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## **Enacting anticipatory heuristics: A tentative methodological proposal for steering responsible innovation**

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# Enacting anticipatory heuristics: A methodological proposal for steering responsible innovation

## Abstract

Over the past decade, various normative 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 dimension or instrument. The article reviews the main challenges to which anticipation has been explicitly or implicitly directed and the respective methodological approaches that have been associated with them. In doing so, the article diagnoses a fragmentation in the methodological treatment of the different challenges. Against this fragmentation, a 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 aims to minimise the uncritical reification of futures.

**Keywords:** foresight; responsible innovation; methods; RRI; technology assessment.

## 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](#); [Guston 2014](#)), Responsible Innovation (RI) ([Stilgoe et al. 2013](#)), Responsible Research or Innovation (RRI) ([European Commission 2013b](#), [2013a](#); [von Schomberg 2013](#)), or recent developments in Technology Assessment (TA) ([Grunwald 2019](#)) are examples of normative approaches that explicitly rely on anticipation as a central—though not the sole—procedural dimension

to improve co-production dynamics in science, technology, and innovation (STI).<sup>1</sup>

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). Following the foundational work of today's dominant futures studies perspectives, the future is understood as a non-existent (and therefore unknowable), open and plural space (e.g. de Jouvenel 1967; Bell and Olick 1989). Yet, the idea that the future cannot be known does not prevent representations of the future from being considered as heuristically fruitful resources for learning and enacting reflection in the present (Rip and te Kulve 2008; Selin 2014). Concordant with non-predictivist approaches, anticipation is understood by AG, RRI, RI, and TA scholars as a key enabling procedural principle to align STI processes, outcomes, and purposes with societal interests, values, and expectations throughout the whole co-production phases (European Commission 2013b, 4). Accommodating various conceptual broadenings of responsibility and its forward-looking character (e.g. Jonas 1984; Groves 2006; Adam and Groves 2011), responsibility is here understood as 'taking care of the future towards collective stewardship of science and innovation in the present' (Stilgoe et al. 2013, 1570), and anticipation is one of the tools used to promote the ongoing, early, and socially robust problematisation of the futures that are (not) at stake through STI developments (Rip et al. 1995; Guston and Sarewitz 2002; Dupuy and Grinbaum 2004).

Against this context, the call for anticipation finds its most direct operative factor in the execution of foresight exercises such as sociotechnical or techno-moral scenarios (Barben et al. 2008, 993; Selin 2011; Arnaldi 2018; Withycombe Keeler et al. 2019).

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<sup>1</sup> Long historical-conceptual roots nourish, support, and inspire AG, RRI, RI, and TA. For more on the origins of these frameworks, see: Barben et al. (2008) and Karinen and Guston (2009) on AG; von Schomberg (2013) and Owen et al. (2012) on RRI; Stilgoe et al. (2013) and Owen and Pansera (2019) on RI; and Grunwald (2019) and Grunwald (2009) on TA.

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. For instance, it has been stated that foresight might serve in the management of visions and expectations ([Warnke and Heimeriks 2008, 79](#)), to shape more systemic thinking for ‘socially-robust risk research’ ([Stilgoe et al. 2013, 1570](#)), or to foster ‘practical wisdom’ ([Boenink 2013](#)) and ‘emancipate’ societal actors ([Withycombe Keeler et al. 2019](#)). These heterogeneous heuristics of foresight only mirror the diversity of epistemologies, schools, and modes of orientation that constitute the plural identity of futures studies ([Sardar 2010](#); [Grunwald 2013](#)).

In the development of such heuristics ascribed to foresight, the processes channelled by the methodology are of paramount importance. However, methodological architectures are surprisingly under-explored and under-problematised in AG, RRI, RI, and TA literature. As [Lehoux et al. \(2020, 1\)](#) diagnoses, ‘there is little empirical research examining how in practice prospective public deliberation processes should be organized to inform anticipatory governance’. The questions of which methods can better shape responsabilisation 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 article seeks to advance the problematisation of methods for enacting anticipatory knowledge and capabilities aimed at promoting socio-politically responsible STI activities. To this end, it first explores how anticipation/foresight is theoretically understood in AG, RRI, RI, and TA and what challenges are associated with this dimension. It is shown that anticipation is understood and approached as addressing heterogeneous challenges, each of which requires specific forms of

engagement with ‘futures’ (Section 2). The article then analyses 17 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 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 the challenges attributed to anticipation 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) (Section 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 4). The article ends with a series of concluding remarks (Section 5).

## ***2. Anticipation as a heuristic resource to foster more responsible research and innovation: conceptualisations and practical challenges***

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. 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 responsabilisation for the tentative governance of STI (see [Kuhlmann et al. 2019](#)).

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, they understand responsibility 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 purposes, processes, and ‘positive’/‘negative’ outcomes) (Stilgoe et al. 2013, 1570; von Schomberg 2014). The (im)plausibility and (un)desirability 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). 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 the 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 notion of responsibility finds operational support in the foresight/anticipation dimension in all these frameworks. Anticipation is one of the operational dimensions that, in symbiosis or mutual reinforcement with the other dimensions of each framework, aims to promote this more socio-politically radical and reflexive notion of responsibility. 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, 110) states, anticipation ‘is perhaps the most crucial and problematic dimension to deal with’, yet it is also the most under-explored dimension: ‘there is less conceptual development around anticipation, and even poorer intuitions’.

A detailed look at the foundational texts of these frameworks can reveal the different roles attributed to anticipation. Table 1 lists some examples of the diverse

engagements with the future that each normative framework establishes in its foundational texts when addressing their corresponding dimension of anticipation/foresight.

1 **Table 1.** 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
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, 993).	Engagement Socio-technical integration	Non-predictivist (does not strive for certainty, or to reduce complexity).  Public engagement exercises aimed at ‘to help frame debates about the societal implications of new technologies’ (Barben et al. 2008, 986).  ‘seek to integrate reflection with everyday decision making’ (Barben et al. 2008, 986).  ‘to bridge the cognitive gap between present and future’ (Barben et al. 2008, 991).	Future scenarios co-constructed in a large-scale through multiple wiki sites  Scenario development or visioning workshops  Science fiction prototyping
Responsible Research and Innovation (RRI)	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, 4)	European Commission – Pillars / Themes: Societal engagement, gender, open access/data, science education, ethics, and governance  The European Treaty as normative anchor point	‘the use of foresight projects can help us to overcome the often too narrowly conceived problem definition scientists implicitly work with’ (von Schomberg 2012, 46)  ‘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, 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, 51)	Technology foresight  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, 1570)	Inclusive deliberation Reflexivity Responsiveness * Openness	<p>'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, 1571)</p> <p>'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, 1570)</p> <p>Anticipatory methodologies 'serve as a useful entry point for reflection on the purposes, promises, and possible impacts of innovation' (Owen et al. 2013, 38)</p>	Foresight Scenario development Horizon scanning Vision assessment Socio-literary futures-thinking
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 2019, 1–2)	Inclusion Complexity	<p>'<i>anticipation</i> addresses the dimension of time when facing an open future: enhancing reflexivity <i>over time</i>' (Grunwald 2019, 2)</p> <p>Anticipation aims to stimulate actors to productively imagine options for desirable technological futures (Decker et al. 2017)</p> <p>'foresight in TA is increasingly oriented towards processes of knowledge co-generation between different actor groups' (Sotoudeh and Gudowsky 2018, 53)</p>	Foresight Scenario development Vision Assessment Hermeneutic Technology Assessment

2 \* Dimensions added by Owen and Pansera (2019).

3 Table 1 shows that AG, RRI, RI, and TA offer negative and positive definitions in their  
4 approaches to anticipation. On the one hand, their negative definitions of anticipation  
5 generally exclude interventive actions informed by predictive approaches to the future.  
6 Prediction-based forms of governance (often operating in the register of ‘probable  
7 futures’) are regarded as social mechanisms of reifying futures and preserving the status  
8 quo (see [Ramírez and Selin 2014](#); [Derbyshire 2017](#)), because of their inability to  
9 visualise the contingent, open-ended, and plural character of futures and to enable a  
10 problematisation of socio-political or normative questions about STI ([Sarewitz et al.](#)  
11 [2000](#)). On the other hand, the common denominator amongst their positive  
12 characterisations of anticipation centres on its functions to develop reflexive heuristics  
13 and capabilities. Anticipation is understood as a means for enhancing the reflective  
14 capital concerning STI orientation throughout their co-production process and at the  
15 early stages of development, before the uncritical closure of sociotechnical co-  
16 evolutionary pathways. It is a dimension oriented towards the collective  
17 problematisation of sociotechnical futures that we enable through STI. In this way,  
18 anticipation is primarily a tool for addressing—which does not mean *solving*—the  
19 general challenge posed by the Collingridge dilemma ([Collingridge 1980](#)).

