticipation *is here distinguished from prediction* in its explicit recognition of the complexities and uncertainties of science and society's co-evolution» (Stilgoe et al., 2013, p. 1571; emphasis added)—see also Guston (2014, pp. 223, 225–226). «An anticipatory disposition *is not* about seeing into the future (prudence) or saying what the future is going to be (prediction) or estimating the chances of a certain outcome (probabilistic forecasting)» (Foley et al., 2018, p. 228; emphasis added).

4.3.2. Anticipation and future(s)-planning: The strategic approach

Another mode of anticipation is strategic in character. It requires constructing and/or approaching an *FS*—regardless of whether it was created through a reflexive process or uncritically taken as given—as a future target of intended realisation or avoidance. The heuristics of interventive strategic anticipatory practices (e.g. scenario planning, corporate foresight) does not lie entirely in the *FS* considered, but rather in the causal chains, "driver forces", or roadmaps, that are projected to point to that future from the present. The establishment of these causal chains is typically based on minimising uncertainty on the basis of knowledge about past and present trends and assumptions about continuities and novelties in the future [Steps 1 & 2]. The considered "branching points" related to "issues" or "events" that might be disruptive are subsequently used to (re)configure the standing strategies or goals in order to avoiding risks, increase the resilience, and/or optimise our present actions towards/against the (partial or total) potential materialisation of an *FS* [Step 3]. The derived strategies are often described as "future-proof" because they are thought to be a vaccine against possible future drawbacks that could undermine the achievement of the pre-established *FS* [Step 4].

This mode of anticipation has been systematically enacted through methods such as scenario planning and strategic/corporate foresight (e.g. backcasting scenarios, relevance trees, or roadmapping exercises) by industrial and governmental actors since the 1950s (e.g. the Shell scenarios). In STI, interventive strategic anticipations are widely used for designing and assessing STI policies and/or research agendas (e.g. European Commission, 2020a; Rohrbeck and Gemunden, 2009); i.e. for creating both technology "pull" and "push"

innovation strategies towards pre-settled desired target futures (Brey, 2017, p. 186).[52] These anticipatory practices have a clear normative force that lies in their capacity to fix the "future paths" and objectives towards which present STI actions *should (not) be* oriented.

While the question of what future ends are considered (un)desirable to pursue through STI processes *and how these should be pursued* seems central to AG and RI, the ways in which strategic anticipations could be included within these frameworks is not free of tensions. To a large extent, such tensions emerge as a result of a contrast between three aspects: (i) The closure of the future caused by the fixation of the *FS*-target and the pathways that may lead to its achievement/evasion, and the dynamics of the aperture of future alternatives that AG and RI seem to encourage regarding both the discussion of future goals to be pursued and the ways to achieve them; (ii) the minimisation of uncertainty required to identify potential pathways and obstacles to achieving *FS*, and the call for AG and RI to embrace intrinsic uncertainties; and (iii) the illusion of determinism or control that strategic anticipatory practices might (re)produce, and the contingent, messy and unruly conception of sociotechnical coevolution that AG and RI endorse—in line with current STS advances.

Perhaps it is these tensions that prompted AG and RI architects to warn of some of the inadequacies of this kind of anticipation in relation to enhancing responsibility. For example, Barben et al. (2008, p. 986) argue that forecasting methods «figure prominently in roadmapping exercises» in their need to limit uncertainty. Strategic anticipation exercises could therefore be affected by the limitations described in the previous subsection. Similarly, while Stilgoe et al. (2013, p. 1571) include scenario planning as a valuable tool for responsibilising innovation, they also warn against the dangers that such techniques (and other anticipatory ones) may entail: «[*U*]*sed narrowly* they risk exacerbating technological determinism». Consequently, assessing whether strategic anticipatory practices are an appropriate tool for promoting AG or RI might require us to examine both how the *FS* considered was fixed and which assumptions and cognitive predispositions towards the future were established in the "roadmapping exercise". This would require a consideration of the concrete socio-epistemic dynamics through which these practices are constructed.

4.3.3. Anticipation and the opening-up of alternative future(s): The exploratory approach

This third mode of anticipation is articulated on the construction and engagement with several *FSs* that have been co-constructed (and that are approached) with diminished epistemic and strategic ambitions. *FSs* are here approached as representations that *explore* a more or less extensive area of alternative plausible and/or desirable futures that might be derivable from a given system.

[52] See, for example, regarding nanotechnology New Zealand Ministry of Research Science and Technology (2006) and Meador et al. (2010).

Perspectives that seek to overcome the predictivist paradigm tend to emphasise that the future is ontologically *open* and deeply *indeterminate*. Rather than being based on representations of *what is likely* to happen, anticipations here are primarily based on *multiple* exploratory sociotechnical or techno-moral alternative future paths, which, while plausible and/or desirable to some, could not seriously be contemplated using traditional forecasting methods. By collectively exploring and projecting alternative and imaginatively controlled future possibilities, *FSs* aim to establish the range of "the plausible" and "the desirable" considering different societal actors' knowledge, preferences, and values, and to integrate the constructive and normative facets of STI.

Exploratory anticipations do not seek to minimise uncertainty about what will or is likely to happen; rather, they aim to recognise and embrace such uncertainty. In contrast to predictive and strategic anticipations, the success of exploratory practices is independent of the realisation of any *FSs*. Rather, their success depends on obtaining heuristics that reflexively enrich the decision-making processes in the present. As such, their objective is not to provide knowledge of the future, but to open up the plurality of plausible and desirable paths that could be considered within present sociotechnical co-construction processes. The aim is to learn through anticipation [Steps 1 & 2].

The heuristics of these exploratory exercises can arise (or be extracted) from both (a) the products of projective practices (i.e. from the co-created *FSs*) and/or (b) the very process of co-creating *FSs* with this exploratory spirit.

On the one hand, (i) in exploratory product-centred anticipations, the *FSs*—alternative sociotechnical (Rip and te Kulve, 2008) or techno-moral scenarios (Arnaldi, 2018; Swierstra et al., 2009)—might illuminate diverse potential sociotechnical and/or techno-moral (re)configurations that might co-evolve from a NEST development (e.g. discovering potential risks, uses, opportunities, drawbacks, etc.). This includes both potential "hard" (e.g. environmental and health risks) and/or "soft" impacts (e.g. power and social relations, understandings, culture, values, morality, etc.) (see van der Burg, 2009a; van der Burg, 2010). Moreover, when exploration is performed by including a normative perspective, *FSs* can illuminate the various options for action that are currently open (e.g. broadening and problematising the variety of future objectives that could be considered for the orientation of actions when performing strategic anticipations). As far as *FSs* here are an illuminating tool for current practice, it is expected that this exploration, while leaving enough room for imagination, will somehow be «informed» or «educated» (van der Burg, 2010, p. 143) and, thus, «be the product of a controlled reflection» (van der Burg, 2009a, p. 99). This aspiration towards epistemic and normative robustness is expressed in the pursuit (and assessment) of the scenarios" plausibility and desirability. This includes, as a matter of principle, information appealing to the past (e.g. possible analogies with past technologies), the present (e.g. a diagnosis of current situations and available knowledge), and the future (e.g. informed assumptions about what might be the case in the future) [Step 3].

On the other hand, (b) the anticipatory heuristics that may emerge from processual (or process-oriented) exploratory anticipations are principally aimed at increasing awareness of

the (relative) openness and contingency of future-making and enhancing reflexivity in respect of the roles and visions that the different societal actors may have about the NESTs at issue. The processes of co-creating and/or co-engaging with *FSs* are based on assumptions that normally remain tacit. When the explorations are accomplished through collective and deliberative processes—i.e. including different societal actors (presumably with different framings, knowledge, values, feelings, etc.)—the different set of values and assumptions involved may lead to the projection of different *FSs*, some of which may be compatible, while others might be incompatible or even incommensurable. The plurality of values and viewpoints that may arise during exploratory anticipatory practices may depict not only the different visions, expectations, assumptions, and frames of thought that co-exist around the NEST at hand. The plurality of *FSs* may also reflect the diversity of socio-political projects (or pragmatic paths of action) that may be worth debating and pursuing/avoiding in the present. As such, they present the diverse "endogenous futures" that might be in-the-making (Rip and te Kulve, 2008). Here the set of *FS*s are regarded as a *medium* (i.e. they are considered to be of relative limited importance). The important elements are the communicative processes themselves and the arrangements and capabilities that are developed from these (e.g. Johnson et al., 2012). "Processual foresight" and "anticipation" could be conceived as interventive socio-epistemic instruments aimed at creating a space for *social learning* and *capability-building* (Betten et al., 2018; Rip et al., 1995).[53] These processual exploratory practices are conceived as exercises for enhancing public engagement and disrupting frames of thought, broadening moral and ethical imagination, creating awareness of the contingency and complexities of future-making practices—the future can be and probably will be "otherwise" (Granjou et al., 2017)—, and reflecting on our roles in current future-making patterns. Through projecting and deliberating on plausible and desirable futures, these activities use the set of *FS*s with the aim of promoting reflexivity regarding the different modes through which we represent, think, feel, and use "the future" while acting in the present. Explorative foresight processes aim to provide heuristics for more socio-politically robust (inclusive, responsive, and reflective) ways of world-making (Vervoort et al., 2015) [Step 3].

Although the activity of collectively conceiving and/or engaging a plurality of scenarios does not offer a concrete orientation per se (Grunwald, 2013), the resulting heuristics are expected to enrich subsequent anticipatory decision-making processes both regarding the *FSs*' content (e.g. broadening considered future impacts/aspects of NESTs and alternatives

[53] The potential learning impacts of foresight—although often poorly monitored and assessed—are claimed to be manifold (Schartinger et al., 2012). Boenink (2013, p. 155) describes how some anticipatory practices, such as sociotechnical and techno-moral scenarios, are «not much about content, but about *training specific capacities and skills of users*». More concretely, she claims that «they offer material to train what the Greeks called *phronesis*: practical wisdom. This is the capacity to judge concrete situations: to interpret the situation and assess what would be the best thing to do in this case» (Boenink, 2013, p. 155). The use of foresight techniques by AG and RI (and other STS) scholars can be read as an example of what counts as "relevant social science" for Bent Flyvbjerg. This is not an attempt to pursue a social science along the lines of the natural sciences (i.e. with an emphasis on *episteme* and *techné*), but rather an attempt to promote socially relevant and practical wisdom (i.e. *phronesis*); a knowledge that is relational, practical, contextual or situated, value-based and sensitive to power relations (Flyvbjerg, 2001).

for STI, enhancing context awareness), and regarding the way *FSs* are constructed and approached (e.g. recognising uncertainties and contingency, overcoming linear and deterministic thinking about technology-society coevolutionary paths) (Selin, 2011, p. 725) [Step 4].

Having its origins in Futures Studies, foresight exploratory practices (both process-centred and processual) have been widely used in multiple disciplines. Already present in CTA (Rip et al., 1995; Rip and te Kulve, 2008), in AG and RI, exploratory foresight exercises are considered an input for public engagement and a means to strengthen moral imagination and risk assessment processes (e.g. Betten et al., 2018; Lehoux et al., 2020; Robinson, 2009; Selin, 2011).

Exploratory anticipations can integrate within their dynamics the next approach to *FSs* that articulates another mode of anticipation: the critical-hermeneutic. Although the process of exploring alternative futures tacitly involves identifying different visions, expectations, assumptions, and values (Konrad and Böhle, 2019, pp. 103–104)—which in turn could help to open up or enrich the *FSs* that are being considered for the orientation of action—, the levels of reflection inherent in these processes (and thus the reproduction or implicitness of certain assumptions rather than others) can assume different degrees of transparency and depth. If a more explicit and radical reflexivity is desired, a further step must be taken: To approach these *FSs* from a critical-hermeneutic perspective.

4.3.4. Anticipation and the analysis of the (production of) existing representations about the future: The critical-hermeneutic approach

The fourth mode of anticipation aims at approaching the *FS*s (and their respective construction dynamics) that serve as substrates for both formal (e.g. predictive, strategic, and exploratory practices) and informal (e.g. imaginaries, visions, and expectations) anticipatory activities as objects of critical scrutiny, reflection, and responsibility.

This type of critical approach has been present in Critical Futures Studies since the early stages of the "discipline" (Ahlqvist and Rhisiart, 2015), although the most systematic critical-hermeneutic theoretical and practical contributions began the late 80s/early 90s (e.g. Inayatullah, 1990; Slaughter, 1998, 2003). Similarly, the study of the performativity of the future in STS began to gain *momentum* in the second half of the 1990s (van Lente, 1993; van Lente and Rip, 1998a), and in the 2000s interventive critical-hermeneutic proposals and methods such as Vision Assessment began to emerge as a response (Grin and Grunwald, 2000; Grunwald, 2004; Nordmann, 2013b) and opened up the way to actual hermeneutic analysis of NESTs (Grunwald, 2014).

The starting point for understanding the rationale of this mode of interventive anticipations is the recognition that diverse *FSs* de facto co-exist in our societies (Decker et al., 2000, p. 1) and configure anticipatory discourses, ways of feeling and knowing, and power relations. For instance, STS scholars have shown how (often highly speculative)

sociotechnical imaginaries (Jasanoff and Kim, 2015), expectations (Selin, 2007), and visions (Lösch, 2006; Schneider and Lösch, 2019) play a strategic and meaning-giving role when supporting the socio-political and technical relevance of certain NESTs (to the detriment of others) (Borup et al., 2006; Konrad et al., 2016). Anticipatory discourses modulate public perception about NESTs and innovation practices (e.g. reproducing deterministic and linear visions of STI), shape the creation of socio-political assemblages, and mobilise and direct human attention and material resources towards specific goals (to the detriment of others) (Konrad and Böhle, 2019)—thus influencing what knowledge could be developed in the future (Dupuy, 2007). Because these anticipatory discourses might be considered as political and socio-epistemic anticipatory artefacts operating within the de facto and tentative governance of science and technology (Kuhlmann et al., 2019; Rip, 2018, pp. 75–96), they are recognised as objects of responsibilisation (Grunwald, 2017, 2019a; Schneider and Lösch, 2019) and governance (Konrad and Alvial Palavicino, 2017; Konrad and Böhle, 2019; Konrad et al., 2016) [Step 1].

Through a critical-hermeneutic engagement with these discourses, the aim is to promote «their deconstruction and hermeneutic reconstruction» (Nordmann, 2013b, p. 93). This entails identifying, understanding, and criticising the underlying epistemic and normative assumptions and the embedded meanings of *FSs* (Inayatullah, 1998; van der Burg, 2014). From a more process-centred perspective, a critical-hermeneutic approach could also include the analysis of the *FSs*' construction processes, the dynamics of assigning meaning to them, and the monitorisation of their impact on society (Grunwald, 2020). Some of the key questions are[54]: What meanings are attributed to *FSs*? Which actors promote these *FSs* and meanings, and why? What interests and power dynamics do *FSs* reflect and reproduce? Who is represented in these *FSs*? Thus, by interacting with existing *FSs*, the aim is not to minimise or embrace uncertainty, but rather to politicise it [Step 2].

As Armin Grunwald argues, these activities can provide relevant information for the responsible development of NESTs. Above all, the analysis provides a diagnosis of our present (Grunwald, 2020): Epistemic and normative assumptions can provide information about the expectations, interests, and beliefs that different social actors have about a NEST. The identification of assumptions and their contextualisation also facilitates the assessment of their plausibility, feasibility, and desirability, eliminating speculative excesses as far as possible (Lucivero, 2016a). The speculative bubbles that have surrounded many NESTs, and the ability of these to shape innovation pathways in an uncritical manner, make this task a highly relevant and timely one (Grunwald, 2018). In addition, when conducted from a more socio-political and relational perspective, they could be used to shed light on the constructive dynamics of these *FSs* and the role they play in shaping current sociotechnical arrangements and decision-making processes (e.g. tracing actors' agency in meaning-assignment processes).

[54] For a more complete list of questions, see Grunwald (2020).

For example, transhumanist discourses might include speculative assumptions about the feasibility of certain NESTs' applications (e.g. nanotechnologies). They might also reflect certain values about our civilisation and the relationships we establish with our bodies and our position as a species-among-species (what values and images of science does transhumanism convey, whose values are these, what sociotechnical assumptions underpin its discourses, are they plausible and desirable?). A critical-hermeneutic analysis would also closely monitor the socio-cultural and political discourses (and actors) that motivate and strengthen these discourses (what are their socio-cultural and political roots, why are they in vogue now, what does this indicate about our societies, who wins and who loses?) (e.g. Coenen, 2014) [Step 3].

The information generated can subsequently help to articulate more self-reflective and informed ways of performing anticipatory practices and developing a political economy of the future. The ultimate aim here is to avoid the uncritical materialisation of technological paths and co-production dynamics through uncritical (formal/informal) anticipations and deterministic ways of approaching the future. Indeed, the aim of interventive critical-hermeneutic practices within Anticipation and Futures Studies is to renegotiate the meanings associated with futures and to emancipate actors from anticipatory power dynamics (Arnaldi, 2008, p. 111). Similarly, some authors suggest that activities based on this critical-hermeneutic approach could contribute to the promotion of "futures literacy" (Miller, 2015). A critical-hermeneutic approach specifically focused on the normative foundations could also serve as a starting point for recognising the current normative state of a system and conducting the continuous normative assessment proposed by Dupuy and Grinbaum (2004) [Step 4].[55]

Vision assessment, which is a clear example of a critical-hermeneutic anticipatory activity, is mentioned as a valuable practice for AG (Barben et al., 2008, p. 985) and RI (Stilgoe et al., 2013, p. 1571). In addition, RI emphasises that «successful anticipation also requires understanding of the dynamics of promising that shape technological futures» (Stilgoe et al., 2013, p. 1571), which could be addressed through critical-hermeneutic anticipations. Moreover, the "reflexivity" dimension of RI has both first- and second-order import. Since critical-hermeneutic anticipations are meta-representational in nature, they explicitly include in their socio-epistemic mechanisms a second-order reflection around the *FSs*-in-use. Although this second-order reflection could also be achieved through exploratory anticipatory processes, this is not their explicit function (its reflective potential could be limited). Given that the issue of futures is transversal for AG and RI's challenges,

[55] The methodology of ongoing normative assessment can serve as an example of the combined character that anticipatory activities can acquire: Starting from an analysis of the state of a system and its normative assumptions (critical-hermeneutic), it aims to evaluate and reflect on them collectively and, if necessary, to create a picture of an alternative desired and plausible normative future (exploratory), in order to take it as a future target for our actions (strategic). Critical-hermeneutic approaches, moreover, seem to clearly embrace a metaphysics of what Dupuy calls "projected time". See Dupuy and Grinbaum (2004, pp. 15–16 and 21–24).

this mode of anticipation—as will be seen below in the dialogue with Nordmann's assessment on anticipation—is a key activity.

4.4. Staying with anticipation? Nordmann's criticisms of the "future talk" for the governance of NESTs

The previous section showed that anticipation is a heterogeneous socio-epistemic practice. It can adopt multiple forms and display multiple heuristics. In addition to the socio-epistemic dynamics that each modality of anticipation establishes with *FSs*, I have shown that while some anticipations are recognised as favourable interventive tools for AG and RI, others are not. Both AG and RI seem to exclude predictivist anticipations, while accepting exploratory and critical-hermeneutic ones. RI also seems to accept strategic foresight practices (e.g. scenario planning is mentioned), while it is less clear to what extent this is also the case for AG.

This heterogeneity contrasts with the homogeneous concept of "anticipation" that its critics typically assume (e.g. Fuller, 2018a, 2018b; Nordmann, 2014). As mentioned in the introduction, I would like to concentrate here on Alfred Nordmann's assessment. In "Responsible innovation, the art and craft of anticipation" (Nordmann, 2014), Nordmann raises a number of concerns about anticipation and concludes that it is not necessary for AG and/or RI.

Nordmann characterises "anticipation" as any socio-epistemic activity that aims to accomplish a governance of science and technology on the basis of «knowledge—no matter how tentative or qualified—of what might be the case in the future» (Nordmann, 2014, p. 87). His assessment focuses mainly on discerning to what extent such knowledge of the future is possible, and whether it is desirable to base the governance of STI on it. In short, he is sceptical about the possibility of knowing what will be the case, and his comments warn of the various shortcomings that a governance based on this knowledge could have. From Nordmann's point of view, anticipation seems not only futile or unnecessary, but can even be (politically) counterproductive.

The concept of anticipation outlined and the analysis conducted in the previous section demonstrates that Nordmann's conception of anticipation is a narrow one, since it does not embrace in all its complexity and richness the diverse ways in which we can engage with (and use) *FSs* (Selin, 2014). Nordmann constrains "anticipations" to predictivist anticipations: Those whose *FSs* have been created and are approximated as models that attempt to minimise the uncertainty of what will be the case. Although no one can question that this is the mainstream way of interpreting anticipation (i.e. that such a mode of anticipation still prevails in the practices and discourses of STI governance) and that it can clearly engender the problems identified by Nordmann, it is precisely this mode of anticipation that AG and RI reject or dispute and aim to respond to via other modes of anticipating.

In fact, if we approach Nordmann's text in light of the characterisations of anticipation offered here, one will find that while he considers "anticipation" unnecessary, he accepts the heuristics of other practices that actually fulfil the characterisation of "anticipation". For instance, Nordmann states that «[i]magined alternative worlds that do not carry the burden of having to serve as possible futures can be judged without incurring the charge or paternalism» (Nordmann, 2014, p. 91). Similarly, the author recognises that «scenario thinking is less encumbered and becomes more versatile, creative, and powerful if the scenarios are considered proposals for alternative sociotechnical arrangements rather than possible or likely images of the future» (Nordmann, 2014, p. 91).

Indeed, Nordmann seems to advocate the need to enhance «mind-sets that can handle contingency that can expect the unexpected and do not fall for false promises or the illusion of intellectual and technical control» (Nordmann, 2014, p. 89), which is precisely the aim of many exploratory exercises and more explicitly of critical-hermeneutic foresight processes. For instance, Nordmann can be considered a defender of the need to approach the *FSs* at stake from a critical-hermeneutic angle (e.g. Nordmann, 2013b)—vision assessment practices are in fact, as this chapter shows, a form of critical-hermeneutic anticipation.

That Nordmann assumes a narrow conception of anticipation (monopolised by a predictivist *modus operandi*) and seems to look favourably upon certain exercises and heuristics that have typically been seen as "anticipatory" suggest that his diagnosis of anticipation being unnecessary for AG and/or RI ought to be relativised and nuanced.

Although Nordmann's assessment does not recognise the heterogeneity of anticipation and its underlying rationale for AG and RI (Boenink, 2013; Selin, 2014; van der Burg, 2014), I nevertheless believe that some lessons can be drawn from his various criticisms of the "future talk". Indeed, these critiques touch on fundamental operational and epistemological aspects that should be considered when assessing whether each form of anticipation can be conceived as a legitimate tool for enhancing the governance of NESTs (Boenink, 2013).

In the following subsections, I will use as a heuristic resource some of the criticisms against the "future talk" raised by Nordmann. In particular, he considers that anticipatory practices, *when performed under certain conditions*, may (i) reify certain future perspectives (e.g. reproducing deterministic visions) (Section 4.4.1), (ii) diminish our ability to see what is happening (Section 4.4.2), and/or (iii) reproduce the illusion of having control over the future (Section 4.4.3). The first of the criticisms is raised in "If and Then: A Critique of Speculative NanoEthics" and was exclusively directed against anticipatory speculative ethics (i.e. its target was never AG and/or RI). By contrast, the latter two criticisms are specifically targeted against anticipation (understood in a predictivist sense) as a tool for AG and RI. Nevertheless, as they all pose challenges on the "use of the future" and the procreation of deterministic mind-sets, I will test these critiques against the different modes of anticipation considered valuable for AG and RI (strategic, exploratory, and critical-hermeneutic) as a mere theoretical exercise.

For this very reason, the purpose of this exercise is not (and cannot be) to contradict Nordmann's criticisms. On the contrary, it is a means for exploring the potential theoretical limits of certain ways of executing each mode of anticipation that is considered valuable for AG and/or RI in the face of these possible shortcomings. This will serve to emphasise two things: (i) The need to focus on the conditions under which anticipatory exercises are conducted; and (ii) that a critical-hermeneutic approach seems to be a robust and vital element in making anticipatory discourse and practice a more legitimate tool for "responsibilisation".

4.4.1. The "if and then" syndrome: Speculative ethics and reifying futures

The first criticism I would like to attend to is the one posed by Nordmann in "If and Then" to a certain *modus operandi* present in speculative ethics. Although this critique was not directed at AG and RI, the exercises to which this critique is directed—as will be shown below—satisfy the definition of anticipations provided in Section 3.1. Some important notes can be extracted from Nordmann's critiques when it comes to operationalising anticipations for AG and RI.[56]

Nordmann's critique of certain types of speculative ethics must be understood within the context from which it emerged. Certain anticipatory discourses or narratives derived a series of speculative (both "positive" and "negative") consequences or impacts from implausible and highly speculative taken-for-granted sociotechnical *FSs* (Nordmann, 2007, 2013a; Nordmann and Rip, 2009). This speculative spirit was (and still is) uncritically mirrored by some ethicists, and this is the main target of one of Nordmann's sharper criticisms against certain misleading ways of using *FSs* as a means for responsibilisation: the "if and then" reasoning syndrome. Nordmann characterises the "if and then" syndrome as follows:

> An if-and-then statement opens by suggesting a possible technological development and continues with a consequence that demands immediate attention. What looks like an improbable, merely possible future in the first half of the sentence, appears in the second half as something inevitable (Nordmann, 2007, p. 32).

This criticism applies to ethical discourse «that constructs and validates an incredible future which it only then proceeds to endorse or critique» (Nordmann, 2007, p. 31). In illustrating his position, Nordmann offers a number of concrete examples. I will mention here two (Nordmann, 2007, p. 33):

[56] For instance David H. Guston, a renowned architect of AG, has dedicated some words to addressing Nordmann's criticisms on speculative ethics, see (Guston, 2013, pp. 114–116; 2014, p. 220).

Example 1. "*If* it should be possible to create a direct interface between brains and machines (X), this research threatens an invasion of privacy (A) when machines are used to read human minds (Y)".

Example 2. "*If* molecular manufacturing were to be achievable within the next 20–50 years (X), we need to prepare for an age of global abundance (Y) and thus a new organization of our economies (A)".

In the movement from "X" to "Y", and immediately treating "Y" as an imminent future that might raise the issue "A", the ethicist reifies an imagined future (the hypothetical "X" and "Y" are treated as a *factum*). Paraphrasing Nordmann: The hypothetical and abstract "X" gets displaced by a supposed actual "Y"; the imagined future "Y" overwhelms the present, directing present efforts towards its treatment (Nordmann, 2007, p. 32).

This movement seems to be misleading for Nordmann for many reasons, for instance:

(i) because it uncritically assumes the feasibility and imminent reality of a (speculative) technological development (it assumes that "X" will be an imminent consequence of the current technological development trajectory, and that it will cause "Y");

(ii) because it contributes to spread strategic promises, reinforce technovisionary futures or expectations, and replicate technological determinist mind-sets; and

(iii) because focusing on "Y" and its associated "A, B, C" issues/challenges displace attention away from actual ("more pressing") concerns and needs and overshadows actual technological developments.

In terms of the concept of anticipation presented in Chapter 3, Section 3.4 (see Figure 2), Nordmann's critique points to the illegitimacy and counterproductivity of the implementation of anticipatory (speculative) practices that take the *FS* substrate as granted, as an imminent pre-given "future present" (Adam and Groves, 2007).

Table 9. Anticipation steps applied to two cases of anticipatory speculative ethics.

	Example 1	**Example 2**
Step 1	An *FS* in which it is possible to create a direct interface between machines and brains (X) and in which machines are used to read human minds (Y) is (co-)created	An *FS* in which molecular manufacturing were to be achievable within the next 20–50 years (X) and it causes a situation of global economic abundance (Y) is (co-)created

	Example 1	Example 2
Step 2	The ethicist (whether consciously or not) engages with *FS* in such a way that: a. [Uncritical validation of *FS*] FS is considered plausible[57] (i.e. the agent(s) blindly assumes that "X" might be the case and that "X" might cause "Y") b. [Closing down of potential alternative *FSs*] FS is not only uncritically validated as plausible, but is also considered as a likely or even the imminent future c. FS is approached as a representation that depicts a future state of our sociotechnical systems	The ethicist (whether consciously or not) engages with *FS* in such a way that: a. [Uncritical validation of *FS*] b. [Closing down of potential alternative *FSs*] c. *FS* is approached as a future-target that depicts a future state to which we should adapt in order to avoid potential economic imbalances
Step 3	The ethicist assesses *FS* and infers that this research threatens an invasion of privacy (A)	The ethicist infers that in order to achieve *FS*, minus the economic injustices, we need to design a new organisation of society (A)
Step 4	The previous assessment compels the ethicist(s) (and perhaps other actors) to consider *FS* as a scenario that should be avoided or to which we must adapt (e.g. creating strategies such as new privacy laws)	The previous assessment compels the ethicist (and perhaps other actors) to design a new organisation of society with the ability to address *FS*

Source of the examples: (Nordmann, 2007, p. 33).

The anticipations described in Example 1 and Example 2 (Table 9) operate formally, albeit speculative in content, under a predictivist and (predictivist +) strategic modality, respectively. The treatment of an abstract *FS* as an impending reality that prompts immediate concerns in the present (i.e. the reification problem), as the reconstructions in Table 9 show, requires the attribution of plausibility to the *FSs* as well as an extreme closure of the future (i.e. that the ethicist perceives the *FS* as plausible and as a likely or as *the* pre-given future). As stated before, the problem of reification arises when (i) there is a process of construction/validation of an abstract *FS* [Step 2a] as a "likely" technical development [Step 2b] that it is then (ii) endorsed or critiqued [Step 3] (Nordmann, 2007).

Leaving aside the debate on the usefulness of these *FSs* when approached not as prognoses but as explorative cases (Grunwald, 2010), here I am interested in highlighting some remarks from Nordmann's assessment that might be useful for AG and RI. The reification problem is not a phenomenon restricted to the use of speculative *FSs*, but may also be present in cases where the attribution of plausibility to *FS* may be well founded—the fact that the reified *FSs* are speculative and implausible only makes the reification problem more acute.

Indeed, reification is at the heart of anticipatory practices articulated on a predictivist approach to *FSs*, especially when these are applied to social conditions (York and Clark, 2007). As Nordmann notes, these predictivist projective *FSs* do not embrace the causal complexity of sociotechnical systems. They subtly neglect the historical contingency that

[57] As Lucivero et al. (2011, p. 138) note, «[t]he concept of "plausibility" is inherently intersubjective: a statement is plausible when it makes sense to a specific audience». See also Chapter 5.

characterises any sociotechnical development, limiting our understanding and conceptualisation of our sociotechnical world as it de facto co-evolves: messy, unpredictable, indeterminate (contingent), and somehow open to limited interventive action. The criticism of reification is basically a criticism of the malpractices that may result from functioning under determinist mind-sets.

The critique of reification may be relevant to AG and RI as it invites us to problematise the *FSs* that are taken into consideration (and their underlying assumptions). The critique can also serve to deflate the possible ontological or epistemic commitments we might have towards *FSs*. This implies, for example, that if RI understands anticipation as "What if" questions, the "ifs" must be themselves taken as the very object of scrutiny, as far as these fix the subject, or frame, of the discussion.

Even the basic strategic question of "*What* kinds of nanotechnological developments should we promote (causal driver) *if we want to promote sustainable cities* (*FS*-target)?" is framed around the limits of easily identifiable assumptions (e.g. the very fact that nanotechnology will/must be developed, the scope of the discourse is limited on cities, to focus on a technical element to solve a problem that is also socio-political and cultural). As far as any fixed *FS* around a NEST is itself an abstraction (it points to *not-yet* existing entities), to subtly consider them as a fixed normative target towards which we should direct our present supposes an act of reification. Naturally avoiding any kind of reification can be difficult in strategic practices (given the need to pre-set an *FS*-target as an operative condition). Nordmann's "if and then" critique can be read as a warning to take care as to which assumptions and *FSs* we consider and with which visions, expectations, and world projects these align.

The problem of reification, however, can be minimised in (and through) exploratory anticipations (both product-based and especially procedural). This is so because these exercises, in addition to the shared methodological call for a "reality check" (Arnaldi, 2018; Grunwald, 2010; Selin, 2011; Selin and Guimarães Pereira, 2013; Swierstra et al., 2009; van der Burg, 2009a, 2010) (thus minimising overly speculative *FSs*), collectively diversify the *FSs* considered and amplify the possibilities taken into account by recognising the uncertainty inherent to sociotechnical and/or techno-moral coevolution processes (against Step 2b, Table 9). This diversification, especially when divergent but plausible scenarios come into play, helps to highlight that there is no such thing as a fixed future. However, the degree of reification that might occur and which futures are (not)[58] reified depend largely on the specific socio-epistemic dynamics that are developed in the situated and concrete anticipatory exercise, as well as on the technique used. As Boenink (2013) notes, some techniques may be more likely to produce reifications than others, yet there is always some room within explorative techniques for steering discourses, which can help to avoid the

[58] It is important to note that there may be contexts in which the lack of reification of certain *FSs* can be seen as unfavourable. The case of the *FSs* on the impacts of climate change and the failure to understand them not as abstract entities but as an immanent global-scale immanent future, could serve as an example here.

reification of certain *FSs*. Obviously, this process of steering discussion and attempting to «reconfigure intent and hence action, now and in the future» (Selin, 2011, p. 734) is not without problems and tensions.

Although exploratory exercises, if well conducted, can be conceived as a valuable tool to visualise alternatives and reflect on the *FSs* that colonise and overwhelm the present, any exploratory exercise entails taking some assumptions as given (and discarding others). Which ones should we accept, and why? Precisely to avoid the uncritical reification of certain assumptions (descriptive and normative) and *FSs*, Nordmann (2007), Grunwald (2004), Lucivero et al. (2011), and others (see also Dupuy and Grinbaum (2004)) propose to commence with a critical-hermeneutic approach: «[A]n ethics beholden to present capabilities, needs, problems, and proposed solutions will begin with vision assessment» (Nordmann, 2007, p. 41). The very rationale of critical-hermeneutic anticipation consists in analysing and assessing (on the basis of currently available information and knowledge) the *FSs*' plausibility and desirability (Lucivero, 2016a) that are assumed as given. In fact, practices such as vision assessment, which involves a critical-hermeneutic approach to representations of the future, require analysis and a questioning of what (and why) *FSs* are constructed and used as meaning-giving instruments in current STI dynamics and practices (van der Burg, 2014).

As far as some degree of reification seems inevitable, the problem is not so much reification per se, but rather *uncritical*, or *unproblematised*, and *non-legitimised* reification and closure of the future (York and Clark, 2007). The objective is to build reflexive capacities that help to resist the uncritical reification and foreclosure of the future-making practices performed in the present. And the critical-hermeneutic approach seems—at least theoretically—like a good candidate for systematically and explicitly pursuing this goal.

4.4.2. "Anticipations may diminish our ability to see what is happening"

Another argument put forward by Nordmann, which strongly connects with the previous point, claims that working with (often speculative) *FSs* can diminish our ability to see what is happening. The "if and then" syndrome «deflects consideration from the transformative technologies of the present» (Nordmann, 2007, p. 31). Engaging with speculative scenarios like the ones presented in the previous section (Examples 1 and 2, Table 9) not only reifies the *FSs* they portray, but also serves «only to distract us from comparatively mundane, yet no less important and far more pressing issues» (Nordmann, 2007, p. 43).

The reason why the "future talk" diminishes our ability to see what is happening seems to be twofold. On the one hand, since intellectual resources and attention are a scarce resource, Nordmann considers that these must not be squandered on incredible, reifying, and distracting *FSs* (Nordmann, 2007, p. 34; Nordmann and Rip, 2009, p. 273). On the other hand, a cognitive state of "living in the future" can dispose us to farsightedness (i.e. to miss STI issues that are happening here and now). While the first issue relates to normative concerns about where and to what extent intellectual resources and attention should be

placed (whether in technologies yet to be developed and whose effects can only be speculated upon or in technologies at more advanced stages of development), the second issue directly appeals to a possible counterproductive effect of interventive anticipations.

As we have seen in Chapter 2 and Section 4.2, AG and RI are committed to an early social intervention which has to be «well-timed so that they are early enough to be constructive but late enough to be meaningful» (Stilgoe et al., 2013, p. 1571). This sense of opportunity, however, as Grunwald notes, must be situated in contexts of uncertainty where it is difficult to discern which technologies and problems might be relevant for early treatment (Grunwald, 2010, pp. 94–95). Furthermore, the consideration of which technologies are considered relevant for treatment in the present is often modulated by expectations and visions. Visions and expectations play a part in determining which STIs/NESTs will be taken as objects of responsibilisation (Grunwald, 2020).

The question of which area of research and development to intervene in is not trivial. It has been convincingly argued that the need to use more or less future-oriented activities depends largely on the specific situation and the stage of development of the technology/innovation to be analysed (Brey, 2012, 2017). On the one hand, participating at an early stage in the governance of a NEST riddled with much-hyped promises and wonders/horrors somehow involves being part of (and benefiting from) the same technovisionary dynamics that point to the need to make such technology an object of responsibility. On the other hand, not to interfere in these technovisionary dynamics (i.e. not trying as far as possible to enhance reflexivity within the co-production of the NEST) would be to embrace passivity (Sarewitz, 2011). The criticism against speculative ethics concerning the misallocation of resources becomes a challenge when extrapolated to AG and RI (which Nordmann did not do). It invites self-reflection on the anticipatory discourses in which AG and RI scholars become involved, the incentives that motivate this involvement, and its possible consequences.

In a more general tone (i.e. referring not only to speculative ethics), Nordmann states in "The art and craft" that «trying too hard to imagine possible or plausible futures may diminish our ability to see what is happening» (Nordmann, 2014, p. 88). A cognitive state of "living in the future" can distract us from seeing what is right in front of our eyes. While in "If and Then" the farsightedness criticism was directed at a hyperbolic and speculative (mis)use of the future by some ethicists (e.g. in the field of anticipatory bioethics (Racine et al., 2014)), in "The art and craft" Nordmann's worries seem to extend to the use of anticipation in AG and RI.

One might begin to recognise that the risk of a misleading "temporal displacement" actually exists with any exercise that involves emphasising one particular temporal tense. Even when the three temporal tenses (past, present, and future) are inherently intertwined, focusing on one of them too much can lead to downgrading the rest. For instance, a cognitive state of "living in the past" can also dispose us to miss what is happening in the present, as well as to miss opportunities to imagine alternative better futures. Similarly, concentrating strictly on the present can deprive us of valuable lessons we can learn from engagements

with the past and imagined futures. Our actions are the result of the interweaving of multiple temporalities, and to achieve a productive balance between these temporalities in foresight and interventive anticipatory exercises is a necessary, albeit not straightforward, task.

One should acknowledge that the "temporal displacement" risk exists (Selin, 2011, p. 735)—although limited in space and time—in both strategic and exploratory interventive anticipations. Whether the emphasis is on the future, the present, and the past and the relationships established between them will depend on the cognitive and socio-epistemic dynamics mobilised during the practice in question. The degree of distancing from the present (and the past) can vary, depending on the dynamics of each exercise.[59] For instance, strategic anticipatory practices require setting an *FS* as a target and continuously modulating present actions in line with its pursuit/avoidance and according to present information and analogies based on past experience. Although this could decrease the degree of farsightedness, the attention to the present could be limited to those aspects that are deemed relevant for the pursuit/avoidance of the *FS*-target (missing potentially relevant information for a better understanding of the current general situation).

In the case of exploratory modes of anticipation, the quality criteria to be met during the *construction phase* of their respective *FSs* typically requires knowledge of the past and present situations. In this sense, the degree of farsightedness will depend on the negotiation dynamics of *FSs*' plausibility. If performed well, exploratory exercises may even serve to contextualise, map, problematise, enrich, and/or raise awareness of the different perspectives concerning the current and potential future state of affairs as well as identify analogous past situations.

The practices of anticipation in which the connection with the present is most radical and evident are obviously the critical-hermeneutic practices (again, this is why Nordmann and other scholars argue for the need to take this approach as the starting point of any process engaging with *FSs*). Rather than displacing the present and diminishing our ability to see what is happening, adopting a critical-hermeneutic approach would situate us in the present: The objective is to take the co-existing *FSs* as products that reflect the contingent temporal horizon from which they have emerged.

4.4.3. "Anticipations may (re)produce an illusion of control over the future"

The third and final considered criticism holds that anticipatory practices could create the illusion that we have some intellectual and/or technical control over the future. Confronted with this illusion, Nordmann stresses that instead of promoting anticipation, we need to emphasise the contingency that constitutes the coevolution of sociotechnical systems

[59] The existence of the problem of temporal dislocation has prompted the emergence of perspectives that call for the interpretation of foresight as «an instantiation of temporal reflexivity» (Cunha, 2004, p. 2), which would imply taking all three temporal orders into consideration simultaneously and continuously (Sarpong et al., 2019).

(Nordmann, 2014, p. 89). As a careful look at the history of technology could certainly remind us, many non-predictable coevolutions of science, technology, and society have been surprising. Against this background, the practice of anticipation might seem not simply futile, but counterproductive. According to Nordmann, anticipation (re)produces a mind-set in which the future is taken as a controllable object of design.

To what extent do the anticipatory practices considered valuable for RI and AG reproduce an illusion of intellectual and/or technical control over the future? The *FSs* on which strategic anticipations are based and the "guidelines for action" derived from them can be interpreted from different perspectives. For example, the *FS*s serving as substrates can be understood from fixed and de facto achievable targets, to *FSs* whose function is merely heuristic (i.e. as regulative ideal targets). In a similar way, the "guidelines for action" derived from these exercises can be interpreted from rigid norms (which must be strictly adhered to and whose effective safeguarding can lead us towards a fixed future), to flexible orientations (which define some practical options for action, but do not guarantee the achievement of the desired future target).

The degree of control (and contingency or surprise) that strategic anticipatory practices can assume will largely depend on the positioning of the actors who implement them in relation to these variables. In other words, the question of whether strategic anticipatory practices reproduce the illusion of control over the future will depend on a number of highly contingent factors that are determined by the dynamics and perspectives from and through which these anticipatory practices are approached and constructed. Although there is a risk that normative anticipatory practices (re)create the illusion of intellectual and technical control over the future, this critique could be minimised by building these practices on mechanisms that recognise and/or emphasise the contingency, fallibility, and openness that characterise (a broad spectrum of) human actions.

Exploratory anticipatory practices are less likely to (re)create the illusion of epistemic and/or technical control over the future because of their less epistemic and normative ambitions: Their aim is not to define addressable future goals, but rather to open up or enrich the space of the *FSs* considered plausible and/or desirable in the present. It is precisely in the processual exploratory anticipatory practices that the emphasis is placed on the plurality of available options and/or the diversity of points of view with the aim to enrich not only the different sociotechnical and techno-moral paths and/or projects that could actually be considered, but also their contingency and possible variability (i.e. learning that the future might always be otherwise (Amsler and Facer, 2017)).

The success of the exploratory anticipatory heuristics will largely depend on the level of reflection on the dynamics that underlie (and constitute) these socio-epistemic activities—which in turn may depend on many other variables, such as the actors involved (and the relations established between them). In this respect, the integration of a critical-hermeneutic approach in the undertaking of exploratory exercises, as Nordmann notes, would be particularly helpful. For instance, a critical-hermeneutic approach would impel us—beyond the provision of information through the explicit analysis and evaluation of the assumptions

and meanings of the *FS*s in question—to place these *FSs* in concrete spatiotemporal horizons and contextualise them in the light of history and the socio-political landscape from which they emerge.

Such historical contextualisation and anchoring to the present could help to relativise our expectations and dreams (including those related to the realisation of AG and RI's goals) without at the same time neglecting the capacity for action we have for the governance and management of socio-political systems. Even if the coevolution of social, moral, and technical systems eludes our overall control to an extent, we can still influence them in the best possible way, considering the resources currently available. Strategic, exploratory, and especially critical-hermeneutic anticipatory practices, in many respects, seem to constitute such a resource.

In "A forensics of wishing", for instance, Nordmann urges us to approach any exercise involving *FSs* with an eminently historical conception of the future, while considering the contingency and precariousness of our present knowledge (a conception of the future which, for him, is in contrast to that anchored in the age of technoscience): «Given that our sphere of influence is limited to the present, it is an impossible dream to control the future development of technology; wanting to do so anyhow is a technoscientific conceit» (Nordmann, 2010, p. 11).

In order to avoid AG and RI falling into the *hubris* of technoscience, it would be positive for these frameworks to assume as a starting point the maxim that Sardar has already established for Anticipation and Future Studies when operationalising foresight/anticipation. Anticipation is, somewhat counterintuitively, a futureless activity in the technical sense: The relevance of its discourse, tools (such as foresight/anticipation), and fruits (anticipatory heuristics) lies in the present (Sardar, 2010). As such, the *FSs* on which it works should not be interpreted as representations denoting what will be the case (predictivist approach), but rather as constructs that express what we currently believe will be the case (and how we frame that future)—under the consideration of certain assumptions. It is precisely those assumptions and frames of thought about the future and not the future per se that comprise the objects of analysis, scrutiny, and negotiation within foresight practices (Chapter 5).

4.5. Responsibility through the search for the future's plausibility and desirability

The previous theoretical analysis noted Nordmann's concerns about how certain practices that engage with futures may render different modes of anticipations at different levels and depths. For instance, the analysis shows not only that critical-hermeneutic anticipations are not affected by these pitfalls, but also that they seem to contribute to avoiding them. In fact, the emergence of the critical-hermeneutic approach can be read in the light of the attempt to evade and respond to the misuses of the future that underlie the above criticisms (which clearly explains why Nordmann himself is an advocate of this mode of anticipation).

His conclusion on the futility of anticipations for AG and RI can then be nuanced, and (re-)interpreted as an argument that speaks to the importance of performing anticipations articulated on a critical-hermeneutic approach—whether alone or in combination with the other modes of anticipation that AG and RI consider worthwhile (i.e. the strategic and exploratory modes). Nordmann's critical points can be rethought not as a means to refute the value of anticipation (understood in a broad sense), but as an invitation to perform better anticipatory practices: Ones in which our *FSs* are contextualised and subjected to continuous scrutiny and in which any denotative pretentiousness is continuously deflated.

In addition, the previous analysis yields another result: Although each mode of anticipation, in virtue of their specific socio-epistemic *modus operandi* and functionalities, is more or less susceptible to fall prey to the shortcomings analysed, to ultimately judge the possible value of anticipation for AG and RI requires real-time and socio-epistemic empirical scrutiny. How are anticipations configured and how are each of its constitutive socio-epistemic steps performed? What kinds of socio-epistemic and political dynamics do they help to generate? This implies that we cannot always totally determine in an aprioristic or pure theoretical manner whether anticipations are (not) a "legitimate" or worthwhile socio-epistemic tool for AG and RI. Rather, we need to assess how each mode of anticipation is performed *in practice*. Before anticipations are taken on as an instrument for "responsibilisation", it is necessary to make their methodological design[60] (Chapter 7) and constitutive socio-epistemic dynamics (from Step 1 to Step 4) objects of responsibility (Lehoux et al., 2020; van der Duin, 2018).

One process that implicitly or explicitly exerts a notorious influence on the socio-epistemic steps of anticipatory practice is that of scrutinising and collectively negotiating the plausibility and desirability of the *FS*s under consideration. On the one hand, this process determines what information is (not) considered in the extraction of the information/heuristics from *FS* (i.e. in Step 3; see Figure 2). Only those *FS*s that are considered plausible and/or (un)desirable are considered an epistemic substrate for orienting action (Step 4). On the other hand, qualifying and evaluating *FS*s and the assumptions on which these are built as "implausible" may lead to their de- or re-construction, producing alternative ones or refining or correcting those that are currently available (thus reactivating Steps 1 and 2 of the anticipatory process; see Figure 2). The evaluation of (im)plausibility and (un)desirability can be considered as the socio-epistemic device that both expands and narrows the space of the *FSs* considered in anticipatory practices (Chapter 5).

If the general objective pursued by RI and AG through anticipatory exercises is precisely to collectively problematise the ends towards which research and innovation are directed,

[60] As with any other interventive tool, the methodological definition and refinement of each mode of anticipation ought to be performed according the pursued objective, intended area of application, actors involved, etc. These methodological concretisations can have different levels of idealisation/specificity. Moreover, the inherently contingent and fallible nature of interventive anticipatory practices prevents us from assuming that, even if the methodological characterisation and the corresponding translation into practice are properly performed, the expected heuristics will necessarily emerge.

and to examine *ex-ante* the possible risks and sociotechnical configurations that could arise from the development of a particular line of scientific and technological research, it seems reasonable to assume that the considerations of the (un)desirability and (im)plausibility of these futures is a crucial point.

The determination of the (un)desirability and (im)plausibility of the *FS*s will largely depend on whether these reflect or are consistent with the beliefs, axiology, hopes, or interests shared by the actors involved in their co-production and/or co-assessment (Chapter 5). Each (group of) actor(s) will consider an *FS* to be more or less (un)desirable or (im)plausible on the basis of (i) the normative and epistemic assumptions they hold at that moment, (ii) how they associate these assumptions, and (iii) how they infer from them what is (not) reasonable/desirable to be expected in the future. Despite the possible existence of common and shared normative and empirical stances (both of which are often intertwined (Mittelstadt et al., 2015)), it seems reasonable to expect that many of these will diverge. The plurality and variability of normative, theoretical, and/or empirical resources and assumptions (about the past, the present, and the future) that the different actors might possess, together with the different ways of relating or articulating/framing them and drawing conclusions, configure different registers of what each (group of) actor(s) might consider a (un)desirable/(im)plausible *FS*. As a result, a wide range of (un)desirable and/or (im)plausible *FS*s could co-exist and compete.

While these divergences could be considered heuristically positive for illuminating alternative action targets or sociotechnical/techno-moral coevolution paths, they can also (due to the existence of irreconcilable values, interests, or beliefs) hinder the communication and consensus required for orienting decision-making (Moniz, 2006). Moreover, even when the option to transform the tension produced by diversity and divergence into a productive and creative social learning exists, the procedural/formal nature of AG and RI and anticipatory exercises does not provide a mechanism for assessing the legitimacy of the judgements that might support the different options (Grunwald, 2013). The assumptions and the cognitive and logical processes used to articulate and to project conclusions from them can arguably have different robustness gradients, and therefore the attributions of (un)desirability/(im)plausibility can be (more or less) justified.

The development of some standards to evaluate the information, values, and the reasoning/argumentative processes that support the attribution of (un)desirability and (im)plausibility seems to be of central importance. However, again, this is not without tensions. Because these standards establish the basic (meta-)rules of what is considered epistemically and normatively "valid", they constrain *ex-ante* which of the *FS*s deemed desirable or undesirable are legitimised to be part of the deliberative process. In this respect, one might argue that there may be certain minimum values and epistemic stances that could preserve legitimacy over space and time. For instance, Ruggiu (2018, 2019) proposes Human Rights as the normative minimum basis for anticipations. However, these minima values are usually capable of accommodating a large number of dissimilar concrete alternatives. For

example, we could envision different models of society that, while satisfying the minimum of human rights, politically encapsulate different social orders or relations with nature.

These methodological, epistemic, and ethico-political difficulties regarding the establishment of "the (un)desirable" and "the (im)plausible" appear when the focus of these criteria is on their *limiting* role (i.e. when they are understood as criteria which function to constrain the space of *FS*s that should be considered as substrates in anticipatory practices). In other words, the previous problems arise when the responsibilisation of anticipation is focused on assuring a minimum epistemic and normative quality of the *FS*s that are used to guide our actions in the present.

However, the emphasis on the limiting role of (im)plausibility and (un)desirability—regardless of how relevant and important this is—needs to be *complemented* by also paying attention to the other function that these criteria (aim to or could) play: The reflective or disruptive one. Here the establishment of "the (un)desirable" and "the (im)plausible" functions to open up the *FSs* under consideration. By discussing and reflecting on the "(un)desirability" and/or "(im)plausibility" of the *FS*s, the aim is not just to perform anticipation on the basis of *FSs* that meet a set of qualifiers or standards, but to shape a second-order reflection on the standards themselves: On the basis of which values, knowledge, assumptions, and frames of thought does the (co-)construction/(co-)evaluation of futures take place?

The enactment of the second role of plausibility requires the identification and clarification of the assumptions and processes at work within the deliberative processes that support the attribution of (un)desirability or (im)plausibility, which inevitably requires the inclusion of a critical-hermeneutic approach within strategic and exploratory anticipatory practices. This involves identifying and considering which actors, knowledges, and assumptions have been considered/excluded when establishing the arena of the (im)plausible and/or the (un)desirable and on what basis. In a landscape where, as Nordmann notes, «actors are trying to persuade each other of what to take seriously» (Nordmann, 2013a, p. 130), the existence of exclusion mechanisms—e.g. epistemic (Fricker, 2007) or argumentative (Bondy, 2010; Linker, 2014) injustices—and power dynamics that permeate and shape the discursive spaces (Valkenburg et al., 2019) should be the focus for responsibilising anticipations. It is precisely the socio-epistemic quality of the argumentative and reasoning dynamics that shapes the construction/assessment of the (un)desirability and (im)plausibility of the *FS*s that will define the potential degree of reflexivity and disruptiveness of the heuristics derived from the anticipatory exercises. These heuristics can become operative afterwards (in Step 4) with different levels of strength, and they can be finally materialised depending on a series of factors influencing whether and how these (un)desirable/(im)plausible *FSs* finally mobilise action (Schmidt-Scheele, 2020a).

The inclusion of a critical-hermeneutic perspective within the strategic and explorative anticipatory dynamics will not resolve the noted tensions, but it might help to reveal the power relations and the existing rhetoric and argumentation patterns that destabilise the balance towards the acceptance of certain arguments or anticipatory discourses in the

defence and articulation of the "(im)plausibility" and "(un)desirability" of certain futures. The introduction of a critical-hermeneutic approach within the iterative processes of (co-)construction and (co-)evaluation of the *FS*s could not only be a necessary (but non-sufficient) condition for preventing anticipatory practices from falling prey to Nordmann's fears of misuse of the future; it may also contribute to steer reflexivity in the process through which arguments and reasons in support of particular *FS*s are developed and established.

4.6. Conclusions

Anticipation has always been a central activity for science and technology policy frameworks. Following this tradition and taking into account a variety of proposals (e.g. Vision Assessment, RTTA), AG and RI frameworks explicitly refer to the need for "foresight" and a range of other intervening anticipatory practices. These practices aim to address and reflect on a range of challenges related to the ongoing governance of science and technology at the early stages of development in order to increase the responsiveness of their processes, motivations, and outcomes.

Notwithstanding the functional value of anticipation in operationalising the concept of procedural responsibility that these frameworks articulate, the description of the kinds of engagements with the future that these processes are designed to enable has remained less explicit. This lack of explicitness and articulation of anticipation, combined with the fact that the predominant way of relating to the future is as a space that needs to be cognitively grasped or designed, has led to the emergence of various critiques that question the value of anticipation.

Based on this diagnosis, this chapter has moved forward in the conceptualisation of anticipation, paying particular attention to the critique of various misuses of the future identified by the philosopher Alfred Nordmann. Such misuses include: the possible reification of futures, the diminution of our capacity to know what is happening, and the reproduction of the illusion of intellectual or technical control over the future. The first critique is directed at anticipatory speculative ethics, while the second and third criticisms extend to anticipation as a tool of AG and RI.

Specifically, starting from the more robust concept of anticipation produced in chapter 3, I distinguished between four different modes of anticipation, each articulated via different approaches to the future: predictivist, strategic, exploratory (in its "product-based" or "processual" genre), and critical-hermeneutic. Each of these modes of anticipation involves the generation of different socio-epistemic dynamics and they can provide differentiated heuristics. In relation to these four modalities, it was noted that AG and RI view some of them negatively (e.g. the predictive in AG and RI and perhaps the strategic in AG) and others more positively (e.g. the exploratory and critical-hermeneutic in AG and RI and the strategic mode in RI) (Section 4.3).

This analysis enabled us to note that Nordmann's contention that anticipation is not a necessary activity for AG and RI is based on a narrow conception of anticipation in which anticipation is limited to its predictive modality (i.e. the very modality that RI and AG reject as useful for operationalising their concept of anticipation). Despite the fact that Nordmann's characterisation of anticipation is not broad enough, his criticisms of anticipation and speculative ethics (the "future talk"), when heuristically extrapolated against the modes of anticipation considered valuable for AG and RI, provide some interesting results (Section 4.4). These can be summarised as follows:

(i) That each mode of anticipation is (not) susceptible to Nordmann's worries (reification, diminishing our ability to see what is happening, and/or reproducing the illusion of control over the future) at different degrees and depths. In order to be more conclusive, there is thus a need to attend to how each interventive practice unfolds in practice (i.e. we need to turn our focus towards the dynamics that constitute interventive anticipations). While making foresight/anticipation an instrument for responsibilising STI, it must simultaneously become an object of responsibilisation.

(ii) That Nordmann's critiques do not compromise critical-hermeneutic anticipation; indeed, this modality of anticipation even seems to be a robust means of avoiding such critiques. The critical-hermeneutic approach (defended by Nordmann and others) finds, in its multiple justifications, an attempt to avoid the critical reification of futures, to emphasise the contingency of the present, and to contribute to a better understanding of what is happening on the basis of an analysis of the *FSs* at stake and their constructive dynamics.

A brief elaboration on "(i)" and "(ii)" stressed the importance of addressing the negotiation dynamics of the quest for plausibility and desirability of the *FSs* that articulate anticipation exercises. One of the issues that requires special attention in implementing this responsibilisation of interventive anticipations is the dynamics by which the (im)plausibility and (un)desirability of the *FSs* that articulate them are determined. This responsibilisation should focus not only on the *limiting* role of "the (im)plausible" and "the (un)desirable" (i.e. on restricting the spectrum of futures under consideration to those that meet minimum, pre-established quality standards), but also on their *enabling* role (i.e. on preventing exclusionary rhetoric and power regimes that unfairly exclude the consideration of alternative or disruptive plausible and/or desirable futures, thus encouraging scrutiny of the standards themselves) (Section 4.5).

CHAPTER 5

Understanding "plausibility": The "methodological-limiting" and "anticipatory-enabling" roles

This chapter is a slightly modified version of the article **Urueña, Sergio** (2019). "Understanding "plausibility": A relational approach to the anticipatory heuristics of future scenarios", *Futures*, *111*, 15–25. doi: 10.1016/j.futures.2019.05.002. It has been reproduced here with the permission of the copyright holder.

Abstract The co-creation of futures scenarios is considered a valuable methodological-interventive tool for shaping an AG/RRI/RI/TA-like responsible governance of emerging STIs/NESTs. Although plausibility is presented as a necessary (but not sufficient) criterion for both performing and assessing methodological-interventive exercises engaging with futures, there is no consensus on its meaning or rationale. Why is plausibility important for? The main objective of this chapter is to contribute to clarifying the meaning of plausibility and the role it plays in the application of foresight/scenario building practices to STI governance. In particular, I will argue that plausibility can be understood as a methodological criterion and as an anticipatory-enabling "political and epistemic device". In this sense, I support the value of theoretically distinguishing between the methodological-limiting and the anticipatory-enabling roles of plausibility in anticipatory methodological-interventive or foresight practices.

5.1. Introduction

The exploration of potential futures has always been of central interest to Futures Studies. However, the principal objectives, assumptions, and methods employed to conduct the relevant activities have changed over time (Son, 2015; van der Duin, 2006). In its early stages, Futures Studies sympathized with the predictivist approach (which clarifies the expanded use of the concept "forecast" at the time) (e.g. Ayres, 1969; Lenz, 1962), but most of the academic community abandoned this orientation after the rise of the "alternative futures" perspective (e.g. Bell, 1964; Miles, 2008; Millett, 2003). Currently, Anticipation and Futures Studies seem to be more constructionist and pragmatic in nature (Chiasson et al., 2018; Fuller and Loogma, 2009). In the dominant (but not exclusive) approach,

practicing foresight does not aim at reducing uncertainty about the ways that sociotechnical systems will co-evolve, but it points out the range of alternative futures to enhance resilience and proactively consider them as sources for present decision-making (Sardar, 2010).

Indeed, foresight is generally practiced within Anticipation and Futures Studies with the explicit or implicit awareness of at least two limitations of the predictive approach. The first limitation is the inherent contingency and complexity of sociotechnical systems, which makes it technically impossible to accurately map their future states of affairs. The second limitation is that prediction is an insufficient method for addressing the many ethical and socio-political challenges posed by technological and societal change (Sarewitz et al., 2000) and for recognizing the open and contingent character of the future. Although prediction may be necessary and epistemologically relevant to some particular domains, it should be *complemented* when dealing with the constructive dimension of socio-political systems. Human activity requires not only knowledge of what will most likely happen, but also of what might possibly and desirably happen. Anticipation and Futures Studies emphasizes this second dimension to learn about the windows of possibility that might be realized and their appropriateness (Bell and Olick, 1989; Miles, 1975). Thus, some practices and methodologies promoted by Anticipation and Futures Studies scholars can be understood as an antidote against deterministic perspectives in which—intentionally or not—the agential power of societal actors to influence development pathways remains unproblematized and the intentional nature of decision-making processes is disguised.

In the context of research and innovation processes, the purpose of devising alternative futures is typically to improve the reflective and anticipatory abilities of the actors involved in the co-production of STI (Jasanoff, 2004). The reason to foster these skills is to develop the co-production as an *intentional* process (Konrad et al., 2016). In this sense, foresight and anticipatory practices are considered valuable heuristic resources for strengthening STI assessment (Rip and te Kulve, 2008) and governance (Wender et al., 2014) (see Chapter 2).

One of the most common tools used by foresight practitioners to promote more robust forms of STI governance is to create hypothetical stories or narratives referred to as "scenarios" (e.g. CRN, 2007; INFU Foresight, 2009; Nanologue, 2006; Selin, 2008). There is no standard approach to scenario building, and several methods create these stories, but they all share many common characteristics (Bishop et al., 2007). One commonality is that all of the proposals and scenario schools emphasize a need to establish a set of criteria for validating those stories and ensuring their heuristic effectiveness (Amer et al., 2013, pp. 36–38).

Among the various criteria currently proposed, the concept of "plausibility" has been presented as central to the development of scenarios (Wilson, 1998), particularly those that aim to support a more robust governance of sociotechnical systems (Selin and Guimarães Pereira, 2013). However, despite its popularity and centrality, this concept has not sufficiently been studied, discussed, or clarified. Ten years after the debate about plausibility began (Selin, 2011), and more than five years after the publication of the special issue on plausibility in *International Foresight and Innovation Policy* (2013, vol. 9, nos. 2/3/4), two

broad questions on plausibility's criteria remain largely unaddressed. The first question relates to the theoretical-conceptual basis of plausibility (i.e. "What does plausibility refer to?"), and the second question relates to its operationalization for evaluating scenarios (i.e. "How can and should the plausibility of a scenario be assessed and determined?").

The lack of consensus regarding the validation criteria is not a trivial problem. The plurality of meanings attributed to the term could be understood as a symptom of a general lack of rigor in Futures Studies and, in particular, an indicator of weaknesses in scenario-planning methodologies. If Futures Studies hopes to overcome the fragmentation and paradoxes from which it currently suffers (e.g. Son, 2015; Spaniol and Rowland, 2018), its academic community must concentrate some of its efforts on justifying and problematizing the theoretical and conceptual bases in the field. The understandings of plausibility directly influences the ways we understand and apply future scenarios methodologies, and therefore they should be considered.

The main objective of this chapter is to contribute to clarifying the meaning of plausibility and the role it may play in scenario building practices applied to STI governance. In particular, I will argue that plausibility can be understood as (1) a methodological criterion, and (2) as an anticipatory-enabling "epistemic device" geared towards the mobilization and re-distribution of what has been labelled here as "modal power" (Chapter 1). In this sense, I support the value of theoretically distinguishing between the anticipatory-enabling and the methodological-limiting roles of plausibility in foresight/methodological-interventive anticipatory practices. The purpose is to clarify and strengthen the concept of "plausibility" in sociotechnical scenarios by analysing some of its most significant theoretical dimensions and enlightening its epistemic and political meaningfulness to STI governance. The relational approach used below is expected to clarify some of the problems around the topic and underline the need to explore some lines of research that it opens.

This chapter is organised into three main sections. Following this introduction, I propose a characterisation of future scenarios as representations or models about the future and identify their main formal or minimal components (Section 5.2). Then, I discuss the issue of the epistemic quality of future models/scenarios with a focus on the concept of "plausibility" (Section 5.3). Next, I point out some consequences of the previous analysis in terms of supporting the anticipatory governance of emerging technologies (Section 5.4). The chapter ends with a series of conclusions (Section 5.5).

5.2. Exploring the components of future scenarios/models

Future scenarios are typically defined as stories or *future modal narratives* (Booth et al., 2009) that attempt to describe plausible future horizons to develop an inclusive space for enhanced flexible decision-making processes. Broadly, creating scenarios can be understood as a socio-epistemic practice, the main purpose of which is to construct conjectural and non-

deterministic representations of future states of affairs to explore and illuminate the human condition and provide practical or *phronetic* knowledge to regulate praxis.

Scenario building practice is performed from various perspectives, and it emphasizes different aspects (Amer et al., 2013). However, and with few exceptions (e.g. Aligica, 2005; Walton, 2008), an analytical perspective is lacking regarding identification and study of the components that comprise the scenarios and their socio-epistemic natures. Although the development of that type of analysis reaches far beyond the scope of this chapter, a brief characterization is provided below. Instead of an exact description of scenario elements, this provisional characterization was developed from a pragmatic orientation intended as an analytical tool to clarify the problem of plausibility. However, if the goal were to provide a precise description of what are the elements that comprise the practice of making scenarios, the following proposal should be refined.

Provisionally, we might consider that scenarios can be theoretically constructed from the interrelationships among at least the four basic elements.

1. S_i: A state comprising events or objects that function as an initial substrate of the narratives.
2. {e}: A set of assumptions, beliefs, ideas, feelings, and values that modulates S_i ($\{e\} = \{e_1, ..., e_n\}$).
3. →: An inferential (abductive, inductive, or deductive) process.[61]
4. $\{S_f\}$: A (set of) narrative(s) or representation(s) created through ("3.") an inferential process based on ("1.") S_i and ("2.") {e} ($\{S_f\} = \{S_{f1}, ..., S_{fn}\}$).

Thus, the production of scenarios could be formalized by the following rationale.

$$(S_i + \{e\}) \rightarrow \{S_f\} \qquad \text{(Equation 1)}$$

For example, suppose a group of people is invited to create scenarios about the future that could open up the possibility of introducing humanoid robots to the hospital they use and/or work in. At this point, the participants could model their current hospital (the starting scenario S_i), considering their knowledge about how the hospital actually works, their knowledge and assumptions about humanoid health robotics, their expectations about how this hospital would change ({e}), and so on. During this modelling process, participants could use different types of inferences (→). For example, they could use deductive thinking (reasoning from general rules to specific conclusions) by concluding that, if all hospitals have patients and they are imagining a hospital, then all scenarios of their future hospital should include patients. Another possibility is that they use inductive reasoning (reasoning from specific observations to general conclusions) to produce a scenario wherein their

[61] Please note that the symbol "→" does not aim to represent a logical implication. This means that it does not attempt to represent a relation of logical necessity and consequence between $\{S_f\}$ and $(S_i + \{e\})$, but simply an inferential process that goes from the premises $(S_i + \{e\})$ to the conclusion $\{S_f\}$.

hospital has been transformed in a manner similar to other hospitals where humanoid health robots have already been implemented. Finally, the participants could also create scenarios following abductive or imaginative reasoning (reasoning from incomplete and uncertain information to plausible general conclusions) in which their hospital becomes more efficient but loses staff, changes its care practices, and so on.

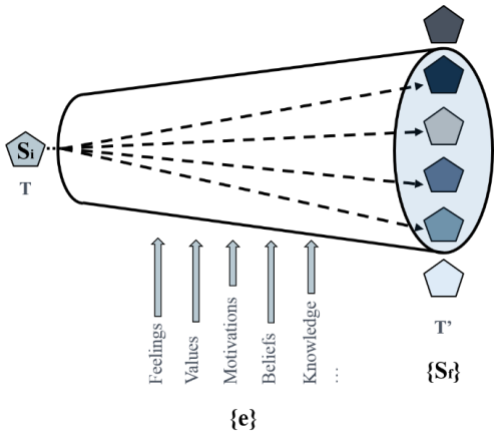

Figure 3. Scenario cone depicting multiple possible scenarios ($\{S_f\}$) applied to the $(S_i + \{e\}) \rightarrow \{S_f\}$ scheme.

Apart from the three general types of inferences that can theoretically guide the process "→" (deduction, abduction, and induction), the elements S_i, $\{e\}$, and $\{S_f\}$ could theoretically have various ontological and epistemic modalities and could be assessed under different sets of values. Moreover, S_i and $\{S_f\}$ could be set in the different time horizons assumed in daily life (past, present, and future). As might be expected, these time horizons are relative to the individual or collective that generates (and assess) the scenarios.

Table 10. Examples of scenario formation that depend on the temporal dimension of the initial scenario (S_i).

(S_i +		{e})	→	{S_f}
(T) Past	*If* Marie Curie had never discovered polonium…	… and, given the tacit/explicit cognitive, affective, and normative assumptions "{e}", …	*then*…	(T') Past, present, or future scenarios
(T) Present	*If* this nano pharmakon comes (now) to market…			
(T) Future	*If* in 2050 it is possible to use cellular therapies to reconstruct organs…			

As Table 10 illustrates, the introduction of time variables in Eq. 1 opens up a multiple scenario typology. Considering the possible time horizons in which S_i and S_f might be situated (i.e. T and T', respectively), nine general types of scenarios could be developed: past-S_f, present-S_f, or future-S_f scenarios (T') generated from past-S_i, present-S_i or future-S_i scenarios (T) (i.e. {past-S_i, present-S_i, future-S_i}×{past-S_f, present-S_f, future-S_f}). In addition, this variety could be augmented if the ontological character of all these scenarios

is considered as a variable. For instance, although future-S_i/S_f scenarios may always be contemplated as fictional because their ontological value cannot be firmly established in the present, both past-S_i/S_f and present-S_i/S_f scenarios could have a real or a fictional character depending on whether they represent a past that has occurred or a present situation that is occurring.

Despite the cognitive possibility of creating this wide variety of scenarios, the scope of Anticipation and Future Studies does not usually include all of them. First, in relation to "{S_f}", the Anticipation and Futures Studies community—as its name suggests—seems especially interested in the generation of narratives whose T' is in the future (i.e. in future-S_f scenarios). Second, in relation to 'S_i", although it is possible to generate these future-S_f scenarios from past-S_i (fictional or real), present-S_i (fictional or real), or fictional future-S_i situations (T), scenario practitioners who seek to explore the window of future possibilities generally do not use *fictional* past-S_i or present-S_i scenarios (i.e. counterfactuals or alternative present-worlds) as starting points. This does not imply that there is no need of (historical) retrospection or potential benefits in working with those kinds of "worlds". Indeed, as Booth et al. (2009) recognize, counterfactuals may contain heuristic power similar to future scenarios (e.g. they may be thought-provoking and emphasize contingency). However, as far as counterfactuals point to states of affairs «that were previously possible *but are no longer possible*» (Byrne, 2005, p. 1; emphasis added) and alternative present-worlds point to unreal present worlds, these narratives seem to have severe limitations as resources for illuminating robust realizable future possibilities. That is, we can hardly explore a robust window of probable, possible, and/or plausible futures *in our actual world* if we start the exploration of futures by "extending" or modelling worlds that we recognize from the beginning as unreal and/or impossible. In the same way, taking future-S_i scenarios as a starting point may be problematic: It seems arduous to assess the credibility of a future-S_f scenario that has been created from a future-S_i scenario whose ontological value—as I mentioned before—cannot be recognized or firmly established in the present (Nordmann, 2013a).

Instead, future scenario practitioners may use real past-S_i or present-S_i situations as a starting point in order to create two or more alternative future-S_f scenarios (van der Heijden, 2011). However, if future-S_f scenarios generated from past-S_i situations have to be modeled extremely realistically until they reach the present (in order to maintain credibility and prevent working with counterfactuals or creating alternative presents), then it may be preferable to start the representation process directly from present-S_i situations (i.e. from "now"). This preference does not imply that past data, facts, or narratives are ignored or that the heuristic value of including historical analogies (Schwarz-Plaschg, 2018a) in the formation of scenarios is rejected. Indeed, one should always consider in "{e}" data referring to all the three parts of the timeline as a matter of principle when modeling robust future-S_f scenarios. As (Selin, 2006b, p. 8) points out, «[g]ood scenarios are typically buttressed with oodles of quantitative, historical and contextual data. Varied rates of change, demographics, economic trends, statistics and other "hard" indicators are included to enhance the overall credibility of the scenarios». Nevertheless, one should distinguish between the "temporal

location" of some data used for creating S_i (i.e. to which part of the timeline {e} refers) and the "temporal location" of S_i (T) from which the modeling process of the future scenario starts.

For all these reasons, future scenarios could be theoretically characterized as representations of type "$(S_i + \{e\}) \rightarrow \{S_f\}$", where S_i should be preferably a real situation set in the present, and "$\{S_f\}$" must be understood as—more or less robust—hypothetical narratives set in the future. Furthermore, the set of assumptions, beliefs, ideas, feelings, and values "{e}" that modulates S_i could refer to all the three parts of the timeline: the past (e.g. historical data, analogies, past trends), the present (e.g. present trends) or the future (e.g. assumptions, visions about what might happen).

Given the diversity of conceivable stories and the multiple modalities and dimensions that may come into play in future scenario-making practices, it is necessary to create a set of criteria that facilitate to identify which of the multiple future scenarios that could potentially comprise the set "$\{S_f\}$" are worthy of decision-making consideration.

5.3. Plausibility as a qualifier?

If future scenarios are not normally created as ways to know or describe *what will happen*, but are intended to explore *what might be* to improve reflexivity in the present (Klein et al., 2010; Mietzner and Reger, 2005), then the assessment of future scenarios does not (or should not) rely on epistemic categories such as *truthfulness* or *verisimilitude* (Guimarães Pereira et al., 2007; Selin, 2011; Selin and Guimarães Pereira, 2013). In other words, the classical epistemic criteria used to evaluate the *relationship* between a representation and what it represents should be relinquished for at least two primary reasons. First, it is not always possible to have precise knowledge of the future, and second, the purpose is not to know the future, but first to open it (i.e. to explore the window of plausible and desirable futures) and then to "close it down" by guiding the decision-making processes. To determine the specific scenarios worthy of consideration for decision-making, other criteria beyond those linked to the concept of correspondence should be proposed. The burning key questions are which ones and how should they be understood and operationalized.

Proposing a validation criteria scenario is a fundamental task presented in the literature on scenario building practices. Because scenarios are presented as tools to support decision-making, the establishment of a group of indicators to evaluate the robustness of these practices is particularly critical to ensuring the efficiency of the processes by which they are framed (Chermack et al., 2001). The problem is to determine the criteria that should be proposed and how to apply them. The diversity of indicators offered, the arbitrariness of their meanings and the complexity of their operationalization have led authors to metaphorically describe this set of scenario qualifiers as a "jungle" (e.g. van der Helm, 2006).

In this jungle of scenario qualifiers, at least two major groups of indicators can be distinguished: Those that are focused on evaluating the robustness of the scenarios as *products* (i.e. focused on S_f) (identified herein as "1") (e.g. Amer et al., 2013), and those that are focused on evaluating the scenario creation *processes* (i.e. focused on "(Si + {e}) → {S_f}" situated in a broad context of action) (identified herein as "2"). Moreover, among the indicators focused on evaluating the representational products "{S_f}", it is possible to find indicators that evaluate {S_f}'s internal (identified herein as "1a") and external (identified herein as "1b") relationships (Amer et al., 2013, p. 36). Both general approaches are compatible and might complement each other, but it is theoretically interesting to note that each focuses on different dimensions of the scenario formation scheme "(S_i + {e}) → {S_f}" and its implementation.

(1a): For example, the following non-exhaustive list contains popular indicators focused on the evaluation of stories or narrative products (S_f) from an internal perspective (e.g. "How well do the narrative elements that constitute the narrative S_f internally relate to each other?").

- Consistency: S_f has no internal built-in contradictions
- Transparency: S_f is easy to recount, understand, or illustrate
- Completeness: S_f has no gaps in the narrative

(1b): Indicators developed to evaluate product narratives (S_f) that focus on their relationships with other elements of the scheme "(S_i + {e}) → {S_f}" include—but are not limited to—the following (e.g. "How well do the narrative elements that comprise {S_f} relate to other elements of "(S_i + {e}) → {S_f}"?).

- Consistency: Some scenarios contained in {S_f} could be integrated or combined
- Possibility: S_f or {S_f} are theoretically able to come into existence (i.e. there are no known primitive or elemental physical and/or technical constraints of S_i that may contradict S_f/{S_f}'s potential occurrence)
- Probability: From certain initial conditions "S_i" and our knowledge and expectations (included in {e}) about how that S_i will evolve and what of S_i will or will not change and remain constant, S_f/{S_f} are objectively/subjectively likely to happen
- Feasibility: S_f or {S_f} are achievable (i.e. there are no known or expected contingent, and specific social, legal, economic and/or political conditions of S_i included in {e} that could hamper S_f/{S_f}'s realization)
- Plausibility: S_f or {S_f} are derivable or can be arguably inferred or concluded from the initial conditions (S_i + {e}); i.e. if we agree that (S_i + {e}), then…
    - *it is reasonable to believe* that S_f or {S_f} *could happen* (Wilson, 1998)
    - S_f or {S_f} are *trustworthy* (Selin, 2006b)

- S_f or $\{S_f\}$ are *credible* (Nordmann, 2013a; van der Helm, 2006)

A clear example of the difference between the application of the scenario criteria from approach (1a) to (1b) is found in the criterion of consistency (as it is contained in both lists). Assessing the consistency of a scenario from an internal perspective (1a) entails evaluating if the S_f narrative has no internal contradictions. However, from an external perspective (1b), consistency implies to asses if some or «all future projections 'fit to each other' (independent of whether they are more or less likely to occur)» (Wiek et al., 2013, p. 135).

The following are examples among the indicators of "2", which are focused on evaluating the representational quality of the scenario generation *processes* (i.e. "How well does the exploration of the future, $(S_i + \{e\}) \rightarrow \{S_f\}$, perform/shape the practices or help to achieve an objective?").

- Utility/Pertinence/Relevance: Scenario-making process is useful to achieve an objective (e.g. contributes to decision-making processes, and enables anticipatory abilities)
- Creativity/Novelty: Scenario-making process challenges the "mainstream" vision(s) of the future

At this point, it is convenient to mention that both the creation of future scenarios and the assessment of whether their products deserve the previous mentioned qualifiers are situated socio-epistemic practices (i.e. activities that involve knowledge and beliefs made in a particular situation and by a particular *individual* or *collective*). If these practices are carried out by certain people, under certain circumstances (e.g. social, historical, cultural, or geographical) and on the basis of specific information that might change over time, then the scenarios generated and whether they fit those qualifiers are susceptible to wide variation (although we have good reasons to accept that the basic theoretical limitations that set the boundaries of "the possible" will remain constant—e.g. physical laws).

For that reason, plausibility can be better understood as a relational-interactional criterion in the sense that it is not an intrinsic property of a scenario, but rather an attribute given by an individual or collective agent situated in a particular context. A scenario is not plausible per se, «[p]lausibility is dependent upon the interpretation the subject is able to assign to a discourse in an appropriate temporal, spatial, causal and intentional framework» (Ehrlich and Charolles, 1991, p. 276). Indeed, «the plausible and the implausible need to be interrogated and better understood in the context they appear» (Selin and Guimarães Pereira, 2013, p. 94). Thus, the previous definition of plausibility may be updated as follows:

> *An individual or collective agent can consider a future scenario as "plausible" when that agent (i) agrees with $(S_i + \{e\})$, and (ii) believes that it is reasonable to conclude from $(S_i + \{e\})$ that S_f may happen.*

There would be much to say about all these qualifier definitions and they are certainly not unproblematic from a philosophical perspective. Indeed, one of the main complex problems that specialized literature on future scenarios has attempted to clarify refers to the difference,

interrelation, and dependence between the three main general methodological-limiting criteria: possibility, probability, and plausibility (e.g. Ramírez and Selin, 2014; van der Helm, 2006; Wiek et al., 2013). All of them can be considered as limiting criteria because *their main role is* to play as a methodological condition that limit the list of scenarios worthy of consideration.

According to the definitions provided above, one of the most basic characteristics that possibility, probability, and plausibility seem to share is that they all limit "$\{S_f\}$" in relation to certain information contained in "$(S_i + \{e\})$". However, the differences between them could be determined by the kind of reasoning ("→") on which they are based (see Nordmann, 2013a, p. 127) and the elements of "$(S_i + \{e\})$" that count as "relevant" during that reasoning process (see Table 11).

Table 11. Type of reasoning and $(S_i + \{e\})$ elements considered relevant for possible, plausible, and probable qualifiers.

Qualifier	**Objective as a methodological-limiting criterion**	**Inferential reasoning**	**Elements of $(S_i + \{e\})$ that are considered relevant**
Possible	To delineate or limit "$\{S_f\}$" to those future scenarios that…	…do not contradict *(deductive reasoning)* …	…the basic theoretical constraints that we know/think S_i has and that we suppose that it will continue to have in the future.
Plausible		…we may reasonably believe or conclude *(abductive / plausible reasoning)* that can happen given …	…a more or less robust: (i) Characterization of S_i, (ii) experience and empirical evidence about past and present (e.g. trends), and (iii) expectations, assumptions, evidence, feelings and/or values about how S_i might or might not unfold.
Probable		…we estimate likely to occur to some extent based on projections (*inductive probabilistic reasoning*) …	…made from known past and present regularities and assumptions about how the future might or might not resemble them (e.g. *ceteris paribus* clauses) into an unknown future.

Against the background shown in Table 11, we may note that "the possible" subsumes "the plausible" and "the probable," and that "the plausible" subsumes "the probable" (i.e. probable ⊂ plausible ⊂ possible). A plausible scenario in a given world is presupposed to be possible in the same world. In the same way, a probable future scenario in a given world is presupposed to be plausible (and, therefore, also possible) in the same world.

However, these criteria maintain fundamental differences, which are mainly defined by their epistemic disposition towards what we should accept and on what basis. While possibility is the least strict criterion because it only requests to apply the non-contradictory test in relation to the fundamental theoretical characteristics of a world that we think or know will persist in the future, plausibility and probability require more lax types of reasoning but considering a broader set of relevant information (which makes them stricter criteria than possibility).

In relation to the relationships between possibility and plausibility, we might note that both may share the same set of background information "$(S_i + \{e\})$":

(i). A more or less robust characterization of S_i

(ii). Experience and empirical evidence about past and present (e.g. trends), and

(iii). Expectations, assumptions, evidence, feelings and/or values about how S_i might or might not unfold

The type of reasoning is what makes the essential difference here. On the one hand, the probabilistic inductive reasoning by which probability is guided requires limiting and specifying the information of that set beforehand in terms of their—"objective" or subjective—statistical significance (i.e. it works by statistical background information) (Jaeger, 2006). Before inferring probable futures there is the need to establish what variables we expect that will remain constant or change and to what extent. In other words, although both plausibility and probability may share "(S_i + {e})", probability requires dealing with the "(S_i + {e})" background information in a specific way: It adjusts "(iii)" in the light of "(ii)" to extrapolate the resulting information on "(i)" in order to obtain a future scenario to which is assigned a certain *degree of belief in its realization*. Plausibility, on the other hand, does not *require* necessarily this prior adjustment of "(S_i + {e})", nor is it intended to assign a degree of belief in the realization of a future—although probable futures may also be generated or considered plausible following an abductive process (probable ⊂ plausible). Instead, what plausibility offers is far humbler: To assess if a future scenario can be reasonably concluded or derived from "(S_i + {e})". In other words, plausibility merely assesses whether "(S_i + {e})" has enough *argumentative force* for seriously considering S_f, and thus establishing a pragmatic relationship based on agreement and/or trust on the premises, values, and processes through which S_f was epistemically constructed (Josephson and Josephson, 1996, pp. 265–272; Rescher, 1976, pp. 21–30). Thus, plausibility «has much to do with how we reason and how we construct a convincing argument» (van der Helm, 2006, p. 24): The focus of attention is more on the validity of the premises and the argumentation process that support the conclusion (i.e. on "(S_i + {e})" and "→"), rather than on the conclusion itself (i.e. on {S_f}).

These differences between probability and plausibility support the hypothesis that "the probable" cannot be considered an adequate methodological-limiting criterion *for those exploratory methodologies of the future that seek to open it up*—although probable futures may be taken into consideration or probability may serve other purposes very well (Ramírez and Selin, 2014). If future scenarios are seen as tools that do not seek to represent or determine what will or is likely to happen but rather to explore the alternative futures that could be seriously realized from our present, then the focus of analysis should not be *limited* to the probable futures, as they only represent the space of futures that are expected to happen according to extrapolations of known past and present trends into the unknown future. However, the focus should not be too broad either as it is the vast terrain of possibility, which contains futures that we can reasonably argue that cannot be derived from our present conditions. Instead, it would be more efficient and reasonable to leave enough room for novelty, intuitions, and imagination that are constrained in "the probable" (Thagard and Shelley, 1997), but closing it enough in order to avoid the speculations allowed by "the

possible". It is in that space of blurred and complex borders that the abductive/plausible reasoning and the plausibility criterion is situated, and where lies its meaning and its epistemic and pragmatic significance for foresight or future scenarios methodologies.

The variability and imaginative freedom that the plausible reasoning allows could lead to several critical considerations. For example, one might think that this criterion is insufficient to constrain the set of future scenarios for decision-making purposes. Certainly, even if a specific set of input data (S_i + {e}) is established, the abductive or imaginative inferential process may theoretically produce a large number of plausible scenarios. However, when scenario building is intended to support decision-making processes, we should understand that plausibility is a necessary but *not sufficient* methodological-limiting criterion.

Plausibility is a necessary criterion because it limits us to narratives within a space of controlled speculation that is not sufficiently constrained but comprehensive enough to facilitate the discovery of potentialities that otherwise would not be possible (Lombardi et al., 2016). However, plausibility is an insufficient criterion for decision-making purposes because it must be applied in combination with other criteria (e.g. feasibility, desirability, consistency). Indeed, internal and external consistency «is also used for conveniently reducing the number of scenarios to a manageable amount» (Amer et al., 2013, p. 137); see also Wiek et al. (2013). In addition, the normative criterion of (un)desirability is also commonly applied to restrict the area of plausible scenarios to those whose end-states are most preferred.

Furthermore, it must be noted that the contingency and "inferential freedom" that characterize plausible reasoning do not imply that scenario building and assessment processes are arbitrary or that they could include anything. In a world in which fake news is common precisely because it is *plausible* for some people, one expects the creation of scenarios to be based not on highly speculative information about the future and false information about the past and the present, but on solid evidence. Because plausibility largely depends on agreement on "(S_i + {e})" and the abductive reasoning process "→", a crucial point is to make them explicit and open to scrutiny. Indeed, one of the key strategies for ensuring the epistemic quality of *plausible* scenario building processes is to vet the information included in "(S_i + {e})" and justify to what extent it allows to infer or imagine "S_f".

However, as we are not just working with past and present facts, but also with uncertainties, expectations, claims, and speculations referring to the unknown and undetermined future, it is not always easy to develop and implement the previous strategy (Michelson, 2013, pp. 193–194). In this regard, some scenario practitioners appeal—resembling the post-normal science framework—to the need to form an extended and inclusive peer community in which the voices of a broad range of disciplines and social actors (with their respective expertise, expectations, beliefs, feelings, and values) are welcome and encouraged to participate. For these authors, strengthening the information included in "(S_i + {e})" and the inferential process "→" «requires negotiation with multiple

stakeholders, from scientist and engineers to policymakers, journalist, and the lay public. In short, generating plausible foresight inevitably involves a strong social component and cross-disciplinary negotiation» (Michelson, 2013, p. 194).

In this post-normal context in which the plausibility of a scenario is considered a matter of social scrutiny and inclusive deliberation (Guimarães Pereira et al., 2007; Selin, 2011), a variety of future horizons and perspectives (and reasons to support them) are expected to emerge, enrichening the elements that comprise "(S_i + {e})" and strengthening the viewpoint about the present and the tacit/explicit cognitive, affective, and normative knowledge and assumptions.

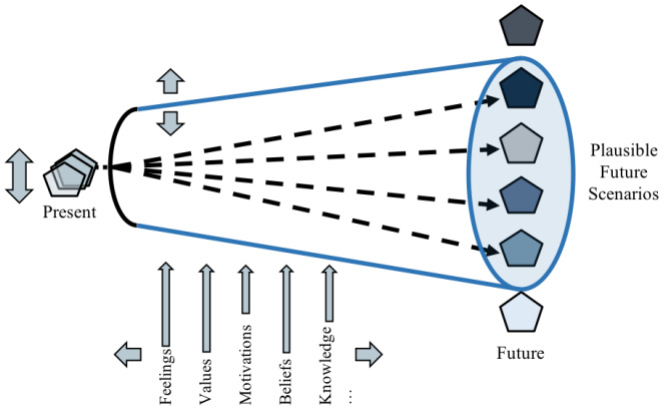

Figure 4. Negotiation of plausibility.

This enrichment, beyond promoting the inclusion of a greater number of voices and increasing the social legitimacy of the process, is what is expected to epistemically enable the anticipatory heuristics of scenario building practices (i.e. promote the identification of alternative futures that might otherwise go unnoticed, and to avoid the uncritical reification of some futures). If the creation of alternative futures fundamentally depends on enrichening "(S_i + {e})", and the negotiation of plausibility requires (i) diversifying, scrutinizing, and problematizing what can or must be accounted for "(S_i + {e})", and (ii) discussing what would be reasonable to derive from it, we may theoretically determine that "plausibility" serves here as a "socio-epistemic tool" whose function is to enable the anticipatory heuristics (see Figure 4).

Situated within this deliberative context, plausibility is above all an epistemic device that demands collective inquiry and reflection upon the foundations of the ways in which we think, project, use, and construct our representations of the future. If scenarios can be conceptualized as «perception devices» (van der Heijden, 2011, p. 29), plausibility may be theoretically understood as the socio-epistemic tool that enables the creation of anticipatory knowledge through opening-up the range of diverse alternative pathways that might be included within our range of visions. Plausibility, understood as an epistemic device, aims to underline the existence of multiple action pathways, reinforcing the contingency of the future, and thus serving as an antidote against deterministic and reifying visions.

At this point, it is interesting to note that the object of this deliberation is not the future per se, but rather *how we think about it here-and-now*. The debate focuses more on reflecting on the (performative) representations we currently have about what might happen (what we know about the future, why we think we know it, and what this knowledge implies; i.e. {e}), rather than trying to guess what is going to happen (i.e. if S_f will or will not be the case). Discussing on plausibility entails to collectively identify and embrace the uncertainties, assumptions, expectations, and hopes about the future that we actually have, and reflect on the robustness of the reasons that support them.

As may be evident, this deliberative process may encounter limitations and tensions in the practical arena that could undermine its expected theoretical effectiveness. Indeed, power relations may shape the negotiation dynamics about what should count as "(S_i + {e})" and what is potentially derivable from there, thus conditioning the results (Chapter 1). In a context in which «actors are trying to persuade each other of what to take seriously» (Nordmann, 2013a, p. 130), perhaps some have more argumentative authority and resources to assert their voices. In this sense, an important element that scenario practitioners should consider when carrying out plausibility negotiation processes is creating the best possible conditions to ensure not only the diversity and quality of the participants, but also the robustness of their interventions and interactions (e.g. trying to minimize or avoid cases of epistemic and hermeneutic injustice; Fricker (2007)). The quality of the deliberative process and outcomes will not only depend on the diversity of participants that are involved, but also on the quality of the dynamics and relationships that they establish, as well as on their responsiveness towards the available evidence and empathy with the viewpoint of others.

In this regard, it would be of great importance to support the rationale of plausibility negotiation providing empirical data and analytical attention on how plausibility negotiation dynamics de facto unfold and how the tensions that may emerge in that process are exploited, shaped, contested, and/or coordinated (see Chapter 6). Furthermore, it would be interesting to empirically assess the impact of this process on the different participants (e.g. how it enriches or helps to change their perspectives, develop anticipation skills, or appeal to action). These issues are of critical importance insofar as the deliberation processes on plausibility are intended to be a space for collective learning, and very often its outcomes are intended not only to assist the training of anticipatory capacities but also to influence decision-making processes.

After addressing the twofold nature of plausibility, two key questions remain open: What is the relationship between these roles, and why is the differentiation of them important?

Firstly, it should be noted that (i) these two roles do not have to necessarily be connected in the order in which they were previously presented (i.e. first methodological-limiting and then the anticipatory enabling), and that (ii) plausibility does not necessarily have to fulfill both roles. Although plausibility always plays its methodological-limiting role, it is not the same with the anticipatory-enabling one. In scenario practices which only aim to *project* a

prefixed "(S_i + {e})" for exploring the set of plausible futures that might be derivable from there, plausibility merely functions as a limiting criterion. However, in scenario practices in which plausibility also plays the anticipatory-enabling role the methodological-delimiting role can be understood as an outcome of the former. In other words, "plausibility" functions *within* the deliberative process as an epistemic device (e.g. envisioning alternative futures and reflecting upon our assumptions, values, and uncertainties regarding the issue at stake). But once this deliberative process is concluded, "plausibility" acts as a criterion that closes down the area of future alternatives on the basis of the negotiated "(S_i + {e})".[62]

Secondly, it is important to note that although both roles are involved in the dialectics of opening-up and closing-down the future, each does this in relation to different aspects. On the one hand, plausibility as a methodological-limiting criterion *opens up the space of future scenarios worthy of consideration beyond "the probable"* and closes them down on the basis of a prefixed "(S_i + {e})". On the other hand, the anticipatory-enabling role has the potential to open up the space of future scenarios not only beyond "the probable," but also in more radical terms. It is in the anticipatory-enabling role where "(S_i + {e})" and "→" are problematized. In this sense:

> Plausibility sparks questions about anticipatory knowledge and even reaches more fundamentally into what we know and how we know it. The very (un)knowability of the future is illuminated in such a way that we can begin to unravel the norms, values, methods, cultures and logics that give rise to a variety of future-oriented practices (Selin and Guimarães Pereira, 2013, pp. 100–101).

The significance of the theoretical distinction between these two roles lies within the fact that although many scenario practices call for "plausibility," not all of them do so in order to enable the anticipatory heuristics that this epistemological tool can provide.

5.4. Revisiting the roles of plausibility: Re-distributing modal power through plausibility negotiations

After previously analyzing the possible roles that "plausibility" may play, it is now necessary to reflect specifically upon the implications that this analysis could have when assessing the plausibility of future scenarios for technological governance.

One important lesson learned over the last 50 years is that STI processes are indeed (partially) shaped by our visions, expectations, and hopes (i.e. anticipations). The interest aroused in the performative role of anticipations is understood in a triple sense: As a

[62] In this regard, several critical questions may arise. For example, an elementary but extremely important issue that has not been sufficiently and explicitly articulated in the specialized literature is how the space of "the plausible" is finally defined and closed. Although it may not be problematic to reach a minimum agreement about what delimits the space of "the possible" in contexts in which the multiple actors involved share alternative but potentially compatible objectives, knowledge, and/or assumptions, this can be problematic in situations where incommensurability between these elements exists.

sociological fact that affects the way in which we understand STI, as an object of critique, and as a resource to promote the governance of STI (Chapter 1).

Despite the criticism that the "future talk" has received when applied to the governance of technologies (Nordmann, 2007, 2010, 2013a, 2014) (see Chapter 4), some authors continue to defend potential benefits that creating future scenarios may have for the governance of emerging technologies (Boenink, 2013; Selin, 2011, 2014; Selin and Guimarães Pereira, 2013). These authors consider the creation of scenarios as a central political-epistemological tool for increasing resilience, preventing potential problems, assessing the suitability of visions for future innovations (Ferrari et al., 2012), and, ultimately, for strengthening decision-making processes through multiple deliberative methodologies in contexts of uncertainty (Selin, 2011). In this context, anticipation implies not only exposing the performativity of technological expectations and the so-called "present futures" (Alvial-Palavicino, 2015; Brown et al., 2000), but also considering their heuristic characters in order to better understand our present (Miller, 2018) and promote a more reflective governance of STI (Guston, 2014).

How can we understand and contextualize the concept of plausibility within this rationale? The previous sections attempted to highlight the enabling and limiting functions that plausibility could have for foresight or scenario building and assessment practices. Since future sociotechnical scenarios are a specific type of scenarios that aim to explore the coevolution and co-production between STI and society, the previous findings are equally applicable to them as well. In this sense, plausibility also may play in this context two roles: As a methodological-limiting criterion and as an anticipatory-enabling "epistemic device". On the one hand, its limiting role refers to the need to create a filter when opening-up the future because not every "sociotechnical world" can happen according to the current situation (S_i) and the actual set of knowledges, beliefs, feelings and so on ({e}). On the other hand, its enabling role refers to the need to problematize what should count as "(S_i + {e})" opening it up to public scrutiny (Selin, 2011). Thereby, it aims to disrupt and mobilise modal power allocations.