20 However, the facilitation of reflexive heuristics for addressing the Collingridge  
21 dilemma can be achieved by focusing on diverse issues. Looking at and synthesising the  
22 descriptions and goals of anticipation presented in Table 1, one can see that anticipation  
23 aims to deal with the Collingridge dilemma by addressing the following three concrete  
24 challenges (see also [Urueña 2021](#)):

25 I. *To explore the different impacts, sociotechnical configurations and ‘endogenous*  
26 *futures’* ([Rip and te Kulve 2008](#)) *that are emerging or might emerge with the*  
27 *development of a particular innovation or technology.* The problematisation of

28 impacts is expected to be as broad as possible, including both so-called  
29 ‘positive’ or ‘negative’ (von Schomberg 2014), and ‘hard’ or ‘soft’ (van der  
30 Burg 2009b; Swierstra and te Molder 2012) impacts through tentative processes  
31 of sociotechnical integration (Fisher 2019). Plausibility is understood here as a  
32 relevant criterion and inferential register to simultaneously delimit speculation  
33 and the futures and aspects that should be considered (van der Burg 2009a;  
34 Boenink 2013), and to pluralise and complexify the considered alternatives for  
35 action (see Ramírez and Selin 2014; Urueña 2019).

36 II. *The comprehensive problematisation (in terms of the concerns considered and*  
37 *the actors involved in the deliberative processes) of the purposes and orientation*  
38 *of STI. The challenge is to take charge of our agency, limited though it may be,*  
39 *when it comes ‘to bending the long arc of technoscience more toward humane*  
40 *ends’ (Guston 2014, 234).*

41 III. *The promotion of critical capacities concerning future representations and ways*  
42 *of using the future that de facto colonise the present of STI governance dynamics*  
43 *(both formal such as predictive regimes of governance, and informal such as*  
44 *governance mechanisms through visions, promises, and expectations). Who*  
45 *creates and mobilises these futures, what assumptions do they carry, who do/did*  
46 *they mobilise and why, how do they become socially established and socio-*  
47 *politically relevant, who is included or excluded in these futures? (Jasanoff*  
48 *2020).*

49 **3. *The operationalisation of anticipation in recent literature: Uses of the***  
50 ***future and challenges addressed***

51 Most of the literature on AG, RRI, RI, and TA focuses on the theoretical development  
52 and critique of the dimensions represented in each of these frameworks. However, less

53 attention has been paid to problematising their interventive practices. How are the above  
54 challenges addressed in the exercises that engage with futures? To what extent are these  
55 challenges addressed comprehensively? What methodological structures define  
56 foresight exercises?

57 This section provides an exploratory analysis of 17 sources that depict  
58 anticipatory intervention exercises for AG, RRI, RI, and TA. Given the exploratory  
59 nature of this analysis, it does not claim to be exhaustive. The analysis is pragmatically  
60 oriented to diagnose some tendencies in the operationalisation of anticipation and to  
61 highlight some of their weaknesses.

62 The selection of the resources under analysis was determined by the  
63 simultaneous fulfilment of three basic conditions:

- 64 1. The exercise presented should have an evident anticipatory-interventive  
65 character. In other words, the resource should showcase a type of exercise that is  
66 based on engagement with futures. This requirement excludes research  
67 concerned with the theoretical underpinnings of the rationale for this type of  
68 interventions.
- 69 2. The operationalisation is explicitly presented as an exercise in the service of  
70 supporting AG, RRI, RI, and/or TA. This excluded from the analysis  
71 anticipatory interventions coming from other fields, such as Futures Studies.
- 72 3. The resource should be sufficiently detailed in the process being followed to  
73 allow for meaningful analysis.

74

75 Eight variables were considered during the analysis: the framework(s) of reference (AG,  
76 RRI, RI, and/or TA), the specific STI that is the subject of the intervention, the  
77 methodology and structure of the exercise, the types of engagement with futures (see

78 below), the participants mentioned, which of the main challenges were addressed (i.e.  
79 whether ‘I.’, ‘II.’, and/or ‘III.’), and the openness and closure dynamics that these  
80 exercises facilitate.

81 These variables are interrelated, especially the challenges addressed and the  
82 types of engagement with the future. The types of engagement with the future and their  
83 interconnections with the challenges are the following (see also [Urueña 2021, 275–6](#)):

- 84 - *Exploratory*: Non-predictive representations of futures which allow to draw a  
85 series of lessons and reinforce a series of capabilities (e.g. moral imagination).
  - 86 ○ *Evocative*: ‘Useful fictions’ depicting hypothetical worlds. Some forms of  
87 evocative scenarios are sociotechnical scenarios and techno-moral  
88 scenarios. While the former evoke potential co-evolutions between STI  
89 and society, the latter focus on potential co-evolutions between STI and  
90 morality. These exercises are especially linked to the challenge of  
91 promoting a more socio-politically robust analysis of STI outcomes (i.e.  
92 ‘I.’).
  - 93 ○ *Normative*: ‘Useful fictions’ depicting hypothetical worlds that certain  
94 subjects consider (un)desirable to pursue. Normative scenarios are usually  
95 used to open deliberative spaces to discuss the purposes that certain social  
96 agents intend to tackle. These exercises are especially useful for  
97 problematising the aims and purposes STI is intended to address (i.e.  
98 challenge ‘II.’).
- 99 - *Strategic*: ‘Useful fictions’ that represent hypothetical milestones and their  
100 respective causal chains that might trigger or avoid the futures in question  
101 (whether those futures are predetermined or derived through exploratory  
102 exercises). These forms of engagement with futures are crucial for the

103 elaboration of practical guidelines that enable action in the face of the outcomes  
104 presented in evocative explorations, or that enable action in the face of the  
105 futures presented in normative explorations.

106 - *Critical-hermeneutic*: It aims to deconstruct the futures that colonise the present  
107 and usually close-down the frames through which the other ways of engaging  
108 with the future mentioned above take place. This kind of engagement with the  
109 future is particularly useful in combating the reifying power of futures (i.e. to  
110 address the challenge 'III.').

**Table 2.** Analysis of interventive anticipatory exercises.

Source	Framework(s) of reference	STI domain of intervention	Methodology & structure	Types of engagements with futures	Participants (as mentioned)	Challenge(s) tackled	Opening aspects	Closure aspects
Rip and te Kulve (2008)	TA	Nanotechnology	<i>Socio-technical scenarios:</i> (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	<i>Techno-moral scenarios:</i> Explore potential pathways for the co-evolution of the innovation with values, obligations, and responsibilities	Exploratory- evocative	--	I	Introduces the co-evolutionary 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	<i>Co-evolutionary scenarios:</i> (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 co-evolutions Problematizes 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 co-evolution for strategy formulation comes at the expense of neglecting the problematisation of the purposes of such strategies
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)

**Table 2.** Analysis of interventive anticipatory exercises.

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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	<p>Policymakers Analysts Regulators Ethics committees Patient organisations Academics (philosophers, social scientists, SynBio researchers) International health organisations Research funders ONGs</p>	I	<p>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</p>	<p>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 co-evolutions Reduces responsibility to the 'ethics management' of ELSI concerns</p>
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)	<p>Experts Public representatives Environmental NGOs</p>	<p>I II</p>	<p>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</p>	<p>Scenarios are not created by the participants, but are pre-set, which can significantly frame the debate</p>
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	<p>Provides insight into the opinions of nanoscientists on the future of their work It might generate reflexivity among nanoscientists</p>	<p>There is no collective debate or problematisation on nano</p>
Lucivero (2016)	TA	Immunosignatures Nanopil	<p><i>Techno-ethical scenarios:</i> Explore potential pathways for the co-evolution of the innovation with values, obligations, and responsibilities <i>Techno-moral vignettes:</i> Narratives that explore potential ('soft') impacts of techs on forms of life, and morality.</p>	Exploratory- evocative	Academics	I	<p>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</p>	<p>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</p>



**Table 2.** Analysis of interventive anticipatory exercises.

Source	Framework(s) of reference	STI domain of intervention	Methodology & structure	Types of engagements with futures	Participants (as mentioned)	Challenge(s) tackled	Opening aspects	Closure aspects
Gudowsky and Sotoudeh (2017)	RRI/TA	Autonomous living of older adults	<i>Transdisciplinary, visioneering co-creation process:</i> (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
Bechtold 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	<i>Retooled Techno-moral scenarios:</i> (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 co-evolution 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
Withycombe Keeler et al. (2019)	Sustainability-oriented RRI	Wastewater Sensing (WWS)	<i>Scenarios (scenario axes):</i> (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)