The quest for plausibility not only appeals to the need to find a comprehensive (not so restrictive, not so speculative) methodological criterion for delimiting the scenarios worthy of consideration in decision-making processes. First and foremost, this quest appeals to the need to increase reflection on the eminently socio-political character of STI co-production and to distribute the value of the alternatives of those often silenced. Given that the concept of plausibility «cannot be established beyond a personal or social process of negotiation» (van der Helm, 2006, p. 26), the deliberative process around "the plausible" can serve as a resource to foster awareness of the contingent, intentional, and malleable nature of sociotechnical systems. The diversity of perspectives of the actors potentially involved in negotiating the plausibility of the scenarios could thus enrich the perspectives from which "S_i" (different perspectives about our present) and "{e}" (knowledges, feelings, values, and so on) are interpreted and the elements that constitute them, thus enlightening and opening the present pragmatic field of plausible actions.

In this way, the discussion on the plausibility of future sociotechnical scenarios aims to show that technological development is a socio-political project—it is not possible to completely control and predict its evolution, but it is possible to shape its development. In other words, the negotiation on the plausibility of future sociotechnical scenarios is a clear resource for the AG of emerging technologies (Barben et al., 2008; Selin, 2011) and the promotion of a RI (Stilgoe et al., 2013, p. 1573).

Nevertheless, and despite the potentially helpful theoretical and practical virtues that scenario creation may have for anticipatory governance of technologies, it should not be forgotten that the plausibility negotiation processes may be subject to the power tensions and disagreements typical of any other socio-political process (van Oudheusden, 2014). The empirical study of these processes and how their results are ultimately "created" and "translated" into truly effective political decision-making is (and hopefully will be) particularly relevant for this promising (and sometimes promissory) field.

5.5. Conclusions

In this chapter, future scenarios were theoretically characterized as representations "$(S_i + \{e\}) \rightarrow \{S_f\}$" where "$S_i$" should be preferably a real situation set in the present, and "$\{S_f\}$" must be understood as—more or less robust—hypothetical narratives set in the future. Furthermore, the set of assumptions, beliefs, ideas, feelings, and values "{e}" that modulates S_i could refer to all the three parts of the timeline: the past (e.g. historical data, analogies, past trends…), the present (e.g. present trends) or the future (e.g. assumptions, visions about what might happen) (Section 5.2).

This characterization was used as a formal tool to explore and clarify the meaning of the term "plausibility" and how it may be approached and applied. Analysing the possibilities for applying the concept of "plausibility", I defended that it can play at least two main roles. On the one hand, "plausibility" can be considered as a methodological criterion with a demarcative role for determining the scenario narratives to be considered in decision-making processes. In this first role, plausibility is considered a limiting criterion because scenarios that arguably cannot be derived from a prefixed "$(S_i + \{e\})$" are discarded. On the other hand, "plausibility" can also be regarded as an "epistemic device" for enabling the anticipatory heuristics of future scenarios. In this second role, the concept of "plausibility" is conceived as a socio-epistemic tool for promoting anticipatory heuristics. This second perspective recognizes the negotiation of "$(S_i + \{e\})$" and what may be derived from it as practice to increase awareness of the openness of the future and to promote anticipatory capabilities (Section 5.3).

Finally, I have examined some of the more direct theoretical implications of the dual role of plausibility for scenario-building processes which aim to promote the anticipatory governance of emerging technologies (Section 5.4). On the one hand, the limiting role invites us to analyse whether the future sociotechnical scenarios are robust enough (i.e. if they

follow "(S_i + {e})") to be used as resources for decision-making. On the other hand, its enabling role stimulates problematizing which elements count as "S_i" and "{e}". In this second facet, plausibility seems to be an extraordinary resource to introduce a critical look at how we think and build our present sociotechnical systems by looking to the future. In times that speculative visions and other sociotechnical imaginaries are at the centre of the social agenda and in many cases act as one of the diverse legitimating elements of scientific-technological policies, plausibility could serve to problematize them, to visualize the role of technology in our societies, and how we can or cannot influence their development.

Beyond the theoretical virtues that plausibility as an epistemic tool might have, there is an evident need to deepen both in the constitutive elements of the scenarios and the way in which plausibility is empirically operationalized. In this regard, it would be particularly important for the field to pay special attention to the conditions and dynamics that shape and transform the plausibility negotiation processes, how these processes influence the different participants, and how their results are concretized in decision-making.

CHAPTER 6

Foresight and responsible innovation: Openness and closure in anticipatory heuristics

This chapter is a slightly modified version of the article **Urueña, Sergio**, Rodríguez, Hannot, & Ibarra, Andoni (2021). "*Foresight and responsible innovation: Openness and closure in anticipatory heuristics*", *Futures, 134*, 102852. doi: 10.1016/j.futures.2021.102852 and has been reproduced here with the permission of the copyright holder.

CrediT author statement: Sergio Urueña [corresponding author]: Conceptualisation (lead), Investigation (lead), Writing – original draft (lead), Writing – review & editing (equal), Supervision (equal), Revisions (equal). **Hannot Rodríguez**: Conceptualisation (supporting), Writing – original draft (supporting), Writing – review & editing (equal), Supervision (equal), Revisions (equal). **Andoni Ibarra**: Conceptualisation (supporting), Writing - review & editing (supporting), Funding acquisition (lead).

Abstract The heuristic versatility of foresight is increasingly positioning this anticipatory instrument as a key resource to promote more responsible STI practices. In a context where foresight's multiple heuristic potential is sometimes wrapped up in a promissory rhetoric that could lead to its being taken for granted, this chapter underlines the need to understand the emergence of these heuristics as being dependent on how foresight's dynamics unfold. By acknowledging the existence of more "open" or "closed" forms of foresight (which in turn can articulate more "open" or "closed" anticipations), the chapter argues that the degree of "openness/closure" of foresight activities is constituted during the *ex-ante*, *ex-dure*, and *ex-post* processes, and according to the relations underlying their constructive dynamics. The main conclusion reached is that a pre-condition for foresight practices to become "instruments for" responsible innovation is to make them "subjects of" responsibility simultaneously. This involves monitoring the socio-epistemic relations whereby foresight practices are designed and executed, as well as monitoring how their emergent heuristics are translated into action.

6.1. Introduction

The main motivations and scope of normative frameworks and activities aimed at responsibilising innovation have varied over time (Ported, 1995; Schot and Rip, 1997). Nevertheless, since their inception they have sought to improve decision-making on the basis of representations of the futures that scientific and technological activities *may* (i.e. possible, probable or plausible futures) and/or *should* (i.e. desirable futures) "open up" (Coates, 1971; Rip et al., 1995). Thus, activities aiming to promote more responsible governance of STI practices have always been carried out in an anticipatory fashion (Poli, 2019a; Poli and Valerio, 2019).

However, the (meta-)theoretical and practical fragmentation of studies and activities that could be subsumed under the controversial umbrella term "Anticipation and Futures Studies" (see Samet, 2010; Sardar, 2010) suggests that there are different approaches and dimensions to address "the future(s)", and different ways of translating them into action (e.g. Bell, 2003; Inayatullah, 1990). The diversity of theoretical and practical approaches currently coexisting in Anticipation and Futures Studies illustrates the heterogeneity of understandings and possible "uses" of "the future(s)", and thus the functional and heuristic diversity of anticipatory practices. The far-reaching conceptual distinction between "forecast" (i.e. empirical-predictivist) and "foresight" (i.e. non-predictivist) (e.g. Cuhls, 2003; Godet, 2012), and the many ways in which these two general approaches "to the future" are specifically conceived and applied in practice, might help to illustrate this diversity (Makridakis et al., 2008; Minkkinen et al., 2019; Porter, 2010). Foresight is typically regarded as the main interventive and identitary terrain of Anticipation and Futures Studies (Son, 2015). It is, however, a polyvalent anticipatory tool defined by different objectives, functions and potential areas of operation. Foresight covers a broad spectrum of heterogeneous methods with different characteristics (in terms of rationales, goals, participants, etc.) and functionalities (compare Giaoutzi and Sapio, 2013; Karlsen and Karlsen, 2013; Minkkinen et al., 2019; Porter, 2010).

Foresight practices are commonly credited with being able to broaden the range of futures considered and enhance future literacies (Rhisiart et al., 2015) (Chapters 2 and 5). The anticipatory heuristics of foresight exercises have been increasingly recognised in contexts focused on promoting more responsible STI co-production practices (Barben et al., 2008; Brey, 2012; Grunwald, 2019b; Stemerding et al., 2019; Swierstra et al., 2009; von Schomberg et al., 2006; Weber et al., 2019). Indeed, over the last two decades, innovation systems (at least in the narratives) have increasingly moved towards more participatory and horizontal forms of governance and decision-making (e.g. Chilvers and Kearnes, 2020; Commission of the European Communities, 2001; Eizagirre et al., 2017; European Commission, 2002) (Section 2.4.1). Within this recent context, it has been claimed that foresight contributes to the better alignment of innovation with societal needs and ethical concerns (i.e. foresight contributes to more responsible innovation). Foresight's anticipatory heuristics are understood as an important entry point for improving critical awareness regarding the way the future is being shaped through science and technology in the present.

This way of conceiving foresight in the context of innovation is not surprising; within Anticipation and Futures Studies, «[f]oresight is 'by default' devised to promote democratic processes through inclusiveness, openness, transparency, public engagement, and multi-stakeholder approaches» (Amanatidou, 2017, p. 1). By «creating transformative spaces for the creation of alternative futures» (Inayatullah, 1998, p. 815), foresight is commonly conceived as being able to empower and capacitate societal actors, integrate knowledge-systems, and/or even create «more whole human beings» (Ramos, 2006, p. 652).

This positive perception of foresight heuristics contrasts with some sceptical views that point to the possible shortcomings that may arise from exercises dealing with representations of the future. Nikolova (2013, p. 8; emphasis added), for instance, warns that (participatory) foresight exercises sometimes «deviate from the initial intentions» and may «create *an illusion* of empowering the public». In the same vein, methods considered highly disruptive within the realm of science and technology governance such as sociotechnical or techno-moral scenarios (e.g. Arnaldi, 2018; Swierstra et al., 2009; Withycombe Keeler et al., 2019) have been challenged by various critiques. In particular, critics, more or less legitimately, point out that the way futures are mobilised and framed in innovation practices are often permeated by biases (Bonaccorsi et al., 2020; Williams, 2008). For example, Nordmann (2014) notes that engaging with future representations may cause long-sightedness (i.e. detachment from the present), reify promises and visions, and/or reproduce misperceptions of control and determinism (Boenink, 2013).

This chapter aims to problematise the arguable substantialisation (or "taken-for-grantedness") of anticipatory heuristics for steering more responsible innovation attributed to foresight exercises. In particular, the chapter underlines the need to understand the emergence of foresight heuristics as being highly dependent on how foresight's dynamics unfold. Foresight is functionally and heuristically variable in terms of the spectrum of potential alternative futures and capabilities that it might anticipatorily enable for (de)construction. Given that this degree of "openness/closure" of foresight depends on its constitutive dynamics, a pre-condition for these exercises to unleash their full potential as "instruments for" responsibilising innovation is to consider them "subjects of" responsibility. Considering foresight exercises as a "subject of" responsibility would entail monitoring the socio-epistemic relations whereby they are progressively co-constructed throughout the whole process (i.e. throughout the *ex-ante*, *ex-dure*, and *ex-post* foresight operationalisation phases).

In order to develop this proposal, first it will be shown how foresight has been increasingly recognised as a valuable "instrument for" steering more responsible research and innovation. This value lies in its alleged potential to problematise (or "open up") the diverse anticipatory dynamics shaping innovation governance (Section 6.2). It will then be argued that anticipatory foresight heuristics and functionalities and their respective degree of "openness/closure" should not be taken for granted, but rather be understood as dependent

on how the constructive relations between its constituents unfold (Section 6.3).[63] More precisely, it will be theoretically argued that foresight's constitutive socio-epistemic dynamics are influenced by a series of sociotechnical constraints (or "hampering (f)actors"). These sociotechnical constraints modulate the "openness/closure" potential of foresight practices during their *ex-ante* (Section 6.3.1), *ex-dure* (Section 6.3.2), and *ex-post* (Section 6.3.3) operationalisation phases. The chapter concludes by emphasising the need to make foresight a "subject of" responsibility whilst simultaneously being used as an "instrument for" responsibilising innovation practices. This responsabilisation of foresight would entail critically examining and problematising, *in real time*, the constitutive socio-epistemic dynamics being (un)favoured and/or (dis)enabled (as well as their underlying rationales) (Section 6.4).

This chapter therefore proposes that the focus be broadened from improving STI design and development processes through foresight to the design and development of foresight itself. Although foresight has the potential to make design and development processes more responsible, such potential depends on how foresight is designed and operationalised within the sociotechnical fabric in which it operates. Foresight thus needs to be "responsibilised" by monitoring (and caring for) its constructive dynamics.

The findings presented here may be of particular interest to foresight practitioners whose main area of operation is STI. For instance, it may be of interest to foresight practitioners engaging with normative frameworks such as Anticipatory Governance (AG), Responsible Research and Innovation (RRI), Responsible Innovation (RI), or Technology Assessment (TA) (among others). Some scholars from Anticipation and Futures Studies may also see this chapter as a modest, reflexive insight into the design, implementation, and assessment of their "worldmaking" practices (Vervoort et al., 2015).

6.2. Anticipations and the governance of sociotechnical systems: Foresight as an "instrument for" responsible innovation

The "use" of the future as a praxiological guide for the present (i.e. anticipation) is a pervasive phenomenon. It crosses and articulates the activity of diverse physical, biological and social systems (Nadin, 2016; Poli, 2017). Over the last three decades, the field of Science and Technology Studies has seen a growing interest in the narratives and discursive elements that permeate and constitute STI practices (Fuglsang, 2001; Hess and Sovacool, 2020). Part of this interest has led to the development of analytical enquiries that aim to highlight, illuminate and critique the performative role of representations of the future steering STI processes. Examples include recent developments in the sociology of expectations (Borup et al., 2006; Brown and Michael, 2003; van Lente and Rip, 1998a) or theoretical proposals

[63] In this sense, the chapter aligns with the constructivist epistemology that seems to articulate (more or less tacitly) Futures Studies nowadays (e.g. Bell, 2003; Fuller, 2017; Fuller and Loogma, 2009; Inayatullah, 1990).

concerning sociotechnical imaginaries (Ballo, 2015; Jasanoff, 2020; Jasanoff and Kim, 2015; McNeil et al., 2017). What all these studies diagnose is that STI activities are not immune to anticipatory embodiments (Brown et al., 2000; Konrad and Böhle, 2019).[64] Indeed, "the future" is largely (if not entirely) rooted under different forms in the macro, meso and micro co-production and assessment of innovation practices (Konrad and Alvial Palavicino, 2017).

In the context of modern, highly industrialised and market-based societies, innovation has been radically associated with the impetus to generate and manage expectations and visions of high economic value (Beckert, 2016). Expectations, visions, and imaginaries are currently understood as anticipatory means to justify and promote certain techno-industrial practices. Indeed, innovation practices are typically understood as eminently knowledge-based and future-oriented. Such practices are aimed at creating *new future action possibilities* with far-reaching socio-economic implications and meanings.

Innovation, however, besides being an element in the construction of realities—an element of "creative destruction" in Schumpeterian terms (Schumpeter, 1942)—, is itself co-constructed (Jasanoff, 2016). It is a co-construction that takes place in broader sociotechnical systems, i.e. systems dynamically and relationally constituted by «heterogeneous ensembles of people, artifacts, infrastructures, research, cultural categories, norms and laws, and natural resources» (Hess and Sovacool, 2020, p. 3). Innovation practices and their outcomes are thus highly and necessarily *dependent* upon varying sorts of resources, interests, inertias, and dominant practices and discourses. Innovation practices and their outcomes are not alien to the relational dynamics constituting the sociotechnical settings in which they take place.

This relational-dynamic ontology emphasises that "social" and "technical" realities are inextricably intertwined and mutually co-produced. The settings in which innovation and anticipation unfold are therefore understood as a *hybrid* sociotechnical fabric. This sociotechnical fabric is dynamically governed by complex dialectics of co-constitution that are not free of tensions and power imbalances. For instance, the dominant (capitalist) economic relations in sociotechnical settings are reflected in the narratives of institutions steering STI policies. These narratives frame innovation as a key driving force to boost social welfare and market competitiveness (European Commission, 2009, 2020b; Rodríguez, 2018). This connection between economic, social and technological progress becomes especially notable in the narratives on "strategic" emergent technologies, which are perceived as highly disruptive (e.g. nanotechnologies, biotechnologies and artificial intelligence).[65] These dominant relationships are typically anchored to a set of inflated

[64] As Selin (2006a) notes, discourses on emerging technologies are located in disparate or different temporal horizons. However, their "not-yet-existent" character often qualifies them as important niches for anchoring promises and speculations about the sociotechnical configurations they might enable.

[65] Specialised literature typically distinguishes between "incremental innovations" (i.e. aimed at improving existing products and processes) and "disruptive innovations" (i.e. aimed at generating dramatic changes in markets and industries) (e.g. Ettlie et al., 1984; Nagy et al., 2016). However, according to the relational-dynamic ontology advocated in this chapter, this distinction is neither essentialist nor categorical. On the one hand, the distinction between "incremental/disruptive"

expectations regarding the socio-economic value of certain techno-industrial innovations (Alvial-Palavicino and Konrad, 2019).

Futures representations and modes of cohabiting "the future" are constitutive elements of the sociotechnical assemblage in which innovation practices take place. Future *time* horizons constitutively permeate the diverse epistemic, social, cultural and ethical-political dynamics articulating the governance of innovation practices (Selin, 2006a). Among the heterogeneous anticipatory phenomena constituting the governance of sociotechnical systems, the performativity of futures nurtured by expectations (e.g. hope, hype, fear), visions and sociotechnical imaginaries has attracted particular attention (Borup et al., 2006; Jasanoff and Kim, 2015; Simakova and Coenen, 2013; van der Helm, 2009). These heterogeneous, mutable and plural coexisting expectations, visions, and imaginaries are co-created and disseminated in many different ways by diverse constellations of actors. These prospective elements convey representations of the future which, operating as "anticipatory devices", modulate a multiplicity of sociotechnical synergies and material assemblages. They disseminate meanings that colonise and shape the "prospective structures" (i.e. the emotional, cognitive and volitional schemata regarding the future) of the various societal actors and fulfil them "by agency" (van Lente and Rip, 1998a). Representations of the future that successfully articulate anticipatory actions help to coordinate the actors and efforts in order to achieve certain goals via certain means. They contribute to the legitimisation and organisation of science and technology (Rommetveit and Wynne, 2017), and help steer socio-political spaces of controversy (Michael, 2017) and contestation (Brown et al., 2000) (Section 1.3). Three examples of basic anticipations at work are: (i) The misleading idea of innovation-based linear progress still present in different policy narratives (Selkirk et al., 2018), (ii) the distribution of funds on the basis of the promissory futures that an emergent technology might "open up" (Beckert, 2016, p. 184), or (iii) orbiting innovation policy agendas around the so-called "Grand Challenges" (Kuhlmann and Rip, 2018). Such anticipations illustrate how the alleged transformation of "prospective structures" engendered by representations of the future may refer not only to *content* (the specific expected, envisioned or imagined futures), but also to the *formal* commitments whereby the future itself is approached (e.g. as (i) a straight trajectory, as (ii) a vantage point and as (iii) a project, respectively).

Together with the aforementioned anticipatory dynamics articulated in visions, expectations and sociotechnical imaginaries that guide innovation practices in a more or less implicit manner, there are other anticipatory dynamics that *intentionally* and *explicitly* aim

---

innovations is not essentialist because "incrementality/disruptiveness" is not perceived an inherent feature of innovations per se, rather as a feature stipulated *in relation to* the characteristics of the sociotechnical setting of which innovations form part. On the other hand, this distinction is not categorical in that the incremental/disruptive nature of innovations is gradual and prone to variation. Moreover, the attribution of "disruptiveness" to an emerging technology is not anticipatorily unproblematic. For instance, attributing "disruptiveness" may respond to an attempt to associate such technology with promising futures. Characterising a technology as "disruptive" can serve as a rhetorical resource to legitimise and promote its current development practices (Berube, 2004).

to promote more responsible innovation governance. Science and technology responsibilisation practices have increasingly articulated their activities in mainly *prospective* accounts. In contrast to *retrospective* accounts of responsibility (where responsibility is reactively *attributed* after the event), *prospective* accounts appraise responsibility proactively. Responsibility here is proactively *taken on* beforehand on the basis of more or less robust models of potential normative or exploratory futures. By including a forward-looking dimension, these responsibilisation activities have often embraced explicit anticipatory behaviours.

Explicit and intentional anticipatory practices are, however, heterogeneous (Poli, 2019b). Different modes of intentionally "engaging with" and "using" future(s) coexist, each one configuring different possible ways of articulating and operationalising future-oriented responsibility (Adam and Groves, 2007).

Among the different ways of approaching the future as a means to promote more responsible innovation, the most conventional is the empirical-predictivist. Empirical-predictivist approaches frame the future as a space that *can* (and perhaps *should*) be epistemically apprehended. This empirical-predictivist mode of anticipation is typically articulated in forecast exercises, which can indeed be highly effective at preventing, avoiding or mitigating some undesirable effects of innovation. This effectiveness especially manifests itself when the target is a system with high ontological stability, and where low degrees of uncertainty exist.[66]

However, this empirical-predictivist mode of conceiving and operationalising responsibility has some theoretical and practical shortcomings that could narrow the scope of innovation responsibilisation processes both intensively (i.e. in terms of how many effects and how comprehensively and systematically they are addressed) and extensively (i.e. in terms of the research and innovation stages to be implemented). For example, the causal complexity characterising certain emergent innovations (e.g. nanotechnologies), together with the ontological openness characterising the sociotechnical and technomoral systems, constrain the intensive scope of this empirical-predictive anticipatory response (Hoffmann-Riem and Wynne, 2002). Moreover, predictive models for responsible innovation hinder the promotion of a contingent, non-linear view of the coevolution of sociotechnical systems and narrows the set of outcomes considered problematic. Since anticipatory practices articulated in empirical-predictive future models often act as mere *external* correctives of innovation's potential *outcomes*, they are also limited in terms of their extensive scope: They are not a proactive instrument for increasing normative reflexivity and problematising the *purposes* and/or underlying values guiding innovation *processes*. Similar to the mobilisation of

[66] The fact that forecast exercises can be more or less effective depending on the context to which they are applied should not lead to the misconception that they can be shielded from critical scrutiny. Among the fundamental elements of forecast exercises that should always be critically considered is the materiality of the forecasting techniques used (e.g. epistemic opacity of some computational models), the socio-cognitive biases that they may (re)produce, or the dangers of narrowing down the considerations to be taken into account regarding the future (Godet, 2012; Meijer and Wessels, 2019; Sarewitz et al., 2000).

expectations, visions and imaginaries, forecast activities can be conceived as subtle reification mechanisms of existing knowledge co-production patterns and their guiding purposes. In short, forecast-based responsabilisation activities subtly reproduce inertias of uncritical "closure" (Feenberg, 1991). They do this by keeping certain outcomes, purposes and processes of innovation safe from socio-political problematisation.

The two anticipatory "closure" dynamics mentioned above, namely the de facto (where visions, expectations and imaginaries play a performative role and shape realities) and the interventive-predictive (where prospective responsibility is narrowly based on forecast exercises), have been widely recognised and contested. On the one hand, proposals such as Vision Assessment (Grin and Grunwald, 2000; Lösch et al., 2017) or "governance *of* and *by* expectations" (Konrad and Alvial Palavicino, 2017; Konrad and Böhle, 2019) seek to increase awareness and reflexivity regarding "closure" dynamics generated by expectations, visions and/or sociotechnical imaginaries. On the other hand, proposals such as Future-Oriented Technology Assessment (Nazarko, 2017), Real-Time Technology Assessment (Guston and Sarewitz, 2002), TA (Sotoudeh and Gudowsky, 2018; Weber et al., 2019) or Anticipatory Ethics (Brey, 2012), seek to problematise and enrich the narrow, empirical-predictivist modes of future-oriented responsabilisation (e.g. by explicitly problematising the political and/or normative factors in the equation). Common to all the previous proposals (and others not mentioned here) is their emphasis on the need for foresight to "open up" the uncritical anticipatory "closure" inertias that permeate their respective fields of action.

The suggestion that foresight should be an "opening-up" resource is even more explicit and radical in normative governance frameworks such as AG (Barben et al., 2008; Guston, 2014), RI (Owen et al., 2013; Stilgoe et al., 2013) or RRI (European Commission, 2013a; von Schomberg, 2013). As showed in Chapters 2 and 4, the inclusion of foresight and anticipation in these frameworks, however systematic, takes on a varying forms and degree of explicitness. This inclusion is clearly evident in the cases of AG and RI in their respective "foresight" and "anticipation" dimensions. In the case of RRI, the inclusion of foresight is reflected in the recognition that RRI's operationalisation «implies, among others, the introduction of broader foresight» (von Schomberg, 2013, p. 51). Indeed, within the RRI framework, foresight is considered an instrument that enables «inclusive and integrated assessments of future science and technology» (European Commission, 2017, p. 9).

The radicality of these frameworks lies in their impetus to problematise diverse domains involved in innovation processes from early stages of development by including a wide range of societal concerns and actors. The degree of radicality, or "openness", of normative proposals is therefore defined in this chapter in terms of: (i) The areas of innovation covered (What domains of innovation are problematised?); (ii) the time variable (When is the innovation problematised?); (iii) the degree of inclusiveness (Who sits at the negotiation and governance table?); and (iv) the degree of embeddedness of STI problematisation in STI practices (Is the problematisation from the outside or from within?) (Section 2.4.1). For example, a normative framework that limits responsibility to impacts may be considered less "radical" than one that broadens its focus to include innovation processes and purposes.

Similarly, an *ex-post* evaluation may be considered less "radical" than one conducted at its early stages of development (the latter allows innovation development to be modulated from the outset so as to avoid "technological lock-in" and sociotechnical entrenchment). Finally, a normative framework that is able to involve a wider variety of actors and concerns can be considered more "radical" than one where governance is confined to a small group of actors (e.g. experts) (see Cuevas Badallo and Urueña, 2019).

Foresight operates in the context of AG, RRI, RI, and TA (alongside other principles and dimensions) as a tool to problematise the values, processes and possible outcomes shaping STI dynamics in a participatory way from their early stages of development. As Barben et al. (2008, p. 986) note, foresight «aims to enrich futures-in-the-making by encouraging and developing reflexivity in the system».

These latter normative frameworks aim to transcend the dominant institutional tendency to understand responsibility according to a top-down approach. Namely, as an exercise that consists of imposing prefixed regulatory norms and values on STI processes and outcomes whose social significance, moreover, is unproblematised (Felt et al., 2007; Owen et al., 2013). These proposals' radicality lies in considering responsibility as a function of meeting a set of "opening-up" *procedural* dimensions (according to a bottom-up approach) (Pellé, 2016). According to AG, responsibility entails the "ensemble" of foresight, engagement and sociotechnical integration (Barben et al., 2008; Guston, 2014). RI claims that responsible practices are the result of conjugating anticipation, reflexivity, inclusion, responsiveness (Stilgoe et al., 2013) and openness (Owen and Pansera, 2019). According to RRI, all societal actors should «work together during the whole research and innovation process in order to better align both the process and its outcomes with the values, needs and expectations of European society» (European Commission, 2013b, p. 4). TA is defended as an inherently activity for the democratisation of STI that requires anticipation, inclusion, and complexity (Grunwald, 2019b). AG, RRI, RI, and recent forms of TA thus reflect a commitment to a "politicised" concept of responsibility, where responsibility depends on how the plurality of interests, factors and actors mobilised around the purposes, processes and outcomes of innovation are embraced and articulated (Eizagirre et al., 2017; Nielsen, 2016). What interests and actors are excluded from research and innovation processes? Whose motivations and what power relations are dominant? What are the socio-economic implications of privilege-based and unequal research and innovation dynamics? These and other similar questions lie at the heart of these more radical responsibility frameworks (Stirling, 2008).

When informed by these frameworks, foresight turns into an anticipatory heuristic resource for politicisation. This requires «the introduction of broader foresight» (von Schomberg, 2013, p. 51). A kind of foresight aimed at problematising and negotiating the visions, expectations, security scenarios, and political preferences involved in innovation dynamics. Problematisation and negotiation that, in turn, aspire to co-produce more socio-epistemically robust alternative futures (e.g. Owen et al., 2013, p. 38). Here foresight is conceived as an instrument to stimulate collective scrutiny of: (i) The (im)plausibility and/or

(un)desirability of the futures shaping innovation practices in the present, and (ii) how the future itself is approached. In other words, here foresight becomes an instrument for «taking care of the future through the collective stewardship of science and innovation in the present» (Stilgoe et al., 2013, p. 1570). The future, in this context, is not primarily approached as a space to be epistemically conquered (Foley et al., 2018), but «as a negotiable political resource and discourse area that can be written on» (Bauer, 2018, p. 38). Foresight thus is conceived as a disruptive instrument which broadens the range of actors and concerns involved in innovation practices. It is an instrument to facilitate the imagining of alternative sociotechnical futures capable of transcending dominant, "business-as-usual", technocratic and economistic realities (Wiek et al., 2016).

In conclusion, foresight is currently conceived and/or used by diverse normative proposals and frameworks as a comprehensive instrument aimed at enacting anticipatory heuristics. It is claimed that these heuristics "open up" the "closure" inertias that de facto constrain innovation futures-making practices. This "opening-up" occurs in multiple domains (outcomes, processes, purposes and/or expectations/visions/imaginaries), and according to different radicalisation gradients (Section 2.4.1). Table 12 exemplifies (without claiming to be comprehensive, and according to ideal-typical[67] domains of application) some of these functions and heuristics for enhancing more responsible innovation ascribed to foresight practices.

Table 12. Examples of anticipatory heuristics and functions ascribed to foresight practices for responsible innovation.

Innovation domains	Examples of expected functions and heuristics
Performativity of expectations, visions, imaginaries	Social refinement / deconstruction of existing visions, expectations, imaginaries and/or development of new, meaningful ones (Grin and Grunwald, 2000; Konrad and Alvial Palavicino, 2017) Diversification and management of visions and expectations (Warnke and Heimeriks, 2008, p. 79)
Outcomes	Configure more "socially-robust risk research": questioning fixed normative, empirical and technical-methodological assumptions and reframing how the assessment of the possible effects (e.g. risks) are being constructed (e.g. what variables are being overlooked; how are they interrelated and framed; what alternatives exist) (Stilgoe et al., 2013, p. 1570) Imagining sociotechnical and technomoral coevolution interplay between technology, society, morality and social practices, as well as exploring the plausible "hard/soft impacts" (Arnaldi, 2018; Boenink, 2013; Swierstra et al., 2009)

[67] The innovation domains listed in Table 12 are ideal-typical in the sense that they do not reflect the inter-domain relationships in all their complexity and interactivity. The relationships between outcomes, processes and purposes are, in practice, rather characteristically messy, unruly and iteratively co-constituted. The apparent linearity responds exclusively to analytical-expository purposes.

Innovation domains	Examples of expected functions and heuristics
Processes	Function as a process moderator (Warnke and Heimeriks, 2008, pp. 81–82): - A tool for wiring up the innovation systems (Martin and Johnston, 1999) by establishing networks between actors (Barben et al., 2008) - Engaging other ways of knowing and co-producing knowledge (Selkirk et al., 2018, p. 6) - Creating inclusive spaces for mutual learning (Könnölä et al., 2007) - Building reflexivity into the design and development of emerging technologies (Selin, 2011, p. 175) - Promoting flexibility in response to ongoing developments (Boenink, 2013, p. 149)
Purposes	Allowing «shared explorations of desirable futures, thereby collecting tacit knowledge as well as social needs and values» (Gudowsky and Peissl, 2016, p. 8) Elucidating public preferences for various alternatives (Selin, 2011, p. 723) Identifying novel strategic opportunities (Arnaldi, 2018; Fuller, 2018b)
Transversal anticipatory capabilities	Enhancing «reflexivity, perspective-taking, and responsible decision-making» (Selkirk et al., 2018, p. 1) Emphasising contingency, and «to better confront the linear model of time so as to recognize the complexities and systematic character of contemporary innovation» (Selkirk et al., 2018, p. 7), «including in particular the possibility of discontinuity and radical change» (Boenink, 2013, p. 152) Training in *phronesis*, or practical wisdom, by exercising imagination, perception, and even empathy (Boenink, 2013, p. 155) Building resilient societies (Barben et al., 2008; Fuller, 2018b)

Instead of taking foresight's positive heuristics for granted, the next section highlights the need to appraise them as the result of foresight practices' actual dynamics. In this sense, rather than approaching foresight exclusively as an anticipatory instrument to promote responsibility, this chapter claims that foresight itself needs to be monitored and be cared for. Thus, this proposal seeks to broaden the analysis of foresight practices. In contrast to more mainstream approaches, which are mostly interested in improving STI design and development processes through foresight and anticipation, the aim here is to highlight the need to monitor foresight's constitutive processes as well (i.e. foresight's design, implementation and evaluation processes).

6.3. Foresight as a "subject of" responsibility: Towards monitoring futures-making dynamics

The previous section shows how foresight exercises have been positioned by various STI governance frameworks or proposals as interventive instruments to "open up" anticipatory "closure" inertias (see Table 12). In this context, foresight practices are recognised as worldmaking mechanisms (Vervoort et al., 2015) serving as "instruments for" responsible innovation. Understanding foresight as an "opening-up" resource is, nonetheless, subject to variation. The *expected* degree of foresight radicality, in terms of its "opening-up" potential, varies in accordance with the normative framework or proposal from which it is framed and intends to serve. The various semantics surrounding "responsibility" affect and are reflected in the different meanings and expectations of "foresight" heuristics (and vice versa).

This variation in the meaning and expectations attributed to foresight's "opening-up" role is one of the factors influencing its heuristic potential, but not the only one. Foresight's heuristic potential is also dynamically and relationally constituted throughout the course of

the foresight design and operationalisation processes. Indeed, as Fuller and Loogma (2009) note, foresight is not only a mechanism for constructing realities, but is itself a construction. Foresight is both an "instrument for" responsible innovation and an innovation in itself. In short, it is an interventive tool made "in-the-making" that is spatially and temporally constituted. All of this implies that the valuable anticipatory heuristics of foresight practices do not arise *ex-nihilo*, but are in turn the contingent and situated outcome of the sociotechnical and socio-epistemic relations taking place throughout their design and operationalisation (Dufva and Ahlqvist, 2015a, 2015b). That is, the emphasis lies here in that both the type of heuristic and its respective degree of "openness/closure" do not arise by default. Instead, they are progressively constituted through the series of dynamics whereby foresight practices are operationalised and constrained. This means that foresight's degree of "openness/closure" stems from the dynamics occurring throughout its *ex-ante*, *ex-dure*, and *ex-post* operationalisation phases.

The degree of "openness/closure" of anticipatory practices might be understood in terms of the amplitude of space for alternative "plausible" and/or "desirable" futures. This amplitude is enabled during the (de)construction of futures in light of the heterogeneous technical, methodological, axiological, volitional, socio-material, epistemic and/or affective constraints explicitly or implicitly established and/or co-negotiated during the whole process (Chapter 5). This means that reifying or substantivizing conceptions where foresight's meaning and performativity are taken for granted should be avoided. Instead of assuming certain virtues of foresight practices, the socio-epistemic processes whereby such practices are performed and constituted need to be addressed. In addition to using foresight practices as "instruments for" responsible innovation, they must be simultaneously appraised as "subjects of" responsibility. This would require real-time monitoring of the conditions constituting foresight heuristics. It is important to elucidate the "enabling/constraining" influence exerted on the unfolding of foresight practices by the sociotechnical networks in which they are put into practice.

This proposal is made in a context where foresight is perceived and presented by certain normative frameworks as an instrument for "opening-up" STI processes. The degree of "openness" (or "disruption") attributed to foresight in AG, RRI, RI, and TA normative frameworks is particularly noteworthy. These frameworks, as outlined in the previous section, understand responsibility as a function of meeting a set of "opening-up" and procedural criteria aimed «at amplifying the still, small voices less often heard in the innovation process» (Guston, 2014, p. 229). In this context, foresight is conceived as an instrument to promote radically inclusive STI processes.

In the context of this tendency to conceive responsibility in inclusivist, or "political", terms (Eizagirre et al., 2017; Nielsen, 2016; Pellé, 2016), the aim here is to note that any foresight operationalisation must deal with sociotechnical inertial factors that seriously hamper achievement of the inclusivist ideal. Dealing with these inertial factors is crucial in order to (de)construct truly alternative and disruptive (i.e. not "business-as-usual") futures. This requires monitoring how "hampering (f)actors" modulate the ongoing socio-epistemic

dynamics of foresight, and thereby its heuristic "opening-up" potential. This is what is meant when the need to make foresight a "subject of" responsibility is underlined.[68]

To be more specific, some possible constraints or "hampering (f)actors" to which particular attention could be devoted when foresight is made the "subject of" responsibility will be highlighted below. These "hampering (f)actors" influence the main operationalisation stages (or "key points") of foresight in which its "openness/closure" potential is progressively determined. In the following sections, the key "opening/closure" points and "hampering (f)actors" will be briefly presented. The presentation specifically relates to each *ex-ante* (6.3.1), *ex-dure* (6.3.2), and *ex-post* (6.3.3) phase of foresight operationalisation or development (summarised in Table 13).

Three considerations related to Table 13 are worth noting here:

(i) "Methodological steps" is an analytical reconstruction. Even though all the steps occur in foresight practices, the pattern does not have to be strictly linear in practice. Indeed, there may be iterative processes between methodological steps (e.g. following a (de)construction step, the need to include other actors and knowledge resources may be identified), as well as background overlaps (e.g. recruitment may be extended during the *ex-dure* phase). The apparent linearity responds solely to analytical-expository purposes.

(ii) The "Key points of "openness/closure" and its associated hampering "closure" factors" do not aim to be comprehensive, and may be susceptible to future refinement and/or elaboration.

(iii) Although Table 13 tentatively assigns some hampering (f)actors to each phase of the foresight process, it should be noted that these (f)actors are always present. The hampering (f)actors are embedded in the sociotechnical system in which foresight is operationalised and permeate throughout the whole foresight process. However, one would expect them to be particularly influential (i.e. especially effective in mobilising modal power towards closure) at the foresight phases where they are mentioned.

[68] Understanding foresight both as a modulating and modelled element naturally follows the relational-dynamic ontology presented in Chapter 1 (see Section 1.2.1) and here in Section 6.2. Ultimately, foresight's performance is the result of a dialectical process involving a heterogeneous set of factors. This dialectical process takes place within the sociotechnical fabric where foresight operates, and intends to modulate.

Table 13. Examples of "openness/closure" key points and associated hampering "closure" factors in the foresight *ex-ante*, *ex-dure*, and *ex-post* development phases.

Phase	Methodological steps	Associated basic activities	Key points of "openness/closure"	Hampering "closure" factors
Ex-ante	Design (or Scoping)	Foresight framing: Defining the rationale, purpose, target users, time horizon, etc. Assembling the project team Designing the methodology (quantitative / qualitative / quantitative-qualitative)	Domain of implementation (expectations, outcomes, processes, purposes of innovation) Approach to the future that is enabled (and reproduced) through the method and technique in play Level of method and technique accessibility so as to include diverse societal actors	Preordained and/or uncontested constraints (e.g. pre-set purposes and processes; exclusive focus on outcomes; unproblematised expectations) Methodological and technical performativities (e.g. futures-limiting material and formal constraints; time-frame dependency; limited resources) Funding biases (e.g. non-independence; lack of incentives for disruption)
	Recruitment	Selection / open call for actors and knowledge sources involved	Which actors and knowledge sources are included/left out and on what basis (i.e. degree of inclusion)	Socio-epistemic hierarchies (e.g. individual or disciplinary epistemic (in)justices; epistemic (in)competences) Exercise taming (e.g. number of participants; (de)complexisation of issues and messages) (Un)balanced resources (e.g. economic inequalities; informational partiality)
Ex-dure	(De)construction (or Generation)	Existing knowledge (codified, articulated, embedded…) is collectively amalgamated, analysed, and synthesised Representations of the future are (de)constructed Other plausible/desirable futures are explored and/or analysed	Conducting the exercise: Topics (not) encouraged to be opened for discussion Quality of the socio-epistemic relations (not) empowered (e.g. degree of reflectivity; responsiveness; inclusiveness) Awareness of the overlooked plausible and/or desirable futures	Procedural performativity (e.g. moderators' abilities; closing-down of concerns; exercise structuring) Socio-epistemic hierarchies (e.g. individual or disciplinary epistemic (in)justices; epistemic (in)competences; argumentative (in)justices) Socio-cultural habits and ideologies (e.g. value-free science; reification of futures; trust in numbers; discipline-based tendencies; cognitive and normative biases
Ex-post	Action	Knowledge generated is translated into action	Degree of effectiveness when translating heuristics into action and maintaining this over time	Responsive rigidity (e.g. status quo and resistance to change; non-binding results; socio-material limitations)
	Renewal	Monitoring and assessment of the possible steered transformations	Effects (not) monitored (why these and not (also) others?)	Funding bias (e.g. confirmatory biases; attention niches; problem reduction) Sociotechnical limitations (e.g. (in)exhaustive monitoring of complexity; error intolerance; deficit in indicators)

Source: The "Methodological steps" and "Associated basic activities" have been adapted from Popper (2008).

6.3.1. *Ex-ante* phase of foresight: Anticipatory "openness/closure" by design

The *ex-ante* phase encompasses both the practical design and recruitment of potential participants. The methodological steps for Design (also called "Scoping") and Recruitment are of great importance as they delimit the foresight framing, personnel and role selection, chosen methodology and/or level of inclusiveness in advance. In other words, they delimit an area of functional possibilities that the foresight exercise can deploy. As with the design of any other innovation, it constrains the affordances of the device in play (Faraj and Azad, 2012; Norman, 2013). By modulating, or guiding, the possible forms of knowledge co-production achievable in the exercise's subsequent phases, the design structures the potentially erectable socio-epistemic processes. It facilitates and/or hinders certain kinds of relations *ex-ante*, thus setting the *potential* "openness/closure" of their heuristics.

"Openness/closure" in this *ex-ante* phase depends on a series of key points regarding the methodological steps of both Design and Recruitment.

Concerning Design, three issues have been identified:

(i) The innovation domain (i.e. expectations, outcomes, processes or purposes) where foresight is implemented.

(ii) The specific approach to the future. This issue concerns the constraints related to certain ways of representing, and cognitively and methodologically approaching, futures (e.g. predictive/empirical, cultural/interpretive and critical) (Inayatullah, 1990).

(iii) The level of techno-methodological accessibility for the actors. This entails monitoring how the methodology or technique in play enables some actors' participation whilst disenabling the inclusion of others.

As for Recruitment, consideration (at least) of the following issue is crucial:

(i) Deciding on the domain of potential participants. This involves considering, for example, how recruitment choices determine "participant" and "non-participant" domains.

These four key points ultimately predetermine the amplitude of alternative futures potentially producible during the *ex-dure* phase. Each of the foresight operationalisation key points mentioned above (whereby "openness/closure" is determined) are embodied in a set of sociotechnical dynamics whose inertias may arguably tend to close down (Stirling, 2008) the constitutive relations (and thus the heuristic potential) of foresight practices.

On the one hand, concerning the methodological Design step, these dynamics are exemplified by hampering "closure" factors such as excessive focus on the outcomes of innovation dynamics (which may curtail, or disable, the potentially critical consideration of alternative processes and/or purposes). Moreover, factors influencing and constraining methodological and technical performativities may act as "hampering (f)actors". For example, constraints imposed by existing material resources, the time-frame chosen or the

specific cognitive process required by each individual technique modulate the scenarios considered and influence the ways "the futures" are approached. Last but not least, funding biases (such as the lack of incentives to produce disruptive futures and non-independence) may tend to align the exercise with those futures ideologically compatible with the principles and interest of the institutions and agencies in charge (Nielsen, 2014).

On the other hand, as for the Recruitment step, selection of the potential participant domain might be "closed-down" on the basis of a series of implicit or explicit factors such as individual or disciplinary epistemic injustices and/or (in)competences (Fricker, 2007). Furthermore, inclinations to make foresight exercises more manageable may result in a reduced number of invited participants. Combined with the fact that such exercises are vulnerable to different kinds of inequalities (ranging from economic to informational), a reduction in the number of participants could lead to the impoverishment (in terms of diversity and complexity) of the envisaged futures.

6.3.2. *Ex-dure* phase of foresight: "Opening-up/closing-down" futures generation

The exercises defining the *ex-ante* phase of foresight constrain the potential of the *ex-dure* (De)construction (also called "Generation") phase. Thus, having designed the foresight exercise and selected its participants, it continues to remain unfinished. Within the operating margins granted by the design and recruitment steps, there is room to develop more or less disruptive futures and thus, more or less "opening-up" heuristics.

The *ex-dure* phase refers to the methodological step of (De)construction, where the sharing and analysis of knowledge takes place among the various participants. The principal objective here is to (de)construct the futures and "open up" the range of possibilities to be considered at the time and/or enable a series of futures literacies. Among the key points that may modulate the "openness/closure" of foresight exercises in this phase are:

(i) How the (de)construction of futures is mediated or curated (e.g. the encouraged limitation of topics identified and addressed).

(ii) The kind and quality of the socio-epistemic dynamics constituting the (de)construction process.

(iii) Awareness of overlooked (im)plausible and/or (un)desirable futures.

Closure dynamics in this phase could be modulated by several "hampering (f)actors". For instance, procedural styles and prevailing inertias may modulate the interactions produced and concerns considered, and could therefore shape the futures to be domesticated or presented and those to be dissipated or hidden. In this sense, foresight practitioners acknowledge that «stimulating debate always involves structuring and thus closing-down particular avenues of concern» (Selin, 2011, p. 734). Epistemic and argumentative (in)justices and/or (in)competences (Fricker, 2007; Linker, 2014) also play an important

"hampering" role by limiting the set of normative-epistemic elements whereby futures are (de)constructed. In addition, the constraining influence of the ideological priorities and impositions underlying the (de)legitimisation of knowledge need to be examined (e.g. excessive trust in numbers, estimations of science as "value-free", and preconceptions of disciplinary hierarchies). Last but not least, personal or psychological biases must also be considered relevant foresight modulators (Bonaccorsi et al., 2020; Schirrmeister et al., 2020; Tichy, 2004).

All these "hampering (f)actors" (more or less explicitly) configure the relationships between actors when (de)constructing different futures (what and whose knowledge is considered). They condition both foresight's processes and its emergent products (what and whose futures are produced/highlighted and in relation to which dimensions). This modulation is of great relevance as only (de)constructed futures anticipatorily inspire action.

6.3.3. *Ex-post* phase of foresight: "Opening-up/closing-down" anticipatory enactments

Finally, the *ex-post* phase encompasses the methodological steps taken once «the heart of the process» (Popper, 2008, p. 48) (i.e. the *ex-dure* phase) has concluded. These steps include translating foresight heuristics into actions (the Action step) and monitoring and assessing the impacts of such actions (the Renewal step). Hence, it is at this point where foresight unfolds into «explicit anticipation» (i.e. a conscious and self-aware action) (Poli, 2017, pp. 266–268).

Similar to the previous two phases, this *ex-post* phase is also affected by key "openness/closure" points. Here, two key points are highlighted.

As for the methodological step relating to Action:

(i) Transferring heuristics into action can occur at different levels of intensity due to a variety of factors. These factors relate to the actors translating the action, and to the sociotechnical system in which the actors are embedded and operate (and aim to transform).

As for the Renewal step:

(i) The assessment criteria for the actual transformations (if any) might be prone to partiality in terms of the issues and considerations to be taken into account when monitoring such foresight impacts. In other words, the indicators used could reflect the interests and expectations pre-attached to foresight practices.

The main closure dynamics concerning the methodological step of Action is the (relative) lack of responsiveness from sociotechnical systems. This lack of responsiveness is the result of phenomena such as status quo resistances, socio-material limitations (e.g. economic and/or technical constraints) or non-binding exercises. The existence of deep-rooted

sociotechnical dynamics (Belot and Picard, 2014) may limit the effectiveness of such practices in bringing about significant and persistent systemic changes (Nielsen, 2014).

One relevant "hampering (f)actor" in the Renewal step is how funding biases incentivise the monitoring of a limited set of transformations. Namely, transformations falling within the universe of interests of those promoting the foresight exercise (thus overlooking other possible collateral transformations). Also, another relevant "hampering (f)actor" affecting this step relates to how sociotechnical constraints encourage the emergence of certain deficits. These deficits concern, for example: (i) Thoroughness when faced with monitoring complexity; (ii) incentives to tolerate and reflectively accept and/or incorporate error, and/or; (iii) the availability and use of non-standard indicators (i.e. those capable of qualifying hard-to-measure-and-control phenomena).

In conclusion, the opening heuristics attributed de facto to foresight practices should be put into perspective. On the one hand, these heuristics are not predetermined, but rather the outcome of a series of socio-epistemically contextualised co-construction processes. On the other, "openness/closure" can occur in different gradients and in relation to different factors. There is always a closing and an opening element. This implies that an essential aspect of making foresight a "subject of" responsibility is to pay attention to (and care for) the socio-epistemic dynamics whereby foresight practices are conducted and constrained. Responsibilising foresight exercises requires that their *ex-ante*, *ex-dure*, and *ex-post* operationalisation phases be monitored.

6.4. Conclusions

The future is a fundamental resource for research and innovation practices. It modulates current scientific and technological processes by constraining the procedures and goals conditioning STI paths. Representations of the future, whether in the form of expectations, visions or sociotechnical imaginaries, or through interventive-intentional foresight exercises, shape the anticipatory dynamics guiding future-making practices.

Foresight has been increasingly valued as an anticipatory interventive-intentional resource with great heuristic potential to promote more "responsible" STI. "Responsibility" here can take different forms and "degrees of radicalisation" depending on (i) the innovation domains to which it applies (outcomes, processes, purposes and/or expectations/visions/perceptions) and the extent to which these domains are influenced and problematised; (ii) when (or how early) the domains are problematised, (iii) the variety of actors and concerns involved; and (iv) the degree of embeddedness of this problematisation of STI within STI practices.

In this respect, normative frameworks such as AG, RRI, RI, and TA exemplify a high degree of radicalisation. Within these frameworks, foresight is conceived as a dimension

which, in conjunction with others, steers towards the problematisation of diverse domains involved in innovation practices from their early stages of development. This comprehensive problematisation of innovation needs to be conducted via the inclusion of a broad range of societal concerns and actors. In the context of these normative frameworks, foresight operates (alongside other principles and dimensions) as an inclusive anticipatory technique that aims to "open up" the values, processes and possible outcomes whereby innovation dynamics can be shaped, contested and negotiated. Foresight is considered an interventive tool designed to trigger a heterogeneous set of reflexive-anticipatory heuristics of great value in terms of facilitating more democratic STI. Such heuristics are heterogeneous (Table 5). It is claimed that they enable the "opening-up" of alternative futures considered "(im)plausible" and "(un)desirable", and reinforce the actors' futures literacies (see Table 12).

This research chapter has confronted the arguable tendency to substantialise the anticipatory heuristics of foresight exercises so as to promote more responsible innovation (whether under more "radical" frameworks or under any other framework). It has been claimed that foresight's anticipatory heuristics are the result of situated socio-epistemic dynamics. This implies that the spectrum of potential alternative futures and enacted capabilities depends on how foresight's socio-epistemic dynamics unfold. This unfolding is not alien to the prevailing dynamics of the broad sociotechnical system in which foresight operates, and intends to modulate. In other words, the anticipatory heuristics' degree of "openness/closure" is progressively built up throughout the entire foresight process, i.e. throughout the *ex-ante*, *ex-dure*, and *ex-post* operationalisation phases. Even the performance of foresight practices under regimes of "radically" inclusive frameworks of responsible innovation such as AG, RRI, RI, and TA is not foreign to these "openness/closure" dynamics.

It has been argued that foresight heuristics' degree of "openness/closure" is progressively resolved throughout the course of the foresight processes themselves. Therefore, focus should *not only* be placed on how foresight practices could improve the design and development of STI. Attention should *also* (and simultaneously) be paid to how foresight is designed and how its anticipatory development is progressively constituted. It demands attention to the crucial stages, or "key points", of foresight operationalisation processes where the "openness/closure" potential of foresight's anticipatory heuristics is modulated. Some "key points" are: The chosen approach to the future, actors included/excluded and ways of conducting the exercise, or how/to what extent the heuristics are translated into action.

This has led to the identification and analysis of certain "hampering (f)actors" such as design-based constraints, methodological oversimplification of the exercise, socio-epistemic and argumentative biases and injustices or lack of responsiveness. "Hampering (f)actors" can modulate foresight heuristics in the direction of "closure". Identifying them then becomes a highly significant task in order to expose the subtle sociotechnical constraints whereby certain potentially conceivable futures are discarded. Illuminating the existing

"hampering (f)actors" may serve to explain what and whose futures resist being envisioned and anticipated (i.e. imagined and translated into action).

This chapter therefore suggests that a pre-condition for foresight exercises to unleash their anticipatory "opening-up" potential (i.e. their potential as "instruments for" responsible innovation) is to consider them in turn "subjects of" responsibility. This would entail identifying and monitoring, *in real time*, the potential "hampering (f)actors" modulating the sociotechnical relations whereby foresight exercises are progressively constructed. In other words, if foresight is intended to be used as a tool for fostering more responsible innovation, it must simultaneously be borne in mind that foresight is itself an innovative practice subject to the sociotechnical dynamics it seeks to influence, and on which it depends. As an innovative practice oriented towards the transformation of reality, the modes and processes constituting foresight must therefore be monitored and cared for (and that is what is meant by stating that foresight must be "subject of" responsibility).

Thorough analysis of such dynamics and their rationales in the terms stated above can help improve the understanding and heuristics of foresight practices (what/whose knowledge and futures are considered, and why these and not others) so as to "open up" the realm of potentially alternative conceivable futures. In other words, elucidating the set of "hampering (f)actors" shaping and constraining the sociotechnical futures that are "(im)plausible" and "(un)desirable" could enhance the capability to critically and reflexively address how futures that impose certain dominant modes of conducting research and innovation are constituted and operate. This capability is a necessary (albeit non-sufficient) condition to propose and implement anticipatory science and technology governance dynamics that are more receptive to the inclusion of voices and concerns traditionally excluded when shaping sociotechnical futures and presents.

CHAPTER 7

Enacting anticipatory heuristics: A multi-foresight proposal for steering responsible innovation

Abstract Over the past decade, various normative proposals and frameworks that aim to promote more responsible governance of research and innovation in terms of better aligning with society's demands and expectations have emerged. Among the common aspects of these normative frameworks and proposals is the reliance on foresight and/or anticipation as a key interventive instrument. The chapter reviews the main challenges to which foresight has been explicitly or implicitly directed and the respective methodological approaches that have been associated with them. In doing so, the chapter diagnoses a fragmentation in the methodological treatment of the different challenges. Against this fragmentation, a flexible qualitative multi-foresight methodology is proposed. The proposed methodology not only addresses the fragmentation problem by embracing the different challenges posed to foresight/anticipation for promoting more socio-politically responsible technoscientific and innovation practices, but also helps to minimise the uncritical reification of futures attributed to anticipation and foresight practices.

7.1. Introduction

Multiple recent umbrella frameworks point to the need for anticipation as an operational dimension for promoting more responsible research and innovation. Anticipatory Governance (AG) (Barben et al., 2008; Foley et al., 2018; Guston, 2014), Responsible Research and Innovation (RRI) (European Commission, 2013a, 2013b; von Schomberg, 2012, 2013), Responsible Innovation (RI) (Owen et al., 2012; Owen et al., 2013; Stilgoe et al., 2013), or recent developments in Technology Assessment (TA) (Grunwald, 2019b) are examples of normative approaches that explicitly rely on anticipation as a central—though not the sole—procedural dimension to improve co-production dynamics STI.

In contrast to the traditional and historically dominant predictive-based approaches to STI governance, anticipation in these normative models takes on a more reflexive character (Guston, 2014; Nelson et al., 2022). The use of futures to guide current action in the present (i.e. anticipation) (Poli, 2017; Poli and Valerio, 2019) is considered within these frameworks as a procedural principle to promote an eminently political notion of responsibility. Responsibility is here understood as «taking care of the future towards collective stewardship of science and innovation in the present» (Stilgoe et al., 2013, p. 1570), and anticipation is one of the tools relied upon to promote the socially robust problematisation of futures that are (not) at stake in STI.

Against this context, the call for anticipation finds its most direct methodological-interventive or operative factor in the execution of foresight exercises such as sociotechnical and techno-moral scenarios (Arnaldi, 2018; Barben et al., 2008, p. 993; Selin, 2011; Withycombe Keeler et al., 2019). The reflexive heuristics to promote a better STI governance attributed to foresight can take various forms and be targeted at different research and innovation dimensions and fields of action (Chapters 2 and 4). For instance, it has been stated that foresight might serve in the management of visions and expectations (Warnke and Heimeriks, 2008, p. 79), to shape more systemic thinking for «socially-robust risk research» (Stilgoe et al., 2013, p. 1570), or even to foster «practical wisdom» (i.e. *phronesis*) (Boenink, 2013) and «emancipate» societal actors (Withycombe Keeler et al., 2019). These heterogeneous heuristics of foresight are only a reflection of the diverse modalities in which future temporality could be approximated and exploited as a resource (Gidley, 2017, pp. 63–81; Muiderman et al., 2020).

In the development of such heuristics ascribed to foresight, the processes channelled by the methodology are of paramount importance. The methods used during the intervention play a functional role in structuring and productively mobilising the different knowledge, actors, and concerns at stake. The methods, understood as artefacts in themselves, functionally modulate the space of possibilities that the interventions can encompass. They prescribe what cognitive dispositions actors may have towards the future and what socio-epistemic processes should be set in motion during the process. They are a central (though not the only) modulating factor in the scope and depth of anticipatory heuristics required to promote more responsible STI practices.

Methods for triggering anticipatory responsibilisation dynamics are particularly relevant to AG, RRI, RI, and TA. However, they are surprisingly under-explored and under-problematised in the literature. As Lehoux et al. (2020, p. 1) diagnoses, «there is little empirical research examining how in practice prospective public deliberation processes should be organized to inform anticipatory governance». The focus in the AG, RRI, RI, and TA literature has tended to be on (i) delineating and justifying the procedural dimensions that jointly constitute the concept of responsibility under consideration, and (ii) attempting to delineate each of these frameworks from one another (e.g. Owen et al., 2012; van Lente et al., 2017). The questions of which methods can better shape responsibilisation heuristics, how and why, have not been at the forefront. Only recently has some conceptual work emerged on the methodological and operational aspects of anticipation within the academic community (e.g. Arnaldi, 2018; Lehoux et al., 2020; Macnaghten, 2021).

This chapter seeks to advance the problematisation of methods for enacting anticipatory knowledge and capabilities aimed at promoting socio-politically responsible STI activities (i.e. aligning STI processes, purposes, and outcomes with societal expectations, demands, and values). To this end, the chapter first reviews previous results on how anticipation/foresight is theoretically understood in AG, RRI, RI, and TA and what challenges are associated with this dimension. It is recalled that anticipation is understood and approached as addressing heterogeneous challenges, each of which

requires specific forms of engagement with the future (Section 7.2). The chapter then analyses 17 sources that highlight practical anticipatory interventions for AG, RRI, RI, and TA. The focus of the analysis is on the methodological structures of the interventions and how these structures enable certain challenges to be addressed and how they open up certain STI issues to problematisation and exclude others. In this context, two main limitations are identified. The first relates to the fragmented ways in which different challenges are addressed (which hinders the development of holistic anticipatory heuristics). The second relates to the reification of futures (which prevents a deep problematisation of STI purposes) (Section 7.3). Finally, given the above diagnosis, a tentative architecture of a multi-foresight process is proposed. This procedural methodology aims to promote a more holistic or integral treatment of the challenges that anticipation addresses and minimise the uncritical reification of futures (Section 7.4). The chapter ends with a series of concluding remarks (Section 7.5).

It is important to clarify that it is not my intention to prescribe a definitive methodology or to attempt to defend it as the "best" solution for responsible innovation. On the contrary, I assume that there is no ideal procedure that could warrant responsible innovation. The assumption that operationalising a methodology will automatically lead to better integration of STI and society naively reduces the ambiguities and complexities of the factors, contexts, and dimensions involved in the dynamics of STI co-production. Nevertheless, some methods are more comprehensive and better suited than others for pursuing specific goals in distinct contexts. The proposal offered here is more modest. Ultimately, my concern is to highlight the relevance of the engagements and grammars of the future that are enabled in interventive exercises and the need to problematise them. In this sense, the anticipatory method proposed here is intended to serve as a heuristic means for (i) recognising that how we engage with the future matters, and consequently (ii) prompting reflection, refinement, and improvement upon the scope of how anticipation is framed to foster responsible innovation. The chapter therefore aims to explore how we can promote the responsibilisation of foresight exercises by addressing one of the first phases of the very design and implementation phases outlined in Chapter 6. In short, my aim here is promoting more responsible forms of foresight from design—without forgetting the dynamics and need to monitor and care for the rest of the intervention processes.

One of the main limitations of the chapter is that it is limited to the theoretical-conceptual presentation of the proposed qualitative methodology and does not include an empirical case study demonstrating its operational potential and/or limitations within a particular empirical context. The proposed methodology is flexible enough to be re-adapted and operationalised for different contexts and STI domains. The description of the dynamics underlying the method operationalisation, the results obtained, and its main limitations will be the subject of future research that could theoretically complement and further refine the theoretical rationale presented here.

7.2. Coming back to previous results: The conceptualisations and practical challenges of anticipation

The future has always been a critical heuristic resource for STI policy decision-making. For instance, institutions of risk regulation have widely used quantitative forecasting methods to try to prevent or mitigate STI "undesirable" effects. Any model that seeks to overcome a reactive responsibility approach (e.g. liability or accountability understandings of responsibility) should somehow appeal to the future. It is this use of future representations that enables *ex-ante* and genuinely proactive responsibility to be taken (Arnaldi and Bianchi, 2016; Arnaldi and Gorgoni, 2016) (Section 2.2).

The semantics and ways of engaging with future temporality have far-reaching connections with understandings of responsibility. How future temporality is used and inhabited and how *ex-ante* responsibility is conceived are symbiotically intertwined (see Urueña 2022b). Thus, different ways of conceiving the future articulate and inform different ways of understanding responsibility, and vice versa (Adam and Groves, 2007, 2011). The dominant ways of living temporality are a constitutive element of the hegemonic processes of STI co-production and governance. It is no coincidence that critiques of technocratic approaches to STI governance are usually accompanied by critiques of the narrow character of quantitative and empirical-predictive approaches to the future (Friedman, 2019). In particular, technocratic and empirical-predictive ways of approaching the future have been criticised in the field of Science and Technology Studies (STS) for tending to narrow the concerns considered, for failing to account for the uncertainty inherent in science-technology co-production and coevolution, and for being a poor resource for fostering the participation of diverse publics and problematising issues related to the values and purposes (i.e. the directionality) of research and innovation practices (e.g. Jasanoff, 2003; Sadowski, 2020; Sarewitz et al., 2000).

The last two decades have been particularly fruitful in the emergence of governance frameworks that attempt to move beyond the tendency to formulate *ex-ante* responsibility solely based on expert-based models of the future with a predictive ambition (i.e. probabilistic forecasts). Normative frameworks such as AG, RRI, RI, and TA are clear examples in this regard. These proposals point to the need to develop more socio-politically robust or radical forms of responsibilisation for the tentative governance of STI (see Kuhlmann et al., 2019) (Chapter 2).

Aside from the normative nuances that qualify and distinguish AG, RRI, RI, and TA frameworks, they all share their genealogies and coincide in at least two fundamental aspects. On the one hand, these frameworks embrace a politicised concept of responsibility. At least in the most radical interpretations, responsible STI is understood in terms of opening-up to collective problematisation the potential coevolutionary future pathways that the emergence of the STI in question may shape (including the deliberation around its goals, processes, and "positive"/"negative" outcomes) (Stilgoe et al., 2013, p. 1570; von Schomberg, 2014). Under these frameworks, the desirability and plausibility of STI sociotechnical and techno-moral pathways and their respective socio-political and

ethical implications are subject to inclusive deliberation. The development of responsible STI would require the involvement of diverse societal actors, concerns, and expertise throughout the whole development process and from its earliest stages (European Commission, 2013a; von Schomberg, 2013, 2019). Responsible STI entails promoting more socio-politically robust and bottom-up, or "upstream" ways of shaping sociotechnical worlds through STI (i.e. more transparent and aligned with different actors' interests, values, and expectations). Traditionally silenced or marginalised voices would be facilitated to speak out during STI co-production and governance practices, thus subverting the current hegemonic, technocratic forms of moral division of labour (Rip, 2016).

On the other hand, this politicised notion of responsibility (Eizagirre et al., 2017) finds operational support in the foresight/anticipation dimension in all these frameworks. Anticipation is one of the qualitative operational tools through which AG, RRI, RI, and TA procedurally aim to promote this more socio-politically radical and reflexive notion of responsibility. Anticipation is one of the operational dimensions that, in conjunction with the other dimensions of each framework, aims to enable processes of responsibilisation.

However, despite this constitutive role given to anticipation, there has not been a robust and systematic conceptualisation of what anticipation entails for these frameworks. As Guston (2013, p. 110) states, anticipation «is perhaps the most crucial and problematic dimension to deal with», yet it is also the most under-explored dimension: «[T]here is less conceptual development around anticipation, and even poorer intuitions». The descriptions that allude to anticipation within these frameworks are often brief and lacking in detail regarding how it is technically operationalised (see Table 5). As Burget et al. (2017) identify in their literature review regarding RRI/RI discourses,[69] while literature related to these frameworks tended to cite the definitions of the dimensions provided in the foundational and institutional texts (including that of anticipation), these definitions «were not substantially further elaborated».

An emerging field of knowledge that aims to render anticipation and its operationalisation a systematic and specific object of research is Anticipation Studies (Miller et al., 2013) (see Section 3.2). Within Anticipation and Futures Studies, anticipation is understood as any action that is informed by representations of the future (Miller et al., 2018; Poli, 2017; Poli and Valerio, 2019). The challenge of shaping responsible STI in the early stages of development to avoid the uncritical reification and entrenchment of sociotechnical coevolutionary pathways requires a forward-looking orientation and thus the promotion of a form of governance that might adequately qualify as "anticipatory".

[69] In their literature review, Burget et al. (2017, p. 1) claim to focus on RRI. However, it might be worth noting that their review disjunctively addresses both RI and RRI literature. Recent advances suggest subtle differences between RI and RRI frameworks, and consequently the need for their differentiation (e.g. Owen and Pansera, 2019; Timmermans and Blok, 2021).

Anticipation, however, is a plural phenomenon (Gidley, 2017). There are different ways of using and working with the future (Poli, 2019b). Therefore, it is crucial to define which forms of anticipation are (not) considered relevant and which are encouraged through anticipatory interventions. Key questions are what kinds of representations of the future and types of cognitive, normative, and epistemic engagements with those representations the frameworks mentioned above intend to activate with anticipation or foresight (i.e. what kinds of relations to the future they consider and emphasise when advocating "anticipation"/"foresight" as dimensions for the responsibilisation of STI).

Analysing the discourses of responsibility in 23 case studies in 12 countries, Pansera and Owen (2020) diagnose the existence of a variety of interpretations regarding the constitutive dimensions of this RI/RRI-like concept of responsibility, including anticipation. Specifically, Pansera and Owen (2020, pp. 46–48) identify two predominant interpretations of what anticipation entails. On the one hand, institutional discourses of responsibility and associated practices tend to narrow the definition of anticipation in terms of non-predictive exploration of the potential impacts of STI. The meaning of anticipation is typically simplified by interpreting it exclusively as an activity aimed at clarifying the potential ethical, legal, environmental, and socioeconomic aspects of STI (see also Schuijff and Dijkstra, 2020, pp. 565–566), thereby echoing the ELSA/ELSI proposals that emerged in the 1980s (Zwart et al., 2014; Zwart and Nelis, 2009). On the other hand, this predominant interpretation of anticipation coexists with another in which it is conceptualised in strategic terms, i.e. as a tool for exploring which STI lines might provide the most significant benefit or the most desirable futures (usually in socioeconomic terms) and thus optimise the management of resources, investment relocation, and planning. This second prevailing interpretation reflects the strategic, technology foresight initiatives that have also been of interest to institutions since the 1980s (e.g. Irvine and Martin, 1984, 1989; Martin, 1995, 2010; Miles et al., 2016).

These two predominant forms of understanding anticipation do not exhaust the variety of relationships to representations of the future that AG, RRI, RI, or TA intend to mobilise. Nor are these dominant modes of conceiving of anticipation the most appropriate for problematising STI from a socio-politically inclusive perspective (Section 4.3, Table 8). For example, practices of technological foresight are easily instrumentalised. They are often guided by a technocratic spirit and are primarily aligned with the promising techno-optimistic narratives that institutions embrace and disseminate; they are subject to the technocratic and promissory spirit that the above-mentioned recent normative frameworks seek to avoid. Similarly, ELSA/ELSI approaches have been criticised for not being sufficiently disruptive (Forsberg, 2015). ELSA/ELSI activities have typically been conducted as satellites or mere add-ons to scientific and technical research. As a result, their scope and impact on the development orientation of STI research have been significantly limited. Manifestos for greater integration of socio-political, ethical, and STI research reflect the need to create a dynamic in which scholars from different disciplines (including the humanities and social sciences) are intertwined in generating STI knowledge to open up possibilities and alternative courses of action (e.g. Balmer et al., 2012; Fisher, 2007; Fisher et al., 2006).

Frameworks such as AG, RRI, RI, and TA embrace this call but, in their more radical interpretations, go beyond it to include not only scientists but also other societal actors. In this sense, operationalising responsible innovation «includes, but goes beyond, existing ethical procedures» (Owen and Pansera, 2019, p. 38).

The common denominator amongst the positive characterisations of anticipation centres on its functions to develop reflexive heuristics and capabilities. Anticipation is understood as a means for enhancing the reflective capital concerning STI orientation throughout their co-production process and at the early stages of development, before the uncritical closure of sociotechnical coevolutionary pathways. It is a dimension oriented towards the collective problematisation of sociotechnical futures that we enable through STI. In this way, anticipation is primarily a tool for addressing—which does not mean solving—the general challenge posed by the Collingridge dilemma (Collingridge, 1980).

However, the facilitation of reflexive heuristics for addressing the Collingridge dilemma can be achieved by focusing on diverse issues. Looking at and synthesising the descriptions and goals of anticipation presented in Section 4.2, as well as the associated techniques mentioned by each framework, one can see that anticipation aims to deal with the Collingridge dilemma by addressing the following three concrete challenges (Table 8):

I. *To explore the different impacts, sociotechnical configurations and "endogenous futures" (*Rip and te Kulve, 2008*) that are emerging or might emerge with the development of a particular innovation or technology*. The problematisation of impacts is expected to be as broad as possible, including both so-called "positive" or "negative" (von Schomberg, 2014), and "hard" or "soft" (Swierstra and te Molder, 2012; van der Burg, 2009b) impacts.[70] The purpose of engaging with futures here is to strengthen diagnostics of the present (e.g. via future-oriented bibliometrics and weak signals) and to promote socially robust risk research (in terms of concerns and knowledge considered) (e.g. via foresight and sociotechnical or techno-moral scenarios). Ultimately, the key issue is to recognise and attend to the constitutively heterogeneous character of risks (Rodríguez, 2016) through tentative processes of sociotechnical integration (Fisher, 2019). This problematisation may include elements with various gradations of speculation, depending on the stage of development of the technology in question and the socio-epistemic resources available at the time (Grunwald, 2010). Plausibility is understood here as a relevant criterion (and inferential register) to simultaneously delimit speculation and the futures and aspects that should be considered (Boenink, 2013; Schmidt-Scheele, 2020a, 2020b; van der

[70] The second-order reflexive dimension that RI, for example, urges to promote would entail problematising whose perspectives and interests are considered in defining an impact as "positive" or "negative" and "hard" or "soft", and on what grounds.

Burg, 2009a), and to pluralise and complexify the considered alternatives for action (see Ramírez and Selin, 2014).

II. *The comprehensive problematisation (in terms of the concerns considered and the actors involved in the deliberative processes) of the purposes and orientation of STI*. This problematisation relates to both instrumental ends (related to the functions of technologies and innovations) and socio-political purposes (related to the socio-political orders that the STI in question might promote). In this context, it is important to keep in mind that problematising the purposes of STI does not involve the assumption that the direction of sociotechnical coevolution is fully predictable or controllable. On the contrary, starting from the premise that the future is impossible to control and open-ended, the challenge is to continually revise the direction STI takes over time, tentatively and within our limited and contingent possibilities for action. The challenge is to take charge of our agency, limited though it may be, when it comes «to bending the long arc of technoscience more toward humane ends» (Guston, 2014, p. 234). This problematisation of STI purposes through anticipatory exercises may be reflected in all those techniques that function by engaging with and unlocking envisioned desirable futures, such as normative scenario practices (e.g. scenario building).

III. *The promotion of critical capacities concerning future representations and ways of using the future that de facto colonise the present of STI governance dynamics (both formal such as predictive regimes of governance, and informal such as governance mechanisms through visions, promises, and expectations)*. Recent studies have shown how visions, sociotechnical imaginaries, or promises play an important role in shaping and directing STI practices. These representations are vehicles for meanings and assumptions about what could and should be the case, about what is possible, plausible, and desirable. They are seen as relevant among the myriad of factors at work in reifying and anchoring futures (i.e. they contribute significantly to fixing future worlds worth pursuing in the present). Against this background, approaches and tools such as Vision Assessment (Grin and Grunwald, 2000; Grunwald, 2009b) or Hermeneutic Technology Assessment (Grunwald, 2016, 2020; van der Burg, 2014) anticipatorily attempt to address the challenge of enacting reflexivity and critical capacities for the sociotechnical meanings and hermeneutic circles fostered by these representations: Who creates and mobilises these futures, what assumptions do they carry, who do/did they mobilise and why, how do they become socially established and socio-politically relevant, who is included or excluded in these futures? (Jasanoff, 2020). In the context of this challenge, anticipation is conceived as a tool for fostering critical capacities concerning the contents and ways in which the future colonises the present (i.e. as a tool for fostering

anticipatory meta-reflexivity about how future representations are used and shape our actions). The use of the future here is akin to the purposes of critical futures studies approaches (Inayatullah, 1998, 2006) or current proposals on developing futures literacies (Miller and Sandford, 2019; Poli, 2021).

7.3. The operationalisation of anticipation in recent literature: Uses of the future and challenges addressed

Most of the literature on AG, RRI, RI, and TA focuses on the theoretical development and critique of the dimensions represented in each of these frameworks. However, less attention has been paid to problematising their interventive practices. How are the above challenges addressed in the exercises that engage with futures? To what extent are these challenges addressed comprehensively? What methodological structures define foresight exercises?

This section provides an exploratory analysis of 17 academic sources that identify anticipatory intervention exercises for AG, RRI, RI, and TA. Given the exploratory nature of this analysis, it does not claim to be exhaustive. The analysis is pragmatically oriented to diagnose some tendencies in the operationalisation of anticipation and to highlight some of their shortcomings. I address and attempt to minimise these shortcomings through the multi-foresight methodological architecture proposed in the following section.

The selection of the resources under analysis was determined by the simultaneous fulfilment of three basic conditions. The first condition was that the exercise presented had an evident anticipatory-interventive character. In other words, the resource should showcase a type of exercise that is based on engagement with futures. This requirement excludes research concerned with the theoretical underpinnings of the rationale for this type of interventions. The second condition was that this operationalisation should be presented as an exercise that somehow aims to serve to support AG, RRI, RI, and TA. This excluded from the analysis interventions coming from other fields, such as Futures Studies. The third condition required that the resource be sufficiently detailed in the process being followed to allow for meaningful analysis.

Eight variables were considered during the analysis: the framework(s) of reference (AG, RRI, RI, and/or TA),[71] the specific STI that is the subject of the intervention, the methodology and structure of the exercise, the types of engagement with futures (see

[71] For the identification of the frameworks for each exercise, it should be noted that a distinction has been made between RRI and RI, as Owen and Pansera (2019) recommend. Although in some cases the label "RRI" was used to identify the framework of Stilgoe et al. (2013), in this chapter the framework developed by Stilgoe et al. (2013) is referred to as "RI", and the framework developed by the European Commission (2013a) and von Schomberg (2013) is referred to as "RRI".

below), the participants mentioned, which of the main challenges were addressed (i.e. whether "I.", "II.", and/or "III."), and the openness and closure dynamics that these exercises facilitate.

These variables are interrelated, especially the challenges addressed and the types of engagement with the future. The types of engagement with the future and their interconnections with the challenges are the following (Section 4.3, Table 8):

- *Exploratory*: Non-predictive representations of futures which allow to draw a series of lessons and reinforce a series of capabilities (e.g. moral imagination).
    - *Evocative*: "Useful fictions" depicting hypothetical worlds. Some forms of evocative scenarios are sociotechnical scenarios and techno-moral scenarios. While the former evoke potential coevolutions between STI and society, the latter focus on potential coevolutions between STI and morality. These exercises are especially linked to the challenge of promoting a more socio-politically robust analysis of STI outcomes (i.e. "I.").
    - *Normative*: "Useful fictions" depicting hypothetical worlds that certain subjects consider (un)desirable to pursue. Normative scenarios are usually used to open deliberative spaces to discuss the purposes that certain social agents intend to tackle. These exercises are especially useful for problematising the aims and purposes STI is intended to address (i.e. challenge "II.").
- *Strategic*: "Useful fictions" that represent hypothetical milestones and their respective causal chains that might trigger or avoid the futures in question (whether those futures are predetermined or derived through exploratory exercises). These forms of engagement with futures are crucial for the elaboration of practical guidelines that enable action in the face of the outcomes presented in evocative explorations, or that enable action in the face of the futures presented in normative explorations.
- *Critical-hermeneutic*: It aims to deconstruct the futures that colonise the present and usually close-down the frames through which the other ways of engaging with the future mentioned above take place. This kind of engagement with the future is particularly useful in combating the reifying power of visions, promises, expectations, and sociotechnical imaginaries (i.e. to address the challenge "III.").

Table 14. Analysis of interventive anticipatory exercises.

Source	Framework(s) of reference	STI domain of intervention	Methodology & structure	Engagements with futures	Participants (as mentioned)	Challenge(s) tackled	Opening aspects	Closure aspects
Rip and te Kulve (2008)	TA	Nanotechnology	*Sociotechnical scenarios*: (i) Construction of the scenarios by the organisers; (ii) discussion of the scenarios with enactors (articulate challenges for the commercialisation/application and ELSI); (iii) articulate approaches and way to deal with the identified challenges	Exploratory-evocative Strategic	Enactors Selectors	I	The discussion is intended to move away from technical particulars, with a focus on generating reflexivity through contestation and articulation of participant's "worlds"	The scenarios are created by the organisers Scenarios are narrowly focused on surpassing the challenges that might hamper the development and commercialisation of nanotechnology: A socio-political critique of the purposes and socio-political projects of nanotechnology is missing
Swierstra et al. (2009)	TA	Obesity Pill	*Techno-moral scenarios*: Explore potential pathways for the coevolution of the innovation with values, obligations, and responsibilities	Exploratory-evocative	--	I	Introduces the coevolutionary aspect between technology and morality Use of scenarios as a heuristic resource to facilitate discussion on the "soft impacts" of techs, and thereby assess their associated ethical and desirability and enhance "moral imagination" Diversity of viewpoints as an asset	The scenarios are created and discussed by the organisers The focus is on potential controversies and not so much in co-production
Robinson (2009)	TA/RRI	Nanotechnology	*Co-evolutionary scenarios*: (i) Construction of the scenarios by the organisers (capture the complexities of innovation journeys and (co-)evolving environments); (ii) discussion of the scenarios with multi-stakeholders (formulation of strategies and concrete steps to take action)	Exploratory-evocative Strategic	Multi-stakeholder	I	Combine concentric and multi-level approaches through emphasising sociotechnical coevolutions Problematises current "endogenous futures" to enable more responsible modulations (emphasis on steps to take action)	The scenarios are created by the organisers The focus on identifying the underlying dynamics of coevolution for strategy formulation comes at the expense of neglecting the problematisation of the purposes of such strategies

Table 14. Analysis of interventive anticipatory exercises.

Source	Framework(s) of reference	STI domain of intervention	Methodology & structure	Engagements with futures	Participants (as mentioned)	Challenge(s) tackled	Opening aspects	Closure aspects
Selin (2011)	AG	Nanotechnology	(i) Development (constructing nano-enabled product scenes with nanoscientists); (ii) vetting (establishing technical plausibility, seeking alternatives); and (iii) deliberation (critique, expansion, and discussion of the scenes by stakeholders)	Exploratory-evocative (development and vetting) Exploratory-normative (deliberation)	Social scientists Nanoscientists Broad range of stakeholders	I	Opens spaces for discussion and reflexivity	Reifies futures of the innovation: Reflections seem to be limited to the functions of the artefacts and their possible impacts (without problematising the goals and underlying visions)
Douglas and Stemerding (2014)	RRI/AG	Synthetic biology	(i) Review reports and articles that highlight potentially promising applications of SynBio; (ii) perform ELSI analysis to these applications; and (iii) negotiate and strengthen the identified ELSI with participants and explore governance approaches to balance benefits and risks	Exploratory-evocative	Policymakers Analysts Regulators Ethics committees Patient organisations Academics (philosophers, social scientists, SynBio researchers) International health organisations Research funders ONGs	I	ELSI questions were kept open in a flexible way to allow for new insights from the participants Involve a wide range of societal actors The organisers acknowledge that the ELSI scenarios did not meet their expectations	Reinforce SynBio's promises related to the selected applications The most important ELSI aspects discussed were identified by the organisers of the intervention The ELSI-SynBio scenarios does not capture the complexity of sociotechnical and techno-moral coevolutions Reduces responsibility to the "ethics management" of ELSI concerns
Mann (2015)	TA	Biodiversity offsets and banking	(i) Identify actors and create scenarios ("endogenous futures"); and (ii) debate the scenarios	Exploratory-evocative Exploratory-normative (deliberation on already co-created futures)	Experts Public representatives Environmental NGOs	I II	Opens spaces for discussion and reflexivity about the purposes and problem-frame of biodiversity Shows that controversies are underpinned by different worldviews and philosophical and political orientations	Scenarios are not created by the participants, but are pre-set, which can significantly frame the debate

Table 14. Analysis of interventive anticipatory exercises.

Source	Framework(s) of reference	STI domain of intervention	Methodology & structure	Engagements with futures	Participants (as mentioned)	Challenge(s) tackled	Opening aspects	Closure aspects
Sadowski and Guston (2016)	AG	Nanotechnology	(i) Identify actors; and (ii) conduct a questionnaire on the future of nanoscientists' research and potential outcomes	Exploratory-normative	Nanoscientists	I	Provides insight into the opinions of nanoscientists on the future of their work It might generate reflexivity among nanoscientists	There is no collective debate or problematisation on nano
Lucivero (2016b)	TA	Immunosignatures Nanopil	*Techno-ethical scenarios*: Explore potential pathways for the coevolution of the innovation with values, obligations, and responsibilities *Techno-moral vignettes*: Narratives that explore potential ("soft") impacts of techs on forms of life, and morality.	Exploratory-evocative	Academics	I	Use of scenarios as a heuristic resource to facilitate discussion on the "soft impacts" of techs, and thereby assess their associated ethical and desirability and enhance "moral imagination" Raises critical questions about the socio-systemic activities and outcomes that the scenarios may enable	The exploration is limited in terms of (i) actors involved, and (ii) variables considered (e.g. "patient-cantered" vs. "doctor-mediated") The discussions are framed by pre-given scenarios
Gudowsky and Sotoudeh (2017)	RRI/TA	Autonomous living of older adults	*Transdisciplinary, visioneering co-creation process*: (i) Citizens produce visions; (ii) experts and stakeholders elicit societal needs based on "(i)" and formulate recommendations for R&D agendas; and (iii) the citizens validate "(ii)" output	Exploratory-normative Strategic	Laypeople Experts Stakeholders	II	Visions have societal issues at their centre: Politics on STI purposes comes first to prevent the problem from being framed in purely technical terms	It assumes an epistemic and moral division of labour among the actors Citizens' visions may be biased by promises, expectations, and previously circulated visions It does not problematise scenarios about the possible consequences of STI and their plausibility and desirability

Table 14. Analysis of interventive anticipatory exercises.

Source	Framework(s) of reference	STI domain of intervention	Methodology & structure	Engagements with futures	Participants (as mentioned)	Challenge(s) tackled	Opening aspects	Closure aspects
Bechtold, Capari, et al. (2017)	TA/RI	Ambient and Assistive Techs (regarding ageing issues)	Scenarios	Exploratory-evocative	Experts Stakeholders Laypersons	I	It displays the common denominators of different publics' perspectives and desires (experts, stakeholders, laypersons) Explorations are focused on how STI will affect different actors, and not so much on the STI itself	It assumes an epistemic and moral division of labour among the actors, and discussions take place in parallel. No scenarios are envisaged where the very existence of the STI at hand can be questioned
Arnaldi (2018)	TA/RRI	Nano neural implant	*Retooled Techno-moral scenarios*: (i) Sketching the landscape (technoscientific, moral and socio-economic); (ii) generating controversies (pros and cons for the creation); and (iii) closure and responsibility regimes (who is responsible, responsibility configurations, means for support responsibility)	Exploratory-evocative (pros and cons) Strategic (who should be responsible, under which means to support certain responsibility regimes)	Publics, experts, stakeholders	I	Introduces explicit reflection on who should be responsible, for what, and in what sense The promises of technologies are criticised	The debate is being framed in controversies, and it would be more fruitful to frame it in terms of modes of co-production. It is unclear to what extent the complexity of the coevolution between technology and morality is reflected in the scenarios The critique of the promises of STI is criticised in terms of underlying "hard" and "soft" negative impacts

Table 14. Analysis of interventive anticipatory exercises.

Source	Framework(s) of reference	STI domain of intervention	Methodology & structure	Engagements with futures	Participants (as mentioned)	Challenge(s) tackled	Opening aspects	Closure aspects
Withycombe Keeler et al. (2019)	Sustainability-oriented RRI	Wastewater Sensing (WWS)	*Scenarios (scenario axes)*: (i) Define focal questions and timeframe; (ii) identify participants; (iii) exploration of analogous technologies, key factors, and critical uncertainties surrounding the development and dissemination of the tech; (iv) brainstorm driving forces; (v) identify critical uncertainties; (vi) select scenario axes; (vii) sketch scenario storylines; (viii) write scenarios narratives; (ix) assess scenarios (SWOT analysis); and (x) create proposals for action.	Exploratory-evocative (explorations of impacts) Strategic (cost-benefit analysis in taking action)	Centre for Environmental Security WWS Researchers Legal Scholars STS and Ethics Scholars Regulators Water Managers Military	I	Scenarios are presented as a means for capability-building The whole process is performed in reflexive feedback with participants It raises important questions regarding who the innovation impacts and benefits It includes proposals for actions	The scenarios do not provide alternatives to the technology itself, rather they indirectly reify its development (albeit improving it) The variables facing the four final scenarios are public/private (ownership) and individual/community (what is sensed) (i.e. multivariate scenarios could have been used)
Stemerding et al. (2019)	RI/TA	Synthetic biology	*Application scenarios*: (i) Define the nature of the problem and the role for SynBio; (ii) consult users and stakeholders about needs and vision; (iii) think about a business case; (iv) identify issues of risk and regulation; (v) consider design choices and requirements in this context; and (vi) combine these elements in an unfolding storyline about future SynBio *Techno-moral scenarios*: (i) Consider "soft impacts" of the application scenario; (ii) identify morally problematic situations; (iii) imagine how people might be affected and respond; and (iv) create a short story as vignette	Exploratory-evocative Exploratory-normative Strategic	Students Societal stakeholders Researchers in SynBio	II I	The intervention was extended in time (>3 years) The attention to the promotion of anticipatory capabilities in the early stages of the scientific career Highlights consideration of societal needs and definition of purpose through stakeholder involvement Considers both "soft" and "hard" impacts	It assumes an epistemic and moral division of labour among the actors: Most of the work and visioning for the future is done by the student team (interaction with stakeholders is limited) SynBio's visions are not criticised: An enlightened view of science is promoted, in which science is presented as a problem solver Emphasis on providing solutions to social problems is addressed through an entrepreneurial approach

Table 14. Analysis of interventive anticipatory exercises.

Source	Framework(s) of reference	STI domain of intervention	Methodology & structure	Engagements with futures	Participants (as mentioned)	Challenge(s) tackled	Opening aspects	Closure aspects
Schneider et al. (2021)	TA	3-D Printing	*Transformative Vision Assessment*: (i) Current analysis (qualitative social science methods); (ii) dialogue (workshops); and (iii) modulation (participatory scenarios)	Critical-hermeneutic (Analysis and dialogue) Exploratory-evocative (Building sociotechnical scenarios) Exploratory-normative (Building more sustainable visions)	Social scientists Stakeholders STEM researchers	III II I	It begins with a critical approach that seeks to problematise existing visions The modulation and modulation of visions is based on both normative and descriptive explorations	It assumes an epistemic and moral division of labour among the actors: Scientists create the scenarios, and scientists and stakeholders discuss them The variables facing the four scenarios are limited to "inclusivity/exclusion" and "sustainability/unsustainability" (i.e. multivariate scenarios could have been used) Scenarios where the STI at hand does not exist are not envisaged
Repo and Matschoss (2019)	RRI	Strategic R&D Policies	*Workshops*: (i) Researchers ask citizens to articulate visions; (ii) experts formulate research priorities based on those visions; and (iii) citizens asses the connections between the priorities and their visions	Exploratory-normative Strategic	Experts Citizens	II	Visions have societal issues at their centre: Politics on STI purposes comes first to prevent the problem from being framed in purely technical terms	It assumes an epistemic and moral division of labour among the actors Citizens' visions may be biased by promises, expectations, and previously circulated visions It does not problematise scenarios about the possible consequences of the STI and their plausibility and desirability
Lehoux et al. (2020)	AG/RRI	Implantable cardiac "rectifier" (genetically at-risk adults)	*Techno-moral scenarios*: (i) Creation of videos depicting how the innovation works, the future context of its use, and two future scenarios; (ii) perform four face-to-face deliberative workshops; and (iii) conduct an online forum for scenarios discussion	Exploratory-evocative (explorations of ethical tensions)	38 individuals (workshops) 57 individuals (forums)	I	Involves participants of all ages. Promotes the exercise of moral imagination as a long-term prerequisite for the promotion of RRI. Even though the study was Exploratory-evocative in nature, some participants expressed concerns about scenarios' underlying promises	The scenarios are created and discussed by the organisers (i.e. not opened up to the co-negotiation between participants) The emergence of critique of visions was dependent on the contingent dynamics of the exercise, not methodologically promoted It is not clarified how the intervention modelled the dynamics of STI co-production

Table 14. Analysis of interventive anticipatory exercises.

Source	Framework(s) of reference	STI domain of intervention	Methodology & structure	Engagements with futures	Participants (as mentioned)	Challenge(s) tackled	Opening aspects	Closure aspects
Kera (2020)	AG/RRI	Blockchain and decentralised ledger technologies	*Simulation game*: (i) Immersive experience in a fictional "smart village"; (ii) deliberative role-play and conclusions of concerns; (iii) develop and prototype based on "(ii)"	Exploratory-evocative Strategic	Citizens	I	Enacts anticipatory capabilities through interactive exercises in a wide range of issues (design prototyping, policy, regulation issues) Supports contextual framing Contemplates the moratorium of the technology as an option	It is unclear to what extent and how these capabilities were transferred to STI practice Participants are "confronted" with scenarios, which frame the simulation game

The results reproduced in Table 14 show the heterogeneity of approaches to anticipation in practice and allow several conclusions to be drawn. Due to space constraints, only the most relevant results are highlighted below. These results will accurately inform the value and theoretical scope of the methodological structure of the multi-foresight process described in the following section.

The most relevant and general conclusion that can be drawn from the above analysis is the existence of a fragmentation when it comes to addressing the various challenges that anticipation poses (i.e. "I.", "II.", and "III.")—an exception is the *Transformative Vision Assessment* method recently proposed by Schneider et al. (2021). The analysis diagnoses that there are few exercises that, in a comprehensive way, promote through their anticipatory exercises heuristics that allow to address (in greater or lesser depth) the different challenges attributed to these frameworks. This lack of comprehensive treatment of STI processes, outcomes, and purposes has consequences for the resulting heuristics and for the gradients of problematisation of STI. In other words, it shows that STI is problematised (promoting dynamics of openness), yet this problematisation is simultaneously typically restricted to different domains of STI (promoting dynamics of closure).

The analysis shows, for example, that there is a strong tendency to understand anticipation in terms of exploring impacts, be they technical, sociotechnical or techno-moral. This is reflected in the widespread use of tools such as sociotechnical and techno-moral scenarios in the implementation of anticipation. The challenge that AG, RRI, RI, and TA tend to address in practice—considering various gradations of inclusivity, responsivity, and reflexivity—is "I.". This may be explained on the basis of the great consequentialist tradition that has prevailed in our understanding of responsibility (e.g. in the ELSI approaches), which aims to promote responsibility on the basis of minimising the impacts considered "negative" and maximising the impacts considered "positive" that a technology can demonstrably have. Of course, the question of on what and whose grounds something is judged to be "positive"/"negative" is not trivial and should be on the table (which is often not the case).

The exploratory-evocative exercises enable ways of opening-up the problematisation of STI outcomes (sociotechnical and techno-moral). However, the ways in which these exploratory exercises are enacted, as well as their monopolisation and exhaustion in many instances of the interventive exercises, reveal the existence of relevant points of closure in the operationalisation of anticipation.

One of the main conclusions is that many of these exercises are still conducted by way of an epistemic, political, and moral division of labour—as promoted by the ELSI paradigm. Very often there is a demarcation between the group of actors who co-construct the scenarios and the group that co-evaluates them. Many of the scenarios are created through desk research processes and then presented to the audience (which otherwise it is appealed to by different terms, each carrying different meanings) for critique and feedback. These mechanisms of subtle closure contrast with exercises wherein all actors collectively co-produce the very scenarios that will later be the subject of collective

critique and a source of reflection. These more open exercises, being a minority, allow for a more inclusive and responsive process in terms of the underlying assumptions to be considered regarding the future, thus opening-up the alternatives to be considered.

Another relevant area of closure arises from connecting the tendency to interpret anticipation with the exploration of impacts with the fragmentation discussed above. Not only is anticipation often linked to the problematisation of impacts, but it is usually reduced to this. This is highly detrimental for a comprehensive operationalisation of AG, RRI, RI, or TA through foresight exercises, which should include not only the problematisation of outcomes, but also the problematisation of STI purposes and processes.

Another central challenge of AG, RRI, RI, and TA is to open up the purposes to which STI is oriented (i.e. "II."). While acknowledging the contingency, impossibility of control, and non-linear nature of STI, the goal is to problematise in real time the nature of the socio-political and techno-moral worlds we mould through STI practices. While this is the case in theory, analysis shows that such problematisation of STI ends does not always occur in practice and that when it does occur, this problematisation has various methodological-operational limitations. As mentioned above, most research focuses on the impact of STI without asking whether (and to what extent) the STI in question itself promotes or hinders society's broader socio-political projects or visions.

In fact, only five sources were identified that explicitly problematise the socio-political objectives of STI. However, these five works present a variety of methodological challenges. For example, Mann (2015) and Stemerding et al. (2019) problematise the purposes, but this problematisation occurs within the framework previously established by projections about the potential merits and pitfalls of the STI in question (the former in terms of future impacts, the latter in terms of potential niches where STI could become valuable or profitable). This means that the problematisation of the purposes is not so much about the socio-political significance of the STI at hand, but rather the modalities under which the STI must be promoted in order not to be socio-politically problematic in the future. In this way, the exercises subtly reify the needs and goals of the STI under study. This problem of reification could be solved by starting the process with an exploratory-normative exercise, as is the case with the exercise executed by Repo and Matschoss (2019). However, this exercise is by no means unproblematic either. Its main problem is that it does not consider that citizens' visions can be distorted by promises and visions, and therefore critically reify the STI lines that represent those visions. For this very reason, Schneider et al. (2021) suggest that the core of the intervention should begin with a critical-hermeneutic engagement with participants' anticipatory assumptions: The aim is to counteract the performative power that some visions might have later in the intervention when goals and implications are explored and reflected upon. The work of Schneider et al. (2021) is the only one of the analysed sources that integrates the critical-hermeneutic approach and thus the only one that addresses the "III." challenge of AG, RRI, RI, and TA. Moreover, the work of Schneider et al. (2021) is the only one that addresses the three challenges of AG, RRI, RI, and TA. However, the way the work is

structured has some shortcomings, the most important being that the possibility of the non-existence of 3D printing is not presented in any scenario, or that 3D printing has been presented as a disruptive element in all scenarios (thus ultimately reproducing the visions that 3D printing campaigners are interested in). The debate should no longer be methodologically closed, so that a moratorium could be conceivable as a plausible scenario. Moreover, as with many other exercises, there is little evidence on how the anticipatory considerations and enabled knowledge were later integrated into STI practice.

At this point, it is also important to bear in mind that the assessment of all these anticipatory interventions cannot be separated from other dimensions that permeate AG, RI, RRI, and TA, such as reflexivity, inclusion, or responsiveness. Regarding reflexivity, it has already been suggested that the different forms of enabling anticipation exerts different degrees of reflexivity on STI. In terms of inclusivity, the presence of closure mechanisms in relation to the actors coming into play and their (sometimes too passive) role in the processes of co-creating and assessing scenarios is worth noting. In addition to the usual epistemic, moral, and political division of labour mentioned earlier, it is remarkable that many of the exercises encountered closure mechanisms in terms of the participants selected. As Irwin et al. (2013) argue, critique should be "a key component" of public engagement to improve the quality of knowledge co-production processes. More attention is needed with regard to (i) the criteria underlying the selection of actors, (ii) the ways in which these actors are referred to and the biases or constraints associated with them (they are heterogeneously presented under labels such as "stakeholders", "lay people", "public", "citizens", "experts", etc.), and (iii) the forms of participation that are actually facilitated in order to strengthen their voices. Finally, regarding responsiveness, in most cases there is no demonstration of how these actions have subsequently impacted on STI systems and how public concerns have been reflected in subsequent STI practices and developments. In this sense, there is a need for more in-depth analysis and monitoring of the ways in which these exercises transform STI practices.