**Table 2.** Analysis of interventive anticipatory exercises.

Source	Framework(s) of reference	STI domain of intervention	Methodology & structure	Types of engagements with futures	Participants (as mentioned)	Challenge(s) tackled	Opening aspects	Closure aspects
Stemerding et al. (2019)	RI/TA	Synthetic biology	<p><i>Application scenarios:</i> (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</p> <p><i>Techno-moral scenarios:</i> (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</p>	Exploratory- evocative Exploratory- normative Strategic	Students Societal stakeholders Researchers in SynBio	II I	<p>The intervention was extended in time (&gt;3 years)</p> <p>The attention to the promotion of anticipatory capabilities in the early stages of the scientific career</p> <p>Highlights consideration of societal needs and definition of purpose through stakeholder involvement</p> <p>Considers both 'soft' and 'hard' impacts</p>	<p>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)</p> <p>SynBio's visions are not criticised: An enlightened view of science is promoted, in which science is presented as a problem solver</p> <p>Emphasis on providing solutions to social problems is addressed through an entrepreneurial approach</p>
Schneider et al. (2021)	TA	3-D Printing	<p><i>Transformative Vision Assessment:</i> (i) Current analysis (qualitative social science methods); (ii) dialogue (workshops); and (iii) modulation (participatory scenarios)</p>	<p>Critical-hermeneutic (Analysis and dialogue)</p> <p>Exploratory- evocative (Building sociotechnical scenarios)</p> <p>Exploratory- normative (Building more sustainable visions)</p>	Social scientists Stakeholders STEM researchers	III II I	<p>It begins with a critical approach that seeks to problematise existing visions</p> <p>The modulation and modulation of visions is based on both normative and descriptive explorations</p>	<p>It assumes an epistemic and moral division of labour among the actors: Scientists create the scenarios, and scientists and stakeholders discuss them</p> <p>The variables facing the four scenarios are limited to 'inclusivity/exclusion' and 'sustainability/unsustainability' (i.e. multivariate scenarios could have been used)</p> <p>Scenarios where the STI at hand does not exist are not envisaged</p>
Repo and Matschoss (2019)	RRI	Strategic R&D Policies	<p><i>Workshops:</i> (i) Researchers ask citizens to articulate visions; (ii) experts formulate research priorities based on those visions; and (iii) citizens assess the connections between the priorities and their visions</p>	Exploratory- normative Strategic	Experts Citizens	II	<p>Visions have societal issues at their centre: Politics on STI purposes comes first to prevent the problem from being framed in purely technical terms</p>	<p>It assumes an epistemic and moral division of labour among the actors</p> <p>Citizens' visions may be biased by promises, expectations, and previously circulated visions</p> <p>It does not problematise scenarios about the possible consequences of the STI and their plausibility and desirability</p>
Lehoux et al. (2020)	AG/RRI	Implantable cardiac 'rectifier' (genetically at-risk adults)	<p><i>Techno-moral scenarios:</i> (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</p>	Exploratory- evocative (explorations of ethical tensions)	38 individuals (workshops) 57 individuals (forums)	I	<p>Involves participants of all ages.</p> <p>Promotes the exercise of moral imagination as a long-term prerequisite for the promotion of RRI.</p> <p>Even though the study was Exploratory- evocative in nature, some participants expressed concerns about scenarios' underlying promises</p>	<p>The scenarios are created and discussed by the organisers (i.e. not opened up to the co-negotiation between participants)</p> <p>The emergence of critique of visions was dependent on the contingent dynamics of the exercise, not methodologically promoted</p> <p>It is not clarified how the intervention modelled the dynamics of STI co-production</p>

**Table 2.** Analysis of interventive anticipatory exercises.

Source	Framework(s) of reference	STI domain of intervention	Methodology & structure	Types of engagements with futures	Participants (as mentioned)	Challenge(s) tackled	Opening aspects	Closure aspects
Kera (2020)	AG/RRI	Blockchain and decentralised ledger technologies	<i>Simulation game:</i> (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

112 The results presented in Table 2 show the heterogeneity of approaches to anticipation in  
113 practice and allow several conclusions to be drawn. Due to space constraints, only the  
114 most relevant results are highlighted below. These results will inform the value of the  
115 methodological structure of the multi-foresight process described in the following  
116 section.

117 The most relevant and general conclusion that can be drawn from the above  
118 analysis is the existence of a fragmentation when it comes to addressing the various  
119 challenges that anticipation poses (i.e. ‘I.’, ‘II.’, and ‘III.’)—an exception is the  
120 *Transformative Vision Assessment* method recently proposed by [Schneider et al. \(2021\)](#).  
121 In other words, the data suggest that the anticipatory exercises for AG, RRI, RRI, and  
122 TA are not comprehensive enough when it comes to problematising the different  
123 dimensions of STIs: their outcomes (‘I.’), their purposes and processes (‘II.’) and their  
124 associated narratives, visions, promises, and expectations (‘III.’). The analysis thus  
125 shows that STI is problematised (promoting dynamics of openness), yet this  
126 problematisation is simultaneously typically restricted to different domains of STIs  
127 (promoting dynamics of closure).<sup>2</sup>

128 The analysis shows, for example, that there is a strong tendency to understand  
129 anticipation in terms of exploring impacts, be they technical, sociotechnical, or techno-  
130 moral. This is reflected in the widespread use of tools such as sociotechnical and  
131 techno-moral scenarios in the implementation of anticipation. The challenge that AG,  
132 RRI, RI, and TA anticipatory exercises tend to address in practice—considering various

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<sup>2</sup> The drivers constituting the fragmentation in the problematisation of the dimensions of STIs are heterogeneous. While exploring the causes of this fragmentation would be a necessary and interesting task, this article is limited to a tentative diagnosis of its existence. Ultimately, the aim is to encourage the design and adoption of anticipatory processes that are not a priori limited to problematising a particular subset of the issues raised by STIs. All this is done in awareness that no method is a panacea. Rather, it is a matter of problematising which “affordances of critique” intervening processes enact.

133 gradations of inclusivity, responsivity, and reflexivity—is ‘I.’. This can be interpreted in  
134 the light of the prominence of the precautionary consequentialist tradition. This tradition  
135 has typically understood responsibility in terms of the exploration of future impacts in  
136 the service of (i) the minimisation (or avoidance) of those impacts that are considered  
137 negative, and (ii) the maximisation of those impacts that are considered positive. Once  
138 the potential impact ‘X’ has been identified and deemed negative, being responsible has  
139 typically been conceived as the minimisation or avoidance of ‘X’. Of course, the  
140 question of on what and whose grounds something is judged to be ‘positive’/‘negative’  
141 is not trivial and should be on the table (which is often not the case in these exercises).

142         This tendency to link anticipation to the problematisation of STI impacts (and  
143 especially negative ones) is particularly problematic on account of the fragmentation  
144 previously noted. Not only is anticipation often linked to the problematisation of  
145 impacts, but it is usually *reduced* to this. The downside is not so much that anticipation  
146 is predominantly related to the challenge of problematising outcomes (i.e. ‘I.’), but that  
147 anticipation is predominantly activated only in relation to this challenge. This is highly  
148 detrimental for a comprehensive operationalisation of AG, RRI, RI, or TA through  
149 foresight exercises, which should include not only the problematisation of outcomes,  
150 but also the problematisation of STI purposes, processes, and  
151 visions/expectations/promises.

152         Indeed, another central challenge of AG, RRI, RI, and TA is to open up the  
153 purposes to which STI is oriented (i.e. ‘II.’). While acknowledging the contingency,  
154 impossibility of control, and non-linear nature of STI, the goal is to problematise in real  
155 time the nature of the socio-political and techno-moral worlds we mould through STI  
156 practices. While this is the case in theory, analysis shows that such problematisation of

157 the STI ends does not always occur in practice and that when it does occur, this  
158 problematisation has various methodological-operational limitations.