Many of the above limitations are of course attributable to time and socio-material constraints (which are unavoidable). However, many other limitations are due to methodological criteria (which are certainly avoidable or minimisable). The discussion above is not intended to highlight things we might be doing wrong, but rather to suggest what we could be doing better. The emphasis on closure in the above critical review should not blind us to the benefits expressed in the exercises cited. These undoubtedly promote more robust forms of STI co-production than the mainstream ones. However, if the ultimate ambition is to open up STI modes to more socio-politically robust forms of co-production, it is worth discussing how the structures that underpin our intervening methods narrow the spaces for discussion and problematisation. In the following section, a preliminary structure of a multi-foresight exercise is proposed that seeks to minimise two limitations identified here: (i) The fragmentation of foresight exercises in addressing the main challenges of AG, RI, RRI, and TA, and (ii) the problem of reifying futures (see Section 4.4.1).

7.4. A comprehensive multi-foresight proposal to operationalise anticipation

The architectures of the methodology adopted during the AG, RRI, RI, and TA intervention and the degree of problematisation and openness of STI practices are interrelated. Methodologies enable and impel the unfolding of specific socio-epistemic processes, which, in turn, enact the emergence of specific anticipatory heuristics (while closing-down the emergence of others). The dimensions of STI that are open (and closed) to deliberative inquiry (e.g. who enters there, what aspects are problematised, and to what extent) are fixed *ex-ante* by the procedural architectures outlined by the particular methodology or technique at hand.

This structuring or channelling relevance of methodology and technique supports the need to examine what socio-epistemic dynamics the intervention exercises are intended to enable and capable of enabling. As the previous chapter suggests, this would mean attending to and caring for how temporality (present, past, and future) intends to be mobilised in the methodological design itself and how it is de facto mobilised throughout the development process. It implies questioning what aspects are considered and problematised during knowledge and anticipatory heuristics generation processes, and why these ones rather than others.

The previous sections diagnosed the significant and operational diversity of recent foresight exercises related to the normative and interventive approaches of AG, RRI, RI, and TA. More importantly, it was noted that there is conceptual and operational fragmentation in the various uses of anticipation/foresight for fostering a more socio-politically robust responsible innovation. There are different ways of operationalising anticipation, each of which focuses on a particular function, dimension, or challenge.

While on the one hand, this functional and methodological plurality is not a problem per se (it indeed expresses the richness and multiple functionalities of our engaging with futures tools), on the other hand, the separate treatment of each challenge has relevant practical consequences. It leads to a situation where each anticipatory intervention, even if laudable and interesting, remains shortened in terms of the potential issues subject to reflection and critique and, consequently, in terms of the heuristics generated or the issues opened-up. Each mode of engagement with the future enables the generation of certain reflexivity around a specific aspect or challenge and therefore allows the opening of futures at stake concerning certain aspects (and not others) (Table 14). A problematisation limited to a specific challenge indirectly leaves the rest of the challenges untreated, thereby minimising the intervention's reflexive scope and holistic character.

This section proposes a tentative structure of a multi-foresight process to support the operationalisation of AG, RRI, RI, and TA. This procedural anticipatory structure is presented as «a methodology of inquiry-in-interaction, which increases reflexivity of the [STI] developments» (Rip and Robinson, 2013, p. 37). It aims to be more amenable to dealing with not only the fragmentation problem commented and identified above, but also the futures reification problem. While the problem of fragmentation emphasises that

what is problematised matters, the problem of reification emphasises that how the problematisation is carried out also matters. Several authors have highlighted that the way innovation assessments are formulated and the way certain engagements with futures are structured can lead to the reification of those futures (see Grin and Grunwald, 2000; Grunwald, 2004; Nordmann, 2007, 2014) (see also Section 4.4.1). For example, problematising futures that might enable certain nano-innovations entails an engagement with nanoscience and nanotechnology that, if not sufficiently critical of the "nano" vision itself, can contribute to its reification (i.e. to seeing it as a reality, instead of as an object of critique, scrutiny, and change). Hence the demand that any engagement with the future must begin with a reflection on how the future de facto colonises the present (i.e. with a critical-hermeneutic way of engaging with the future) (see Lösch, Böhle, et al., 2019).

While the problem of fragmentation is addressed through a systematic engagement with the multiple challenges underlying AG, RRI, RI, and TA (see the end of Section 7.2), the problem of the reification of futures is addressed through the integration of critical-hermeneutic processes during the intervention process. While some degree of reification is inevitable, the aim is to introduce "upstream" reflexivity through foresight so that any reification is *as uncritical as possible*.

It should be noted that the fact that the methodology proposed here aims to be less vulnerable to these two problems or challenges does not mean naively supposing that it will not be subject to the limitations and contingencies inherent in any interventive operationalisation. The exercise does not claim to be a solution or panacea to the closure of alternatives and reification of futures that permeate our sociotechnical systems. On the contrary, it is assumed that these closure processes will always exist and influence the intervention exercises (as components of the power dynamics that underlie future-making processes). Instead, it is a tentative ideal-typical proposal that can be further critiqued and elaborated. Ultimately, it aims to promote intervention mechanisms that, from their conception, are more sensitive to the reification of futures and attend to the politics of anticipation in which they are embroiled and which are propagated through them. I intend to promote a critical debate on the tools and routines of fostering AG, RRI, RI, or TA through foresight processes. The proposed multi-foresight process aims to enrich the aspects of STI that are problematised during the intervention process, maximising the alternatives that the interventive research can open up (and minimising those that it can close down). In doing so, I intend to generate second-order reflexivity about how methodologies engage with modal power dynamics (Chapter 1).

7.4.1. Towards an anticipatory interventive architecture operationalised through a multi-foresight process

The description of the processes constituting the qualitative foresight process proposed here is structured according to the three main phases common to all foresight methods (see Popper, 2008).

1. The first or *ex-ante* phase involves the preparatory processes that precede the intervention.
2. The second or *ex-dure* phase refers to the very interventive processes. It is thus the operational and heuristic core of the process, which involves developing the anticipatory heuristics that are expected to foster more responsible STI.
3. Finally, the third *ex-post* phase includes the activities to assess and monitor the potential impact of the intervention dynamics, the evolution of the foresight processes, and the extent to which the pre-established foresight aims have been achieved.

Although the division of dynamics into these three phases in the description may make it appear that the dynamics have a linear progression, there might (and should) be intense iterative processes and feedback loops between the activities that internally constitute each of these phases, resulting in multiple rounds of ongoing "social learning". Indeed, iterativity, nonlinearity, and dynamism are widely recognised as characteristics of foresight exercises (e.g. Popper, 2008, p. 45; Saritas, 2013; Wippel, 2014, pp. 97–111). The main characteristics of these three phases are briefly summarised in Figure 5.

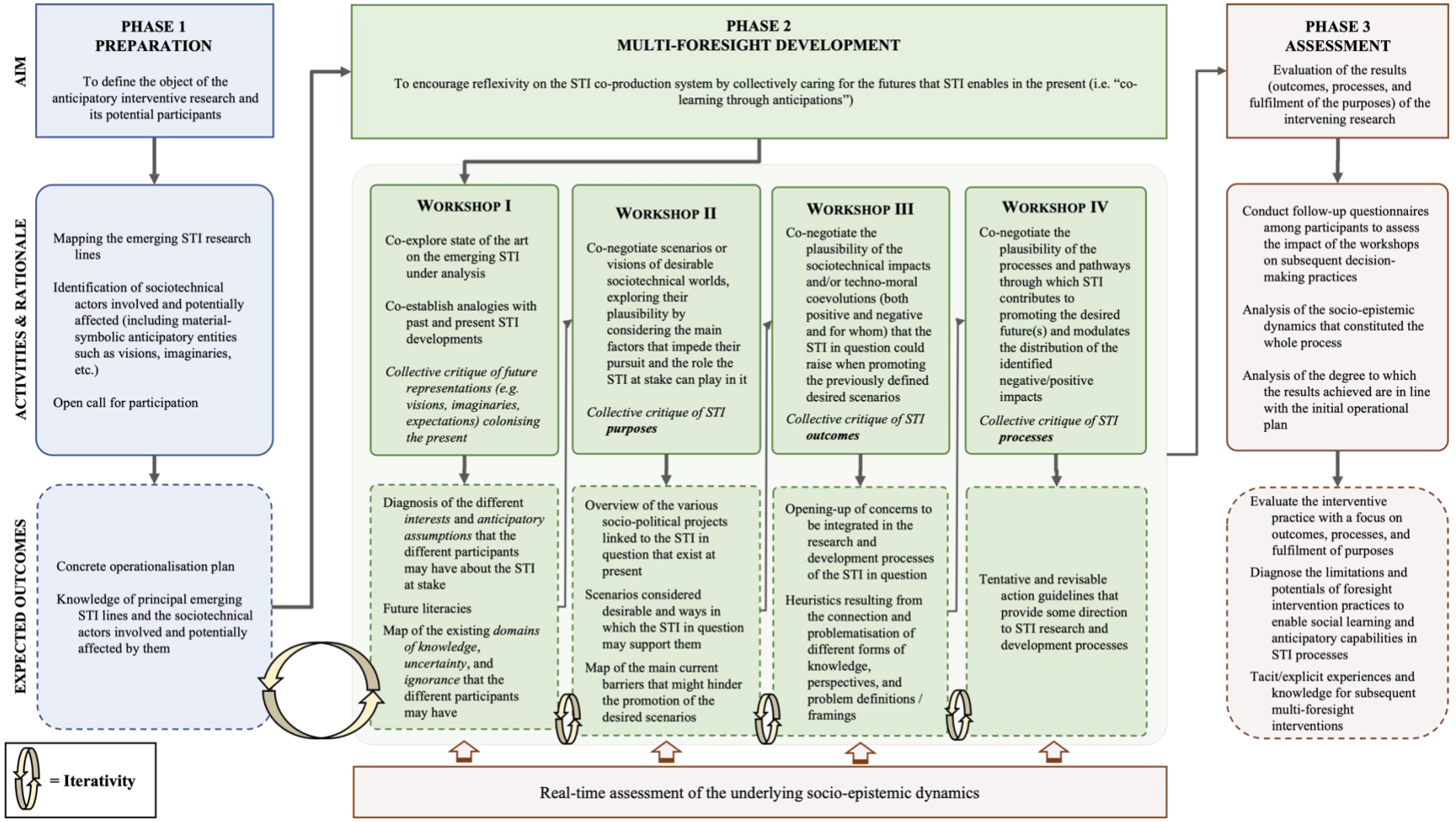

Figure 5. General schema of the proposed multi-foresight procedure for a comprehensive operationalisation of anticipation.

PHASE 1: PREPARING THE INTERVENTIVE PRACTICE

All interventive exercises begin with the delineation of the niche of intervention. The definition of the intervention niche of anticipatory exercises involves consideration of at least (i) the field or domain or STI lineage that is the object of the intervening design, (ii) the actors who should or could a priori be involved in the exercise, and (iii) the heuristics that it seeks to activate and the techniques of engagement with representations of the future that will be used to this end. Clearly, these three elements, along with many others, are interrelated. The determination of each element has implications for the appropriate consideration of the other elements (Figure 6).

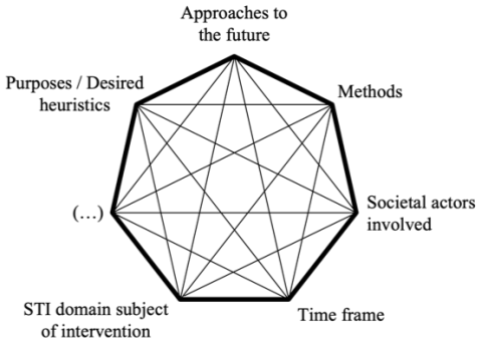

Figure 6. Interrelated factors in foresight practices.

The conception and/or preparation phase of interventive activities is crucial precisely because of this intertwining relationship between the methodology used and the other variables. The team conducting the interventive research needs to be particularly sensitive and self-reflective about the contextual factors that may influence their choices on these variables. Reflexivity is required insofar as their decisions will determine the heuristics of the exercise and in relation to which aspects the alternatives will be opened up or closed down.

One of the factors that require special attention in this process are the hermeneutic circles and sociotechnical meanings in which the anticipatory intervention is entangled. As Grunwald (2017, 2020) argues, the choice of which technology or innovation to make the subject of assessment is often conditioned by the sociotechnical meanings that have emerged around them. These meanings are co-configured and mobilised by different actors and may be embedded in sociotechnical visions, expectations, and imaginaries (Grunwald, 2019a). If an STI field has attracted the attention of certain STS scholars to consider it the target of their interventions, it is because there have been prior socio-political dynamics and a proliferation of meanings that have helped to elevate its importance as an object of responsibility. The various hype movements around biotechnology (e.g. the GMO cases), nanotechnology, and now artificial intelligence explain the various niches of interventive governance that have continuously emerged in the STS field. Deciding on the STI line for which the exercise is being conducted is already a first relevant closure point (it draws attention to a particular STI line to the detriment of possible others).

Another important factor is the question of which actors should be involved in the foresight process to problematise the STI in question. A call for participation is inevitable—even if the call remains open. A key question is which actor profiles with their respective values, desires, expectations, capabilities, and knowledges will be primarily involved. Furthermore, there is a need to consider how the involvement of actors whose socio-material conditions do not allow or facilitate their participation can be supported. Closing-down the diversity of different contributions during the negotiation process may facilitate decision-making, but it may also impoverish the potential of the concerns raised as well as reproduce prejudices and "business-as-usual" practices. If the focus of the exercise is to promote the capabilities of specific actors (e.g. future literacy capabilities), the question of which actors are given the opportunity to practise and improve these is non-trivial.

Both the performativity of the hermeneutic circles and the relevance of the participant profiles involved in the processes not only invite self-reflexivity in the design and preparation of the anticipatory intervention. They also invite to consider the positive character of promoting iterative processes between the phases of the intervention by keeping the actors involved and the problematised STI area as open issues. Maintaining the possibility of iteration between phases of intervention development is key to avoiding reification of the futures under consideration, and therefore the foresight exercise must be open to reformulation and enrichment regarding the STI areas deemed urgent or in need of attention and the actors involved.

Phase 2: The multi-foresight process

The second phase of the intervention exercise is considered the heart of the interventive process, as it is here that the possibilities of STI are discussed, and the anticipatory heuristics are closed/opened. It is in this *ex-dure* phase that the politics of anticipation, meant to be mobilised and scrutinised, are at play. The openness gradient of the exercise is constituted throughout the process and finds its first constructive step in the methodological choices mentioned above. However, within this abstract space of possibilities made possible by the design and mode of setting up the exercise, the de facto possibilities that are open can fluctuate according to the socio-epistemic activities that define the core of the exercise. This is why the structure, framing, and modes of mediation are so important at this stage (Macnaghten, 2017, 2021).

The multi-foresight exercise outlined here proposes to divide this heart of the process into four sub-phases, each of which focuses on facilitating engagement with the future under different modalities and dispelling temporality from different dimensions (see Table 15). The socio-epistemic activities facilitated in these sub-phases, as well as the challenges they target, determine (i) the scope and depth of the intervention. Similarly, the way in which engagement with the future is structured determines (ii) the gradients of uncritical reification of futures (i.e. which aspects are considered (im)plausible and (un)desirable and which aspects therefore become non-problematisable). On the one hand, in view of the problem of

completeness, the multi-foresight exercise proposes that its four (sub-)phases comprehensively address the three main challenges that AG, RRI, RI, and TA seek to address (Sections 4.2 and 7.2). On the other hand, in the face of the problem of uncritical reification, the exercise is structured in such a way that it encourages starting the foresight process with a critical-hermeneutic approach to the futures that colonise the present (first sub-phase) and prioritising normative or visionary exploration over hypothetical-projective exploration (second sub-phase).

In the following, each of these sub-phases (each developed in a specific workshop) will be briefly explained. The focus is on their respective justifications or their ideal-typical function in dealing with the problem of fragmentation and minimising the problem of uncritical reification. Following current methodological-interventive proposals (Brey et al., 2021), the scheme presented is generic enough to be re-adapted in different contexts and in relation to different STI domains. At the same time, it is concrete enough to illustrate the importance of giving structure to the analytical modes of engagement with the future during anticipatory exercises.

Table 15. Sub-phases of Phase 2. General challenges raised in each workshop, areas of temporality affected, and promoted modes of engagement with the future.

Workshop / subphase	General challenges associated to responsible innovation	Main temporal domains involved	Type of engagement with futures
Workshop I	"I.": To explore "endogenous futures" "III.": To promote critical capacities concerning future representations and ways of using the future that de facto colonise the present of STI governance dynamics (both formal and informal)	*Present*: Identifying current STI developments *Past*: Revisiting previous STIs, experiences *Deflation of futures-in-the-present*: Identification and critique of promises, visions, expectations, imaginaries, and "endogenous futures"	*Critical-hermeneutic*: Identify and emancipate from futures colonisations in the present
Workshop II	"II.": To problematise the purposes and orientations of STI	*Present*: Analyse the available resources and the limits imposed by current sociotechnical orders and their materiality *Future*: Opening-up of the set of sociotechnical desirable futures considered	*Exploratory-normative*: Opening-up the desirable futures
Workshop III	"I.": To explore the different impacts, and sociotechnical configurations, that might coevolve with the development of STI	*Future*: Opening-up the range of issues and concerns considered regarding the STI at stake	*Exploratory-evocative*: Opening-up the potential impacts
Workshop IV	"II.": To problematise the purposes and orientations of STI	*Future*: Draw up guidelines for current actions to promote the realisation of the desirable visions of the future already problematised	*Strategic*: Outlining guiding actions

Workshop I – Setting the stage of plausibility and desirability negotiations

The first workshop aims to prepare certain grounds for the subsequent negotiation of the plausibility and desirability of futures. These bases are intended to be established through the generation of reflexive dynamics that address both past and present temporality, as well as the critique of the futures-in-the-present that materialise in visions, expectations, and sociotechnical imaginaries.

As Derbyshire and Wright (2017) argue, many scenario-building exercises based on intuitive logics currently devote «little attention to the consideration of either the present state or how it has come to be», even though the treatment of the past and present can generate many heuristics that can be particularly valuable for the responsibilisation of STI. Given that the lenses or assumptions through which we look at the past and present are multi-layered (different actors could underline different dimensions of the present and the past), and many of the discrepancies about the future will be driven by divergences of the present and past, it is necessary to address and co-negotiate the plausibility of these from the outset.

The aim of fostering dynamics of reflection on the current state is not so much intended to establish a common ground (i.e. to impose a uniform or monolithic state of the art), but rather to consider the different dimensions and starting points that de facto exist (i.e. to consider the different perspectives on the present from which actors perceive and interpret reality); both in relation to the sociotechnical system in which the intervention takes place, and more specifically in relation to the STI at stake. Indeed, it has been recognised in the literature that the opening of a wider range of futures (i.e. the plausibilisation of other futures) also depends on the plausibilisation and possibilities of reframing the present (Fischer and Dannenberg, 2021) (Chapter 5).

It might also be particularly fruitful to problematise how we relate the past to the present of the STI in question, as well as the past to its future. Schwarz-Plaschg (2018a, p. 153), for example, has pointed out how analogies from the past (i.e. comparisons of the past and the present) are used «to make arguments and enforce framings». She has also highlighted how analogical imagination and enhanced analogical sensibility can help promote RRI (Schwarz-Plaschg, 2018b). The case of nanotechnology is a clear example of a non-presentist field where the use of both the pasts and futures has helped to mobilise the imaginations and opinions of different publics (favourable or unfavourable to legitimise nano-development) (Mody, 2004; Schwarz-Plaschg, 2018b; Selin, 2006a). Despite the value of past knowledge for the responsibilisation of STI, there are calls to increase both the use of this knowledge and its problematisation (Zimmer-Merkle and Fleischer, 2017). The inclusion of past temporality intended here also underlines this.

The case of the use and mobilisation of analogies illustrates that the colonisation of the spaces of plausibility and desirability is not carried out by future representations alone. However, this does not mean that the latter are excluded. The inclusion of the problematisation of futures in the present is intended to prevent the performative power of promises, expectations, and sociotechnical imaginaries from limiting the later explorations

of the multi-foresight process. As Groves (2013, p. 186) notes, «technological future imaginaries may help to prevent scrutiny of assumptions about innovation pathways and to exclude alternative visions of the future from discussion, thus making progress on the procedural elements of RRI more difficult». The proposed problematisation of these artefacts from the outset aims to enable a basic form of "futures literacies" (Miller and Sandford, 2019) that neutralises as much as possible their power to reify certain possibilities and thus impede the opening-up of alternatives to be considered in later workshops.

This first workshop activates the negotiation of plausibility as an epistemic process in the service of critically opening-up the past, present, and futures-in-the-present that de facto colonise reality and modulate the way we imagine, explore, and confront it. This first workshop is ultimately proposed as a social learning exercise aimed at opening/acquiring capacities for opening-up the representative artefacts that, exploiting temporality in each historical moment, constrain our explorations and visions of the future, thereby closing-down the spaces of possibility deemed desirable and plausible. The purpose is to operationalise the demand to begin every exploration by such critical assessments (Grin and Grunwald, 2000; Konrad and Alvial Palavicino, 2017; Nordmann, 2013b, 2014), as well as to offer a response to calls for the introduction and promotion of hermeneutic anticipation (Grunwald, 2016, 2020; van der Burg, 2014).

Workshop II – Giving our STI practices a desirable and plausible direction

Once a critique and hermeneutics of the ways in which the present is colonised by representational artefacts for the past, present, and future has been conducted, and the constricting power of these artefacts has been minimised, it is possible to begin explorations of potential futures. While it would be naïve to assume that these artefacts will no longer have power in subsequent phases, it is possible to assert that the necessary and possible mechanisms have been created to ensure that their impact is lessened as much as possible.

In contrast to exploratory foresight exercises that start from "product scenes" and problematise their desirability and plausibility later, this sub-phase of the multi-foresight exercise aims to problematise upfront the problems, challenges, or purposes with which we align STI. Ultimately, the aim is to discuss the sociotechnical and techno-moral worlds to which STI is expected to contribute and the ways in which it can/could contribute to them. This way of structuring the debate prioritises discussion of the plausibility and desirability of the framing and policy purposes underpinning the STI in question over exploration of its potential impacts (without, however, neglecting the latter). The aim is to address the problem already explicitly identified and criticised by von Schomberg (2012, p. 7):

> In order to help mitigate this, foresight projects could benefit from a prior analysis of potential relationships between types of plausible technological pathways and particular (social) problem-definitions, rather than starting with "naïve product scenes," which are, as Selin outlines them, "short vignettes that describe in technical detail, much like technical sales literature, a nano-enabled

> product of the future"[72] (…) thereby methodologically ignoring the underlying problem definitions.

By first exploring here which futures can be considered desirable and plausible and what role STI might play in relation to these futures, and then problematising the possible outcomes of STI in pursuing these futures (see Workshop III), the aim is to avoid limiting the debate on the desirability of STI by the (normative and descriptive) assumptions (i.e. the modal spaces) underlying the "product scene".

Suppose we co-design an anticipatory process. Its first exercise consists of co-projecting and negotiating the plausibility and desirability of sociotechnical scenarios that could arise from stratospheric sulphate injection as a measure in the face of climate change. These scenarios will depict diverse negative and positive configurations that the various participants are able to envision and justify. However, once we enter the debate on the (im)plausibility and (un)desirability of these scenarios, we would be doing so not only at the expense of taking the technology itself as plausible but also indirectly accepting a way of dealing with the climate change problem that can and should be explicitly problematised. For example, we would be assuming the Enlightenment paradigm of technological solutionism, where the solution is posited as technical rather than sociotechnical and organisational. The "product scene" enframes a definition of the problem and its corresponding resolution. The problem is climate change, and it is enframed as a technical problem—thus with its corresponding technical solution. The solution is to solve the effects of climate change by minimising the effects caused by our current forms of industrial production. The "product scene" presents a solution to one of our Grand Challenges, but it frames those solutions so that it shields the causes of the problem from problematisation, focusing only on counteracting the effects. It situates us in a scenario where the aim is to solve the effects of climate change caused by our current systems, but without promoting a fundamental debate on the necessity and relevance of changing our current sociotechnical systems and their productive constellations. This way of framing the problem subtly promotes the perpetuation of the same organisational scheme that causes the problem by not promoting the conception of alternative socio-economic and techno-industrial forms of organisation that would address or minimise the problem at its root.[73]

The absence of an explicit opening-up mechanism to unpack the potential relationships between types of plausible STI pathways and particular problem definitions would entail leaving it to chance whether these relationships are reified. The aim of interventive anticipatory exercises is not to leave these issues to chance, but to promote reflexivity as deeply as possible (Guston, 2014). The proposal here, then, is to explicitly incorporate these mechanisms of reflexivity by first asking what futures we want and in what ways technology might help us shape them. The typical lack of an explicit mechanism in the hypothetical-

[72] See Selin (2011, p. 5).

[73] Examples of geoengineering scenario practices that retain this type of framework can be found in Bodansky (2013) and Rabitz (2016). For a critique see Sweeney (2014).

projective exercises for encouraging and securing deeper debates about the relationships between STI pathways and problem definitions supports the suggestion that the second phase of the multi-foresight process should begin with exploratory normative exercises that explicitly address these kinds of questions. These exercises begin by looking at what futures are seen as desirable and how STI may or may not contribute to them (while also questioning how we navigate these relationships). In doing so, the exercise aims to address the issues of definition, perception, and framing that influence which modal spaces are opened up during the process, thus problematising the politics of anticipation that the intervention exercises themselves help to solidify.

Workshop III – Enriching our normative futures

Once the futures deemed desirable have been explored, it is important to enrich them with reflections on the possible negative/positive outcomes that might occur both in the process of pursuing these futures and in the hypothetical situation in which these become a reality (to some degree).

The reason for such hypothetical-projective explorations lies in the need to problematise that the pursuit of a desirable future is neither neutral nor free from tensions or imbalances. As Adam and Groves (2007, 2011) observe, any form of future-making is a form of future-taking, and even the future(s) negotiated (and closed-down) as desirable would not be free of depicting and embracing power asymmetries. This process aims precisely to explore the sociotechnical and techno-moral coevolutions that might occur. Questions around (i) what effects there might be (e.g. effects on techno-moral or sociotechnical orders) and (ii) what the distribution of these effects is (e.g. for whom they are seen as positive or negative and under what conditions) would be the subject of social examination and enrichment. This phase is thus ultimately about enriching the normative futures co-negotiated in Workshop II through reflexivity. Which actors do they (not) favour? In what ways?

At this point, one might ask whether the exercise does not reify the normative future dealt with in Workshop II. The answer is that a certain degree of reification, i.e. the assumption of a certain future as given, is unavoidable. If any kind of action is to be anticipatorily informed, it is necessary to close the space of possibilities under consideration. In this sense, the problem here is not so much reification per se, but uncritical reification (see Section 4.4.1). In other words, the problem is the reifications produced on the basis of futures that are little discussed and negotiated, and thus on futures with little socio-epistemic and socio-political legitimacy. The multi-foresight process therefore aims to minimise this problem by discussing the consequences within futures that have been previously problematised. The futures that set the frame, however, must be kept open for re-examination. In this sense, the results of this workshop may lead to a reconsideration of the visions of desirable futures themselves by reactivating the socio-epistemic processes defined in the previous sub-phase.

Workshop IV – Co-creating action plans

The fourth and final workshop has the difficult task of translating all the heuristics coming from the previous opening-up processes into practical guidance for STI exercises. Ultimately, as is common in strategic and visioneering exercises, the aim is to create an execution plan. This essentially consists of identifying how, given the resources available and the diagnosis of the current situation previously established in Workshop I, actions can be triggered to promote the emergence of the negotiated plausible and desired future(s).

The results of Workshop IV may lead to revisions of the futures or visions considered plausible and desirable, or of the specific issues considered in these. As a result, it may be possible to return to earlier stages of the multi-foresight process (e.g. revisiting the findings of Workshops II and III).

There are at least two aspects of this *ex-dure* sub-phase that are important to comment on. The first refers to the need to keep the implementation plan under continuous review, as an open plan. This is important to be able to adapt it to the contingencies that emerge during the process. Moreover, it is also important to insist during the mediation process that processes and plans are fallible in nature, and their significance is merely heuristic-orientational. Even when the outlined plan is accurately followed, it is important to emphasise that the desirable future may not be achieved (although following the instructions will more likely approximate this than otherwise). Ultimately, these forms of mediation are important to prevent the multi-foresight exercise from falling into the illusion of looking at the future as a space that can be the target of our design (see Section 4.4.3). The future, in this sense, must be maintained throughout the process as a space that is intrinsically uncertain, complex, contingent, and relatively open.[74]

PHASE 3: FORESIGHT DISSEMINATION AND ASSESSMENT

The third phase includes all the activities that take place after the completion of the interventive visioning or foresight exercise. These *ex-post* activities focus mainly—but not only—on (i) the dissemination of the results and (ii) the systematic and mainly qualitative (although it may be complemented by quantitative data) monitoring and evaluation of the foresight process. The systematic and *ex-post* nature is precisely what distinguishes this evaluation from the evaluation that could (and should) be carried out in real time throughout the operationalisation process (e.g. during *ex-ante* and *ex-dure* activities).

[74] The relative openness of the future is given by the socio-material constraints imposed by the sociotechnical systems in which we are immersed. These socio-material bases enable the creation and destruction of certain alternatives and sociotechnical pathways. In this sense, the future is not entirely open as various Futures Studies scholars seem to suggest (e.g. Sardar, 2010). The socio-material basis of each present enables the movement towards certain futures, while hindering the movement towards others: Long-term change is always possible, but difficult and costly (see Section 1.2).

The comprehensive nature that the assessment here seeks to achieve invites going further (without implying that one has to do without) than those practices that limit the assessment only to the efficiency of the foresight process (i.e. invites going beyond an evaluation that focuses solely on the extent to which the foresight process has fulfilled the objectives set out in its implementation plan). In contrast, the evaluation proposed here is intended to invite a focus on (i) the processes that constituted the interventive research, (ii) the impacts or outcomes (i.e. the heuristics derived from the intervention), and (iii) the extent and degree to which the overall objectives for which the foresight was designed have been achieved. I will briefly expand on each of these issues individually below.

The assessment of the processes

The assessment of the processes would focus on analysing the underlying dynamics of anticipatory knowledge co-creation that underpins the intervention exercise at hand (Dufva and Ahlqvist, 2015a, 2015b), as well as how the various anticipatory capacities were meant to be developed or strengthened (Rhisiart et al., 2015). Engaging with the socio-epistemic dynamics constitutive of interventive anticipations can serve to shed light on the underlying power dynamics and hampering (f)actors functioning during anticipation processes. For example, assessing processes can make a useful contribution to identifying and explaining which voices were heard or silenced, and which spaces of possibility were thereby selected or discarded, and on what grounds. This diagnosis would reveal the types of relationships and their respective qualities and asymmetries that endure between different actors (e.g. identifying instances of argumentative and epistemic injustices (Bondy, 2010; Fricker, 2007)). Indeed, the identification of these "hampering (f)actors" (see e.g. Table 13) could enrich further interventions and operationalisation plans aimed at promoting more socio-politically robust forms of STI co-production by supporting the inclusion of voices that have been identified as silenced. In this sense, conducting this process evaluation could serve to draw practical operational lessons to feed into subsequent anticipation exercises.

The realisation of the process assessment would have as a necessary condition the creation of documentary records of the processes (e.g. audio, video, field notebooks). These data and records could then be analysed and interpreted using various well established qualitative research methods in the social sciences and humanities—especially those typically applied in the STS.

The assessment of the outcomes

The evaluation of outcomes would focus on (i) identifying and analysing what heuristics and/or anticipatory knowledge or skills were de facto activated (Guimarães Pereira et al., 2007; von Schomberg et al., 2006). This includes observing the emergence of immediate, intermediate, and final heuristics, knowledge and/or capabilities, including those unexpected or undesired. In addition, the evaluation of outcomes would include a qualitative assessment of the impact of these outcomes in changing hegemonic STI dynamics and realities.

In addition to the analysis and identification of "what" outcomes, the outcome evaluation processes must simultaneously be situated in space and time. It must take into

consideration the relational network of actors that make up the sociotechnical reality and its associated coevolutions in time. In this sense, the questions of "what" must be supplemented simultaneously with the questions of "when" and "for whom and in what sense".

Attending to (ii) "when" would involve identifying and assessing how stable these heuristics have been over time, how the knowledge generated has evolved, and whether the capacities that were reinforced or emerged during the interventive exercise have developed, atrophied, or been maintained. The inertias of the socio-material systems in which we are embedded as actors (e.g. the prevailing modes of organisation of STI systems) act as closure mechanisms that might re-modulate anticipatory heuristics and prevent their maintenance over time. Existing constrictions will render it difficult for emergent heuristics both to become effective and to be prolonged over time, hence the need to attend to the coevolutionary variable over time of the outcomes.

Addressing (iii) the "for whom and in what sense" would involve identifying and assessing which actors do (not) benefit from these outcomes and in relation to which aspects this is the case. Given that the mobilisation of futures and futures literacies is at the heart of the politics of anticipation, the questions of who these futures and futures literacies are and who is (not) empowered through them are of great relevance. The diagnoses resulting from these evaluations will determine the truly inclusive nature of the interventive exercise.

The assessment of the purposes

Finally, the evaluation of the purposes would consist of analysing to what extent the outcomes reached match the initial operationalisation plan (i.e. to what extent the visions of responsibilisation have been realised and under what forms or gradients). As the fulfilment of the purposes depends on the (long-term/medium-term/short-term) outcomes, their assessment of the former can be more or less extensive in terms of time.

To support the realisation of these assessment processes, the elaboration of certain indicators focused on the qualitative characterisation of relational assemblages could be helpful and relevant. However, the creation and development of indicators that can assist in the assessment of anticipation is still an unexplored territory within the AG, RRI, RI, or TA literature—see Barrenechea and Ibarra (2020) for a tentative proposal in this respect.

7.4.2. Operative and normative foundations of the designed multi-foresight process

The proposed methodology—resembling AG, RRI, RI, and TA values and rationales—assumes the following core normative procedural characteristics:

- *"Upstream" and coevolutionary*: The methodology is intended to be integrated into STI co-production and coevolution processes in real time and from early stages. Ultimately,

it is a methodology that aims to serve «as a useful entry point for reflection on the purposes, promises, and possible impacts of innovation» (Owen et al., 2013, p. 38).

- *Reflexive* or *meta-representational*: The goal of the interventive dynamics is not to co-generate more or less robust representations of what might be the case (which would bring us closer to the predictivist pretensions of forecasting exercises). In contrast, the methodology is designed to stimulate reflection on the underlying assumptions, mindsets, and prevalent representational contents (both descriptive and normative) that inform STI future-making practices at the present. The use of future images thus takes on a purely instrumental character. It is a heuristic resource that aims to make explicit the socio-epistemic foundations that structure and give meaning and direction to STI governance (i.e. to reflect on the technical, ethical, and socio-political robustness and completeness of STI governance). Ultimately, the goal is to generate first- and second-order reflections (Owen and Pansera, 2019, p. 31) on the epistemic, volitional, and normative foundations that colonise our dispositions and orientations towards the future concerning STI. Accordingly, plausibility negotiation processes will focus not primarily on delineating a space of what will happen but on making visible and problematising the central assumptions we have about the world (Fischer and Dannenberg, 2021); that is, plausibility negotiations function as an "epistemic device" to enable the development of critical or reflexive-anticipatory heuristics (Fischer and Dannenberg, 2021) (see also Chapter 5). This includes attending to the conditions of production of the exercise and the factors that could permeate the foresight exercise (see Chapter 6).

- *Processual*: In connection with the previous point, the relevance of the exercise is not in the future representations that are generated and re- or deconstructed, but in the connecting processes between different actors, concerns, and knowledges that occur during the intervention. It is thus an intervening experiment that focuses on promoting "social learning"—a demand already raised by Constructive TA approaches (e.g. Genus, 2006; Rip et al., 1995; Wynne, 1995). It is about stimulating dynamics of "learning by anticipation" that aim to enrich and build relational assemblies with greater self-reflexive and critical capabilities (e.g. Asveld and Stemerding, 2015, p. 18; Parandian, 2012, pp. 34–43).

- *Flexible*: The processes that define the anticipatory exercise proposed here are flexible to be adapted to different STI areas (e.g. artificial intelligence, robotics, new materials, genetic engineering, and biotechnology) and hence to meet their particular needs (e.g. technical characteristics, stage of development, expected level of disruption, urgency of treatment). The method is deliberately general to be suitable for all areas of technology and innovation but specific enough in terms of the individual steps and potential assistive techniques to be meaningful and operationalisable.

- *Context-dependent and context-sensitive*: Any anticipatory interventive exercise that intends to have any kind of significant impact must take into consideration the reality in which it operates, adapting and being responsive to its particularities. This also implies

focusing on the relational quality of the dynamics fostered and generated during the exercise, as well as the perpetuation of these dynamics beyond the exercise.

- *Inclusive*: According to the current normative principles of AG, RRI, RI, and TA, the methodological process must comply with the principle of inclusivity. Inclusivity is defined as the diversity of actors, concerns, and knowledge integrated or mobilised throughout the process.
- *Intuitive logics*: The development of anticipatory techniques such as scenarios is intimately rendered by multiple logics and mindsets of approaching the future (Amer et al., 2013; Frith and Tapinos, 2020; Muiderman et al., 2020). The methodology proposed here has broad connections with "intuitive logics" approaches (Derbyshire and Wright, 2017; Wilson, 1998). It shares the following characteristics with "intuitive logics" approaches:
    - *Qualitative*: Future forecasting models based on quantitative modelling of futures typically aim to reduce the degree of uncertainty about what will be the case. In contrast, the methodology proposed here aims to embrace empirical and normative uncertainty qualitatively. It relies on qualitative forms of exploration, reflection, and critique to enact more flexible and creative forms of thinking and reasoning capable of challenging conventional thinking while searching for plausibility.
    - *Multifactorial*: The flexibility of qualitative approaches is particularly relevant to comprehensively address different factors (e.g. social, technological, economic, ecological, symbolic, cultural, political) and explore their intertwining and symbiotic nature (Derbyshire and Wright, 2017).[75]
    - *It encompasses the entire temporal spectrum*: Although the future is the temporal sphere most emphasised discursively, problematisation is not limited to the future. Considering the interconnectedness of the present, past, and future, the exercise addresses and problematises assumptions about and dispositions towards the past, present, and future (and their interrelationships).

7.5. Conclusions

The concern to promote more responsible STI through anticipations has been constant. However, what has changed are the prevailing semantics of responsibility and its associated ways of engaging with futures (Chapter 2). Today, different understandings of responsibility and their respective conceptions about the future coexist.

[75] "Intuitive logic" often refers to the need to include STEEP analysis. STEEP is an acronym for social, technological, economic, environmental, and political values and factors.

In the last two decades, however, the demand has prevailed to frame the responsibility of science and technology in eminently political terms and to operationalise it through the dimensions of "foresight" or "anticipation". In this context, being responsible implies taking care of STI by collective problematisation of its future-making outcomes, purposes, and processes. Examples of frameworks and policy proposals that exemplify this trend include Anticipatory Governance (AG), Responsible Research and Innovation (RRI), Responsible Innovation (RI), and more recent formulations of Technology Assessment (TA).

Anticipation, however, is an open or umbrella concept that encompasses various techniques engaging with the future. Each of these techniques is designed to address different goals and enable diverse capabilities. Consequently, each of these techniques involves different ways of mobilising and relating cognitively and affectively to the futures embodied in STI practices. Indeed, AG, RI, RRI, and TA propose anticipation as a dimension through which to address various challenges: Enabling a socio-politically robust exploration of ("I.") outcomes ("positive" and "negative", "soft" and "hard"), ("II.") purposes and processes, and ("III.") critiquing the performative power of STI visions, imaginaries, promises, and expectations.

Delving into how anticipation has recently been operationalised for AG, RI, RRI, and TA, it was identified that there is some operational fragmentation within the recently proposed exercises. In theory, anticipation is mobilised to delve into various interrelated challenges. However, in practice, it is carried out with a narrow focus on a few of these challenges (thus leaving challenges and issues unproblematised and subtly promoting reification of some frames and futures).

The heterogeneous and simultaneously fragmented nature of anticipatory practices in their application has motivated the proposal of a flexible and general qualitative foresight process. This methodological structuring is ultimately designed to respond both to such fragmentation and to address the need to ensure that the problematisations of STI through futures «begin with vision assessment» (Nordmann, 2007, p. 41).

On the one hand, the process presented here invites the joint and interrelated problematisation of the identified challenges attributed to foresight or anticipatory exercises in promoting AG, RRI, RI, or TA. The structure that constitutes the foresight process presented here is intended to promote more comprehensive or richer interventive anticipatory processes in terms of the kinds of engagements with temporality that are made and the elements that are descriptively and normatively problematised through it.

On the other hand, the exercise is vertebrated in self-reflexive processes regarding both (i) how the framing of the interventive exercise is itself framed and fixed (*ex-ante* phase) and (ii) how the temporal triad (past, present, and future) and its tensions and interrelationships are navigated and problematised (*ex-dure* phase). This renders the foresight process less susceptible—though arguably never immune—to the uncritical reification of certain visions, imaginings, and expectations and the "business-as-usual" way of moulding technological pathways. In other words, the proposed foresight process aims to

generate reflexivity in STI systems through foresight and encourage the foresight processes themselves to undergo a form of "upstream" reflexivity. The emphasis is on attending to the futures or sociotechnical worlds, and STI pathways that are (not) envisaged throughout the process: The emphasis is on the spaces of (im)plausibility and (un)desirability that are prefixed.

By emphasising the importance of the design and procedures that constitute anticipatory-interventive practices, the chapter has highlighted the responsibility of social scientists in shaping and opening certain spaces of reflection (while closing others) therein (Flyvbjerg, 2001; Macnaghten, 2017; Selin, 2011). As such, this chapter constitutes a further tentative step in problematising the relations between the politics of anticipation and anticipatory methodologies announced by Macnaghten (2021), in proposing to further problematise how interventive anticipatory tools can be developed to assist in the difficult but laudable task of shaping better future sociotechnical worlds through the shaping of more socio-politically robust STI practices. In other words, the problematisation presented here aims to make visible that the ways in which we methodologically intervene in the dynamics of modal power referred to at the beginning of this dissertation matter.

CONCLUSION

The principal research objective of this dissertation was to develop a more robust conceptualisation of anticipation as a methodological-interventive tool to promote a more socio-politically responsible Science, Technology, and Innovation (STI). This conceptualisation has arguably allowed a better understanding of anticipation regarding both (i) its functional and heuristic heterogeneity and (ii) its interpretative and context-dependent character (as a situated socio-epistemic practice subject to potentials and limitations).

The robustness of the generated concept of anticipation lies not only in the specification and deepening of its operational meaning through the theoretical-conceptual recognition of its heterogeneity and contingency when it comes to promoting socio-politically responsible STI dynamics. The concept's robustness is also reflected in the fact that it has a clear applied and operative focus aimed at improving STI practice. The precision and robustness of the anticipation concept facilitate moving towards more nuanced ways of promoting responsible STI through anticipation.

a. Main conceptual and operational results

The main outcome of the dissertation, presented in Chapter 7, is the development of a multi-foresight architecture to operationalise anticipation. This multi-foresight architecture has its main *raison d'être* in enabling more open, or critically inclusive, ways of using the future in an intervening way during STI co-production processes (Section 7.4.2). While the present dissertation lacks a case study illustrating the practical possibilities and limitations of this architecture, I hope that its empirical testing and consequent refinement can be done in the future. The defence and substantiation of the merits of the anticipatory architecture presented here rest on its design. The relevance lies in the formal processes that this architecture is designed to enable.

More specifically, the proposed multi-foresight exercise finds its potential for openness in its formal capacity to accommodate the many different challenges I have identified that could be attributed to anticipation (and consequently in the integration of the different modes of mobilisation and engagement with representations of the future that each of these challenges requires for their realisation). In this way, this method aims at a high degree of radical STI problematisation. At least from the perspective of the design of the multi-foresight architecture, it exhibits a greater radicality of STI problematisation than the

anticipatory exercises previously proposed and practised by frameworks such as Anticipatory Governance (AG), Responsible Research and Innovation (RRI), Responsible Innovation (RI), and Technology Assessment (TA).

The analysis of 17 practical cases where foresight exercises were promoted in the service of frameworks such as AG, RRI, RI, and newer forms of TA was indeed useful to highlight two things at the same time. The (i) first one refers to the fact that these exercises often remain constrained, especially in terms of (a) the aspects of STI that are amenable to problematisation (i.e. in terms of the challenges that foresight addresses), and (b) the actors that are considered in the process. The (ii) second relates to the need for careful design regarding the areas of problematisation opened up by foresight techniques. The multi-foresight process developed in this work responds to these issues and aims to address some of the shortcomings observed in the current literature with regard to the operationalisation of anticipation (Section 7.3).

The methodological architecture presented herein makes sense not only in accommodating the various identified challenges that anticipation might confront, but also in the sequencing through which these challenges are addressed. By initiating the exercise with a critique of the futures that colonise the present (i.e. with a mode of anticipation that has been identified in this thesis as "critical-hermeneutic"), as well as with the subsequent exploration of desirable and plausible futures, the intention was to avoid certain futures and modes of framing problems being taken as given. The reification of these futures and frames is relevant in the sense that they mark the scope of the negotiation of plausibility at stake, and thereby the realms within which the STI problematisation unfolds. In this way, the methodological structure finds its justification in being more favourable, at least from a theoretical point of view, to radically open up the future of STI compared to the structures used to date (without at the same time denying the difficulties it may encounter in its implementation and its limitations) (Section 7.4).

Therefore, the proposal may be of great relevance for current interventive proposals that aim to foster a more socio-politically robust STI through anticipatory exercises (see Section 2.3). Furthermore, the architecture proposed provides a first step in the elaboration of a much-needed debate on anticipatory methodologies and how they engage in the politics of anticipation (Macnaghten, 2021). However, it is still necessary to advance in this respect to make the contribution even more significant. Thus, for example, it would be necessary to enrich the architecture presented here with an analysis and assessment of the concrete techniques that would support each of the *ex-dure* workshops that constitute it. The proposal is general enough to accommodate different contexts, and yet detailed enough to capture its rationale: The next step would be to specify its possible techniques in relation to certain STI contexts. Another aspect that could enrich the proposed exercise would be its operationalisation. Operationalising the multi-foresight exercise would provide information about the potential dynamics it can favour and serve to refine and concretise its design (in real time and through learning-by-doing processes).

However, this multi-foresight operational proposal cannot be understood if one does not look at its conceptual basis. In order to arrive at this operational and meaningful result, it was necessary to deepen the theoretical-conceptual issues posed in the main research objective. Indeed, the multi-foresight architecture could be interpreted as a cluster outcome that incorporates and requires the other outcomes to acquire materiality and meaning (see Section 7.2). In other words, the proposed methodology cannot be understood and evaluated without considering the more robust conceptualisation of anticipation developed in this thesis.

The heterogeneity of the modalities of mobilisation of the future that this methodology encompasses, the different challenges addressed, and the sequences of implementation must be situated in relation to the results obtained from the previous theorisation exercises. Both the analysis of the 17 practice cases that underpin the rationale of the proposed methodology and the modes of mobilising futures that the methodology integrates refer to (i) specific modes of mobilising futures (i.e. using anticipation), (ii) which in turn enable specific challenges facing STI responsibilisation to be addressed. However, the very question of what these challenges were and what kinds of mobilisation of the future were intended or could be mobilised to foster more radical forms of STI governance were not self-evident in the literature. Moreover, the aim was to advance the understanding and operationalisation of anticipation in order to promote more socio-politically radical forms of governance and problematisation of STI. However, there were not (iii) explicit criteria under which we could consider the radicality of different forms of responsibilisation and governance of STI. The rationale and design of this operational architecture required prior and simultaneous elucidation in relation to these three aspects.

Through a brief historical review of different normative frameworks that sought to promote forms of accountability (Section 2.3), anticipation was found to be a pervasive feature (Section 2.4). This pervasiveness of anticipation, however, took on heterogeneous meanings depending on the framework from which it was interpreted. While many frames referred to anticipation or foresight as a tool of reference to problematise the governance of STI, these problematisations varied, and with them the modes of governance and responsibility that were intended to be activated (Section 2.4.1). The key question to ask is not so much whether a framework includes "anticipation" as a dimension, but rather what kind of analytical engagements with the future it seeks to promote, what socio-political challenges these engagements are intended to respond to, and how each framework aims to do so. Indeed, Future-Oriented Technology Analysis, AG, RRI, RI, and diverse forms of TA are just examples of different frameworks that integrate anticipation to pursue their respective—and sometimes overlapping—visions of STI governance.

These visions of responsible STI present different openness radicalities. Indeed, RI was identified as the most open framework, followed by RRI, AG, and new forms of TA. This radicality of openness could be identified based on the following variables: The temporal variable (when is STI problematised?); the inclusive variable (who problematises STI?); the objectual variable (which dimensions of STI are problematised?); and the operational

variable (are STI problematised from the outside or from within?) (Section 2.4.1). The aforementioned frameworks, notwithstanding their specificities, show a high degree of openness. This is because they attempt to problematise the processes and outcomes (and in the case of RI, clearly also the purposes) of STI throughout the whole process and at early stages by involving different social actors as agents of change and decision-making.

An analysis of the definitions of anticipation offered by these frameworks suggested that they are not very informative (hence the need to explore this dimension further). There are commonalities such as the emphasis on moving away from predictive activities, as well as the search for generating reflexivity. However, the definitions were somewhat unspecific in terms of the conditions under which this reflexivity should be promoted (see Table 5). In other words, the definitions of anticipation are not informative enough regarding what issues and what kind of engagements with the future should be mobilised. Since anticipation can be expected to inherit the openness and interpretative radicality of the framework from which it is interpreted, a basic definition of anticipation was proposed that could serve AG, RRI, RI, and TA:

> *An STI system can be described as AG/RRI/RI/TA-anticipatory when the collective, or inclusive, early, and ongoing problematisation of its plausible and desirable (present, past, and) future states enable its actors' capabilities to envision existing alternative courses of action and to intervene intentionally and reflexively in its present co-production.*

This definition, developed in Section 2.4.2, provided a minimal basis for moving forward in the search for a more robust and informative concept of anticipation. However, for greater precision and for the purposes of the study, it was necessary to clarify the tasks and challenges that anticipation is meant to address in promoting the basic guiding principles of AG, RRI, RI, and TA. A detailed analysis of the implicitly mentioned challenges faced by these frameworks suggested that the challenges of these frameworks and anticipation are multiple. While the overarching challenge to be addressed through the use of futures is the Collingridge dilemma, it was found that the specific way in which this dilemma could be approached could at least be unpacked around the following specific challenges (Section 4.2):

I. To explore the different impacts, sociotechnical configurations and "endogenous futures" that are emerging or might emerge with the development of a particular innovation or technology.

II. The comprehensive problematisation (in terms of the concerns considered and the actors involved in the deliberative processes) of the purposes and orientation of STI.

III. The promotion of critical capacities concerning future representations and ways of using the future that de facto colonise the present of STI governance dynamics (both formal ones, such as predictive regimes of governance, and informal ones, such as governance mechanisms through visions, promises, and expectations).

This pluralistic identification of the challenges targeted by anticipation contrasts with the way anticipation is understood in the literature, where it is reduced to or overly focused on impact research (i.e. in "I."). The analysis of the 17 case studies conducted to underpin the need for a more comprehensive anticipatory methodology showed that the question of impacts was prominent in many of the interventions conducted to date (see Table 14). The explicit expansion of the challenges that anticipation could and should address in promoting more robust forms of responsible STI constitutes a recognition of the functions that this tool can and should fulfil. The various challenges that anticipation can and should address have shown that anticipation is a heterogeneous instrument in functional terms.

Similarly, but in terms of progress on the nature of engagements with futures, it was found that frameworks such as AG, RRI, RI, and recent forms of TA promote the following types of engagements with futures (each rendering a mode of anticipation): strategic, exploratory (either based on futures or future-building processes, whether normative or evocative), and critical-hermeneutic (Section 4.3). Each of these forms of anticipation has a different operational meaning in relation to the above challenges for promoting better STI governance (see Table 8). This heterogeneous view that anticipation takes formally and operationally counters an understanding of anticipation that erroneously reduces it to predictive or exploratory engagements with the future. Identifying the different ways of engaging with the future not only allows for a more complex picture of anticipation, but also qualifies and revisits some of the criticisms levelled at the use of the future to promote better governance of STI. In particular, the identification of the diverse modes of engagements with the future that anticipation might embrace enabled us to gain a more nuanced picture of the scope of these criticisms, as well as the susceptibility of each of the identified modes of anticipation to fall into the pitfalls attributed to anticipation (in general) (Section 4.4).

However, the task of identifying these forms of engagement with the future that enable different forms of anticipation was not a straightforward one. Rather, this identification was supported by an analysis of the techniques subtly mentioned in the various foundational texts of the AG, RRI, RI, and TA frameworks (Section 4.3). This analysis, in turn, was supported by a previously created extended concept of anticipation. Specifically, the identification of ways of engaging with the future was made possible through the application of a concept of anticipation created by extending the concept used by Anticipation and Future Studies (see Section 4.2).

As it is typically used in Anticipation and Futures Studies, the term "anticipation" highlights the act of translating a future into action (Section 3.2). However, the move of "translating a future into action" is insufficient to illuminate the different forms of anticipation. Indeed, the socio-epistemic steps that capture the definition of anticipation put forward by Anticipation and Future Studies have been simultaneously identified as too loose and too narrow. While the loose character endangers the specificity of Anticipation Studies, the narrow character proves this concept insufficient or of little analytical usefulness in the quest to illuminate anticipation for AG, RRI, RI, and TA (Section 3.3). The issue of exploring how the vague character of the basic concept of anticipation handled by

Anticipation and Futures Studies might affect the legitimation of the field "as a discipline" was left open. The future is indeed a pervasive element of our forms of experiencing temporality. Thus, the distinctions between anticipatory actions and other kinds of action become fuzzy (turning into a question of the degree of prevalence of the future temporal order, rather than whether it is present per se). In contrast, the focus was on enriching the narrow character of the anticipation concept by expanding the socio-epistemic steps considered constitutive of anticipatory behaviours. The expansion from two to four steps, incorporating the approach to and engagement with the future as a concrete step in the account of anticipatory behaviour (Section 3.4, Figure 2), is precisely the move that made it possible to address the engagements with the future that the different or heterogeneous modes of performing anticipations may represent (Section 4.3).

This conceptual strengthening of anticipation as an interventive tool would not have been comprehensive enough if it had not also included self-reflection on, or recognition of, the limits of anticipation in order to disrupt hegemonic modes of STI co-production. The conceptualisation of anticipation in the present dissertation not only acknowledged that the variation of anticipation occurs in conceptual-interpretative terms. It has also pointed out that anticipation in practice takes on different forms and gradations of disruption depending on the kinds of relations it maintains with the settings in which it is produced. That is, to the functional and interpretative heterogeneity of anticipation is added the factual heuristic heterogeneity. Anticipation will indeed employ different heuristics with different gradations of disruptiveness and openness not only depending on how they are interpreted and what mobilisations of the future they promote. These heuristics are also particularly conditioned by the socio-material operationalisation contexts in which anticipatory practices emerge, are contextualised, and acquire interventive significance. This shows that it is necessary not only to focus on the conceptualisations and interpretations of anticipation, but also to pay attention to the socio-material conditions of production of anticipatory practices (the conceptual and interpretative constructions are, however, of utmost relevance as they inform and formally constrain the sense-making of anticipation and its subsequent implementation in practice).

Precisely to support this self-reflexivity of anticipation and to promote a critical and non-substantivised view of these practices, anticipatory practices such as those of foresight were conceptualised in Chapter 6 as context-dependent and situated socio-epistemic constructs. This entailed recognising that the anticipatory heuristics of foresight are not given, but are enabled/constrained by the dynamics of the sociotechnical systems from which they emerge and in which they are intended to operate. Following this logic, anticipation has been conceptualised not only as an "instrument for" responsibilising STI, but also as a tool that must be a "subject of" responsibility (Section 6.3). This conceptualisation of anticipation, which is attentive to the socio-epistemically situated and contextual dynamics that constitute anticipation, was supported by two main findings:

(i) Understanding anticipation as a tool that functions in sociotechnical contexts colonised by futures that, through the exercise and mobilisation of modal power,

open/close spaces deemed (im)plausible and thereby shape the dynamics of these sociotechnical contexts or systems; and

(ii) The conceptualisation of anticipatory practices as practices which, in their processes of opening-up the futures under consideration (i.e. dealing with modal power), are ongoingly modulated by a series of hampering (f)actors.

The first of the above findings (i.e. "(i)") was achieved by situating in the productive interconnection the theory of technological *momentum* proposed by Hughes (1969, 1994), the concept of "modal power" recently mentioned by Fuller (2018b), and the interpretation of reality as governed by ambivalent processes of openness and closure outlined by Stirling (2007, 2008) (Chapter 1). Specifically, the various representational artefacts of a prospective nature (e.g. visions, expectations, imaginaries, scripts) and their respective regimes of temporality were conceptualised as components of the sociotechnical assemblage that constitutes reality. These representative artefacts are not given, but have in turn been co-produced within the possibilities and limitations marked by the sociotechnical system from which they emerge, to which they belong, and which they dynamically co-constitute.

The importance of these anticipatory artefacts was shown to lie not only in their quality as components of the sociotechnical assemblage, but also in the roles they play within the relational network of the broader sociotechnical network to which they belong and which they constitute. Specifically, these representative artefacts (re-)order the prospective structures of the sociotechnical assemblage by orienting it towards the realisation of certain spaces of possibility (and keeping it away from others). In Hughes' words, the various representative artefacts not only configure "the mass" of the sociotechnical system in question, but colonise the "directionality" of the co-evolutionary processes of this network by orienting the system towards certain future paths; they are teleological constituents of the dynamics of the system. In this sense, they function as modulators of the possibilities whose materialisation is considered plausible and desirable. In Stirling's sense, they are components (not the only ones, but important components because of their future-oriented and teleological character) involved in the opening-up and closing-down of the sociotechnical paths and dynamics that continuously constitute the dynamics of sociotechnical systems (Section 1.2). If, as Fuller (2018b) argues, modal power is a form of control over what is deemed (im)possible and (im)plausible, we can conclude that representations of the future play a relevant role in the processes of distribution and execution of modal power in different ways. Relevant questions are therefore which actors are behind the creation of these futures and who benefits from or is harmed by the transformations that these futures (aim to) enact. In this sense, anticipatory dynamics were explained as active elements in the political life of opening-up/closing-down the *momentum* of sociotechnical systems through the modulation of the futures spaces deemed "(im)plausible" (Section 1.3).

This model serves to recognise and situate within a common empirical reality the dimensions under which anticipation is considered and understood in the literature. There were three dimensions identified: empirical-descriptive, critical-normative, and

methodological-interventive. In addition, the model also highlighted and explained some of the interrelationships between these dimensions (Section 1.5). In this manner, the model offered a tentative response (i.e. one that can be further developed and nuanced) to the demand made by various STS authors to provide some theoretical apparatus to interconnect and make sense of the anticipatory-interventive variable in the light of the *de facto* anticipatory dynamics (see Borup et al., 2006; Konrad et al., 2016).

The methodological-interventive uses of the future that AG, RRI, RI, and TA suggest should therefore be understood within contexts where the mobilisation of futures shapes the politics of anticipation. These interventions have motivations of openness. Through the use of foresight, the mentioned frameworks aim to mobilise the futures at stake, and they do so by engaging in practices that rely on the quest for plausibility (Sections 1.4 and 4.5). Within this context, it was identified how plausibility is positioned not only as a methodological criterion that limits the futures to be considered (as it tends to be understood). In contrast, it was identified that plausibility is intended to play an enabling role. Plausibility can be simultaneously understood as a criterion that limits the futures under consideration, as well as an inference register (a "political-epistemic device") that enables the opening-up of futures. In contrast to positions that interpret plausibility as an objective criterion that applies to the considered futures, it was conceptualised here as an instrument in the service of the evaluation of our assumptions about the (past, present, and) future (Section 5.3). Plausibility, and its negotiation processes activated through foresight exercises, was precisely addressed as a mechanism to address modal power dynamics (Sections 1.4 and 5.4).[76] However, the breadth of futures open to scrutiny and negotiation will always be limited, and therefore the openness of futures achieved through plausibility negotiation processes can acquire different degrees of openness. The assumptions taken for granted and the frames that mesh them are of vital importance here.

The second result, which underpins the heterogeneous and contingent nature of anticipatory heuristics (i.e. "(ii)"), shows how the plausibility spaces that can be opened by anticipatory exercises are constructed in real time and during the ongoing processes of anticipatory development and implementation. The opening-up/closing-down of the plausibility spaces is constituted during the *ex-ante*, *ex-dure*, and *ex-post* foresight operationalisation processes and depends on how the constitutive dynamics of the exercise deal with a set of hampering (f)actors that tend to close the futures under consideration. Precisely because addressing the politics of anticipation in a responsible manner is a matter of what/whose futures and concerns are considered during the STI co-production processes, the dynamics of openness/closure must be turned into "subjects of" responsibility (Section 6.3). The constituent dynamics of foresight need to be monitored and cared for. After identifying a number of key closure/opening points that could impact on each phase of operationalising foresight, a number of relevant hampering (f)actors were associated with

[76] One aspect that warrants future investigation is whether plausibility plays a specific sub-role in each of the forms of anticipation identified here.

each of these phases and key closure/opening points (see Table 13). The identification of possible hampering (f)actors was done, however, on a purely conceptual level (i.e. the hampering (f)actors identified emerged from a desk research process). One avenue that was not pursued here, but could be of particular interest, would be to expand the mentioned hampering (f)actors through concrete empirical case studies. Moreover, it would be interesting to capture, during the operationalisation processes of foresight, the hampering (f)actors that ongoingly modulate anticipatory heuristics. Similarly, it would be necessary and interesting to develop a set of assessment indicators that, contextually and carefully applied, can help identify potentially hampering (f)actors and thus motivate and implement the call for foresight as an object of responsibilisation.

The identification of the hampering (f)actors has also helped to point out that although the openness/closure of anticipatory heuristics is settled throughout the whole process, one element that particularly shapes or constrains this process is the specific foresight techniques chosen (Section 7.4). The architecture of the techniques, by (dis)activating specific engagements with the future, constrains the potential heuristics that might emerge during later phases. The methodological design of the foresight exercises was thus positioned as an *ex-ant*e constraint that deserves attention. It was precisely the identification that attention must be given to the ways in which the design of anticipatory exercises enables the opening-up of certain futures rather than others (Section 6.3.1) that prompted attention being paid to the multi-foresight architectures that are mobilised (Section 7.3), and which motivated the production of the architecture discussed at the beginning of this Conclusion.

The following main statements summarise the results discussed above as well as the claims defended in this dissertation:

- Anticipation is a constitutive element of STI dynamics, modulating modal power distributions through futures and thereby shaping the directionality that characterises the *momentum* of sociotechnical systems (Chapter 1).
- Anticipation as an intervening instrument in the service of normative frameworks such as AG, RRI, RI, and TA should be understood as a tool for opening-up modal power allocations. However, these openings can take on different meanings and degrees of radicality (Chapter 2).
- The basic concept of anticipation provided by Anticipation and Futures Studies is a narrow one for the purpose of providing answers to unresolved questions in the literature: How is anticipation to be understood for AG, RRI, RI, and TA and what are the different forms of anticipation? An expansion of this basic concept is needed (Chapter 3).
- There are three general types of anticipation that are considered valuable for promoting more socio-politically responsible STI: strategic, exploratory (normative/evocative and product/process-based), and critical-hermeneutic (Chapter 4).

- The recognition of the heterogeneity of the types of anticipation enables a more nuanced criticism of anticipation (insofar as these critiques assume a univocal notion of anticipation) (Chapter 4).
- Plausibility is not only a limiting criterion, but an inferential register that functions within the practices of foresight as a socio-epistemic and political inferential register that enables the inclusive opening-up of futures (and thus dealing with modal power) (Chapter 5, Sections 1.4 and 4.5).
- The anticipatory heuristics of foresight are not granted, but are constructed throughout the operationalisation process, during which the range of futures considered plausible is modulated by a number of hampering (f)actors. For this reason, foresight should be seen simultaneously as an "instrument for" responsibilisation and a "subject of" responsibility (Chapter 6).
- The multi-foresight process proposed in this thesis is a tentative mechanism to theoretically address at least two identified limitations of anticipatory practices: (i) the lack of comprehensiveness in problematising STI and (ii) the tendency to reify futures (Chapter 7).

All these results, comprehensively taken together, provide conclusive support for the hypothesis formulated in the introduction to this thesis. Namely, these findings support the claim that anticipation is a semantically and methodologically heterogeneous instrument for promoting a more socio-politically responsible STI, exhibiting heuristics of heterogeneous (i) types and (ii) radicalities. In relation to the heterogeneity of the heuristics considered valuable for promoting a more responsible STI, it was found that this can be subsumed under three general types: strategic, exploratory, and critical-hermeneutic. In relation to the different radicalities, it was sustained that they depend on two aspects. First, on (a) which spaces of problematisation are *formally* enabled by the frameworks in which anticipation is instrumentally interpreted and adopted. Ultimately, this *formal* radicality is *empirically* settled depending on (b) how the (im)plausibility negotiation processes of the sociotechnical futures at stake deal with the openness/closure (anticipation) dynamics and hampering (f)actors that prevail in the sociotechnical system in which anticipatory exercises de facto operate.

The path taken in this thesis in respect of clarifying the concept of anticipation consisted mainly in pointing out (some of) the formal and constitutively plural complexities of this instrument. The conceptual strengthening of anticipation was not achieved through its simplification, but through its deconstruction, generalisation, and complexification. The strengthening of the anticipation concept was achieved through a theoretical-conceptual exercise of openness, not through the search for conceptual univocity and closure. Hence the emphasis on the heterogeneity of anticipation.

The results obtained here can not only serve to obtain a more substantiated and complex picture of what "anticipation" entails from a methodological-interventive point of view. But they also call for the realisation of anticipations that are especially sensitive to the spaces of

(im)plausibility and (un)desirability that are reified in their processes. Ultimately, it calls for the realisation of anticipations, or foresight exercises, more sensitive to the spaces of plausibility that are opened up through them (and to whom and in what ways it creates benefits or hindrances). If frameworks such as AG, RI, RRI, and TA, among others, seek to make anticipation a resource for promoting more socio-politically robust modes of STI governance, they must start from a recognition and knowledge of the socio-material realities in which these exercises take place and the mechanisms of power mobilisation that they help to maintain or disrupt.

In conclusion, this thesis has helped to advance the conceptualisation and problematisation of anticipation as an interventive tool to promote a more socio-politically responsible STI. The present work is just a modest attempt to emphasise that forms of engagements with futures are forms that participate in the modulation of modal power. Any form of future-making is a form of future-taking. Hence the need to problematise the ways in which sociotechnical futures are interventively modulated. It matters how futures are constructed, and how these are used, approached, and translated into action.

This thesis can be seen as a (mere) step towards the still long but necessary path of investigating and reinforcing conceptually and methodologically-operationally the ways in which we use representations of the future to socio-epistemically and politically enrich the construction and enabling of sociotechnical futures in the present through STI. Perhaps the present thesis marks a further step in strengthening those "poor intuitions" and deficiencies in the conceptual development about anticipation that David H. Guston (2013)—one of the architects of Real-Time Technology Assessment and AG approaches—diagnosed and denounced.

b. Academic and political-institutional relevance

The operative and conceptual results here obtained and described below could be of *relevance in both academic and institutional settings*.

On the one hand, the findings obtained in this thesis can serve in an *academic context* to critically support the rationales of recent frameworks such as AG, RRI, RI, and TA, and to highlight the importance of attending to the ways in which these frameworks understand and operationalise anticipation. The call to attend to the gradations of openness that both frameworks and their anticipatory dimensions assume becomes relevant in an academic context where, in many cases, the openness heuristics of the above-mentioned frameworks and their associated anticipatory practices are taken for granted. This thesis located anticipatory normative intervention practices within sociotechnical landscapes shaped by hampering (f)actors and modal power dynamics exercised through futures. The emphasis on the situated, context-dependent, and contingent nature of the constructive dynamics of anticipatory processes complicates the substantivist framing of anticipation. This emphasis also invites us to monitor, and care for, the socio-material conditions of production of STI responsibilisation anticipatory practices (in real time and throughout their whole process).

This monitorisation applies to how hampering (f)actors and de facto anticipatory modal power mobilisations modulate the processes of negotiating plausible futures.

On the other hand, the results achieved here could be important in *institutional settings* for the creation of more open anticipatory STI policies. This relevance can be observed at the regional, national and European levels:

Firstly, and at the regional level, it can be observed how the Science, Technology and Innovation Plan (PCTI, the Spanish acronym for "Plan de Ciencia, Tecnología e Innovación") of the Basque Government of 2020 already stressed the need to promote an "open and participatory" STI (see Gobierno Vasco, 2014, pp. 13–14). This open and inclusive process included «participation in the design, implementation and actualisation of priorities, and encouraging the alignment of each actor's own strategies» (Gobierno Vasco, 2014, p. 45).[77] The actors included were businesses, researchers, public administration, and society. The PCTI 2030, currently in operation, seeks to reinforce this line, specifically through its third pillar: "Open Innovation", which includes among its fundamental lines of action a call to strengthen the role of the public sector and citizens in innovation in a holistic manner: Covering «all phases of the innovation process, from the conception of the idea to public acquisition» (Gobierno Vasco, 2019, p. 49).[78] This thesis has focused on the need to foster this inclusive facet of STI co-production, and sought to conceptually and operatively reinforce it. Specifically, this thesis has stressed the need to delve into the design of anticipatory procedures in order to promote through them the most radical socio-politically possible openings of STI. The multi-foresight process outlined here aims to encourage radically open forms of negotiation of the plausibility of futures. The multi-foresight architecture might indeed be appropriate in meeting, for instance, two objectives of the PCTI 2030: (i) «[S]trengthening programmes and instruments that facilitate the collaborative development of research, validation and demonstration activities for new technologies and equipment»[79] and, on that basis, (ii) «improving democratic governance and citizens' participation»[80] in STI (Gobierno Vasco, 2019, p. 49).

The results obtained here also carry potential value and usability at the Spanish state level. In the Spanish State Plan for Scientific and Technical Research and Innovation ("Plan Estatal de Investigación Científica y Técnica y de Innovación") for the period 2021–2023 we find "Open Science" as an essential pillar to promote one of its five basic principles: "Social and economic responsibility". This social responsibility would involve «the

[77] Original text: «[L]a participación en el diseño, implementación y actualización de las prioridades e impulsar el alineamiento de las estrategias propias de cada agente» (Gobierno Vasco, 2014, p. 45).

[78] Original text: «[T]odas las fases del proceso innovador, desde la concepción de la idea hasta la compra pública» (Gobierno Vasco, 2019, p. 49).

[79] Original text: «[R]eforzar los programas e instrumentos que faciliten el desarrollo conjunto de actividades de investigación, validación y demostración de nuevas tecnologías y equipamientos» (Gobierno Vasco, 2019, p. 49).

[80] Original text: «[M]ejorar la gobernanza democrática y la participación de los ciudadanos» (Gobierno Vasco, 2019, p. 49).

application of co-creation mechanisms and open access policies, as well as the alignment of R&D&I with social and economic values, needs and expectations» (Gobierno de España, 2020, p. 16).[81] As was the case at the regional level, the conceptual and, above all, operational advances generated here, are geared towards supporting these inclusive and open anticipatory co-creation mechanisms. By delving into the limits and possibilities of anticipation in order to open up the futures at stake through negotiations of plausibility, the thesis is fundamentally problematising the limits and possibilities of realising this effective social (and political) responsibility. Another area in which the advances made here could be useful is in relation to the "Spain 2050" ("España 2050") project. Anticipation is one of its operational pillars. In fact, the need to foster an "anticipatory governance" is made explicit (see Oficina Nacional de Prospectiva y Estrategia del Gobierno de España, 2021, p. 28). Although the scope of the research here is limited to the STI field, the results obtained in relation to the treatment of anticipation as a heuristic tool to promote this notion of responsibility can also be relevant for enriching and expanding the ways of thinking and observing this "anticipatory governance". For example, the research has supported the need to go beyond the operationalisation of anticipation under prospective-strategic modalities, such as those expressed in the "Spain 2050" project.

Finally, the EC formulated the need to promote RRI in its "Horizon 2020" Framework Programme (2014–2020). RRI is conceived as a normative principle that should articulate transversally all the priority STI lines. Anticipation (through foresight) is a key operational dimension for RRI. The progress made here on the socio-epistemic challenges that anticipation might address, and the respective methodological modalities through which these can be addressed, enables the envisioning of more robust ways of promoting RRI through anticipation. The analytical and methodological strengthening of anticipation presented here is of direct relevance to the goals and plans at the European level concerning the promotion of an RRI-like governance of STI.

While the thesis can be useful in relation to these policies and projects operating in institutional contexts, it should not be forgotten that the thesis also invites considerations that go beyond the narratives that typically support the demand for inclusivity in these settings. By proposing the identification and problematisation of the meanings and gradients gained through the openness promoted, the thesis encourages a critical consideration of these narratives and their tendency to instrumentalise anticipatory exercises for the legitimisation of predefined socio-political projects. In other words, the exercise of multiple foresight can be effective in these contexts, but it must be applied with a view to the constraints, tensions and possibilities that may influence negotiations of the plausibility of futures throughout the process. Tracing the subtle modes in which modal power is exercised is a prerequisite for the promotion of more open forms of future-making through anticipations.

[81] Original text: «[L]a aplicación de mecanismos de co-creación y las políticas de acceso abierto, así como el alineamiento de la I+D+I con los valores, necesidades y expectativas sociales y económicas» (Gobierno de España, 2020, p. 16).

c. Future research avenues

Beyond the results obtained and their potential significance and usefulness in academic and institutional domains, it is clear that there is still a lot more important research avenues that need to be explored. Among the various aspects that have not been addressed here—either because they were not part of the research objectives or because they have emerged during the research process—there are *two research avenues that merit consideration for future exploration*:

The first line of research is to conduct a more systematic and detailed analysis of the various usages of the future that have been adopted to promote responsible STI. This analysis could be done by operationalising as evaluation criteria the gradients of radicality regarding the problematisation of STI (and refining these criteria during the process) (Table 4). The analysis presented here has been instrumental in showing that anticipation is a pervasive and heterogeneous element. However, the heterogeneity and radicality that these practices assume should be made more complex and clearer through a deeper and more systematic examination of the practices and (mis)uses of the future that have been promoted to foster responsible STI. This analytical-historical exercise will not only serve to broaden our understanding of anticipation as an interventive tool (and thus refine or reinforce some of the theses argued here). It will also provide a more nuanced account of the relationships between the way the future is conceived and used on the one hand, and the way that "responsible STI" is thought about and promoted on the other (Urueña 2022b).

The second research line to be considered in the future, parallel to the previous one, relates to the deepening of the philosophical-theoretical rationales underlying anticipatory techniques (e.g. in terms of their ontological and epistemic assumptions and their respective political implications). This will inevitably require further engagement with the theoretical findings of Anticipation and Futures Studies. This must be done without losing the critical focus found in STS. The research findings that emerge from this second line of future research can be productive for both STS (especially for the STS normative-interventive branch) and Anticipation and Futures Studies (e.g. by enriching the approaches from which anticipation is canonically considered). Greater engagement with the theoretical and methodological tradition of Anticipation and Futures Studies is also essential to further strengthen and specify the techniques that can be used in each of the iterative processes involved in the four workshops that constitute the architecture presented in this dissertation.

Further research in these directions would be of great importance in refining the debate on the value of anticipation as an interventive tool and proposing concrete anticipatory operationalisation procedures that allow for a more socio-politically robust STI future-making practices.

References

Adam, B. (1990). *Time and Social Theory*. Philadelphia: Temple University Press.

Adam, B. (2008). Future matters: futures known, created and minded. *Twenty-First Century Society, 3*(2), 111–116. doi:10.1080/17450140802095102

Adam, B., & Groves, C. (2007). *Future Matters: Action, Knowledge, Ethics*. Leiden and Boston: Brill.

Adam, B., & Groves, C. (2011). Futures Tended: Care and Future-Oriented Responsibility. *Bulletin of Science, Technology & Society, 31*(1), 17–27. doi:10.1177/0270467610391237

Ahlqvist, T., & Rhisiart, M. (2015). Emerging pathways for critical futures research: Changing contexts and impacts of social theory. *Futures, 71*, 91–104. doi:10.1016/j.futures.2015.07.012

Akrich, M. (1992). The De-Scription of Technical Objects. In W. E. Bijker & J. Law (Eds.), *Shaping Technology / Building Society. Studies in Sociotechnical Change* (pp. 205–224). Cambridge, MA and London: The MIT Press.

Akrich, M. (1995). User Representations: Practices, Methods and Sociology. In A. Rip, T. J. Misa, & J. Schot (Eds.), *Managing Technology in Society. The approach of Constructive Tecghnology Assessment* (pp. 167–184). London and New York: Pinter Publishers.

Aligica, P. D. (2005). Scenarios and the growth of knowledge: Notes on the epistemic element in scenario building. *Technological Forecasting and Social Change, 72*(7), 815–824. doi:10.1016/j.techfore.2005.01.001

Almazán, A. (2021). *Técnica y tecnología: Cómo conversar con un tecnolófilo*. Salamanca: Taugenit.

Alvial-Palavicino, C. (2015). The Future as Practice. A Framework to Understand Anticipation in Science and Technology. *TECNOSCIENZA. Italian Journal of Science & Technology Studies, 6*(2), 135–172.

Alvial-Palavicino, C., & Konrad, K. (2019). The rise of graphene expectations: Anticipatory practices in emergent nanotechnologies. *Futures, 109*, 192–202. doi:10.1016/j.futures.2018.10.008

Amanatidou, E. (2017). "Foresight process impacts: Beyond any official targets, foresight is bound to serve democracy". *Futures, 85*, 1–13. doi:10.1016/j.futures.2016.11.003

Amer, M., Daim, T. U., & Jetter, A. (2013). A review of scenario planning. *Futures, 46*, 23–40. doi:10.1016/j.futures.2012.10.003

Amsler, S., & Facer, K. (2017). Introduction to 'Learning the Future Otherwise: Emerging Approaches to Critical Anticipation in Education'. *Futures, 94*, 1–5. doi:10.1016/j.futures.2017.09.004

Andersen, I.-E., & Jæger, B. (1999). Scenario workshops and consensus conferences: Towards more democratic decision-making. *Science and Public Policy, 26*(5), 331–340. doi:10.3152/147154399781782301

Anderson, B. (2007). Hope for nanotechnology: anticipatory knowledge and the governance of affect. *Area, 39*(2), 156–165. doi:10.1111/j.1475-4762.2007.00743.x

Andersson, J. (2018). *The Future of the World: Futurology, Futurists, and the Struggle for the Post Cold War Imagination*. New York: Oxford University Press.

Appadurai, A. (2013). *The Future as Cultural Fact: Essays on the Global Condition*. London and New York: Verso.

Arnaldi, S. (2008). Framing Pragmatic Validity: Theoretical Reorientations of the Regio Futures. In A. Gąsior-Niemiec, A. Kukliński, & W. lamentowicz (Eds.), *Faces of the 21st Century* (pp. 108–121). Poland: Oficyna Wydawnicza Rewasz.

Arnaldi, S. (2018). Retooling Techno-Moral Scenarios. A Revisited Technique for Exploring Alternative Regimes of Responsibility for Human Enhancement. *NanoEthics, 12*(3), 283–300. doi:10.1007/s11569-018-0329-6

Arnaldi, S., & Bianchi, L. (2016). *Responsibility in Science and Technology. Elements of a Social Theory*. Berlin: Springer VS.

Arnaldi, S., & Gorgoni, G. (2016). Turning the tide or surfing the wave? Responsible Research and Innovation, fundamental rights and neoliberal virtues. *Life Sciences, Society and Policy, 12*(1), 6. doi:10.1186/s40504-016-0038-2

Arthur, W. B. (1989). Competing Technologies, Increasing Returns, and Lock-In by Historical Events. *The Economic Journal, 99*(394), 116–131. doi:10.2307/2234208

Asveld, L., & Stemerding, D. (2015, 24–25 August). *Synthetic biology as a social experiment: the case of Ecover.* Paper presented at the Fourth International MVI Conference. Responsible Innovation 2015 A European Agenda?, The Hague.

Atkisson, A. (2011). *Believing Cassandra: How to be an Optimist in a Pessimist's World*. London: Earthscan.

Ayres, R. U. (1969). *Processing the Future: Technological Forecasting and Long-Range Planning*. New York: McGraw-Hill.

Ballo, I. F. (2015). Imagining energy futures: Sociotechnical imaginaries of the future Smart Grid in Norway. *Energy Research & Social Science, 9*, 9–20. doi:10.1016/j.erss.2015.08.015

Balmer, A., Bulpin, K., Calvert, J., Kearnes, M., Mackenzie, A., Marris, C., . . . Schyfter, P. (2012). Towards a manifesto for experimental collaborations between social and natural scientists. Retrieved 10/09/2019 from https://experimentalcollaborations.wordpress.com/

Barben, D., Fisher, E., Selin, C., & Guston, D. H. (2008). Anticipatory Governance of Nanotechnology: Foresight, Engagement, and Integration. In E. J. Hackett, O. Amsterdamska, M. Lynch, & J. Wajcman (Eds.), *The Handbook of Science and Technology Studies, Third Edition* (pp. 979–1000). Cambridge, MA and London: The MIT Press.

Barber, B. R. (1984). *Strong Democracy. Participatory Politics for a New Age*. Berkeley, CA: University of California Press.

Barrenechea, J., & Ibarra, A. (2020). Criterios, principios e indicadores de conectividad para la inclusividad responsable en ciencia y tecnología. *Caleidoscopio - Revista Semestral De Ciencias Sociales Y Humanidades, 24*(43). doi:10.33064/43crscsh2288

Bauer, A. (2018). When is the future? Temporal ordering in anticipatory policy advice. *Futures, 101*, 36–45. doi:10.1016/j.futures.2018.06.002

Baumeister, R. F., Vohs, K. D., & Oettingen, G. (2016). Pragmatic Prospection: How and Why People Think about the Future. *Review of General Psychology, 20*(1), 3–16. doi:10.1037/gpr0000060

Bechtold, U., Capari, L., & Gudowsky, N. (2017). Futures of ageing and technology – comparing different actors' prospective views. *Journal of Responsible Innovation, 4*(2), 157–176. doi:10.1080/23299460.2017.1360721

Bechtold, U., Fuchs, D., & Gudowsky, N. (2017). Imagining socio-technical futures – challenges and opportunities for technology assessment. *Journal of Responsible Innovation, 4*(2), 85–99. doi:10.1080/23299460.2017.1364617

Beckert, J. (2011). *Imagined Futures: Fictionality in Economic Action*. Cologne: Max Planck Institute for the Study of Societies.

Beckert, J. (2016). *Imagined Futures: Fictional Expectations and Capitalist Dynamics*. Cambridge, MA: Harvard University Press.

Beckert, J. (2018). The future in economic action: a reply to the reviewers. *Distinktion: Journal of Social Theory, 19*(3), 344–352. doi:10.1080/1600910X.2018.1527707

Beckert, J., & Bronk, R. (2018). *Uncertain Futures: Imaginaries, Narratives, and Calculation in the Economy*. Oxford: Oxford University Press.

Bell, D. (1964). Twelve Modes of Prediction: A Preliminary Sorting of Approaches in the Social Sciences. *Daedalus, 93*(3), 845–880.

Bell, W. (2003). *Foundations of Futures Studies: Volume 1: History, Purposes, and Knowledge* (Vol. 1). London: Tylor & Francis.

Bell, W., & Olick, J. K. (1989). An epistemology for the futures field: Problems and possibilities of prediction. *Futures, 21*(2), 115–135. doi:10.1016/0016-3287(89)90001-3

Belot, R., & Picard, F. (2014). The Three Ages of Fuel Cell Research in France: A Socio-Technical System's Resistance to Change. *Fuel Cells, 14*(3), 525–532. doi:10.1002/fuce.201300230

Bennett, I., & Sarewitz, D. (2006). Too Little, Too Late? Research Policies on the Societal Implications of Nanotechnology in the United States. *Science as Culture, 15*(4), 309–325. doi:10.1080/09505430601022635

Berger, G. (1967). *Etapes de la prospective*. Paris: Press Universitaires de France.

Berkhout, F. (2006). Normative expectations in systems innovation. *Technology Analysis & Strategic Management, 18*(3-4), 299–311. doi:10.1080/09537320600777010

Berne, R. W. (2008). Science Fiction, Nano-Ethics, and the Moral Imagination. In E. Fisher, C. Selin, & J. M. Wetmore (Eds.), *The Yearbook of Nanotechnology in Society, Volume 1. Presenting Futures* (pp. 291–302). Dordrecht: Springer.

Berube, D. M. (2004). The Rhetoric of Nanotechnology. In D. Baird, A. Nordmann, & J. Schummer (Eds.), *Discovering the Nanoscale* (pp. 173–192). Amsterdam: IOS Press.

Betten, A. W., Rerimassie, V., Broerse, J. E. W., Stemerding, D., & Kupper, F. (2018). Constructing future scenarios as a tool to foster responsible research and innovation among future synthetic biologists. *Life Sciences, Society and Policy, 14*(1), 21. doi:10.1186/s40504-018-0082-1

Bijker, W. E. (1993). Do Not Despair: There Is Life after Constructivism. *Science, Technology, & Human Values, 18*(1), 113–138. doi:10.1177/016224399301800107

Bijker, W. E. (2001). Understanding Technological Culture through a Constructivist View of Science, Technology, and Society. In S. H. Cutcliffe & C. Mitcham (Eds.), *Visions of STS: Counterpoints in Science, Technology, and Society Studies* (pp. 19–34). Albany, NY: State University of New York Press.

Bijker, W. E., Hughes, T. P., & Pinch, T. J. (1987). *The Social Construction of Technological Systems*. Cambridge, MA: The MIT Press.

Bijker, W. E., & Law, J. (1992). *Shaping Technology / Building Society. Studies in Sociotechnical Change*. Cambridge, MA and London: The MIT Press.

Bishop, P., Hines, A., & Collins, T. (2007). The current state of scenario development: an overview of techniques. *Foresight, 9*(1), 5–25. doi:10.1108/14636680710727516

Blok, V. (2017). Toward an Eco-centric Concept of Biomimetic Technologies in the Anthropocene. *Techné: Research in Philosophy and Technology, 21*(2/3), 127–149. doi:10.5840/techne201752363

Bodansky, D. (2013). The who, what, and wherefore of geoengineering governance. *Climatic Change, 121*(3), 539–551. doi:10.1007/s10584-013-0759-7

Boenink, M. (2013). Anticipating the future of technology and society by way of (plausible) scenarios: fruitful, futile or fraught with danger? *International Journal of Foresight and Innovation Policy, 9*(2/3/4), 148–161. doi:10.1504/ijfip.2013.058608

Boenink, M., Swierstra, T., & Stemerding, D. (2010). Anticipating the Interaction between Technology and Morality: A Scenario Study of Experimenting with Humans in Bionanotechnology. *Studies in Ethics, Law, and Technology, 4*(2). doi:10.2202/1941-6008.1098

Bogner, A., & Torgersen, H. (2018). Precaution, Responsible Innovation and Beyond – In Search of a Sustainable Agricultural Biotechnology Policy. *Frontiers in Plant Science, 9*. doi:10.3389/fpls.2018.01884

Bonaccorsi, A., Apreda, R., & Fantoni, G. (2020). Expert biases in technology foresight. Why they are a problem and how to mitigate them. *Technological Forecasting and Social Change, 151*, 119855. doi:10.1016/j.techfore.2019.119855

Bondy, P. (2010). Argumentative injustice. *Informal Logic, 30*(3), 263–278.

Booth, C., Rowlinson, M., Clark, P., Delahaye, A., & Procter, S. (2009). Scenarios and counterfactuals as modal narratives. *Futures, 41*(2), 87–95. doi:10.1016/j.futures.2008.07.037

Borup, M., Brown, N., Konrad, K. E., & Van Lente, H. (2006). The Sociology of Expectations in Science and Technology. *Technology Analysis & Strategic Management, 18*(3/4), 285–298. doi:10.1080/09537320600777002

Boslaugh, S. (2011). Technological Momentum. In D. Mulvaney (Ed.), *Green Technology: An A-to-Z Guide*. Thousand Oaks, CA: Sage Publications.

Bourdieu, P. (1984). *Homo Academicus*. Paris: Editions de Minuit.

Brey, P. A. E. (2000). Method in computer ethics: Towards a multi-level interdisciplinary approach. *Ethics and Information Technology, 2*(2), 125–129. doi:10.1023/A:1010076000182

Brey, P. A. E. (2012). Anticipatory Ethics for Emerging Technologies. *NanoEthics, 6*(1), 1–13. doi:10.1007/s11569-012-0141-7

Brey, P. A. E. (2017). Ethics of Emerging Technologies. In S. O. Hansson (Ed.), *The Ethics of Technology: Methods and Approaches* (pp. 175–192). London and New York: Bowman & Littlefield.

Brey, P. A. E., Dainow, B., Erden, Y. J., Matar, A., Jansen, P., Rodrigues, R., . . . Hoevel, P. (2021). *SIENNA D6.3: Methods for translating ethical analysis into instruments for the ethical development and deployment of emerging technologies*. Retrieved 21/11/2021 from https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5db4bbeed&appId=PPGMS

Bridges, D. (2006). The Disciplines and Discipline of Educational Research. *Journal of Philosophy of Education, 40*(2), 259–272. doi:10.1111/j.1467-9752.2006.00503.x

Broncano, F. (2009). *La melancolía del ciborg*. Barcelona: Herder.

Brown, N., & Michael, M. (2003). A Sociology of Expectations: Retrospecting Prospects and Prospecting Retrospects. *Technology Analysis & Strategic Management, 15*(1), 3–18. doi:10.1080/0953732032000046024

Brown, N., Rappert, B., & Webster, A. (2000). *Contested Futures: A Sociology of Prospective Techno-Science*. Aldershot and Burlington, VT: Ashgate.

Brownsword, R. (2009). Nanoethics: Old Wine, New Bottles? *Journal of Consumer Policy, 32*(4), 355–379. doi:10.1007/s10603-009-9100-2

Bryant, R., & Knight, D. M. (2019). *The Anthropology of the Future*. Cambridge: Cambridge University Press.

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The Brain's Default Network. *Annals of the New York Academy of Sciences, 1124*(1), 1–38. doi:10.1196/annals.1440.011

Burgelman, J.-C., Chloupková, J., & Wobbe, W. (2014). Foresight in support of European research and innovation policies: The European Commission is preparing the funding of grand societal challenges. *European Journal of Futures Research, 2*(1), 55. doi:10.1007/s40309-014-0055-4

Burget, M., Bardone, E., & Pedaste, M. (2017). Definitions and Conceptual Dimensions of Responsible Research and Innovation: A Literature Review. *Science and Engineering Ethics, 23*(1), 1–19. doi:10.1007/s11948-016-9782-1

Bush, V. (1945). *Science: The endless frontier*. North Stratford, NH: Ayer Company Publishers.

Byrne, R. M. J. (2005). *The Rational Imagination: How People Create Alternatives to Reality*. Cambridge, MA: Cambridge University Press.

Callon, M. (1990). Techno-economic Networks and Irreversibility. *The Sociological Review, 38*(sup1), 132–161. doi:10.1111/j.1467-954X.1990.tb03351.x

Callon, M. (2007). What Does It Mean To Say that Economics Is Performative? In D. MacKenzie, F. Muniesa, & L. Siu (Eds.), *Do economists make markets? On the performativity of economics* (pp. 311–357). Princeton, NJ: Princeton University Press.

Chakrabarti, P. (2004). *Western Science in Modern India: Metropolitan methods, Colonial practices*. Ranikhet: Permanent Black.

Chermack, T. J., Lynham, S. A., & Ruona, W. E. A. (2001). A review of scenario planning literature. *Futures Research Quarterly, 17*(2), 7–32.

Chiasson, M., Davidson, E., & Winter, J. (2018). Philosophical foundations for informing the future(S) through IS research. *European Journal of Information Systems, 27*(3), 367–379. doi:10.1080/0960085X.2018.1435232

Chilvers, J., & Kearnes, M. (2020). Remaking Participation in Science and Democracy. *Science, Technology, & Human Values, 45*(3), 347–380. doi:10.1177/0162243919850885

CNS-ASU. (2005). History. Retrieved 20/03/2020 from http://cns.asu.edu/about/history

Coates, J. F. (1971). Technology Assessment: The Benefits… the Costs… the Consequences. *The Futurist, 5*, 225–231.

Coates, J. F., Mahaffie, J. B., & Hines, A. (1994). Technological forecasting: 1970–1993. *Technological Forecasting and Social Change, 47*(1), 23–33. doi:10.1016/0040-1625(94)90037-X

Coates, V., Farooque, M., Klavans, R., Lapid, K., Linstone, H. A., Pistorius, C., & Porter, A. L. (2001). On the Future of Technological Forecasting. *Technological Forecasting and Social Change, 67*(1), 1–17. doi:10.1016/S0040-1625(00)00122-0

Coenen, C. (2014). Transhumanism and its Genesis: The Shaping of Human Enhancement Discourse by Visions of the Future. *HUMANA.MENTE - Journal of Philosophical Studies, 7*(26), 35–58.

Coenen, C., & Simakova, E. (2013). Introduction. STS Policy Interactions, Technology Assessment and the Governance of Technovisionary Sciences. *Science, Technology & Innovation Studies, 9*(2), 3–20.

Cole, H. S., Freeman, C., Jahoda, M., & Pavitt, K. L. R. (Eds.). (1973). *Thinking about the Future: a Critique of the Limits to Growth.* London: Chatto and Windus for Sussex University Press.

Collingridge, D. (1980). *The Social Control of Technology*. London: Francis Pinter Ltd.

Commission of the European Communities. (2001). *European Governance: A White Paper. Brussels, 25.7.2001, COM(2001), 428 final.* Brussels: Commission of the European Communities.

Commission of the European Communities. (2004). *Communication from the Commission - Towards a European strategy for nanotechnology. COM(2004) 338 final. (12.05.2004).* Brussels: Commission of the European Communities.

Conley, S. N. (2013). Anticipatory Governance in Practice? Nanotechnology Policy in Cambridge, Massachusetts. In S. A. Hays, J. S. Robert, C. A. Miller, & I. Bennett (Eds.), *Nanotechnology, the Brain, and the Future* (pp. 373–392). Dordrecht: Springer.

Cozzens, S. E. (1993). Whose Movement? STS and Social Justice. *Science, Technology, & Human Values, 18*(3), 275–277. doi:10.1177/016224399301800301

CRN. (2007). *The Center for Responsible Nanotechnology Scenario Project*. Retrieved 13/09/2021 from http://openscenarios.ida.org/scenarios/65-CRN_Secret_Military_Development.pdf

Cuevas Badallo, A., & Urueña, S. (2019). Públicos y actores en la democratización de la actividad científica. *Revista Iberoamericana de Ciencia, Tecnología y Sociedad - CTS, 14*(42), 9–29.

Cuhls, K. (2003). From forecasting to foresight processes—new participative foresight activities in Germany. *Journal of Forecasting, 22*(2/3), 93–111. doi:10.1002/for.848

Cunha, M. P. E. (2004). Time traveling: Organizational foresight as temporal reflexivity. In H. Tsoukas & J. Shepherd (Eds.), *Managing the Future: Foresight in the Knowledge Economy* (pp. 133–149). Oxford: Blackwell Publishing.

Cutcliffe, S. H., & Mitcham, C. (Eds.). (2001). *Visions of STS. Counterpoints in Science, Technology, and Society Studies*. New York: State University of New York Press.

Dator, J. (2019). What Futures Studies Is, and Is Not. In J. Dator (Ed.), *Jim Dator: A Noticer in Time: Selected work, 1967-2018* (pp. 3–5). Cham: Springer.

Davies, S., Macnaghten, P., & Kearnes, M. (2009). *Reconfiguring Responsibility: Lessons for Public Policy (Part 1 of the report on Deepening Debate on Nanotechnology)*. Duhram: Duhram University.

de Jouvenel, B. (1967). *The art of conjecture*. London: Weidenfeld & Nicolson.

Decker, M., Grin, J., Grunwald, A., Mambrey, P., Reuzel, R., Tepper, A., & van der Wilt, G. J. (2000). Outline. In J. Grin & A. Grunwald (Eds.), *Vision Assessment: Shaping Technology in 21st Century Society. Towards a Repertoire for Technology Assessment* (pp. 1–6). Berlin and Heidelberg: Springer.