159 In fact, only five sources were identified that explicitly problematise the socio-  
160 political purposes of STI. However, these five works present a variety of  
161 methodological challenges. For example, [Mann \(2015\)](#) and [Stemerding et al. \(2019\)](#)  
162 problematise the purposes, but this problematisation occurs within the frame previously  
163 established by projections about the potential merits and pitfalls of the STI in question  
164 (the former in terms of future impacts, the latter in terms of potential niches where STI  
165 could become valuable or profitable). This means that the problematisation of the  
166 purposes is not so much about the socio-political significance of the STI at hand, but  
167 rather the modalities under which the STI must be promoted in order not to be socio-  
168 politically (so) problematic in the future. In this way, the exercises subtly reify the  
169 needs and goals of the STIs under study. This problem of reification could be solved by  
170 starting the process with an exploratory-normative exercise, as is the case with [Repo  
171 and Matschoss \(2019\)](#)'s exercise. However, this exercise is by no means unproblematic  
172 either. Its main problem is that it does not consider that citizens' visions can be distorted  
173 by promises and visions, and therefore critically reify the STI lines that represent those  
174 visions. For this very reason, [Schneider et al. \(2021\)](#) suggest that the core of the  
175 intervention should begin with a critical-hermeneutic engagement with participants'  
176 anticipatory assumptions: The aim is to counteract the performative power that some  
177 visions might have later in the intervention when goals and implications are explored  
178 and reflected upon.

179 The work of [Schneider et al. \(2021\)](#) is indeed the only one of the analysed  
180 sources that integrates the critical-hermeneutic approach and thus the only one that  
181 addresses the 'III.' challenge of AG, RRI, RI, and TA. Moreover, the work of [Schneider](#)

182 [et al. \(2021\)](#) is the only one that addresses the three challenges of AG, RRI, RI, and TA.  
183 However, the way the work is structured has some shortcomings, the most important  
184 being that the possibility of the non-existence of 3D printing is not presented in any  
185 scenario, or that 3D printing has been presented as a disruptive element in all scenarios  
186 (thus ultimately reproducing the visions that 3D printing campaigners are interested in).  
187 The debate should no longer be methodologically closed, so that a moratorium could be  
188 conceivable as a plausible scenario. Moreover, as with many other exercises, there is  
189 little evidence on how the anticipatory considerations and enabled knowledge were later  
190 integrated into STI practice.

191         As previously mentioned, the assessment of the anticipatory dimension cannot  
192 be separated from other dimensions that permeate AG, RI, RRI, and TA, such as  
193 reflexivity, inclusion, or responsiveness. Regarding reflexivity, it has already been  
194 suggested that the different forms of enabling anticipation exert different degrees of  
195 reflexivity on STI. In terms of inclusivity, the presence of closure mechanisms in  
196 relation to the actors coming into play and their (sometimes too passive) role in the  
197 processes of co-creating and assessing scenarios is worth noting. Many of these  
198 exercises remain undertaken within the framework of an epistemic, political, and moral  
199 division of labour (e.g. there is very often a demarcation between the group of actors  
200 who co-construct the scenarios and the group that co-assesses them). Many of the  
201 scenarios are created by desk research and then presented to various participants for  
202 critique and feedback; participants who are in turn referred to using a variety of labels,  
203 each having different semantic connotations. These mechanisms of subtle closure  
204 contrast with exercises wherein all actors collectively co-produce the very scenarios that  
205 will later be the subject of collective critique and a source for reflection. These more  
206 open exercises, being a minority, are expected to allow for a more inclusive and

207 responsive process in terms of the underlying assumptions to be considered, thus  
208 opening-up the alternatives to be considered. The findings of the analysis suggest that  
209 more attention needs to be given to (i) the criteria underlying the selection of actors, (ii)  
210 the ways in which these actors are referred to and the biases or constraints associated  
211 with them (they are heterogeneously presented under labels such as ‘stakeholders’, ‘lay  
212 people’, ‘public’, ‘citizens’, ‘experts’, etc.), and (iii) the forms of participation that are  
213 actually facilitated in order to strengthen their voices and allow for a more robust socio-  
214 political critique of STI. As [Irwin et al. \(2013\)](#) argue, critique should be ‘a key  
215 component’ of public engagement to improve the quality of knowledge co-production  
216 processes. Finally, regarding responsiveness, in most cases there is no demonstration of  
217 how these actions have subsequently impacted on STI systems and how public concerns  
218 have been reflected in subsequent STI practices and developments. In this sense, there is  
219 a need for more in-depth analysis and monitoring of the ways in which these exercises  
220 transform STI practices.

221         Many of the above limitations are of course attributable to time and socio-material  
222 constraints (which are unavoidable). However, many other limitations are due to  
223 methodological criteria (which are certainly avoidable or minimisable). The discussion  
224 above is not intended to highlight things we might be doing wrong, but rather to suggest  
225 what we could be doing better. The emphasis on closure in the above critical review  
226 should not blind us to the benefits expressed in the exercises cited. These undoubtedly  
227 promote more robust forms of STI co-production than the mainstream ones. However, if  
228 the ultimate ambition is to open up STI modes to more socio-politically robust forms of  
229 co-production, it is worth discussing how the structures that underpin our interventive  
230 methods narrow the spaces for discussion and problematisation.



231 **4. A comprehensive methodological proposal to operationalise anticipation**

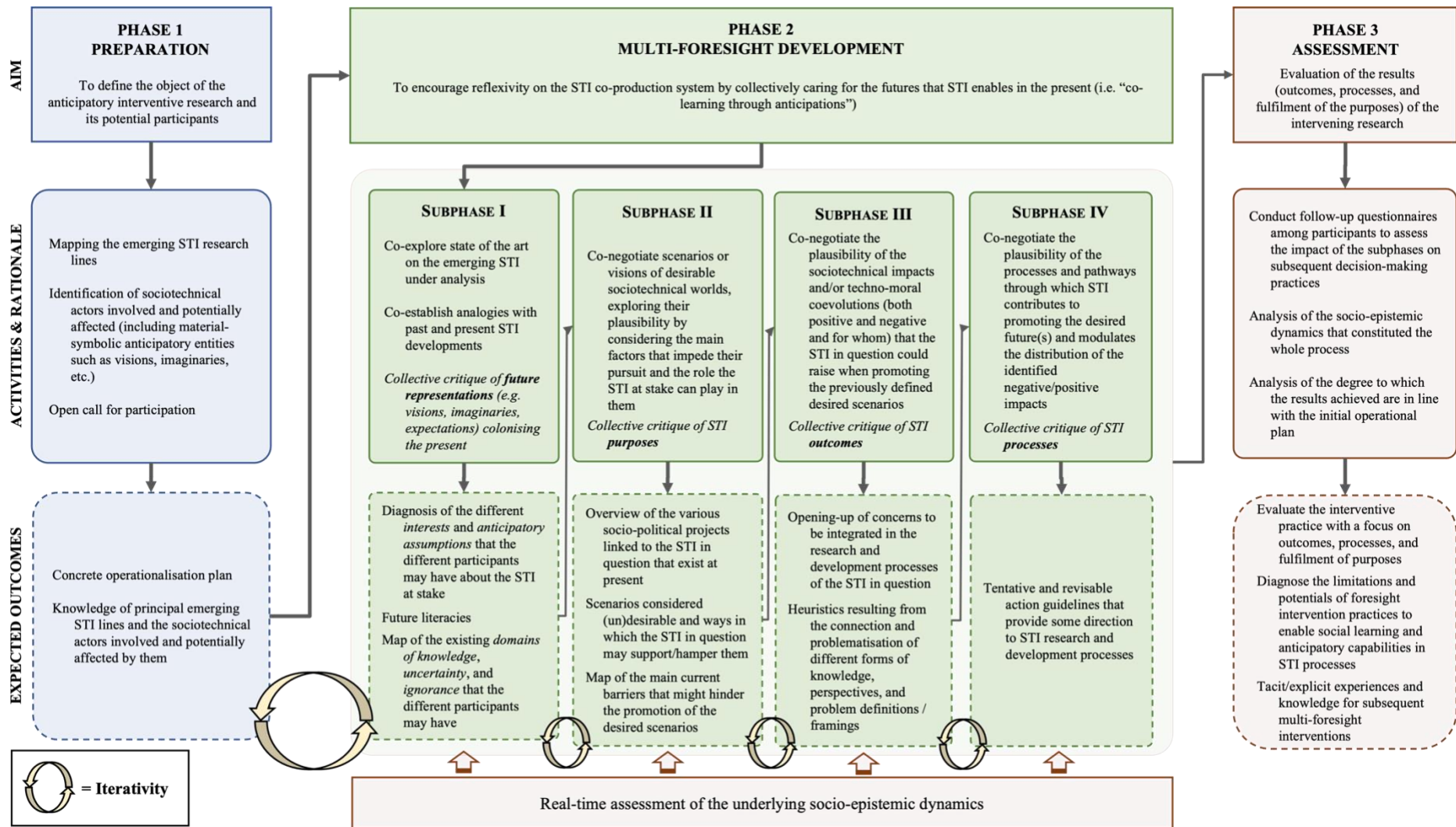
232 This section proposes a tentative structure of a (multi-)foresight process to support the  
233 operationalisation of AG, RRI, RI, and TA. This procedural anticipatory structure is  
234 presented as ‘a methodology of inquiry-in-interaction, which increases reflexivity of the  
235 [STI] developments’ (Rip and Robinson 2013, 37). The tentative structure of the multi-  
236 foresight exercise seeks to minimise the two main limitations identified above: (i) the  
237 fragmentation of foresight exercises in addressing the main challenges of AG, RI, RRI,  
238 and TA, and (ii) the problem of reifying futures.