Decker, M., Weinberger, N., Krings, B.-J., & Hirsch, J. (2017). Imagined technology futures in demand-oriented technology assessment. *Journal of Responsible Innovation, 4*(2), 177–196. doi:10.1080/23299460.2017.1360720

Derbyshire, J. (2017). The siren call of probability: Dangers associated with using probability for consideration of the future. *Futures, 88*, 43–54. doi:10.1016/j.futures.2017.03.011

Derbyshire, J., & Wright, G. (2017). Augmenting the intuitive logics scenario planning method for a more comprehensive analysis of causation. *International Journal of Forecasting, 33*(1), 254–266. doi:10.1016/j.ijforecast.2016.01.004

Dierkes, M., Hoffmann, U., & Marz, L. (1992). *Leitbild und Technik: zur Entstehung und Steuerung technischer Innovationen*. Berlin: Edition Sigma.

Doll, B. B., Duncan, K. D., Simon, D. A., Shohamy, D., & Daw, N. D. (2015). Model-based choices involve prospective neural activity. *Nature Neuroscience, 18*(5), 767–772. doi:10.1038/nn.3981

Doubleday, R. (2007). The Laboratory Revisited: Academic Science and the Responsible Development of Nanotechnology. *NanoEthics, 1*(2), 167–176. doi:10.1007/s11569-007-0017-4

Douglas, C. M. W., & Stemerding, D. (2014). Challenges for the European governance of synthetic biology for human health. *Life Sciences, Society and Policy, 10*(1), 6. doi:10.1186/s40504-014-0006-7

Dufva, M., & Ahlqvist, T. (2015a). Elements in the construction of future-orientation: A systems view of foresight. *Futures, 73*, 112–125. doi:10.1016/j.futures.2015.08.006

Dufva, M., & Ahlqvist, T. (2015b). Knowledge creation dynamics in foresight: A knowledge typology and exploratory method to analyse foresight workshops. *Technological Forecasting and Social Change, 94*, 251–268. doi:10.1016/j.techfore.2014.10.007

Dupuy, J.-P. (2007). Complexity and Uncertainty: A Prudential Approach to Nanotechnology. In F. Allhoff, P. Lin, J. H. Moor, J. Weckert, & M. C. Roco (Eds.), *Nanoethics. The Ethical and Social Implications of Nanotechnology* (pp. 119–132). Hoboken, NJ: Wiley.

Dupuy, J.-P., & Grinbaum, A. (2004). Living with Uncertainty: Toward the Ongoing Normative Assessment of Nanotechnology. *Techné: Research in Philosophy and Technology, 8*(2), 4–25. doi:10.5840/techne2004822

Durant, J. (1999). Participatory technology assessment and the democratic model of the public understanding of science. *Science and Public Policy, 26*(5), 313–319. doi:10.3152/147154399781782329

Ehrlich, M.-F., & Charolles, M. (1991). Aspects of Textual Continuity Psycholinguistic Approaches. In G. E. Stelmach & P. A. Vroon (Eds.), *Advances in Psychology* (Vol. 79, pp. 269–285). Hauppauge, NY: North-Holland.

Eizagirre, A., Rodríguez, H., & Ibarra, A. (2017). Politicizing Responsible Innovation: Responsibility as Inclusive Governance. *International Journal of Innovation Studies, 1*(1), 20–36. doi:10.3724/sp.J.1440.101003

Emirbayer, M., & Mische, A. (1998). What Is Agency? *American Journal of Sociology, 103*(4), 962–1023. doi:10.1086/231294

Enzer, S. (1972). Cross-impact techniques in technology assessment. *Futures, 4*(1), 30–51. doi:10.1016/0016-3287(72)90023-7

Ettlie, J. E., Bridges, W. P., & O'Keefe, R. D. (1984). Organization Strategy and Structural Differences for Radical Versus Incremental Innovation. *Management Science, 30*(6), 682–695. doi:10.1287/mnsc.30.6.682

European Commission. (2002). *Science and Society Action Plan*. Luxembourg: Office for Official Publications of the European Communities.

European Commission. (2004). *Nanotechnologies: A Preliminary Risk Analysis on the Basis of a Workshop Organized in Brussels on 1–2 March 2004 by the Health and Consumer Protection Directorate General of the European Commission*. Luxembourg: Office for Official Publications of the European Communities.

European Commission. (2007). *Work Programme 2007 – Capacities, Part 5: Science in Society, C(2007)563 of 26 February 2007*. Brussels: European Commission.

European Commission. (2009). *Preparing for our future: developing a common strategy for key enabling technologies in the EU, COM(2009) 512 final od 30 September 2009*. Brussels: European Commission.

European Commission. (2010). *Work Programme 2010 – Capacities, Part 5: Science in Society, C(2009)5905 of 29 July 2009*. Retrieved 09/07/2019 from https://ec.europa.eu/research/participants/portal4/doc/call/fp7/fp7-inco-2010-3/12987-u_wp_201001_en.pdf

European Commission. (2013a). Horizon 2020 — Responsible research & innovation. Retrieved 02/04/221 from https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation

European Commission. (2013b). *Horizon 2020, Work Programme 2014–2015: 16. Science with and for Society, C(2013)8631 of 10 December 2013*. Retrieved 13/01/2019 from https://ec.europa.eu/research/participants/portal4/doc/call/h2020/common/1587807-16._swafs_wp2014-2015_en.pdf

European Commission. (2017). *Horizon 2020, Work Programme 2016–2017: 16. Science with and for Society, C(2017)2468 of 24 April 2017*. Retrieved 26/11/2020 from https://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-swfs_en.pdf

European Commission. (2020a). *2020 Strategic Foresight Report – Charting the course towards a more resilient Europe*. Retrieved 04/11/2021 from https://ec.europa.eu/info/sites/default/files/strategic_foresight_report_2020_1.pdf

European Commission. (2020b). *Horizon 2020, Work Programme 2018–2020: 16. Science with and for Society, C(2020)1862 of 25 March 2020*. Retrieved 18/04/2019 from https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-swfs_en.pdf

European Commission. (2022a). Beyond the Horizon: foresight in support of future EU research and innovation policy (BOHEMIA). Retrieved 20/04/2022 from https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/shaping-eu-research-and-innovation-policy/foresight/bohemia_en

European Commission. (2022b). Strategic foresight. Retrieved 20/03/2022 from https://ec.europa.eu/info/strategy/strategic-planning/strategic-foresight_en

European Parliament. (2019). *POSITION OF THE EUROPEAN PARLIAMENT adopted at first reading on 17 April 2019 with a view to the adoption of Decision (EU) …/… of the European Parliament and of the Council on establishing the specific programme implementing Horizon Europe – the Framework Programme for Research and Innovation (EP-PE_TC1-COD(2018)0225)*. Brussels: European Parliament.

European Science Foundation. (2013). *Science in Society: caring for our futures in turbulent times (Science Policy Briefing)*. Strasbourg: European Science Foundation.

Faraj, S., & Azad, B. (2012). The Materiality of Technology: An Affordance Perspective. In P. M. Leonardi, B. A. Nardi, & J. Kallinikos (Eds.), *Materiality and Organizing: Social Interaction in a Technological World* (pp. 237–259). Oxford: Oxford University Press.

Faucheux, S., & Hue, C. (2001). From irreversibility to participation: towards a participatory foresight for the governance of collective environmental risks. *Journal of Hazardous Materials, 86*(1), 223–243. doi:10.1016/S0304-3894(01)00260-6

Feenberg, A. (1991). *Critical Theory of Technology*. New York: Oxford University Press.

Feenberg, A. (1999). *Questioning Technology*. London and New York: Routledge.

Feenberg, A. (2002). *Transforming Technology. A Critical Theory Revisited*. Oxford: Oxford University Press.

Feenberg, A. (2017). Critical theory of technology and STS. *Thesis Eleven, 138*(1), 3–12. doi:10.1177/0725513616689388

Felt, U., Fochler, M., Müller, A., & Strassnig, M. (2009). Unruly ethics: on the difficulties of a bottom-up approach to ethics in the field of genomics. *Public Understanding of Science, 18*(3), 354–371. doi:10.1177/0963662507079902

Felt, U., Wynne, B., Callon, M., Gonçalves, M. E., Jasanoff, S., Jepsen, M., . . . Tallacchini, M. (2007). *Taking European Knowledge Society Seriously. Report of the Expert Group on Science and Governance to the Science, Economy and Society Directorate, Directorate-General for Research, European Commission (EUR 22700)*. Luxembourg: Office for Official Publications of the European Communities.

Fergnani, A. (2019). Mapping futures studies scholarship from 1968 to present: A bibliometric review of thematic clusters, research trends, and research gaps. *Futures, 105*, 104–123. doi:10.1016/j.futures.2018.09.007

Ferrari, A., Coenen, C., & Grunwald, A. (2012). Visions and Ethics in Current Discourse on Human Enhancement. *NanoEthics, 6*(3), 215–229. doi:10.1007/s11569-012-0155-1

Ferrari, A., & Lösch, A. (2017). How Smart Grid Meets In Vitro Meat: on Visions as Socio-Epistemic Practices. *NanoEthics, 11*(1), 75–91. doi:10.1007/s11569-017-0282-9

Fiorino, D. J. (1990). Citizen Participation and Environmental Risk: A Survey of Institutional Mechanisms. *Science, Technology, & Human Values, 15*(2), 226–243. doi:10.1177/016224399001500204

Fischer, N., & Dannenberg, S. (2021). The social construction of futures: Proposing plausibility as a semiotic approach for Critical Futures Studies. *Futures, 129*, 102729. doi:10.1016/j.futures.2021.102729

Fisher, E. (2007). Ethnographic Invention: Probing the Capacity of Laboratory Decisions. *NanoEthics, 1*(2), 155–165. doi:10.1007/s11569-007-0016-5

Fisher, E. (2019). Governing with ambivalence: The tentative origins of socio-technical integration. *Research Policy, 48*(5), 1138–1149. doi:10.1016/j.respol.2019.01.010

Fisher, E., & Mahajan, R. L. (2006). Contradictory intent? US federal legislation on integrating societal concerns into nanotechnology research and development. *Science and Public Policy, 33*(1), 5–16. doi:10.3152/147154306781779181

Fisher, E., Mahajan, R. L., & Mitcham, C. (2006). Midstream Modulation of Technology: Governance From Within. *Bulletin of Science, Technology & Society, 26*(6), 485–496. doi:10.1177/0270467606295402

Flechtheim, O. K. (1970). *Futurologie. Der Kampf um die Zukunft*. Cologne: Verlag Wissenschaft und Politik.

Flyvbjerg, B. (2001). *Making Social Science Matter: Why Social Inquiry Fails and How It Can Succeed Again*. Cambridge: Cambridge University Press.

Foley, R. W., Guston, D. H., & Sarewitz, D. (2018). Towards the anticipatory governance of geoengineering. In J. J. Blackstock & S. Low (Eds.), *Geoengineering our Climate? Ethics, Politics, and Governance* (pp. 223–243). London: Routledge.

Forsberg, E.-M. (2015). ELSA and RRI – Editorial. *Life Sciences, Society and Policy, 11*(1), 2. doi:10.1186/s40504-014-0021-8

Freeman, C. (1982). *The Economics of Industrial Innovation*. London: Frances Printer.

Freeman, C. (1984). Prometheus unbound. *Futures, 16*(5), 494–507. doi:10.1016/0016-3287(84)90080-6

Freeman, C. (1987). *Technology Policy and Economic Performance: Lessons from Japan*. London and New York: Frances Printer.

Freeman, C. (Ed.) (1990). *The Economics of Innovation*. Aldershot: Edward Elgar.

Freeman, C. (1994). The economics of technical change. *Cambridge Journal of Economics, 18*(5), 463–514.

Freeman, C. (1995a). The 'National System of Innovation' in historical perspective. *Cambridge Journal of Economics, 19*(1), 5–24. doi:10.1093/oxfordjournals.cje.a035309

Freeman, C. (1995b). Preface. In A. Rip, T. J. Misa, & J. Schot (Eds.), *Managing Technology in Society. The approach of Constructive Tecghnology Assessment* (pp. viii–ix). London and New York: Pinter Publishers.

Freeman, C., Dosi, G., Nelson, R., Silverberg, G., & Soete, L. (Eds.). (1988). *Japan: a new national system of innovation?* London: Frances Printer.

Freeman, C., & Soete, L. (1997). *The Economics of Industrial Innovation* (Third Edition ed.). Cambridge, MA: The MIT Press.

Fricker, M. (2007). *Epistemic Injustice: Power and the Ethics of Knowing*. New York: Oxford University Press.

Friedman, J. (2019). *Power without Knowledge: A Critique of Technocracy*. New York: Oxford University Press.

Frith, D., & Tapinos, E. (2020). Opening the 'black box' of scenario planning through realist synthesis. *Technological Forecasting and Social Change, 151*, 119801. doi:10.1016/j.techfore.2019.119801

Fuglsang, L. (2001). Three Perspectives in STS in the Policy Context In S. H. Cutcliffe & C. Mitcham (Eds.), *Visions of STS: Counterpoints in Science, Technology, and Society Studies* (pp. 35–49). Albany, NY: State University of New York Press.

Fuller, S. (2009). Review of "Edward J. Hackett; Olga Amsterdamska; Michael Lynch; Judy Wajcman (Editors). The Handbook of Science and Technology Studies. xi + 1,080 pp., illus., indexes. Third edition. Cambridge, Mass./London: MIT Press, 2007. $55 (cloth)". *Isis, 100*(1), 207–209. doi:10.1086/599701

Fuller, S. (2018a). In Praise of Precipitatory Governance as a (Meta-)Principle of Responsible Innovation. *RT. A Journal on Research Policy and Evaluation, 6*(1).

Fuller, S. (2018b). *Post-Truth: Knowledge As A Power Game*. New York: Anthem Press.

Fuller, T. (2017). Anxious relationships: The unmarked futures for post-normal scenarios in anticipatory systems. *Technological Forecasting and Social Change, 124*, 41–50. doi:10.1016/j.techfore.2016.07.045

Fuller, T., & Loogma, K. (2009). Constructing futures: A social constructionist perspective on foresight methodology. *Futures, 41*(2), 71–79. doi:10.1016/j.futures.2008.07.039

Funtowicz, S. O., & Ravetz, J. R. (1990). *Uncertainty and Quality in Science for Policy*. Dordrecht: Kluwer Academic Publishers.

Funtowicz, S. O., & Ravetz, J. R. (1996). Risk management, post-normal science, and extended peer communities. In C. Hood & D. K. C. Jones (Eds.), *Accident and Design–Contemporary Debates in Risk Management* (pp. 172–181). London: UCL Press.

Galison, P., & Hevly, B. W. (1992). *Big Science: The Growth of Large Scale Research*. Stanford, CA: Stanford University Press.

Gavigan, J. P., & Scapolo, F. (1999). A comparison of national foresight exercises. *Foresight, 1*(6), 495–517. doi:10.1108/14636689910802368

Genus, A. (2006). Rethinking constructive technology assessment as democratic, reflective, discourse. *Technological Forecasting and Social Change, 73*(1), 13–26. doi:10.1016/j.techfore.2005.06.009

Genus, A., & Stirling, A. (2018). Collingridge and the dilemma of control: Towards responsible and accountable innovation. *Research Policy, 47*(1), 61–69. doi:10.1016/j.respol.2017.09.012

Gerber, A., Forsberg, E.-M., Shelley-Egan, C., Arias, R., Daimer, S., Dalton, G., . . . Steinhaus, N. (2020). Joint declaration on mainstreaming RRI across Horizon Europe. *Journal of Responsible Innovation, 7*(3), 708–711. doi:10.1080/23299460.2020.1764837

Gerring, J. (1999). What Makes a Concept Good? A Criterial Framework for Understanding Concept Formation in the Social Sciences. *Polity, 31*(3), 357–393. doi:10.2307/3235246

Giaoutzi, M., & Sapio, B. (2013). In Search of Foresight Methodologies: Riddle or Necessity. In M. Giaoutzi & B. Sapio (Eds.), *Recent Developments in Foresight Methodologies* (pp. 3–9). Boston, MA: Springer.

Gidley, J. M. (2017). *The Future. A very Short Introduction*. Oxford: Oxford University Press.

Gieryn, T. F. (1983). Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists. *American Sociological Review, 48*(6), 781–795. doi:10.2307/2095325

Gieryn, T. F. (1999). *Cultural Boundaries of Science: Credibility on the Line*. Chicago and London: University of Chicago Press.

Giraud, P.-N. l., & Godet, M. (1987). *Radioscopie du Japon*. Paris: Press Universitaires de France.

Gjefsen, M. D. (2013). Limits to prediction: Europeanizing technology in an expert forum. *European Journal of Futures Research, 1*(1), 24. doi:10.1007/s40309-013-0024-3

Glenn, J. C., & Gordon, T. J. (2009). *Futures Research Methodology — Version 3.0*. Washington D.C.: The Millennium Project.

Gobierno de España. (2020). *Plan Estatal de Investigación Científca, Técnica y de Innovación 2021-2023*. Madrid: Secretaría General Técnica del Ministerio de Ciencia e Innovación.

Gobierno Vasco. (2014). *Plan de Ciencia, Tecnología e Innovación Euskadi 2020*. Vitoria-Gasteiz: Servicio Central de Publicaciones del Gobierno Vasco.

Gobierno Vasco. (2019). *Plan de Ciencia, Tecnología e Innovación Euskadi 2030*. Vitoria-Gasteiz: Servicio Central de Publicaciones del Gobierno Vasco.

Godet, M. (2012). To Predict or to Build the Future? *The Futurist, 46(3),* 46–49. Retrieved

Godin, B. (2006). The Linear Model of Innovation: The Historical Construction of an Analytical Framework. *Science, Technology, & Human Values, 31*(6), 639–667. doi:10.1177/0162243906291865

Godin, B. (2016). Technological Innovation: On the Origins and Development of an Inclusive Concept. *Technology and Culture, 57*(3), 527–556. doi:10.1353/tech.2016.0070

Godin, B., & Vinck, D. (2017). *Critical Studies of Innovation: Alternative Approaches to the Pro-Innovation Bias*. Cheltenham and Northampton, MA: Edward Elgar.

González Esteban, E. (2019). ¿Qué tipo de reflexividad se necesita para fomentar la anticipación en RRI? Una visión ético-crítica. In H. Rodríguez, S. Urueña, A. Eizagirre, & O. Imaz (Eds.), *Anticipación e innovación responsable. La construcción de futuros alternativos para la ciencia y la tecnología*. Madrid and Barcelona: Biblioteca Nueva.

Government of New Zealand. (2006). *Precautionary Principle: Origins, Definitions, and Interpretations*. Wellington: Treasury Publication.

Granjou, C., Walker, J., & Salazar, J. F. (2017). The politics of anticipation: On knowing and governing environmental futures. *Futures, 92*, 5–11. doi:10.1016/j.futures.2017.05.007

Grin, J., & Grunwald, A. (2000). *Vision Assessment: Shaping Technology in 21st Century Society. Towards a Repertoire for Technology Assessment*. Berlin and Heidelberg: Springer.

Grinbaum, A., & Christopher, G. (2013). What Is "Responsible" about Responsible Innovation? Understanding the Ethical Issues. In R. Owen, J. R. Bessant, & M. Heintz (Eds.), *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society* (pp. 119–142). Chichester: Wiley.

Groves, C. (2013). Horizons of care: from future imaginaries to responsible research and innovation. In K. Konrad, C. Coenen, A. Dijkstra, C. Milburn, & H. van Lente (Eds.), *Shaping Emerging Technologies: Governance, Innovation, Discourse* (pp. 185–202). Amsterdam: IOS Press.

Grunwald, A. (2004). *Vision Assessment as a new element of the Technology Futures Analysis Toolbox.* Paper presented at the New Horizons and Challenges for Future-Oriented Technology Analysis. Proceedings of the EU-US Scientific Seminar. New Technology Foresight, Forecasting & Assessment Methods, JRC-IPTS, Seville (Spain), May 13–14.

Grunwald, A. (2009a). Technology Assessment: Concepts and Methods. In A. Meijers (Ed.), *Philosophy of Technology and Engineering Sciences* (pp. 1103–1146). Amsterdam: North-Holland.

Grunwald, A. (2009b). Vision Assessment Supporting the Governance of Knowledge – the Case of Futuristic Nanotechnology. In G. Bechmann, V. Gorokhov, & N. Stehr (Eds.), *The Social Integration of Science* (pp. 147–170). Baden-Baden: Nomos.

Grunwald, A. (2010). From Speculative Nanoethics to Explorative Philosophy of Nanotechnology. *NanoEthics, 4*(2), 91–101. doi:10.1007/s11569-010-0088-5

Grunwald, A. (2011). Responsible Innovation: Bringing together Technology Assessment, Applied Ethics, and STS research. *Enterprise and Work Innovation Studies, 7*, 9–31.

Grunwald, A. (2013). Modes of orientation provided by futures studies: making sense of diversity and divergence. *European Journal of Futures Research, 2*(1), 30. doi:10.1007/s40309-013-0030-5

Grunwald, A. (2014). The hermeneutic side of responsible research and innovation. *Journal of Responsible Innovation, 1*(3), 274–291. doi:10.1080/23299460.2014.968437

Grunwald, A. (2016). *The Hermeneutic Side of Responsible Research and Innovation*. London and Hoboken, NJ: ISTE and Wiley.

Grunwald, A. (2017). Assigning meaning to NEST by technology futures: extended responsibility of technology assessment in RRI. *Journal of Responsible Innovation, 4*(2), 100–117. doi:10.1080/23299460.2017.1360719

Grunwald, A. (2018). The Spreading of Techno-visionary Futures. In A. Bunde, J. Caro, J. Kärger, & G. Vogl (Eds.), *Diffusive Spreading in Nature, Technology and Society* (pp. 295–309). Cham: Springer.

Grunwald, A. (2019a). El papel de la definición y caracterización tempranas de las nuevas tecnologías en los procesos RRI. In H. Rodríguez, S. Urueña, A. Eizagirre, & O. Imaz (Eds.), *Anticipación e innovación responsable: la construcción de futuros alternativos para la ciencia y la tecnología* (pp. 129–155). Madrid y Barcelona: Biblioteca Nueva.

Grunwald, A. (2019b). The inherently democratic nature of technology assessment. *Science and Public Policy, 46*(5), 702–709. doi:10.1093/scipol/scz023

Grunwald, A. (2020). The objects of technology assessment. Hermeneutic extension of consequentialist reasoning. *Journal of Responsible Innovation, 7*(1), 96–112. doi:10.1080/23299460.2019.1647086

Grupp, H. (1999). National foresight projects. *Technological Forecasting and Social Change, 60*, 1–94.

Gudowsky, N., & Peissl, W. (2016). Human centred science and technology—transdisciplinary foresight and co-creation as tools for active needs-based innovation governance. *European Journal of Futures Research*, *4*(1), 8. doi:10.1007/s40309-016-0090-4

Gudowsky, N., & Sotoudeh, M. (2017). Into Blue Skies—a Transdisciplinary Foresight and Co-creation Method for Adding Robustness to Visioneering. *NanoEthics, 11*(1), 93–106. doi:10.1007/s11569-017-0284-7

Guimarães Pereira, Â., von Schomberg, R., & Funtowicz, S. (2007). Foresight knowledge assessment. *International Journal of Foresight and Innovation Policy, 3*(1), 53–75. doi:10.1504/IJFIP.2007.011421

Gupta, A. (2001). *Searching for Shared Norms: Global Anticipatory Governance of Biotechnology.* (Doctoral Dissertation). Yale University.

Guston, D. H. (2001). Boundary Organizations in Environmental Policy and Science: An Introduction. *Science, Technology, & Human Values, 26*(4), 399–408. doi:10.1177/016224390102600401

Guston, D. H. (2008). Preface. In E. Fisher, C. Selin, & J. M. Wetmore (Eds.), *The Yearbook of Nanotechnology in Society, Volume I: Presenting Futures* (pp. v-viii). Dordrecht: Springer.

Guston, D. H. (2013). "Daddy, Can I Have a Puddle Gator?": Creativity, Anticipation, and Responsible Innovation. In R. Owen, J. R. Bessant, & M. Heintz (Eds.), *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society* (pp. 109–118). Chichester: Wiley.

Guston, D. H. (2014). Understanding 'anticipatory governance'. *Social Studies of Science, 44*(2), 218–242. doi:10.1177/0306312713508669

Guston, D. H., & Sarewitz, D. (2002). Real-time technology assessment. *Technology in Society, 24*(1/2), 93–109. doi:10.1016/s0160-791x(01)00047-1

Habermas, J. (1985). *The Theory of Communicative Action: Volume 1: Reason and the Rationalization of Society*. Boston, MA: Beacon Press.

Hackett, E. J., Amsterdamska, O., Lynch, M., & Wajcman, J. (Eds.). (2008). *The Handbook of Science and Technology Studies, Third Edition*. Cambridge, MA and London: The MIT Press.

Hanseth, O., Monteiro, E., & Hatling, M. (1996). Developing Information Infrastructure: The Tension Between Standardization and Flexibility. *Science, Technology, & Human Values, 21*(4), 407–426. doi:10.1177/016224399602100402

Hanson, V. L. (2011). Envisioning Ethical Nanotechnology: The Rhetorical Role of Visions in Postponing Societal and Ethical Implications Research. *Science as Culture, 20*(1), 1–36. doi:10.1080/09505430903505782

Haraway, D. (2006). A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late 20th Century. In J. Weiss, J. Nolan, J. Hunsinger, & P. Trifonas (Eds.), *The International Handbook of Virtual Learning Environments* (pp. 117–158). Dordrecht: Springer.

Harbers, H. (Ed.) (2005). *Inside the Politics of Technology: Agency and Normativity in the Co-Production of Technology and Society*. Amsterdam: Amsterdam University Press.

Harris, J., & Holm, S. (2002). Extending Human Lifespan and the Precautionary Paradox. *The Journal of Medicine and Philosophy: A Forum for Bioethics and Philosophy of Medicine, 27*(3), 355–368. doi:10.1076/jmep.27.3.355.2983

Hartog, F. (2003). *Régimes d'historicité: présentisme et expériences du temps*. Paris: Éditions du Seuil.

Hellige, H. D. (1996). *Technikleitbilder auf dem Prüfstand : Leitbild-Assessment aus Sicht der Informatik- und Computergeschichte*. Berlin: Edition Sigma.

Hennen, L. (1999). Participatory technology assessment: A response to technical modernity? *Science and Public Policy, 26*(5), 303–312. doi:10.3152/147154399781782310

Hess, D. J., & Sovacool, B. K. (2020). Sociotechnical matters: Reviewing and integrating science and technology studies with energy social science. *Energy Research & Social Science, 65*, 101462. doi:10.1016/j.erss.2020.101462

Hoffmann-Riem, H., & Wynne, B. (2002). In risk assessment, one has to admit ignorance. *Nature, 416*(6877), 123. doi:10.1038/416123a

Holm, S., & Harris, J. (1999). Precautionary principle stifles discovery. *Nature, 400*(6743), 398–398. doi:10.1038/22626

Hölscher, L. (2016). *Die Entdeckung der Zukunft*. Göttingen: Walltein-Verlag.

Hölscher, L. (2018). Future-Thinking. A Historical Perspective. In G. Oettingen, T. A. Sevincer, & P. M. Gollwitzer (Eds.), *The Psychology of Thinking about the Future*. New York and London: The Guildford Press.

Hopkins, R. (2019). *From What Is to What If: Unleashing the Power of Imagination to Create the Future We Want*. London: Chelsea Green Publishing.

Hughes, T. P. (1969). Technological momentum in history: hydrogenation in Germany, 1893–1933. *Past & Present, 44*(1), 106–132. doi:10.1093/past/44.1.106

Hughes, T. P. (1983). *Networks of Power: Electrification in Western Society, 1880–1930*. Baltimore, MD and London: Johns Hopkins University Press.

Hughes, T. P. (1987). The Evolution of Large Technological Systems. In W. E. Bijker, T. P. Hughes, & T. J. Pinch (Eds.), *The Social Construction of Technological Systems. New Directions in the Sociology and History of Technology* (pp. 51–82). Cambridge, MA and London: The MIT Press.

Hughes, T. P. (1994). Technological Momentum. In M. R. Smith & L. Marx (Eds.), *Does Technology Drive History? The Dilemma of Technological Determinism* (pp. 101–103). Cambridge, MA: The MIT Press.

Hullmann, A. (2008). *European activities in the field of ethical, legal and social aspects (ELSA) and governance of nanotechnology*. Retrieved 18/03/2022 from https://www.kowi.de/textonly/Portaldata/2/Resources/fp7/coop/elsa-governance-nano-en.pdf

Inayatullah, S. (1990). Deconstructing and reconstructing the future: Predictive, cultural and critical epistemologies. *Futures, 22*(2), 115–141. doi:10.1016/0016-3287(90)90077-U

Inayatullah, S. (1998). Causal layered analysis: Poststructuralism as method. *Futures, 30*(8), 815–829. doi:10.1016/S0016-3287(98)00086-X

Inayatullah, S. (2006). Anticipatory action learning: Theory and practice. *Futures, 38*(6), 656–666. doi:10.1016/j.futures.2005.10.003

INFU Foresight. (2009). *Innovation Futures in Europe: A Foresight Exercise on emerging Patterns of Innovation*. Retrieved 11/02/2021 from https://cordis.europa.eu/project/id/225229/reporting/fr

Irvine, J., & Martin, B. R. (1984). *Foresight in Science: Picking the Winners*. London: Pinter.

Irvine, J., & Martin, B. R. (1989). *Research Foresight: Priority-setting in Science*. London: Pinter.

Irwin, A. (2008). STS Perspectives on Scientific Governance. In E. J. Hackett, O. Amsterdamska, M. Lynch, & J. Wajcman (Eds.), *The Handbook of Science and Technology Studies, Third Edition* (pp. 583–607). Cambridge, MA and London: The MIT Press.

Irwin, A., Jensen, T. E., & Jones, K. E. (2013). The good, the bad and the perfect: Criticizing engagement practice. *Social Studies of Science, 43*(1), 118–135. doi:10.1177/0306312712462461

Jaeger, M. (2006). A Logic for Inductive Probabilistic Reasoning. In W. van der Hoek (Ed.), *Uncertainty, Rationality, and Agency* (pp. 11–78). Dordrecht: Springer.

Jasanoff, S. (1990). *The Fifth Branch: Science Advisers as Policymakers*. Cambridge, MA and London: Harvard University Press.

Jasanoff, S. (1996). Beyond Epistemology: Relativism and Engagement in the Politics of Science. *Social Studies of Science, 26*(2), 393–418. doi:10.1177/030631296026002008

Jasanoff, S. (2003). Technologies of Humility: Citizen Participation in Governing Science. *Minerva, 41*(3), 223–244. doi:10.1023/a:1025557512320

Jasanoff, S. (2004). *States of Knowledge: The Co-production of Science and the Social Order*. London and New York: Routledge.

Jasanoff, S. (2005). *Designs on Nature: Science and Democracy in Europe and the United States*. Princeton, NJ: Princeton University Press.

Jasanoff, S. (2015). Future Imperfect: Science, Technology, and the Imaginations of Modernity. In S. Jasanoff & S.-H. Kim (Eds.), *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power* (pp. 1–33). Chicago: University of Chicago Press.

Jasanoff, S. (2016). *The Ethics of Invention: Technology and the Human Future*. New York and London: W. W. Norton & Company.

Jasanoff, S. (2020). Imagined worlds: The politics of future-making in the twenty-first century. In A. Wenger, U. Jasper, & M. Dunn Cavelty (Eds.), *The Politics and Science of Prevision: Governing and Probing the Future* (pp. 27–44). London: Routledge.

Jasanoff, S., & Kim, S.-H. (2009). Containing the Atom: Sociotechnical Imaginaries and Nuclear Power in the United States and South Korea. *Minerva, 47*(2), 119–146. doi:10.1007/s11024-009-9124-4

Jasanoff, S., & Kim, S.-H. (2013). Sociotechnical Imaginaries and National Energy Policies. *Science as Culture, 22*(2), 189–196. doi:10.1080/09505431.2013.786990

Jasanoff, S., & Kim, S.-H. (Eds.). (2015). *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*. Chicago: University of Chicago Press.

Johnson, C. (1982). *MITI and the Japanese Miracle: The Growth of Industrial Policy 1925–1975*. Stanford: Stanford University Press.

Johnson, K. A., Dana, G., Jordan, N. R., Draeger, K. J., Kapuscinski, A., Schmitt Olabisi, L. K., & Reich, P. B. (2012). Using Participatory Scenarios to Stimulate Social Learning for Collaborative Sustainable Development. *Ecology and Society, 17*(2). doi:10.5751/ES-04780-170209

Josephson, J. R., & Josephson, S. G. (Eds.). (1996). *Abductive Inference: Computation, Philosophy, Technology*. Cambridge: Cambridge University Press.

Joss, S. (2002). Toward the Public Sphere—Reflections on the Development of Participatory Technology Assessment. *Bulletin of Science, Technology & Society, 22*(3), 220–231. doi:10.1177/02767602022003006

Joss, S., & Bellucci, S. (Eds.). (2002). *Participatory Technology Assessment: European Perspectives*. London: Center for the Study of Democracy.

Joy, B. (2000, 04/01/2000). Why the Future Doesn't Need Us. *Wired, 8(4)*, 238–262.

Kaplan, L. R., Farooque, M., Sarewitz, D., & Tomblin, D. (2021). Designing Participatory Technology Assessments: A Reflexive Method for Advancing the Public Role in Science Policy Decision-making. *Technological Forecasting and Social Change, 171*, 120974. doi:10.1016/j.techfore.2021.120974

Karinen, R., & Guston, D. H. (2009). Toward Anticipatory Governance: The Experience with Nanotechnology. In M. Kaiser, M. Kurath, S. Maasen, & C. Rehmann-Sutter (Eds.), *Governing Future Technologies: Nanotechnology and the Rise of an Assessment Regime* (pp. 217–232). Dordrecht: Springer.

Karlsen, J. E., & Karlsen, H. (2013). Classification of Tools and Approaches Applicable in Foresight Studies. In M. Giaoutzi & B. Sapio (Eds.), *Recent Developments in Foresight Methodologies* (pp. 27–52). Boston, MA: Springer.

Kera, D. R. (2020). Anticipatory Policy as a Design Challenge: Experiments with Stakeholders Engagement in Blockchain and Distributed Ledger Technologies (BDLTs). In J. Prieto, A. K. Das, S. Ferretti, A. Pinto, & J. M. Corchado (Eds.), *Blockchain and Applications. BLOCKCHAIN 2019. Advances in Intelligent Systems and Computing* (pp. 87–92). Cham: Springer.

Kinsner-Ovaskainen, A., Ponti, J., Norlén, H., Altmeyer, S., Andreoli, C., Bogni, A., . . . Eom, I. (2014). *Interlaboratory comparison study of the Colony Forming Efficiency assay for assessing cytotoxicity of nanomaterials (Report EUR 27009 EN)*. Luxembourg: Office for Official Publications of the European Communities.

Klaassen, P., Rijnen, M., Vermeulen, S., Kupper, F., & Broerse, J. (2019). Technocracy versus experimental learning in RRI: On making the most of RRI's interpretative flexibility. In R. Gianni, J. Pearson, & B. Reber (Eds.), *Responsible Research and Innovation: From Concepts to Practices* (pp. 77–98). New York: Routledge.

Klein, G., Swoden, D., & Pin, C. L. (2010). Anticipatory Thinking. In L. M. Kathleen & U. M. Fischer (Eds.), *Informed by Knowledge: Expert Performance in Complex Situations* (pp. 235–245). New York: Psychology Press.

Kline, S. J., & Rosenberg, N. (1986). An Overview of Innovation. In N. Rosenberg & R. Landau (Eds.), *The Positive Sum Strategy: Harnessing Technology for Economic Growth* (pp. 275–305). Washington D.C.: National Academy Pres.

Könnölä, T., Brummer, V., & Salo, A. (2007). Diversity in foresight: Insights from the fostering of innovation ideas. *Technological Forecasting and Social Change, 74*(5), 608–626. doi:10.1016/j.techfore.2006.11.003

Konrad, K. (2006). The social dynamics of expectations: The interaction of collective and actor-specific expectations on electronic commerce and interactive television. *Technology Analysis & Strategic Management, 18*(3/4), 429–444. doi:10.1080/09537320600777192

Konrad, K., & Alvial Palavicino, C. (2017). Evolving Patterns of Governance of, and by, Expectations: The Graphene Hype Wave. In D. M. Bowman, E. Stokes, & A. Rip (Eds.), *Embedding New Technologies into Society: A Regulatory, Ethical and Societal Perspective* (pp. 187–218). Singapore: Pan Stanford Publishing.

Konrad, K., & Böhle, K. (2019). Socio-technical futures and the governance of innovation processes—An introduction to the special issue. *Futures, 109*, 101–107. doi:10.1016/j.futures.2019.03.003

Konrad, K., van Lente, H., Groves, C., & Selin, C. (2016). Performing and Governing the Future in Science and Technology. In U. Felt, R. Fouche, C. A. Miller, & L. Smith-Doerrv (Eds.), *The Handbook of Science and Technology Studies, Fourth Edition* (pp. 465–493). Cambridge, MA: The MIT Press.

Konrad, S., van Deursen, M., & Gupta, A. (2021). Capacity building for climate transparency: neutral 'means of implementation' or generating political effects? *Climate Policy*, 1–19. doi:10.1080/14693062.2021.1986364

Koselleck, R. (2004). *Futures Past: On the Semantics of Historical Time*. New York: Columbia University Press.

Krishnan, A. (2009). What Are Academic Disciplines? Some Observations on the Disciplinarity vs. Interdisciplinarity Debate. *NCRM Working Paper. National Centre for Research Methods*. Retrieved 03/04/2021 from https://eprints.ncrm.ac.uk/id/eprint/783/

Kudina, O. (2019). *The technological mediation of morality: value dynamism, and the complex interaction between ethics and technology.* (Doctoral Dissertation). University of Twente.

Kuhlmann, S., & Rip, A. (2018). Next-Generation Innovation Policy and Grand Challenges. *Science and Public Policy, 45*(4), 448–454. doi:10.1093/scipol/scy011

Kuhlmann, S., Stegmaier, P., & Konrad, K. (2019). The tentative governance of emerging science and technology—A conceptual introduction. *Research Policy, 48*(5), 1091–1097. doi:10.1016/j.respol.2019.01.006

Latour, B. (1987). *Science in Action: How to Follow Scientists and Engineers Through Society*. Cambridge, MA: Harvard University Press.

Latour, B. (1992). Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts. In W. E. Bijker & J. Law (Eds.), *Shaping Technology / Building Society. Studies in Sociotechnical Change* (pp. 225–258). Cambridge, MA and London: The MIT Press.

Latour, B. (1993). *We Have Never Been Modern*. Cambridge, MA: Harvard University Press.

Latour, B. (2005). *Reassembling the Social: An Introduction to Actor-Network Theory*. Oxford: Oxford University Press.

Law, J. (2008). STS as Method. In E. J. Hackett, O. Amsterdamska, M. Lynch, & J. Wajcman (Eds.), *The Handbook of Science and Technology Studies, Third Edition* (pp. 31–57). Cambridge, MA, London: The MIT Press.

Lehoux, P., Miller, F. A., & Williams-Jones, B. (2020). Anticipatory governance and moral imagination: Methodological insights from a scenario-based public deliberation study. *Technological Forecasting and Social Change, 151*, 119800. doi:10.1016/j.techfore.2019.119800

Lenoir, T. (1997). *Instituting Science: The Cultural Production of Scientific Disciplines*. Stanford, CA: Stanford University Press.

Lenz, R. C. (1962). *Technological forecasting, report ASD-TDR-62-414*. Wright-Patterson Air Force Base: US Air Force.

Linker, M. (2014). Epistemic Privilege and Expertise in the Context of Meta-debate. *Argumentation, 28*(1), 67–84. doi:10.1007/s10503-013-9299-6

Lombardi, D., Nussbaum, E. M., & Sinatra, G. M. (2016). Plausibility Judgments in Conceptual Change and Epistemic Cognition. *Educational Psychologist, 51*(1), 35–56. doi:10.1080/00461520.2015.1113134

López, J. J., & Lunau, J. (2012). ELSIfication in Canada: Legal Modes of Reasoning. *Science as Culture, 21*(1), 77–99. doi:10.1080/09505431.2011.576240

Lösch, A. (2006). Anticipating the futures of nanotechnology: Visionary images as means of communication. *Technology Analysis & Strategic Management, 18*(3/4), 393–409. doi:10.1080/09537320600777168

Lösch, A., Böhle, K., Coenen, C., Dobroc, P., Heil, R., Grunwald, A., . . . Wentland, A. (2019). Technology Assessment of Socio-Technical Futures—A Discussion Paper. In A. Lösch, A. Grunwald, M. Meister, & I. Schulz-Schaeffer (Eds.), *Socio-Technical Futures Shaping the Present: Empirical Examples and Analytical Challenges* (pp. 285–308). Wiesbaden: Springer VS.

Lösch, A., Grunwald, A., Meister, M., & Schulz-Schaeffer, I. (Eds.). (2019). *Socio-Technical Futures Shaping the Present: Empirical Examples and Analytical Challenges*. Wiesbaden: Springer VS.

Lösch, A., Heil, R., & Schneider, C. (2017). Responsibilization through visions. *Journal of Responsible Innovation, 4*(2), 138–156. doi:10.1080/23299460.2017.1360717

Low, S. (2017). Engineering imaginaries: Anticipatory foresight for solar radiation management governance. *Science of The Total Environment, 580*, 90–104. doi:10.1016/j.scitotenv.2016.07.200

Lucivero, F. (2016a). Promises, Expectations and Visions: On Appraising the Plausibility of Socio-Technical Futures. In *Ethical Assessments of Emerging Technologies: Appraising the moral plausibility of technological visions* (pp. 37–61). Cham: Springer.

Lucivero, F. (2016b). Scenarios as "Grounded Explorations". Designing Tools for Discussing the Desirability of Emerging Technologies. In *Ethical Assessments of Emerging Technologies: Appraising the moral plausibility of technological visions* (pp. 155–190). Cham: Springer.

Lucivero, F., Swierstra, T., & Boenink, M. (2011). Assessing Expectations: Towards a Toolbox for an Ethics of Emerging Technologies. *NanoEthics, 5*(2), 129–141. doi:10.1007/s11569-011-0119-x

Lund Declaration. (2009). Europe Must Focus on the Grand Challenges of our Time. In U. Svedin (Ed.), *New Worlds – New Solutions. Research and Innovation as a Basis for Developing Europe in a Global Context (The Swedish EU Presidency Conference – Final report)* (pp. 40–41). Lund.

Macnaghten, P. (2017). Focus Groups as Anticipatory Methodology: A Contribution from Science and Technology Studies Towards Socially Resilient Governance. In R. S. Barbour & D. L. Morgan (Eds.), *A New Era in Focus Group Research: Challenges, Innovation and Practice* (pp. 343–363). London: Palgrave Macmillan.

Macnaghten, P. (2021). Towards an anticipatory public engagement methodology: deliberative experiments in the assembly of possible worlds using focus groups. *Qualitative Research, 21*(1), 3–19. doi:10.1177/1468794120919096

Makridakis, S., Wheelwright, S. C., & Hyndman, R. J. (2008). *Forecasting: Methods and Applications, 3rd Edition*. New Delhi: Wiley.

Mallard, G., & Lakoff, A. (2011). How Claims to Know the Future are Used to Understand the Present. Techniques of Prospection in the Field of National Security. In M. Lamont, N. Gross, & C. Camic (Eds.), *Social Knowledge in the Making* (pp. 339–377). Chicago and London: University of Chicago Press.

Mann, C. (2015). Strategies for sustainable policy design: Constructive assessment of biodiversity offsets and banking. *Ecosystem Services, 16*, 266–274. doi:10.1016/j.ecoser.2015.07.001

Marien, M. (2002). Futures studies in the 21st Century: a reality-based view. *Futures, 34*(3), 261–281. doi:10.1016/S0016-3287(01)00043-X

Martin, B. R. (1994). *Report of the ad hoc .Weeting oj Experts on Gort'mmeni fivesight Exercises, 14 September 1994 (DSTI/STP/TIP(94)17, 1994)*. Paris: OECD.

Martin, B. R. (1995). Foresight in science and technology. *Technology Analysis & Strategic Management, 7*(2), 139–168. doi:10.1080/09537329508524202

Martin, B. R. (2010). The origins of the concept of 'foresight' in science and technology: An insider's perspective. *Technological Forecasting and Social Change, 77*(9), 1438–1447. doi:10.1016/j.techfore.2010.06.009

Martin, B. R., & Johnston, R. (1999). Technology Foresight for Wiring Up the National Innovation System: Experiences in Britain, Australia, and New Zealand. *Technological Forecasting and Social Change, 60*(1), 37–54. doi:10.1016/S0040-1625(98)00022-5

Masini, E. (2006). Rethinking futures studies. *Futures, 38*(10), 1158–1168. doi:10.1016/j.futures.2006.02.004

McNeil, M., Arribas-Ayllon, M., Haran, J., Mackenzie, A., & Tutton, R. (2017). Conceptualizing Imaginaries of Science, Technology, and Society. In U. Felt, R. Fouché, C. A. Miller, & L. Smith-Doerr (Eds.), *The Handbook of Science and Technology Studies, Fourth Edition* (pp. 435–463). Cambridge, MA and London: The MIT Press.

Meador, M. A., Files, B., Li, J., Manohara, H., Powell, D., & Siochi, E. J. (2010). *DRAFT Nanotechnology Roadmap Technology Area 10*. Washington, D.C.: National Academies Press.

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W. (1972). *The Limits to Growth. A Report for the Club of Rome's Project on the Predicament of Mankind*. New York: Universe Books.

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W. (1973). A response to Sussex. *Futures, 5*(1), 135–152. doi:10.1016/0016-3287(73)90062-1

Meijer, A., & Wessels, M. (2019). Predictive Policing: Review of Benefits and Drawbacks. *International Journal of Public Administration, 42*(12), 1031–1039. doi:10.1080/01900692.2019.1575664

Michael, M. (2000). Futures of the Present: From Performativity to Prehension. In N. Brown, B. Rappert, & A. Webster (Eds.), *Contested Futures: A Sociology of Prospective Techno-Science* (pp. 21–39). Aldershot and Burlington, VT: Ashgate.

Michael, M. (2017). Enacting Big Futures, Little Futures: Toward an ecology of futures. *The Sociological Review, 65*(3), 509–524. doi:10.1111/1467-954X.12444

Michelson, E. S. (2013). 'Getting there early': strategies for seeking policy influence and anticipating nanotechnology's alternative futures. *International Journal of Foresight and Innovation Policy, 9*(2/3/4), 188–212. doi:10.1504/IJFIP.2013.058609

Mietzner, D., & Reger, G. (2005). Advantages and disadvantages of scenario approaches for strategic foresight. *International Journal of Technology Intelligence and Planning, 1*(2), 220–239. doi:10.1504/IJTIP.2005.006516

Miles, I. (1975). *The poverty of prediction*. Farnborough: Saxon House.

Miles, I. (2008). From Futures to Foresight. In L. Georghiou, J. C. Harper, M. Keenan, I. Miles, & R. Popper (Eds.), *The Handbook of Technology Foresight. Concepts and Practice* (pp. 24–43). Cheltenham: Edward Elgar.

Miles, I., Saritas, O., & Sokolov, A. (2016). *Foresight for Science, Technology and Innovation*. Cham: Springer.

Miller, C. A., & Bennett, I. (2008). Thinking longer term about technology: is there value in science fiction-inspired approaches to constructing futures? *Science and Public Policy, 35*(8), 597–606. doi:10.3152/030234208x370666

Miller, R. (2015). Learning, the Future, and Complexity. An Essay on the Emergence of Futures Literacy. *European Journal of Education, 50*(4), 513–523. doi:10.1111/ejed.12157

Miller, R. (Ed.) (2018). *Transforming the Future: Anticipation in the 21st Century*. Paris and New York: Routledge.

Miller, R., & Poli, R. (2010). Anticipatory systems and the philosophical foundations of futures studies. *Foresight, 12*(3). doi:10.1108/fs.2010.27312caa.001

Miller, R., Poli, R., & Rossel, P. (2013). *The Discipline of Anticipation: Exploring Key Issues. Global/Local Anticipatory Capacities Working Paper #1*. Paris: UNESCO/The Rockefeller Foundation.

Miller, R., Poli, R., & Rossel, P. (2018). The Discipline of Anticipation: Foundations for Futures Literacy. In R. Miller (Ed.), *Transforming the Future: Anticipation in the 21st Century* (pp. 51–65). Paris and New York: UNESCO and Routledge.

Miller, R., & Sandford, R. (2019). Futures Literacy: The Capacity to Diversify Conscious Human Anticipation. In R. Poli (Ed.), *Handbook of Anticipation: Theoretical and Applied Aspects of the Use of Future in Decision Making* (pp. 73–91). Cham: Springer.