239 While the problem of fragmentation is addressed through a systematic  
240 problematisation of the diverse STI domains (purposes, processes, and outcomes), the  
241 problem of the reification of futures is addressed through the integration of a critical-  
242 hermeneutic approach to future narratives and representations during the intervention.  
243 Since some degree of reification is inescapable, the enemy is not reification per se, but  
244 rather *uncritical* reification. The aim is to introduce ‘upstream’ reflexivity in STI  
245 practices through foresight so that the sociotechnical futures that are in constant co-  
246 production are anticipatorily shaped in the most transparent, inclusive, and reflective  
247 way possible (Jasanoff 2020).

248 It should be noted that the fact that the methodology proposed here aims to be  
249 less vulnerable to these two problems does not mean naively supposing that it will not  
250 be subject to the limitations and contingencies inherent in any interventive  
251 operationalisation. The exercise does not claim to be a solution or panacea. Instead, it is  
252 a tentative ideal-typical proposal that can be further critiqued and elaborated.

253 Ultimately, it aims to promote intervention mechanisms that, from their conception, are  
254 more sensitive to the reification of futures and attend to the politics of anticipation in  
255 which they are embroiled, and which are propagated through them.

256           The multi-foresight architecture proposed is structured in three phases: the *ex-*  
257 *ante* (phase 1), *ex-dure* (phase 2), and *ex-post* (phase 3). Phase 2 comprises the core  
258 activities for activating the anticipatory heuristic and is itself subdivided into four  
259 subphases (see Figure 1). The distinction between the subphases is determined  
260 pragmatically and heuristically by the STI domains that are primarily problematised and  
261 by the type of socio-epistemic activities required to carry out this problematisation.  
262 Needless to say, the STI domains to be problematised are constitutively interwoven.  
263 Problematisation in one dimension may influence problematisation in another. In this  
264 sense, and although the division of foresight dynamics into (sub)phases may make it  
265 appear that these have a linear progression, there might (and should) be intense iterative  
266 processes and feedback loops between them, resulting in multiple rounds of ongoing  
267 ‘social learning’. Indeed, iterativity, nonlinearity, and dynamism are widely recognised  
268 as characteristics of foresight exercises (e.g. Popper 2008, 45). Iteration is important  
269 because it allows going back and forth between the different (sub)phases. On the one  
270 hand, iterativity between the general phases is important so that foresight itself remains  
271 open to reformulation and enrichment throughout the whole process. On the other hand,  
272 iterativity between the subphases of phase 2 is important in order to make connections  
273 between the different STI domains that are problematised (i.e. outcomes, purposes,  
274 processes, visions/narratives/promises/expectations). In the following, these (sub)phases  
275 and their respective rationales are further elaborated.



276

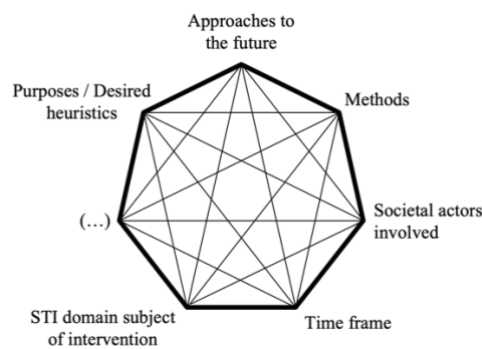
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**Figure 1.** General schema of the proposed methodological procedure for a comprehensive operationalisation of foresight/anticipation practice

278 *Phase 1: Preparing the interventive practice*

279 All interventive exercises begin with the delineation of the niche of intervention. The  
280 definition of this intervention niche involves consideration of at least (i) the field or  
281 domain or STI lineage that is the object of the intervening design, (ii) the actors who  
282 should or could a priori be involved in the exercise, (iii) the heuristics that it seeks to  
283 activate, and (iv) the techniques of engagement with representations of the future that  
284 will be used to this end. Clearly, these four elements, along with many others, are  
285 interrelated. The determination of each element has implications for the appropriate  
286 consideration of the other elements (Figure 2).

287



288

289

**Figure 2.** Interrelated factors in foresight practices.

290 The team conducting the interventive research needs to be particularly sensitive and  
291 self-reflective about the contextual factors that may influence their choices on these  
292 variables. Reflexivity is required insofar as their decisions will shape the alternatives  
293 that will be opened up or closed down and in relation to which aspects these apply

294

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296

297

One of the factors that require special attention in this process are the  
hermeneutic circles and sociotechnical meanings in which the anticipatory intervention  
may be entangled. As [Grunwald \(2020\)](#) argues, the choice of which technology or  
innovation to make the subject of assessment is often conditioned by the sociotechnical

298 meanings that have emerged around them. If an STI field has attracted the attention of  
299 certain scholars to consider it the target of their interventions, it is because there have  
300 been prior socio-political dynamics and a proliferation of meanings that have helped to  
301 elevate its importance as an object of responsibility. Deciding on the STI line for which  
302 the exercise is being conducted is already a first relevant closure point (it draws  
303 attention to a particular STI line to the detriment of possible others).

304 Another important factor is which actors should be involved in the foresight  
305 process to problematise the STI in question. A call for participation is inevitable—even  
306 if the call remains open. A key question is which actor profiles with their respective  
307 values, desires, expectations, capabilities, and knowledges will be primarily involved.  
308 Furthermore, there is a need to consider how the involvement of actors whose socio-  
309 material conditions do not allow or facilitate their participation can be supported.  
310 Closing-down the diversity of different contributions during the negotiation process  
311 may impoverish the concerns raised as well as reproduce prejudices and ‘business-as-  
312 usual’ practices. If the focus of the exercise is to promote the capabilities of specific  
313 actors (e.g. futures literacy capabilities), the question of which actors are given the  
314 opportunity to practise and improve these is non-trivial.

315 The ‘selection’ of participants is also important because the exercise is meant to  
316 involve all of them ‘during the whole process’ ([European Commission 2013b, 4](#); [von  
317 Schomberg 2013](#)). Obviously, this would be the ideal, and diverse constraints may limit  
318 inclusiveness. The participation of a plurality of actors is supported both by fulfilling  
319 the ‘inclusion/engagement’ normative dimensions of AG, RRI, RI, and TA (see Table  
320 1) and by promoting a more epistemically robust critique. While a plurality of voices  
321 does not guarantee such robustness, it is expected to enrich the range of perspectives  
322 and broaden central and hegemonic narratives ([Popa and Blok 2022](#)), minimise

323 potential epistemic and hermeneutic (Fricker 2007) or argumentative (Bondy 2010)  
324 injustices, and identify, make visible, and minimise potential biases in research (see  
325 Braun and Starkbaum 2023) and agenda-setting (e.g. Boudreau et al. 2016) processes.

### 326 *Phase 2: The multi-foresight process*

327 The second phase of the intervention exercise is considered the heart of the interventive  
328 process, as it is here that the possibilities of STI are discussed, and the anticipatory  
329 heuristics are closed/opened. It is in this *ex-dure* phase that the politics of anticipation  
330 are at play. These politics of anticipation are meant to be mobilised and scrutinised  
331 through negotiation processes regarding the (im)plausibility and (un)desirability of  
332 pasts, presents, and futures (Selin 2011). During these (im)plausibility and  
333 (un)desirability deliberations, a great heterogeneity of interconnected and contextual  
334 variables (e.g. epistemic, normative, axiological, emotive, aesthetic) come into play  
335 (Adam and Groves 2007; Selin and Guimaraes Pereira 2013; Ramírez and Selin 2014;  
336 Urueña 2019; Fenton-O'Creevy and Tuckett 2022). These variables may refer strictly to  
337 the STI under study and/or to more general concerns (e.g. visions and narratives  
338 encoding frames on cultural and political orders).

339 The multi-foresight exercise outlined here proposes to divide this heart of the  
340 process into four subphases, each of which focuses on facilitating engagement with the  
341 future under different modalities and dispelling temporality from different dimensions  
342 (see Table 3). The socio-epistemic activities facilitated in these subphases, as well as the  
343 challenges they target, determine (i) the scope and depth of the intervention. Similarly,  
344 the way in which engagement with the future is structured determines (ii) the gradients  
345 of uncritical reification of futures (i.e. which aspects are considered (im)plausible and  
346 (un)desirable and which aspects therefore become non-problematisable). On the one  
347 hand, in view of the problem of fragmentation, the multi-foresight exercise proposes

348 that its four subphases comprehensively address the main challenges that AG, RRI, RI,  
 349 and TA seek to address (Section 2). On the other hand, in the face of the problem of  
 350 uncritical reification, the exercise is structured in such a way that it encourages starting  
 351 the foresight process with a critical-hermeneutic approach to the futures and narratives  
 352 that colonise and enframe the present (first subphase) and prioritising normative or  
 353 visionary exploration over hypothetical-projective exploration (second subphase).

354 In the following, each of these subphases will be briefly explained. The focus is  
 355 on their respective justifications or their ideal-typical function in dealing with the  
 356 problem of fragmentation and minimising the problem of uncritical reification. The  
 357 scheme presented is generic enough to be re-adapted in different contexts and in relation  
 358 to different STI domains. At the same time, it is concrete enough to illustrate the  
 359 importance of the structure to anticipatory exercises. Structuring organizes the different  
 360 ways of engaging with the future and relates them to each other. This sequence and  
 361 relationships are key to intervening practices.

362

363 **Table 3.** General challenges raised in each subphase of phase 2, areas of temporality affected, and promoted modes  
 364 of engagement with the future.

<b>Subphases of phase 2</b>	<b>Principal challenge associated with responsible innovation</b>	<b>Main temporal domains involved</b>	<b>Type of engagement with futures</b>
<i>Subphase 2.I</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)	<i>Present:</i> Identifying current STI developments	<i>Critical-hermeneutic:</i> Identify and emancipate from futures colonisations in the present
		<i>Past:</i> Revisiting previous STIs, experiences  <i>Deflation of futures-in-the-present:</i> Identification and critique of promises, visions, expectations, imaginaries, and ‘endogenous futures’	
<i>Subphase 2.II</i>	‘II.’: To problematise the sociotechnical configurations, purposes, and orientations of the STI	<i>Present:</i> Analyse the available resources and the limits imposed by current sociotechnical orders and their materiality  <i>Future:</i> Opening-up of the set of sociotechnical desirable futures considered	<i>Exploratory:</i> Opening-up the desirable futures

<i>Subphase 2.III</i>	'I.': To explore the different impacts that might coevolve with the development of the STI	<i>Future:</i> Opening-up the range of issues and concerns considered regarding the STI at stake	<i>Exploratory:</i> Opening-up the potential impacts
<i>Subphase 2.IV</i>	'II.': To problematise the processes and orientations of the STI	<i>Future:</i> Draw up guidelines for current actions to promote the realisation of the desirable futures already problematised	<i>Strategic:</i> Outlining guiding actions

365

366 Subphase 2.I – Setting the stage of plausibility and desirability negotiations

367 The first subphase aims to prepare certain grounds for the subsequent negotiation of the  
368 plausibility and desirability of futures. These bases are intended to be established  
369 through the generation of reflexive dynamics that address both past and present  
370 temporality, as well as the critique of the futures-in-the-present that materialise in  
371 visions, expectations, and sociotechnical imaginaries.

372 As [Derbyshire and Wright \(2017\)](#) argue, many scenario-building exercises  
373 currently devote 'little attention to the consideration of either the present state or how it  
374 has come to be', even though the treatment of the past and present can generate many  
375 heuristics that can be particularly valuable for STI responsabilisation. Given that the  
376 lenses or assumptions through which we look at the past and present are multi-layered  
377 (different actors could underline different dimensions of the present and the past), and  
378 many of the discrepancies about the future will be driven by divergences of the present  
379 and past, it is necessary to address and co-negotiate the plausibility of these from the  
380 outset.

381 The aim of fostering dynamics of reflection on the current state is not so much  
382 intended to establish a common ground (i.e. to impose a uniform or monolithic state of  
383 the art), but rather to consider the different perspectives on the present from which  
384 actors perceive and interpret reality; both in relation to the sociotechnical system in  
385 which the intervention takes place, and more specifically in relation to the STI at stake.  
386 Indeed, it has been recognised in the literature that the plausibilisation of other futures



387 also depends on the plausibilisation and possibilities of reframing the presents (Urueña  
388 2019; Fischer and Dannenberg 2021).

389 It might also be particularly fruitful to problematise how we relate the past to the  
390 present of the STI in question, as well as the past to its future. Schwarz-Plaschg (2018a,  
391 153), for example, has pointed out how analogies from the past (i.e. comparisons of the  
392 past and the present) are used ‘to make arguments and enforce framings’. She has also  
393 highlighted how analogical imagination and enhanced analogical sensibility can help  
394 promote RRI (Schwarz-Plaschg 2018b). The case of nanotechnology is a clear example  
395 of a non-presentist field where the use of both the pasts and futures has helped to  
396 mobilise the imaginations and opinions of different publics (favourable or unfavourable  
397 to legitimise nano-development) (Mody 2004; Selin 2006; Schwarz-Plaschg 2018b).  
398 Despite the value of past knowledge for STI responsabilisation, there are calls to  
399 increase both the use of this knowledge and its problematisation (Zimmer-Merkle and  
400 Fleischer 2017). The inclusion of past temporality intended here also underlines this.

401 The case of the use and mobilisation of analogies illustrates that the colonisation  
402 of the spaces of plausibility and desirability is not carried out by future representations  
403 alone. However, this does not mean that the latter are excluded. The inclusion of the  
404 problematisation of futures-in-the-present is intended to prevent the performative power  
405 of promises, expectations, and sociotechnical imaginaries from limiting the later  
406 explorations of the multi-foresight process. As Groves (2013, 186) notes, ‘technological  
407 future imaginaries may help to prevent scrutiny of assumptions about innovation  
408 pathways and to exclude alternative visions of the future from discussion, thus making  
409 progress on the procedural elements of RRI more difficult’. The proposed  
410 problematisation of these artefacts from the outset aims to enable a basic form of  
411 ‘futures literacies’ (Miller and Sandford 2019) that neutralises *as much as possible* their

412 power to reify certain possibilities and thus impede the opening-up of alternatives to be  
413 considered in later subphases. While it would be naïve to assume that these artefacts  
414 will no longer have power in subsequent phases, it is possible to assert that the  
415 necessary and possible mechanisms have been created to ensure that their impact is  
416 lessened as much as possible.

417

418

419 In conclusion, this first subphase activates the negotiation of plausibility as an epistemic  
420 process in the service of critically opening-up the past, present, and futures-in-the-  
421 present that de facto colonise and modulate the way we imagine, explore, and confront  
422 reality. This first subphase is ultimately proposed as a social learning exercise aimed at  
423 opening/acquiring capacities for opening-up the representative artefacts that, exploiting  
424 temporality in each historical moment, constrain our explorations and visions of the  
425 future, thereby closing-down the spaces of possibility deemed desirable and plausible.  
426 The purpose is to operationalise the demand to begin every exploration by such critical  
427 assessments ([Grin and Grunwald 2000](#); [Nordmann 2014](#)), as well as to offer a response  
428 to calls for the introduction and promotion of hermeneutic anticipation ([van der Burg](#)  
429 [2014](#); [Grunwald 2020](#)).

430

#### 431 Subphase 2.II – Giving our STI practices a desirable and plausible direction

432 In contrast to exploratory foresight exercises that start from ‘product scenes’ and  
433 problematise their (un)desirability and (im)plausibility later, this second subphase of the  
434 multi-foresight exercise aims to problematise upfront the problems, challenges, or  
435 purposes with which we align the STI. Ultimately, the aim is to discuss the  
436 sociotechnical and techno-moral worlds to which the STI is expected to contribute and

437 the ways in which it can/could contribute to them. This way of structuring the debate  
438 prioritises discussion of the plausibility and desirability of the problem-framing and  
439 policy purposes underpinning the STI in question over exploration of its potential  
440 impacts. The aim is to address the problem already explicitly identified and criticised by  
441 [von Schomberg \(2012, 7\)](#):

442

443 [F]oresight projects could benefit from a prior analysis of potential relationships between  
444 types of plausible technological pathways and particular (social) problem-definitions, rather  
445 than starting with ‘naïve product scenes,’ (...) thereby methodologically ignoring the  
446 underlying problem definitions.