Millett, S. M. (2003). The future of scenarios: challenges and opportunities. *Strategy & Leadership, 31*(2), 16–24. doi:10.1108/10878570310698089

Milojević, I., & Inayatullah, S. (2015). Narrative foresight. *Futures, 73*, 151–162. doi:10.1016/j.futures.2015.08.007

Minkkinen, M., Auffermann, B., & Ahokas, I. (2019). Six foresight frames: Classifying policy foresight processes in foresight systems according to perceived unpredictability and pursued change. *Technological Forecasting and Social Change, 149*, 119753. doi:10.1016/j.techfore.2019.119753

Misa, T. J. (1992). Controversy and Closure in Technological Change: Constructing "Steel". In W. E. Bijker & J. Law (Eds.), *Shaping Technology / Building Society: Studies in Sociotechnical Change* (pp. 109–139). Cambridge, MA and London: The MIT Press.

Misa, T. J. (1994). Retrieving Sociotechnical Change from Technological Determinism. In M. R. Smith & L. Marx (Eds.), *Does Technology Drive History? The Dilemma of Technological Determinism* (pp. 115–141). Cambridge, MA: The MIT Press.

Mische, A. (2009). Projects and Possibilities: Researching Futures in Action. *Sociological Forum, 24*(3), 694–704. doi:10.1111/j.1573-7861.2009.01127.x

Mische, A. (2014). Measuring futures in action: projective grammars in the Rio + 20 debates. *Theory and Society, 43*(3), 437–464. doi:10.1007/s11186-014-9226-3

Mitcham, C. (1997). Justifying public participation in technical decision making. *IEEE Technology and Society Magazine, 16*(1), 40–46. doi:10.1109/44.584650

Mitcham, C., & Muñoz, D. (2010). Humanitarian Engineering. *Synthesis Lectures on Engineers, Technology, and Society, 5*(1), 1–87.

Mittelstadt, B. D., Stahl, B. C., & Fairweather, N. B. (2015). How to Shape a Better Future? Epistemic Difficulties for Ethical Assessment and Anticipatory Governance of Emerging Technologies. *Ethical Theory and Moral Practice, 18*(5), 1027–1047. doi:10.1007/s10677-015-9582-8

Mody, C. C. M. (2004). Small, but Determined: Technological Determinism in Nanoscience. *HYLE – International Journal for Philosophy of Chemistry, 10*(2), 99–128.

Moniz, A. B. (2006). Scenario-Building Methods as a Tool for Policy Analysis. In B. Rihoux & H. Grimm (Eds.), *Innovative Comparative Methods for Policy Analysis: Beyond the Quantitative-Qualitative Divide* (pp. 185–209). Boston, MA: Springer.

Moss, T. (2009). Intermediaries and the Governance of Sociotechnical Networks in Transition. *Environment and Planning A: Economy and Space, 41*(6), 1480–1495. doi:10.1068/a4116

Muiderman, K., Gupta, A., Vervoort, J., & Biermann, F. (2020). Four approaches to anticipatory climate governance: Different conceptions of the future and implications for the present. *WIREs Climate Change, 11*(6), e673. doi:10.1002/wcc.673

Nadin, M. (2016). *Anticipation Across Disciplines*. Cham: Springer.

Nagy, D., Schuessler, J., & Dubinsky, A. (2016). Defining and identifying disruptive innovations. *Industrial Marketing Management, 57*, 119–126. doi:10.1016/j.indmarman.2015.11.017

Nanologue. (2006). *Europe-wide dialogue on social, ethical and legal impacts of nanotechnology*. Retrieved 10/03/2018 from http://www.nanologue.net

National Science and Technology Council. (2004). *National Nanotechnology Initiative Strategic Plan*. Washington D.C.: National Science and Technology Council Committee on Technology. Subcommittee on Nanoscale Science, Engineering, and Technology.

Nazarko, Ł. (2017). Future-Oriented Technology Assessment. *Procedia Engineering, 182*, 504–509. doi:10.1016/j.proeng.2017.03.144

Nelson, J. P., Selin, C., Lambert, L., & Guston, D. H. (2022). Amplifying the Call for Anticipatory Governance. *The American Journal of Bioethics, 22*(1), 48–50. doi:10.1080/15265161.2021.2001109

New Zealand Ministry of Research Science and Technology. (2006). *nanoscience + nanotechnologies*. Wellington: Ministry of Research, Science, and Technology.

Nielsen, M. V. (2014). *Horizontal Foresight to Address Societal Challenges in Danish Priority-Setting for Strategic Research*. Retrieved 26/09/2019 from http://res-agora.eu/assets/TEKNO-1-Stage-2.pdf

Nielsen, M. V. (2016). The concept of responsiveness in the governance of research and innovation. *Science and Public Policy, 43*(6), 831–839. doi:10.1093/scipol/scv078

Nikolova, B. (2013). The rise and promise of participatory foresight. *European Journal of Futures Research, 2*(1), 33. doi:10.1007/s40309-013-0033-2

Nordmann, A. (2007). If and Then: A Critique of Speculative NanoEthics. *NanoEthics, 1*(1), 31–46. doi:10.1007/s11569-007-0007-6

Nordmann, A. (2010). A forensics of wishing: technology assessment in the age of technoscience. *Poiesis & Praxis, 7*(1/2), 5–15. doi:10.1007/s10202-010-0081-7

Nordmann, A. (2013a). (Im)Plausibility². *International Journal of Foresight and Innovation Policy, 9*(2/3/4), 125–132. doi:10.1504/ijfip.2013.058612

Nordmann, A. (2013b). Visioneering Assessment. On the Construction of Tunnel Visions for Technovisionary Research and Policy. *Science, Technology & Innovation Studies, 9*(2), 89–94.

Nordmann, A. (2014). Responsible innovation, the art and craft of anticipation. *Journal of Responsible Innovation, 1*(1), 87–98. doi:10.1080/23299460.2014.882064

Nordmann, A., & Rip, A. (2009). Mind the gap revisited. *Nature Nanotechnology, 4*(5), 273–274. doi:10.1038/nnano.2009.26

Norman, D. (2013). *The Design of Everyday Things*. New York: Basic Books.

Novoplansky, A. (2016). Future Perception in Plants. In M. Nadin (Ed.), *Anticipation Across Disciplines* (pp. 57–70). Cham: Springer.

Nowotny, H., Scott, P. B., & Gibbons, M. T. (2001). *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty*. Cambridge: Polity Press.

NUCLEUS, RESPONSIBLE RESEARCH AND INNOVATION IN PRACTICE, PRO|SO, NEW HORRIZON, SUPER MoRRI, GRECO, . . . TeRRIFICA. (2019). *The Future of Responsible Research and Innovation (RRI) in "Horizon Europe", June 2019*. Retrieved 05/02/2022 from http://pathways2019.eu/wp-content/uploads/2019/07/RRI_Declaration.pdf

Nye, D. E. (2006). *Technology Matters: Questions to Live With*. Cambridge, MA and London: The MIT Press.

Oettingen, G., Sevincer, T. A., & Gollwitzer, P. M. (2018). *The Psychology of Thinking about the Future*. New York and London: The Guildford Press.

Oficina Nacional de Prospectiva y Estrategia del Gobierno de España. (2021). *España 2050: Fundamentos y propuestas para una Estrategia Nacional de Largo Plazo*. Madrid: Ministerio de la Presidencia.

Ogden, C. K., & Richards, I. A. (1923). *The Meaning of Meaning: A Study of the Influence of Language upon Thought and of the Science of Symbolism*. London and New York: Harcourt, Brace & Company, Inc.

Ogle, V. (2019). Time, Temporality and the History of Capitalism. *Past & Present, 243*(1), 312–327. doi:10.1093/pastj/gtz014

Owen, R., Macnaghten, P., & Stilgoe, J. (2012). Responsible research and innovation: From science in society to science for society, with society. *Science and Public Policy, 39*(6), 751–760. doi:10.1093/scipol/scs093

Owen, R., & Pansera, M. (2019). Responsible Innovation and Responsible Research and Innovation. In D. Simon, S. Kuhlmann, J. Stamm, & W. Canzler (Eds.), *Handbook on Science and Public Policy* (pp. 26–48). Cheltenham and Northampton, MA: Edward Elgar.

Owen, R., Stilgoe, J., Macnaghten, P., Gorman, M., Fisher, E., & Guston, D. H. (2013). A Framework for Responsible Innovation. In R. Owen, J. R. Bessant, & M. Heintz (Eds.), *Responsible Innovation* (pp. 27–50). Chichester: Wiley.

Pansera, M., & Fressoli, M. (2021). Innovation without growth: Frameworks for understanding technological change in a post-growth era. *Organization, 28*(3), 380–404. doi:10.1177/1350508420973631

Pansera, M., & Owen, R. (2018). Innovation for de-growth: A case study of counter-hegemonic practices from Kerala, India. *Journal of Cleaner Production, 197*, 1872–1883. doi:10.1016/j.jclepro.2016.06.197

Pansera, M., & Owen, R. (2020). Multiplicidad interpretativa en las prácticas de investigación e innovación responsables en 12 países: análisis y resultados. *Caleidoscopio – Revista Semestral de Ciencias Sociales y Humanidades, 24*(43). doi:10.33064/42crscsh1980

Parandian, A. (2012). *Constructive TA of Newly Emerging Technologies Stimulating learning by anticipation through bridging events*. (Doctoral Dissertation). Technical University Delft.

Parandian, A., Rip, A., & Te Kulve, H. (2012). Dual dynamics of promises, and waiting games around emerging nanotechnologies. *Technology Analysis & Strategic Management, 24*(6), 565–582. doi:10.1080/09537325.2012.693668

Parvin, N., & Pollock, A. (2020). Unintended by Design: On the Political Uses of "Unintended Consequences". *Engaging Science, Technology, and Society, 6*, 320–327. doi:10.17351/ests2020.497

Passell, P., Roberts, M., & Ross, L. (1972, 02/04/1972). The Limits to Growth. *The New York Times*. Retrieved 10/04/2018 from https://www.nytimes.com/1972/04/02/archives/the-limits-to-growth-a-report-for-the-club-of-romes-project-on-the.html

Pellé, S. (2016). Process, outcomes, virtues: the normative strategies of responsible research and innovation and the challenge of moral pluralism. *Journal of Responsible Innovation, 3*(3), 233–254. doi:10.1080/23299460.2016.1258945

Pfotenhauer, S. M., & Juhl, J. (2017). Innovation and the Political State: Beyond the Myth of Technologies and Markets. In B. Godin & D. Vinck (Eds.), *Critical Studies of Innovation: Alternative Approaches to the Pro-Innovation Bias* (pp. 68–94). Cheltenham: Edward Elgar.

Pinch, T. J., & Bijker, W. E. (1984). The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other. *Social Studies of Science, 14*(3), 399–441. doi:10.1177/030631284014003004

Poli, R. (2010). The many aspects of anticipation. *Foresight, 12*(3), 7–17. doi:10.1108/14636681011049839

Poli, R. (2011). Steps Toward an Explicit Ontology of the Future. *Journal of Futures Studies, 16*(1), 67–78.

Poli, R. (2014). Anticipation: What about turning the human and social sciences upside down? *Futures, 64*, 15–18. doi:10.1016/j.futures.2014.10.003

Poli, R. (2015). The implicit future orientation of the capability approach. *Futures, 71*, 105–113. doi:10.1016/j.futures.2015.03.002

Poli, R. (2016). Belief Systems and the Modeling Relation. *Foundations of Science, 21*(1), 195–206. doi:10.1007/s10699-015-9413-3

Poli, R. (2017). *Introduction to Anticipation Studies* (Vol. 1). Cham: Springer.

Poli, R. (2018). A note on the classification of future-related methods. *European Journal of Futures Research, 6*(1), 15. doi:10.1186/s40309-018-0145-9

Poli, R. (2019a). *Handbook of Anticipation. Theoretical and Applied Aspects of the Use of the Future in Decision Making*. Cham: Springer.

Poli, R. (2019b). *Working with the Future: Ideas and Tools to Govern Uncertainty*. Milano: Bocconi University Press.

Poli, R. (2021). The challenges of futures literacy. *Futures, 132*, 102800. doi:10.1016/j.futures.2021.102800

Poli, R., & Valerio, M. (Eds.). (2019). *Anticipation, Agency and Complexity*. Cham: Springer.

Pollock, N., & Williams, R. (2010). The business of expectations: How promissory organizations shape technology and innovation. *Social Studies of Science, 40*(4), 525–548. doi:10.1177/0306312710362275

Popper, R. (2008). Foresight Methodology. In L. Georghiou, J. Cassingena Harper, M. Keenan, I. Miles, & R. Popper (Eds.), *The handbook of technology foresight: Concepts and practice* (pp. 44–88). Cheltenham and Northampton, MA: Edward Elgar.

Ported, A. L. (1995). Technology Assessment. *Impact Assessment, 13*(2), 135–151. doi:10.1080/07349165.1995.9726087

Porter, A. L. (2010). Technology foresight: types and methods. *International Journal of Foresight and Innovation Policy, 6*(1/2/3), 36–45. doi:10.1504/IJFIP.2010.032664

Povlock, P. A. (2016). *Environmental Ethics and The Electric Power Grid: A Case for Technological Momentum.* (Doctoral Dissertation). Salve Regina University.

Rabitz, F. (2016). Going rogue? Scenarios for unilateral geoengineering. *Futures, 84*, 98–107. doi:10.1016/j.futures.2016.11.001

Racine, E., Martin Rubio, T., Chandler, J., Forlini, C., & Lucke, J. (2014). The value and pitfalls of speculation about science and technology in bioethics: the case of cognitive enhancement. *Med Health Care Philos, 17*(3), 325–237. doi:10.1007/s11019-013-9539-4

Ramírez, R., & Ravetz, J. (2011). Feral futures: Zen and aesthetics. *Futures, 43*(4), 478–487. doi:10.1016/j.futures.2010.12.005

Ramírez, R., & Selin, C. (2014). Plausibility and probability in scenario planning. *Foresight, 16*(1), 54–74. doi:10.1108/FS-08-2012-0061

Ramos, J. M. (2006). Dimensions in the confluence of futures studies and action research. *Futures, 38*(6), 642–655. doi:10.1016/j.futures.2005.10.008

Reijers, W., Wright, D., Brey, P., Weber, K., Rodrigues, R., O'Sullivan, D., & Gordijn, B. (2018). Methods for Practising Ethics in Research and Innovation: A Literature Review, Critical Analysis and Recommendations. *Science and Engineering Ethics, 24*(5), 1437–1481. doi:10.1007/s11948-017-9961-8

Remmenn, A. (1995). Pollution Prevention, Cleaner Technologies and Industry. In A. Rip, T. J. Misa, & J. Schot (Eds.), *Managing Technology in Society. The approach of Constructive Tecghnology Assessment* (pp. 199–223). London and New York: Pinter Publishers.

Repo, P., & Matschoss, K. (2019). Considering expert takeovers in citizen involvement processes. *Journal of Responsible Innovation, 6*(2), 119–142. doi:10.1080/23299460.2019.1568145

Rescher, N. (1976). *Plausible Reasoning: An Introduction to the Theory and Practice of Plausibilistic Inference*. Assen: Van Gorcum.

Reyns, B. W., Burek, M. W., Henson, B., & Fisher, B. S. (2013). The unintended consequences of digital technology: Exploring the relationship between sexting and cybervictimization. *Journal of Crime and Justice, 36*(1), 1–17.

Rhisiart, M., Miller, R., & Brooks, S. (2015). Learning to use the future: developing foresight capabilities through scenario processes. *Technological Forecasting and Social Change, 101*, 124–133. doi:10.1016/j.techfore.2014.10.015

Rip, A. (2005a). *There Is Mainstreaming, Loss of Critical Distance: Are STS Scholars Finally Growing Up?* Paper presented at the Does STS Mean Business Too?, Said Business School, Oxford.

Rip, A. (2005b). Verschuivingen in het sociaal contract: wetenschappelijke en technologische ontwikkelingen in nieuwe maatschappelijke kaders. In W. H. M. Zijm, A. Rip, H. H. F. Wijffels, H. A. Harwigm, D. N. Reinhoudt, & W. A. Smit (Eds.), *Innovatie en Maatschappelijke Ontwikkeling: Omgaan met een Haat-Liefdeverhouding* (pp. 15–24). The Hague: MSO.

Rip, A. (2006). Folk Theories of Nanotechnologists. *Science as Culture, 15*(4), 349–365. doi:10.1080/09505430601022676

Rip, A. (2016). The clothes of the emperor. An essay on RRI in and around Brussels. *Journal of Responsible Innovation, 3*(3), 290–304. doi:10.1080/23299460.2016.1255701

Rip, A. (2018). *Futures of Science and Technology in Society*. Wiesbaden: Springer VS.

Rip, A., & Kemp, R. (1998). Technological Change. In S. Rayner & E. L. Malone (Eds.), *Human Choice and Climate Change, Volume 2: Resources and Technology* (pp. 327–399). Columbus, OH: Battelle Press.

Rip, A., Misa, T. J., & Schot, J. (Eds.). (1995). *Managing technology in society: the approach of constructive technology assessment*. London and New York: Pinter Publishers.

Rip, A., & Robinson, D. K. R. (2013). Constructive Technology Assessment and the Methodology of Insertion. In N. Doorn, D. Schuurbiers, I. van de Poel, & M. E. Gorman (Eds.), *Early engagement and new technologies: Opening up the laboratory* (pp. 37–53). Dordrecht: Springer.

Rip, A., & te Kulve, H. (2008). Constructive Technology Assessment and Socio-Technical Scenarios. In E. Fisher, C. Selin, & J. M. Wetmore (Eds.), *The Yearbook of Nanotechnology in Society, Volume I: Presenting Futures* (pp. 49–70). Dordrecht: Springer.

Roache, R. (2008). Ethics, Speculation, and Values. *NanoEthics, 2*(3), 317–327. doi:10.1007/s11569-008-0050-y

Robinson, D. K. R. (2009). Co-evolutionary scenarios: An application to prospecting futures of the responsible development of nanotechnology. *Technological Forecasting and Social Change, 76*(9), 1222–1239. doi:10.1016/j.techfore.2009.07.015

Rodríguez, H. (2016). From objective to constituted risk: an alternative approach to safety in strategic technological innovation in the European Union. *Journal of Risk Research, 19*(1), 42–55. doi:10.1080/13669877.2014.940596

Rodríguez, H. (2018). Nanotechnology and Risk Governance in the European Union: the Constitution of Safety in Highly Promoted and Contested Innovation Areas. *NanoEthics, 12*(1), 5–26. doi:10.1007/s11569-017-0296-3

Rodríguez, H., Eizagirre, A., & Ibarra, A. (2019). Dynamics of responsible innovation constitution in European Union research policy: tensions, possibilities and constraints. In R. von Schomberg & J. Hankins (Eds.), *International Handbook on Responsible Innovation* (pp. 167–180). Cheltenham and Northampton, MA: Edward Elgar.

Rodríguez, H., Fisher, E., & Schuurbiers, D. (2013). Integrating science and society in European Framework Programmes: Trends in project-level solicitations. *Research Policy, 42*(5), 1126–1137. doi:10.1016/j.respol.2013.02.006

Rodríguez, H., & Urueña, S. (2020). RRI y ambivalencia en el sistema de innovación de la UE: la heurística de la anticipación y sus límites. *Caleidoscopio - Revista Semestral De Ciencias Sociales Y Humanidades, 24*(43).

Rodríguez, H., Urueña, S., & Ibarra, A. (2020). Anticipatory responsible innovation. Futures construction in the face of the techno-economic imperative. *NOvation: Critical Studies of Innovation*, (2), 127–142.

Roelofsen, A., Broerse, J. E. W., de Cock Buning, T., & Bunders, J. F. G. (2008). Exploring the future of ecological genomics: Integrating CTA with vision assessment. *Technological Forecasting and Social Change, 75*(3), 334–355. doi:10.1016/j.techfore.2007.01.004

Rohrbeck, R., & Gemunden, H. G. (2009). *Making your R&D future proof: The roles of corporate foresight in innovation management.* Paper presented at the PICMET'09-2009 Portland International Conference on Management of Engineering & Technology, Portland, OR.

Rommetveit, K., & Wynne, B. (2017). Technoscience, imagined publics and public imaginations. *Public Understanding of Science, 26*(2), 133–147. doi:10.1177/0963662516663057

Rosen, R. (1985). *Anticipatory Systems. Philosophical, Mathematical and Methodological Foundations*. Oxford: Pergamon Press.

Rosen, R. (1991). *Life Itself. A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*. New York: Columbia University Press.

RRI in Horizon Europe. (2020). Position Paper. Retrieved 27/04/2021 from https://rri-in-horizon-europe.net/position-paper-from-the-core-group/

Rubino, C. A. (2000). The Politics of Certainty: Conceptions of Science in an Age of Uncertainty. *Science and Engineering Ethics, 6*(4), 499–508. doi:10.1007/s11948-000-0008-0

Ruggiu, D. (2018). Implementing a responsible, research and innovation framework for human enhancement according to human rights: the right to bodily integrity and the rise of 'enhanced societies'. *Law, Innovation and Technology, 10*(1), 82–121. doi:10.1080/17579961.2018.1452177

Ruggiu, D. (2019). Models of Anticipation Within the Responsible Research and Innovation Framework: the Two RRI Approaches and the Challenge of Human Rights. *NanoEthics, 13*(1), 53–78. doi:10.1007/s11569-019-00337-4

Ruggiu, D. (2020). Inescapable Frameworks: Ethics of Care, Ethics of Rights and the Responsible Research and Innovation Model. *Philosophy of Management, 19*(3), 237–265. doi:10.1007/s40926-019-00119-8

Sadowski, J. (2020). Rediscovering a risky ideology: technocracy and its effects on technology governance. *Journal of Responsible Innovation, 7*(sup1), 112–116. doi:10.1080/23299460.2020.1816345

Sadowski, J., & Guston, D. H. (2016). 'You caught me off guard': Probing the futures of complex engineered nanomaterials. *Journal of Nanoparticle Research, 18*(7), 208. doi:10.1007/s11051-016-3485-z

Samet, R. H. (2010). Futurists and their schools: A response to Ziauddin Sardar's 'the namesake'. *Futures, 42*(8), 895–900. doi:10.1016/j.futures.2010.04.026

Sardar, Z. (2010). The Namesake: Futures; futures studies; futurology; futuristic; foresight—What's in a name? *Futures, 42*(3), 177–184. doi:10.1016/j.futures.2009.11.001

Sarewitz, D. (2011). Anticipatory Governance of Emerging Technologies. In G. E. Marchant, B. R. Allenby, & J. R. Herkert (Eds.), *The Growing Gap Between Emerging Technologies and Legal-Ethical Oversight: The Pacing Problem* (pp. 95–105). Dordrecht: Springer.

Sarewitz, D. R., Pielke, R. A., & Byerly, R. (2000). *Prediction: Science, Decision Making, and the Future of Nature*. Washington D.C.: Island Press.

Saritas, O. (2013). Systemic Foresight Methodology. In D. Meissner, L. Gokhberg, & A. Sokolov (Eds.), *Science, Technology and Innovation Policy for the Future: Potentials and Limits of Foresight Studies* (pp. 83–117). Berlin and Heidelberg: Springer.

Sarpong, D., Eyres, E., & Batsakis, G. (2019). Narrating the future: A distentive capability approach to strategic foresight. *Technological Forecasting and Social Change, 140*, 105–114. doi:10.1016/j.techfore.2018.06.034

Schartinger, D., Wilhelmer, D., Holste, D., & Kubeczko, K. (2012). Assessing immediate learning impacts of large foresight processes. *Foresight, 14*(1), 41–55. doi:10.1108/14636681211210350

Schirrmeister, E., Göhring, A.-L., & Warnke, P. (2020). Psychological biases and heuristics in the context of foresight and scenario processes. *Futures & Foresight Science, 2*(2), e31. doi:10.1002/ffo2.31

Schmidt-Scheele, R. (2020a). *The Plausibility of Future Scenarios: Conceptualising an Unexplored Criterion in Scenario Planning*. Bielefeld: Transcript Verlag.

Schmidt-Scheele, R. (2020b). 'Plausible' energy scenarios?! How users of scenarios assess uncertain futures. *Energy Strategy Reviews*, 100571. doi:10.1016/j.esr.2020.100571

Schneider, C., & Lösch, A. (2019). Visions in assemblages: Future-making and governance in FabLabs. *Futures, 109*, 203–212. doi:10.1016/j.futures.2018.08.00

Schneider, C., Roßmann, M., Lösch, A., & Grunwald, A. (2021). Transformative Vision Assessment and 3-D Printing Futures: A New Approach of Technology Assessment to Address Grand Societal Challenges. *IEEE Transactions on Engineering Management*, 1–10. doi:10.1109/TEM.2021.3129834

Schneider, C., Wilke, N., & Lösch, A. (2022). Contested Visions for Transformation—The Visions of the Green New Deal and the Politics of Technology Assessment, Responsible Research and Innovation, and Sustainability Research. *Sustainability, 14*(3), 1505. doi:10.3390/su14031505

Schot, J. (2001). Towards New Forms of Participatory Technology Development. *Technology Analysis & Strategic Management, 13*(1), 39–52. doi:10.1080/09537320120040437

Schot, J., & Rip, A. (1997). The past and future of constructive technology assessment. *Technological Forecasting and Social Change, 54*(2/3), 251–268. doi:10.1016/S0040-1625(96)00180-1

Schuijff, M., & Dijkstra, A. M. (2020). Practices of Responsible Research and Innovation: A Review. *Science and Engineering Ethics, 26*(2), 533–574. doi:10.1007/s11948-019-00167-3

Schumpeter, J. A. (1942). *Capitalism, Socialism and Democracy*. New York and London: Harper & Brothers.

Schwarz-Plaschg, C. (2018a). Nanotechnology is like … The rhetorical roles of analogies in public engagement. *Public Understanding of Science, 27*(2), 153–167. doi:10.1177/0963662516655686

Schwarz-Plaschg, C. (2018b). The Power of Analogies for Imagining and Governing Emerging Technologies. *NanoEthics, 12*(2), 139–153. doi:10.1007/s11569-018-0315-z

Sekhsaria, P. (2016). *Enculturing Innovation. Indian engagements with nanotechnology.* (Doctoral Dissertation). Maastricht University.

Seligman, M. E. P., Railton, P., Baumeister, R. F., & Sripada, C. (2016). *Homo Prospectus*. Oxford and New York: Oxford University Press.

Selin, C. (2006a). Time Matters: Temporal harmony and dissonance in nanotechnology networks. *Time & Society, 15*(1), 121–139. doi:10.1177/0961463X06061786

Selin, C. (2006b). Trust and the illusive force of scenarios. *Futures, 38*(1), 1–14. doi:10.1016/j.futures.2005.04.001

Selin, C. (2007). Expectations and the Emergence of Nanotechnology. *Science, Technology, & Human Values, 32*(2), 196–220. doi:10.1177/0162243906296918

Selin, C. (2008). The Sociology of the Future: Tracing Stories of Technology and Time. *Sociology Compass, 2*(6), 1878–1895. doi:10.1111/j.1751-9020.2008.00147.x

Selin, C. (2011). Negotiating Plausibility: Intervening in the Future of Nanotechnology. *Science and Engineering Ethics, 17*(4), 723–737. doi:10.1007/s11948-011-9315-x

Selin, C. (2014). On not forgetting futures. *Journal of Responsible Innovation, 1*(1), 103–108. doi:10.1080/23299460.2014.884378

Selin, C., & Guimarães Pereira, Â. (2013). Pursuing plausibility. *International Journal of Foresight and Innovation Policy, 9*(2/3/4), 93–109. doi:10.1504/ijfip.2013.058616

Selin, C., Rawlings, K. C., de Ridder-Vignone, K., Sadowski, J., Altamirano Allende, C., Gano, G., . . . Guston, D. H. (2017). Experiments in engagement: Designing public

engagement with science and technology for capacity building. *Public Understanding of Science, 26*(6), 634–649. doi:10.1177/0963662515620970

Selkirk, K., Selin, C., & Felt, U. (2018). A Festival of Futures: Recognizing and Reckoning Temporal Complexity in Foresight. In R. Poli (Ed.), *Handbook of Anticipation: Theoretical and Applied Aspects of the Use of Future in Decision Making* (pp. 1–23). Cham: Springer.

Sharif, N. (2006). Emergence and development of the National Innovation Systems concept. *Research Policy, 35*(5), 745–766. doi:10.1016/j.respol.2006.04.001

Simakova, E., & Coenen, C. (2013). Visions, Hype, and Expectations: A Place for Responsibility. In R. Owen, J. Bessant, & M. Heintz (Eds.), *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society* (pp. 241–267). Chichester: Wiley.

Slaughter, R. A. (1998). Futures Studies as an Intellectual and Applied Discipline. *American Behavioral Scientist, 42*(3), 372–385. doi:10.1177/0002764298042003008

Slaughter, R. A. (2003). *Futures Beyond Dystopia: Creating Social Foresight*. London and New York: Routlege.

Son, H. (2015). The history of Western futures studies: An exploration of the intellectual traditions and three-phase periodization. *Futures, 66*, 120–137. doi:10.1016/j.futures.2014.12.013

Sotoudeh, M., & Gudowsky, N. (2018). Participatory foresight for technology assessment. Towards an evaluation approach for knowledge co-creation. *TATuP - Zeitschrift für Technikfolgenabschätzung in Theorie und Praxis, 27*(2), 53–59. doi:10.14512/tatup.27.2.53

Sovacool, B. K., & Hess, D. J. (2017). Ordering theories: Typologies and conceptual frameworks for sociotechnical change. *Social Studies of Science, 47*(5), 703–750. doi:10.1177/0306312717709363

Spaniol, M. J., & Rowland, N. J. (2018). The scenario planning paradox. *Futures, 95*, 33–43. doi:10.1016/j.futures.2017.09.006

Stemerding, D. (2015). iGEM as laboratory in responsible research and innovation. *Journal of Responsible Innovation, 2*(1), 140–142. doi:10.1080/23299460.2014.1002171

Stemerding, D., Betten, W., Rerimassie, V., Robaey, Z., & Kupper, F. (2019). Future making and responsible governance of innovation in synthetic biology. *Futures, 109*, 213–226. doi:10.1016/j.futures.2018.11.005

Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework for responsible innovation. *Research Policy, 42*(9), 1568–1580. doi:10.1016/j.respol.2013.05.008

Stirling, A. (2007). Deliberate futures: precaution and progress in social choice of sustainable technology. *Sustainable Development, 15*(5), 286–295. doi:10.1002/sd.347

Stirling, A. (2008). "Opening Up" and "Closing Down": Power, Participation, and Pluralism in the Social Appraisal of Technology. *Science, Technology, & Human Values, 33*(2), 262–294. doi:10.1177/0162243907311265

Stirling, A. (2017). Precaution in the Governance of Technology. In R. Brownsword, E. Scotford, & K. Yeung (Eds.), *The Oxford Handbook of Law, Regulation and Technology* (pp. 645–668). Oxford: Oxford University Press.

Suddendorf, T., & Redshaw, J. (2017). Anticipation of Future Events. In J. Vonk & T. Shackelford (Eds.), *Encyclopedia of Animal Cognition and Behavior* (pp. 1–9). Cham: Springer.

Sunstein, C. R. (2003). Beyond the Precautionary Principle. *University of Pennsylvania Law Review, 151*(3), 1003–1058. doi:10.2307/3312884

Sutcliffe, H. (2011). *A report on Responsible Research & Innovation (Prepared for DG Research and Innovation, European Commission)*. Retrieved 27/03/2019 from http://www.diss.unimi.it/extfiles/unimidire/243201/attachment/a-report-on-responsible-research-innovation.pdf

Sweeney, J. A. (2014). Command-and-control: Alternative futures of geoengineering in an age of global weirding. *Futures, 57*, 1–13. doi:10.1016/j.futures.2013.12.005

Swierstra, T., & Rip, A. (2007). Nano-ethics as NEST-ethics: Patterns of Moral Argumentation About New and Emerging Science and Technology. *NanoEthics, 1*(1), 3–20. doi:10.1007/s11569-007-0005-8

Swierstra, T., Stemerding, D., & Boenink, M. (2009). Exploring Techno-Moral Change: The Case of the ObesityPill. In P. Sollie & M. Düwell (Eds.), *Evaluating New Technologies: Methodological Problems for the Ethical Assessment of Technology Developments* (pp. 119–138). Dordrecht: Springer.

Swierstra, T., & te Molder, H. (2012). Risk and Soft Impacts. In S. Roeser, R. Hillerbrand, P. Sandin, & M. Peterson (Eds.), *Handbook of Risk Theory: Epistemology, Decision Theory, Ethics, and Social Implications of Risk* (pp. 1049–1066). Dordrecht: Springer.

Taylor, C. (2004). *Modern Social Imaginaries*. Durham, NC: Duke University Press.

te Kulve, H., & Rip, A. (2011). Constructing Productive Engagement: Pre-engagement Tools for Emerging Technologies. *Science and Engineering Ethics, 17*(4), 699–714. doi:10.1007/s11948-011-9304-0

Thagard, P., & Shelley, C. (1997). Abductive Reasoning: Logic, Visual Thinking, and Coherence. In M. L. Dalla Chiara, K. Doets, D. Mundici, & J. van Benthem (Eds.), *Logic and Scientific Methods: Volume One of the Tenth International Congress of Logic, Methodology and Philosophy of Science, Florence, August 1995* (pp. 413–427). Dordrecht: Springer.

Tichy, G. (2004). The over-optimism among experts in assessment and foresight. *Technological Forecasting and Social Change, 71*(4), 341–363. doi:10.1016/j.techfore.2004.01.003

Tijink, D. (1996). *Foresight in science and technology policy as participatory policy analysis.* Paper presented at the 1996 International Symposium on Technology and Society Technical Expertise and Public Decisions. Proceedings.

Timmermans, J., & Blok, V. (2021). A critical hermeneutic reflection on the paradigm-level assumptions underlying responsible innovation. *Synthese*, (198), 4635–4666. doi:10.1007/s11229-018-1839-z

Torgersen, H., & Fuchs, D. (2017). Technology assessment as a myth buster: deconstructing myths around emerging technologies. *Journal of Responsible Innovation, 4*(2), 118–137. doi:10.1080/23299460.2017.1320157

Tran, T. A., & Daim, T. (2008). A taxonomic review of methods and tools applied in technology assessment. *Technological Forecasting and Social Change, 75*(9), 1396–1405. doi:10.1016/j.techfore.2008.04.004

Tribe, L. H. (1973). Technology Assessment and the Fourth Discontinuity: The Limits of Instrumental Rationality. *Southern California Law Review, 46*(3), 617–660.

UNESCO. (2006). *The Ethics and politics of nanotechnology*. Paris: United Nations Educational, Scientific and Cultural Organization.

UNESCO. (2021). Home. Project Anticipation. Retrieved 23/09/2021 from http://www.projectanticipation.org/

Uprichard, E. (2011). Narratives of the Future: Complexity, Time and Temporality. In M. Williams & W. P. Vogt (Eds.), *The SAGE Handbook of Innovation in Social Research Methods* (pp. 103–119). London: SAGE.

Urueña, S. (2019). Understanding "plausibility": A relational approach to the anticipatory heuristics of future scenarios. *Futures, 111*, 15–25. doi:10.1016/j.futures.2019.05.002

Urueña, S. (2021). Responsibility through Anticipation? The 'Future Talk' and the Quest for Plausibility in the Governance of Emerging Technologies. *NanoEthics, 15*(3), 271–302. doi:10.1007/s11569-021-00408-5

Urueña, S. (2022a, forthcoming). Anticipation and modal power: Opening-up and closing-down the momentum of sociotechnical systems. *Social Studies of Science*.

Urueña, S. (2022b, forthcoming). La anticipación en la búsqueda de una innovación responsable: Gradientes de radicalidad ético-política. *Recerca. Revista de Pensament i Anàlisi, 27*(2).

Urueña, S., Rodríguez, H., & Ibarra, A. (2021). Foresight and responsible innovation: Openness and closure in anticipatory heuristics. *Futures, 134*, 102852. doi:10.1016/j.futures.2021.102852

Valkenburg, G., Mamidipudi, A., Pandey, P., & Bijker, W. E. (2019). Responsible innovation as empowering ways of knowing. *Journal of Responsible Innovation, 7*(1), 6–25. doi:10.1080/23299460.2019.1647087

van Asselt, M., & van 't Klooster, S. (Eds.). (2010). *Foresight in Action: Developing Policy-Oriented Scenarios*. Abingdon: Routledge.

van de Poel, I. (2016). An Ethical Framework for Evaluating Experimental Technology. *Science and Engineering Ethics, 22*(3), 667–686. doi:10.1007/s11948-015-9724-3

van den Bos, R. (2019). Animal Anticipation: A Perspective. In R. Poli (Ed.), *Handbook of Anticipation: Theoretical and Applied Aspects of the Use of Future in Decision Making* (pp. 235–247). Cham: Springer.

van der Burg, S. (2009a). Imagining the Future of Photoacoustic Mammography. *Science and Engineering Ethics, 15*(1), 97–110. doi:10.1007/s11948-008-9079-0

van der Burg, S. (2009b). Taking the "Soft Impacts" of Technology into Account: Broadening the Discourse in Research Practice. *Social Epistemology, 23*(3/4), 301–316. doi:10.1080/02691720903364191

van der Burg, S. (2010). Ethical Imagination: Broadening Laboratory Deliberations. In S. Roeser (Ed.), *Emotions and Risky Technologies* (pp. 139–155). Dordrecht: Springer.

van der Burg, S. (2014). On the hermeneutic need for future anticipation. *Journal of Responsible Innovation, 1*(1), 99–102. doi:10.1080/23299460.2014.882556

van der Duin, P. (2006). *Qualitative futures research for innovation*. Delft: Eburon Uitgeverij BV.

van der Duin, P. (2018). Toward "Responsible Foresight": Developing Futures that Enable Matching Future Technologies with Societal Demands. *World Futures Review, 11*(1), 69–79. doi:10.1177/1946756718803721

van der Heijden, K. (2011). *Scenarios: The Art of Strategic Conversation*. New York: Wiley.

van der Helm, R. (2006). Towards a clarification of probability, possibility and plausibility: how semantics could help futures practice to improve. *Foresight, 8*(3), 17–27. doi:10.1108/14636680610668045

van der Helm, R. (2009). The vision phenomenon: Towards a theoretical underpinning of visions of the future and the process of envisioning. *Futures, 41*(2), 96–104. doi:10.1016/j.futures.2008.07.036

Van Eijndhoven, J. C. M. (1997). Technology assessment: Product or process? *Technological Forecasting and Social Change, 54*(2), 269–286. doi:10.1016/S0040-1625(96)00210-7

van Lente, H. (1993). *Promising Technology. The Dynamics of Expectations in Technological Developments*. (Doctoral Dissertation). University of Twente.

van Lente, H., & Rip, A. (1998a). Expectations in Technological Developments: An Example of Prospective Structures to be Filled in by Agency. In C. Disco & B. van der Meulen (Eds.), *Getting New Technologies Together: Studies in Making Sociotechnical Order* (pp. 203–230). Berlin and New York: Walter de Gruyter.

van Lente, H., & Rip, A. (1998b). The Rise of Membrane Technology: From Rhetorics to Social Reality. *Social Studies of Science, 28*(2), 221–254. doi:10.1177/030631298028002002

van Lente, H., Spitters, C., & Peine, A. (2013). Comparing technological hype cycles: Towards a theory. *Technological Forecasting and Social Change, 80*(8), 1615–1628. doi:10.1016/j.techfore.2012.12.004

van Lente, H., Swierstra, T., & Joly, P.-B. (2017). Responsible innovation as a critique of technology assessment. *Journal of Responsible Innovation, 4*(2), 254–261. doi:10.1080/23299460.2017.1326261

van Merkerk, R. O., & Smits, R. E. H. M. (2008). Tailoring CTA for emerging technologies. *Technological Forecasting and Social Change, 75*(3), 312–333. doi:10.1016/j.techfore.2007.01.003

van Oudheusden, M. (2014). Where are the politics in responsible innovation? European governance, technology assessments, and beyond. *Journal of Responsible Innovation, 1*(1), 67–86. doi:10.1080/23299460.2014.882097

Veflen Olsen, N., & Motarjemi, Y. (2014). Food Safety Assurance Systems: Food Safety and Ethics. In Y. Motarjemi (Ed.), *Encyclopedia of Food Safety* (pp. 340–344). Waltham: Academic Press.

Verbeek, P.-P. (2005). Artifacts and Attachment: A Post-Script Philosophy of Mediation. In H. Habers (Ed.), *Inside the Politics of Technology: Agency and Normativity in the Co-Production of Technology and Society*. Amsterdam: Amsterdam University Press.

Verbeek, P.-P. (2012a). Expanding Mediation Theory. *Foundations of Science, 17*(4), 391–395. doi:10.1007/s10699-011-9253-8

Verbeek, P.-P. (2012b). Toward a Theory of Technological Mediation. In J. K. B. Friis & R. P. Crease (Eds.), *Technoscience and Postphenomenology: The Manhattan Papers* (pp. 189–204). Dordrecht and Boston, MA: Reidel.

Verbeek, P.-P. (2015). COVER STORY Beyond Interaction: A Short Introduction to Mediation Theory. *interactions, 22*(3), 26–31. doi:10.1145/2751314

Vermaas, P., Kroes, P., van de Poel, I., Franssen, M., & Houkes, W. (2011). *A Philosophy of Technology: From Technical Artefacts to Sociotechnical Systems*. San Rafael, CA: Morgan & Claypool.

Vervoort, J. M., Bendor, R., Kelliher, A., Strik, O., & Helfgott, A. E. R. (2015). Scenarios and the art of worldmaking. *Futures, 74*, 62–70. doi:10.1016/j.futures.2015.08.009

Vogel, E. F. (1979). *Japan as Number One: Lessons for America*. Cambridge, MA: Harvard University Press.

von Schomberg, L., & Blok, V. (2021). Technology in the Age of Innovation: Responsible Innovation as a New Subdomain Within the Philosophy of Technology. *Philosophy & Technology, 34*(2), 309–323. doi:10.1007/s13347-019-00386-3

von Schomberg, R. (2012). Prospects for technology assessment in a framework of responsible research and innovation. In M. Dusseldorp & R. Beecroft (Eds.), *Technikfolgen abschätzen lehren: Bildungspotenziale transdisziplinärer Methoden* (pp. 39–61). Wiesbaden: VS Verlag für Sozialwissenschaften.

von Schomberg, R. (2013). A Vision of Responsible Research and Innovation. In R. Owen, J. R. Bessant, & M. Heintz (Eds.), *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society* (pp. 51–74). Chichester: Wiley.

von Schomberg, R. (2014). The Quest for the 'Right' Impacts of Science and Technology: A Framework for Responsible Research and Innovation. In J. van den Hoven, N. Doorn, T. Swierstra, B.-J. Koops, & H. Romijn (Eds.), *Responsible Innovation 1: Innovative Solutions for Global Issues* (pp. 33–50). Dordrecht: Springer.

von Schomberg, R. (2019). Why responsible innovation? In R. von Schomberg & J. Hankins (Eds.), *International Handbook on Responsible Innovation. A Global Resource* (pp. 12–32). Cheltenham and Northampton, MA: Edward Elgar.

von Schomberg, R., Guimarães Pereira, Â., & Funtowicz, S. (2006). *Deliberating Foresight Knowledge for Policy and Foresight Knowledge Assessment*. Luxembourg: Office for Official Publications of the European Communities.

Voß, J.-P., & Freeman, R. (2016). Introduction: knowing governance. In J.-P. Voß & R. Freeman (Eds.), *Knowing Governance. Palgrave Studies in Science, Knowledge and Policy* (pp. 1–33). London: Palgrave Macmillan.

Walton, J. S. (2008). Scanning Beyond the Horizon: Exploring the Ontological and Epistemological Basis for Scenario Planning. *Advances in Developing Human Resources, 10*(2), 147–165. doi:10.1177/1523422307304101

Wang, P., & Burton Swanson, E. (2008). Customer relationship management as advertised: Exploiting and sustaining technological momentum. *Information Technology & People, 21*(4), 323–349. doi:10.1108/09593840810919662

Warnke, P., & Heimeriks, G. (2008). Technology Foresight as Innovation Policy Instrument: Learning from Science and Technology Studies. In C. Cagnin, M. Keenan, R. Johnston, F. Scapolo, & R. Barré (Eds.), *Future-Oriented Technology Analysis: Strategic Intelligence for an Innovative Economy* (pp. 71–87). Berlin and Heidelberg: Springer.

Weber, K. M., Gudowsky, N., & Aichholzer, G. (2019). Foresight and technology assessment for the Austrian parliament — Finding new ways of debating the future of industry 4.0. *Futures, 109*, 240–251. doi:10.1016/j.futures.2018.06.018

Weinberg, A. M. (1972). Science and trans-science. *Minerva, 10*(2), 209–222. doi:10.1007/BF01682418

Wells, H. G. (1913). *The Discovery of the Future*. New York: B. W. Huebsch.

Wender, B. A., Foley, R. W., Hottle, T. A., Sadowski, J., Prado-Lopez, V., Eisenberg, D. A., . . . Seager, T. P. (2014). Anticipatory life-cycle assessment for responsible research and innovation. *Journal of Responsible Innovation, 1*(2), 200–207. doi:10.1080/23299460.2014.920121

Wetmore, J. M. (2004). Redefining Risks and Redistributing Responsibilities: Building Networks to Increase Automobile Safety. *Science, Technology, & Human Values, 29*(3), 377–405. doi:10.1177/0162243904264486

Wiek, A., Foley, R. W., Guston, D. H., & Bernstein, M. J. (2016). Broken promises and breaking ground for responsible innovation – intervention research to transform business-as-usual in nanotechnology innovation. *Technology Analysis & Strategic Management, 28*(6), 639–650. doi:10.1080/09537325.2015.1129399

Wiek, A., Withycombe Keeler, L., Schweizer, V., & Lang, D. J. (2013). Plausibility indications in future scenarios. *International Journal of Foresight and Innovation Policy, 2/3/4*(9), 133–147. doi:10.1504/IJFIP.2013.058611

Williams, R. (2008). Compressed Foresight and Narrative Bias: Pitfalls in Assessing High Technology Futures. In E. Fisher, C. Selin, & J. M. Wetmore (Eds.), *Presenting Futures* (pp. 265–289). Dordrecht: Springer.

Wilson, I. (1998). Mental maps of the future: an intuitive logics approach to scenarios. In L. Fahey & R. M. Randall (Eds.), *Learning from the future: Competitive foresight scenarios* (pp. 81–108). New York: Wiley.

Winner, L. (1980). Do Artifacts Have Politics? *Daedalus, 109*(1), 121–136.

Wippel, N. (2014). *Multinational Strategic Foresight of Environmental Trends in the Automobile Industry Using Internal Resources*. Vienna: LIT Verlag.

Withycombe Keeler, L., Bernstein, M. J., & Selin, C. (2019). Intervening Through Futures for Sustainable Presents: Scenarios, Sustainability, and Responsible Research and Innovation. In A. Lösch, A. Grunwald, M. Meister, & I. Schulz-Schaeffer (Eds.), *Socio-Technical Futures Shaping the Present. Empirical Examples and Analytical Challenges* (pp. 255–282). Wiesbaden: Springer VS.

Woolgar, S., Coopmans, C., & Neyland, D. (2009). Does STS Mean Business? *Organization, 16*(1), 5–30. doi:10.1177/1350508408098983

Wynne, B. (1975). The rhetoric of consensus politics: a critical review of technology assessment. *Research Policy, 4*(2), 108–158. doi:10.1016/0048-7333(75)90028-1

Wynne, B. (1995). Technology Assessment and Reflexive Social Learning: Observations from the Risk Field. In A. Rip, T. J. Misa, & J. Schot (Eds.), *Managing technology in society: the approach of constructive technology assessment* (pp. 19–36). London and New York: Pinter Publishers.

Wynne, B. (2001). Creating Public Alienation: Expert Cultures of Risk and Ethics on GMOs. *Science as Culture, 10*(4), 445–481. doi:10.1080/09505430120093586

Yesley, M. S. (2008). What's ELSI got to do with it? Bioethics and the Human Genome Project. *New Genetics and Society, 27*(1), 1–6. doi:10.1080/14636770701843527

York, R., & Clark, B. (2007). The Problem with Prediction: Contingency, Emergence, and the Reification of Projections. *The Sociological Quarterly, 48*(4), 713–743.

Yoshizawa, G., Ho, C. W.-L., Zhu, W., Hu, C., Syukriani, Y., Lee, I., . . . Kato, K. (2014). ELSI practices in genomic research in East Asia: implications for research collaboration and public participation. *Genome Medicine, 6*(5), 39. doi:10.1186/gm556

Zimmer-Merkle, S., & Fleischer, T. (2017). Eclectic, random, intuitive? Technology assessment, RRI, and their use of history. *Journal of Responsible Innovation, 4*(2), 217–233. doi:10.1080/23299460.2017.1338105

Zwart, H., Landeweerd, L., & van Rooij, A. (2014). Adapt or perish? Assessing the recent shift in the European research funding arena from 'ELSA' to 'RRI'. *Life Sciences, Society and Policy, 10*(1), 11. doi:10.1186/s40504-014-0011-x

Zwart, H., & Nelis, A. (2009). What is ELSA genomics? *EMBO reports, 10*(6), 540–544. doi:10.1038/embor.2009.115