447

448 Suppose we co-design an anticipatory process. Its first exercise consists of co-projecting  
449 and negotiating the (im)plausibility and (un)desirability of sociotechnical scenarios that  
450 could arise from stratospheric sulphate injection as a measure in the face of climate  
451 change. These scenarios will depict diverse negative and positive configurations that the  
452 various participants are able to envision and justify. However, once we enter the debate  
453 on the (im)plausibility and (un)desirability of these scenarios, we would be doing so not  
454 only at the expense of taking the technology itself as plausible but also indirectly  
455 accepting a way of dealing with the climate change problem that can and should be  
456 explicitly problematised. For example, we would be assuming the Enlightenment  
457 paradigm of technological solutionism, where the solution is posited as technical rather  
458 than sociotechnical and organisational. The ‘product scene’ enframes a definition of the  
459 problem and its corresponding resolution. The problem is climate change, and it is  
460 enframed as a technical problem—thus with its corresponding technical solution. The  
461 solution is to solve the effects of climate change by minimising the effects caused by  
462 our current forms of industrial production. The ‘product scene’ presents a solution to  
463 one of our Grand Challenges, but it frames those solutions so that it shields the causes

464 of the problem from problematisation, focusing only on counteracting the effects. It  
465 situates us in a scenario where the aim is to solve the effects of climate change caused  
466 by our current systems, but without promoting a fundamental debate on the necessity  
467 and relevance of changing our current sociotechnical systems and their productive  
468 constellations. This way of framing the problem subtly promotes the reification or  
469 perpetuation of the same organisational scheme that causes the problem by not  
470 promoting the conception of alternative socio-economic and techno-industrial forms of  
471 organisation that would address or minimise the problem at its root.

472         The absence of an explicit opening-up mechanism to unpack the potential  
473 relationships between types of plausible STI pathways and particular problem  
474 definitions would entail leaving it to chance whether these relationships are maintained  
475 or transformed. The aim of interventive anticipatory exercises is not to leave these  
476 issues to chance, but to promote reflexivity as deeply as possible ([Guston 2014](#)). The  
477 aim of subphase 2.II should therefore be to explicitly de- and reconstruct the problem  
478 definitions and the STI purposes these embody. This includes, for example, questioning  
479 the extent to which these problem definitions and STI purposes correspond to the  
480 wishes, expectations, and interests of the social actors involved. The proposed critique  
481 should be not only deconstructive but also constructive. The exercise has to remain  
482 open to the suggestion of alternatives. If there are voices that consider the STI purposes  
483 and issues to be ‘implausible’ and/or ‘undesirable’, these voices should suggest  
484 ‘plausible’ and ‘desirable’ ones as a counterpoint.

485         This collective problematisation of the futures considered ‘(un)desirable’ and  
486 their grounds/frames can obviously lead to the activation of problematisation processes  
487 that will require calling on or revisiting the results of the previous subphase (e.g. taking  
488 into account the extent to which narratives and meanings close the purposes).

489 Furthermore, this problematisation may also require activating socio-systemic processes  
490 that would correspond to the next subphase (e.g. conducting risk explorations of either  
491 the socio-technical project in question or of those alternatives considered most  
492 desirable). It is therefore expectable that iterative and back and forth processes will exist  
493 between these subphases. The rationale for placing this subphase in this second position  
494 within the structure is to prevent problem definitions from uncritically pre-setting  
495 possibility spaces outside of which alternatives cannot be envisaged.

496

#### 497 Subphase 2.III – Enriching our normative futures

498 Once the futures deemed desirable have been explored, it is important to enrich them  
499 with reflections on the possible negative/positive outcomes that might arise both in the  
500 process of pursuing these futures and in the hypothetical situation in which these  
501 become a reality (to some degree).

502         The reason for such hypothetical-projective explorations lies in the need to  
503 problematise that the pursuit of a desirable future is neither neutral nor free from  
504 tensions or imbalances. As [Adam and Groves \(2007, 2011\)](#) observe, any form of future-  
505 making is a form of future-taking, and even the future(s) negotiated as ‘desirable’ would  
506 not be free of depicting and embracing power asymmetries. This process aims precisely  
507 to explore the sociotechnical and techno-moral co-evolutions that might occur.

508 Questions around (i) what effects there might be (e.g. effects on techno-moral or  
509 sociotechnical orders) and (ii) what the distribution of these effects is (e.g. for whom  
510 they are seen as positive or negative and under what conditions) would be the subject of  
511 social examination and enrichment. This phase is thus ultimately about enriching the  
512 normative futures co-negotiated in subphase 2.II through reflexivity.

513           At this point, one might ask whether the exercise does not reify the normative  
514 future(s) dealt with in subphase 2.II. The answer is that a certain degree of reification is  
515 unavoidable. If any kind of action is to be anticipatorily informed, it is necessary to  
516 close the space of possibilities under consideration. In this sense, the problem here is  
517 not so much reification per se, but *uncritical* reification. In other words, the problem is  
518 the reifications produced on the basis of futures that are little discussed and negotiated,  
519 and thus on futures with little socio-epistemic and socio-political legitimacy. The multi-  
520 foresight process therefore aims to minimise this problem by discussing the  
521 consequences within futures that have been previously problematised.

522           The futures of subphase 2.II that set the frame of this subphase 2.III, however,  
523 must be kept open for re-examination. The results of subphase 2.III may lead to a  
524 reconsideration of the visions of desirable futures themselves by reactivating the  
525 previous subphase.

526

#### 527 Subphase 2.IV – Co-creating action plans

528           The fourth and final subphase has the difficult task of translating all the heuristics  
529 coming from the previous opening-up processes into practical guidance for the STI  
530 exercises. Ultimately, as is common in strategic and visioning exercises, the aim is to  
531 create an execution plan. This essentially consists of identifying how, given the  
532 resources available and the diagnosis of the current situation previously established in  
533 subphase 2.I, actions can be triggered to promote the emergence of the negotiated  
534 plausible and desired future(s).

535           There are at least two aspects of this *ex-dure* subphase that are important to  
536 comment on. The first refers to the need to keep the implementation plan under  
537 continuous review, as an open plan. This is important to be able to adapt it to the

538 contingencies that emerge during the process. Moreover, it is also important to insist  
 539 during the mediation process that processes and plans are fallible in nature, and their  
 540 significance is merely heuristic-orientational. Even when the outlined plan is accurately  
 541 followed, it is important to emphasise that the desirable future may not be achieved  
 542 (although following the instructions will more likely approximate this than otherwise).  
 543 Ultimately, these forms of mediation are important to prevent the multi-foresight  
 544 exercise from falling into the illusion of looking at the future as a space that can be the  
 545 target of our design. The future, in this sense, must be maintained throughout the  
 546 process as a space that is intrinsically uncertain, complex, contingent, and relatively  
 547 open.

548         The results of subphase 2.IV may lead to revisions of the futures or visions  
 549 considered plausible and desirable, or of the specific issues considered in these. As a  
 550 result, it may be possible to return to earlier stages of the multi-foresight process (e.g.  
 551 revisiting the findings of subphases 2.II and/or 2.III).

552 *Phase 3: Foresight dissemination and assessment*

553 The third phase includes all the activities that take place after the completion of the  
 554 multi-foresight exercise. These *ex-post* activities focus mainly—but not only—on (i) the  
 555 dissemination of the results and (ii) the systematic and mainly qualitative (although it  
 556 may be complemented by quantitative data) monitoring and evaluation of the foresight  
 557 processes, outcomes, and purposes (Table 4). The systematic and *ex-post* nature is  
 558 precisely what distinguishes this evaluation from the evaluation that could (and should)  
 559 be carried out in real time throughout the whole operationalisation process.

560

561 **Table 4.** Examples of key questions to address during the foresight assessment process

Examples of key question(s)	Potential key heuristics
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<b>Processes</b>	<ul style="list-style-type: none"> <li>• What underlying dynamics of anticipatory knowledge co-creation underpinned the exercise?</li> <li>• How were the various anticipatory capabilities intended to be developed or reinforced?</li> <li>• Which/whose voices were heard/silenced, which/whose capacities were enhanced, and which/whose spaces of possibility were selected/discarded, and on what grounds</li> </ul>	<p>Identification of power dynamics and hampering (f)actors functioning during anticipation processes</p> <p>Types of relationships and their respective qualities and asymmetries (e.g. identifying instances of argumentative and epistemic injustices)</p>
<b>Outcomes</b>	<ul style="list-style-type: none"> <li>• What heuristics and/or anticipatory knowledge or capabilities were de facto activated? (in the long/medium/short term)</li> <li>• Did the hegemonic dynamics and realities of STI change? Which ones? When? To whom and in what sense?</li> </ul>	<p>Knowledge about the emergence of immediate, intermediate, and final heuristics (including those unexpected or undesired) and how they evolved in time (whether they were reinforced, atrophied, or maintained)</p> <p>Identification of the actors who benefited (or not) from the results and in relation to which aspects</p>
<b>Purposes</b>	To what extent do the outcomes match the initial operationalisation plan?	Reflection on the intervening performance and the adequacy of the initial operationalisation plan

562

563 The realisation of this assessment would have as a necessary condition the creation of  
564 documentary records of the processes (e.g. audio, video, field notebooks). These data  
565 and records could then be analysed and interpreted using various well established  
566 qualitative research methods in the social sciences and humanities—especially those  
567 typically applied in the STS. Conducting this process evaluation could serve to draw  
568 practical operational lessons to feed into subsequent anticipation exercises.

569 **5. Conclusions**

570 AG, RI, RRI, and TA propose anticipation as a key dimension through which to shape  
571 more responsible innovation. This paper has provided an exploratory overview of how  
572 anticipation has been operationalised recently for AG, RI, RRI, and TA. This overview  
573 points to an operational fragmentation in addressing the theoretical challenges  
574 associated with anticipation. In theory, anticipation is mobilised to delve into at least  
575 three interrelated challenges: Enabling a socio-politically robust exploration of STI (I.)  
576 outcomes (‘positive’/‘negative’, ‘soft’/‘hard’), (II.) purposes and processes, and (III.)  
577 critiquing the performative power of STI visions, imaginaries, promises, and  
578 expectations. However, in practice, anticipation is carried out with a narrow focus on a



579 few of these challenges (thus leaving challenges and issues unproblematised and subtly  
580 promoting reification of some frames and futures).

581         The heterogeneous and simultaneously fragmented nature of anticipatory  
582 practices has motivated the proposal of a flexible and general qualitative foresight  
583 process. The foresight process outlined here proposes to structure the exercise from its  
584 very inception into self-reflexive processes regarding how the framing of the  
585 interventive exercise is itself framed and fixed (phase 1, ex-ante). This means, among  
586 other considerations, that the openness and closure mechanisms involved in the  
587 selection of the STI as a target for intervention (to the detriment of others) or in the  
588 invitation of actors to participate in the process should be critically considered. Let us  
589 imagine that in this first or ex-ante or preparatory phase, it was decided to carry out the  
590 anticipatory exercise on stratospheric sulphate injection as a sociotechnical measure in  
591 the face of climate change. Moreover, a heterogeneous group of actors have been  
592 reflexively and critically identified and invited to participate in order to have different  
593 perspectives and interests among these actors (in relation either to this technology in  
594 particular or to more general concerns).

595         The next phase (i.e. phase 2, ex-dure) would encompass the socio-epistemic and  
596 deliberative processes for the activation of anticipatory heuristics. The structure  
597 proposes to initiate the process by enacting a critical-hermeneutic approach (subphase  
598 2.I). This approach would include activities focused on collectively identifying the lines  
599 of research that point to the development of this STI, reviewing similar technologies  
600 that are occurring in the present or have occurred in the past, and in particular critiquing  
601 the frames, narratives, and futures (e.g. visions, imaginaries, promises) that are  
602 mobilised in relation to this STI. The goal is to problematise the (perspectives on) past  
603 and current state of affairs and simultaneously to avoid (or minimise) that the

604 assumptions and frames underlying the futures that are mobilised in the present  
605 uncritically foreclose the space of potentially conceivable alternatives in later  
606 subphases. The issues addressed and aspects that emerge will contingently depend on  
607 each process and the mediation performed. However, one might expect, for example,  
608 the identification and problematisation of the myth of technological solutionism or  
609 technical hubris that underlies this STI in the face of the climate change challenge.

610         The next subphase (2.II) would address considerations of the (im)plausibility  
611 and (un)desirability of this sociotechnical project by focusing on the purposes  
612 underlying its development. This would include problematising the values and  
613 sociotechnical orders that this sociotechnical project could (re)produce or the normative  
614 frameworks that it contains, as well as assessing their (un)desirability. For example, it  
615 would be pertinent to question the extent to which this technological project does not  
616 reproduce or perpetuate the very socio-economic orders that have caused the problem it  
617 seeks to address (i.e. climate change), in what ways and in what gradations different  
618 actors benefit or are disadvantaged by it, and to what extent alternative STI projects or  
619 ways of addressing the problem are (im)plausible and (un)desirable. The aim is to open  
620 up a variety of alternatives (and to discuss the reasons justifying them).

621         Once the (un)desirability and (im)plausibility of the sociotechnical orders and  
622 normative frames that the STI project might encode and promote have been assessed,  
623 the intervention may follow different paths depending on its constitutive and contingent  
624 dynamics. These pathways cover a spectrum of possibilities ranging from declaring  
625 stratospheric sulphate injection to be completely undesirable and proposing alternative  
626 STIs and approaches to climate change, to considering its partial desirability and  
627 proposing only some revisions. The next subphase (2.III) would focus on assessing and  
628 enriching these alternatives/revisions to stratospheric sulphate injection discussed

629 earlier by problematising their respective potential outcomes (in the broadest sense).  
630 The last subphase of this second phase (2.IV) would focus on clarifying and  
631 problematising the different processes that could be activated (and the associated  
632 difficulties) for promoting the desirable futures deliberated on in 2.II and enriched in  
633 2.III.

634 Finally, the anticipatory procedure is recommended to be completed by a follow-  
635 up exercise (e.g. interviews, surveys, field studies) to assess the scope and depth of the  
636 capacities and/or heuristics co-shaped (phase 3, *ex-post*).

637 This methodological structuring is ultimately designed to respond both to the  
638 fragmentation regarding the STI dimensions that are problematised (i.e. outcomes,  
639 processes, purposes) and to the need to ensure that the problematisations of STI through  
640 futures ‘begin with vision assessment’ (Nordmann 2007, 41). The ‘upstream’ (meta-  
641 )reflexivity that should guide the foresight process renders it less susceptible—though  
642 never immune—to the uncritical reification of visions, imaginaries, and expectations.

643 While the course of the process from subphase 2.I to 2.IV acquires a certain  
644 directionality, in practice the process does not need to be (nor is it desirable for it to be)  
645 strictly linear. Each of the subphases could lead to a revision of the results of the  
646 previous subphases, which supports back-and-forth learning processes and thus  
647 accommodates iterativity. It is obvious that the problems of purposes, outcomes, and  
648 processes are constitutively interconnected. The open and iterative nature of the  
649 architecture allows for transitions between the critical reflective activities that  
650 characterise the different subphases of phase 2, thus enabling interrelated  
651 problematisation of the different dimensions and challenges of the STI at stake.  
652 Iterativity can be extended indefinitely and concluded in accordance with the final  
653 implementation schedule of the intervention project.

654           This structure is flexible and general enough to be adaptable both to the various  
655 constraints that may limit the intervention project (e.g. time, material and human  
656 resources, the context) and to the specific needs of the STI in question. For example, it  
657 can be conducted in one or several interactive workshops, depending on available  
658 resources and needs. However, the architecture is specific enough to promote a diversity  
659 of socio-epistemic activities that allow for an intersecting, reflexive, and critical  
660 approach to the different dimensions and challenges of STI (i.e. outcomes, processes,  
661 goals) and for minimising the reification of hegemonic futures and narratives related to  
662 STI (e.g. imaginaries, visions, expectations).

663           The proposed procedural anticipatory architecture is, of course, neither a  
664 panacea nor a guarantee for the promotion of responsible STI, nor is it intended to be.  
665 The heuristic disruptiveness of the practices consistent with the architecture will  
666 inevitably be modulated by the socio-material constraints and resistances imposed by  
667 the prevailing trends of the sociotechnical milieu in which these practices are embedded  
668 and which they seek to transform ([Uruña et al. 2021](#); [Uruña 2022](#)). The purpose and  
669 contribution of the anticipatory structure is that it stimulates and affords by its very  
670 design a broader problematisation of STI.

671           By emphasising the importance of the design and procedures that constitute  
672 anticipatory-interventive practices, the article has highlighted the responsibility of social  
673 scientists in shaping and opening certain spaces of reflection (while closing others)  
674 therein. The emphasis is on attending to the futures or sociotechnical worlds, and STI  
675 pathways that are (not) envisaged and problematised throughout anticipatory  
676 interventive process (i.e. on attending to the spaces of (im)plausibility and  
677 (un)desirability that are prefixed). As such, this article constitutes a further tentative  
678 step in inquiring into the relations between the politics of anticipation and the

679 architectures of anticipatory methodologies (Macnaghten 2021). If this article  
680 prescribes anything, it is first and foremost that there is a need to further problematise  
681 how interventive anticipatory tools can be developed to assist in the difficult but  
682 laudable task of shaping better future sociotechnical worlds through the shaping of more  
683 socio-politically robust STI practices.

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