Understanding "plausibility": A relational approach to the anticipatory heuristics of future scenarios

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ABSTRACT

The creation of future scenarios is considered a valuable methodological tool for shaping the anticipatory governance of emerging technologies. Although plausibility is presented as a necessary (but not sufficient) criterion for assessing future scenarios, there is no consensus on its meaning or operationalization. The main objective of this paper is to contribute to clarifying the meaning of plausibility and the theoretical role it plays in the application of scenario building practices to technological governance. In particular, I will argue that plausibility can be understood as a methodological criterion and as an anticipatory-enabling 'epistemic device.' In this sense, I support the value of theoretically distinguishing between the methodological-limiting and the anticipatory-enabling roles of plausibility in foresight practices.

Keywords: Plausibility, Future Scenarios, Anticipation, Epistemology, Heuristics, Technological Governance

1. Introduction

The exploration of potential futures has always been of central interest to Futures Studies. However, the principal objectives, assumptions, and methods employed to conduct the relevant activities have changed over time (Son, 2015; van der Duin, 2006). In its early stages, Futures Studies sympathized with the predictivist approach (which clarifies the expanded use of the concept "forecast" at the time) (e.g., Ayres, 1969; Lenz, 1962), but most of the academic community abandoned this orientation after the rise of the "alternative futures" perspective (e.g., Miles, 2008; Millet, 2003; Bell, 1974). Currently, Futures Studies seem to be more constructionist and pragmatic in nature (Chiasson, Davidson, & Winter, 2018; Fuller & Loogma, 2009). In the dominant (but not exclusive) approach, practicing foresight does not aim at reducing uncertainty about the ways that socio-technical systems will co-evolve, but it points out the range of alternative futures to enhance resilience and proactively consider them as sources for present decision-making (Sardar, 2010).

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

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

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

Among the various criteria currently proposed, the concept of "plausibility" has been presented as central to the development of scenarios (Wilson, 1998), particularly those that aim to support the anticipatory governance of socio-technical systems (Selin & Guimarães Pereira, 2013). However, despite its popularity and centrality, this concept has not sufficiently been studied, discussed, or clarified. Ten years after the debate about plausibility began (Selin, 2011), and more than five years after the publication of the special issue on plausibility in *International Foresight and Innovation Policy* (2013, vol. 9, nos. 2/3/4), two broad questions on plausibility's criteria remain largely unaddressed. The first question relates to the theoretical-conceptual basis of plausibility (i.e., "What does plausibility refer to?"), and the second question relates to its operationalization for evaluating scenarios (i.e., "How can and should the plausibility of a scenario be assessed and determined?").

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

The main objective of this paper is to contribute to clarifying the meaning of plausibility and the theoretical role it may play in scenario building practices applied to technological governance. In particular, I will argue that plausibility can be understood as (1) a methodological criterion, and (2) as an anticipatory-enabling 'epistemic device.' In this sense, I support the value of theoretically distinguishing between the importance of distinguishing between the anticipatory-enabling and the methodological-limiting roles of plausibility in foresight practices. The purpose is to clarify and strengthen the concept of "plausibility" in socio-technical scenarios by analyzing some of its most significant theoretical dimensions and enlightening its epistemic meaningfulness to science and technology governance. The relational approach used below is expected to clarify some of the problems around the topic and underline the need to explore some lines of research that it opens.

This paper is organized into three main sections. Following this introduction, I propose a characterization of future scenarios as representations about the future and identify their main components. Then, I discuss the issue of the epistemic quality of future scenarios with a focus on the concept of "plausibility." Next, I point out some consequences of the previous analysis for supporting the anticipatory governance of emerging technologies. The paper ends with a series of conclusions.

2. Setting the stage: Exploring scenario components

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

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

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

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

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

$$(S_i + \{e\}) \rightarrow \{S_f\} \qquad\qquad\qquad (Eq.\ 1)$$

For example, suppose a group of people is invited to create scenarios about the future that could open up the possibility of introducing humanoid robots to the hospital they use and/or work in. At this point, the participants could model their current hospital (the starting scenario S_i), considering their knowledge about how the hospital actually works, their knowledge and assumptions about humanoid health robotics, their expectations about how this hospital would change ($\{e\}$), and so on. During this modelling process, participants could use different types of inferences ($\rightarrow$). For example, they could use deductive thinking (reasoning from general rules to specific conclusions) by concluding that, if all hospitals have patients and they are imagining a hospital, then all scenarios of their future hospital should include patients. Another possibility is that they use inductive reasoning (reasoning from specific observations to general conclusions) to produce a scenario wherein their hospital has been transformed in a manner similar to other hospitals where humanoid health robots have already been implemented. Finally, the participants could also create scenarios following abductive or imaginative reasoning (reasoning from incomplete and uncertain information to plausible general conclusions) in which their hospital becomes more efficient but loses staff, changes its care practices, and so on.

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[1] Please note that the symbol "$\rightarrow$" does not aim to represent a logical implication. This means that it does not attempt to represent a relation of logical necessity and consequence between $\{S_f\}$ and $(S_i + \{e\})$, but simply an inferential process that goes from the premises $(S_i + \{e\})$ to the conclusion $\{S_f\}$.
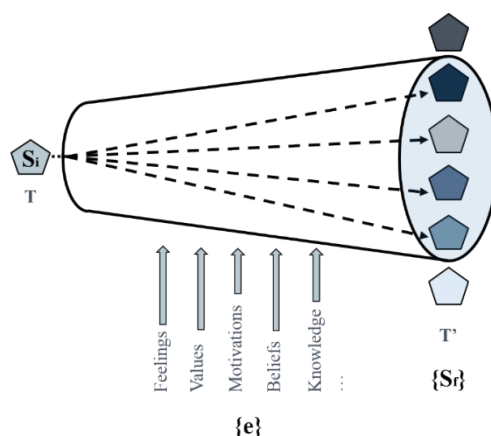
Fig. 1. Scenario cone depicting multiple possible scenarios ($\{S_f\}$) applied to the $(S_i + \{e\}) \rightarrow \{S_f\}$ scheme

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

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

Table 1. Examples of scenario formation that depend on the temporal dimension of the initial scenario (S_i)

As Table 1 illustrates, the introduction of time variables in Eq. 1 opens up a multiple scenario typology. Considering the possible time horizons in which S_i and S_f might be situated (i.e., T and T', respectively), nine general types of scenarios could be developed: past-S_f, present-S_f, or future-S_f scenarios (T') generated from past-S_i, present-S_i or future-S_i scenarios (T) (i.e., {past-S_i, present-S_i, future-S_i}×{past-S_f, present-S_f, future-S_f}). In addition, this variety could be augmented if the ontological character of all these scenarios is considered as a variable. For instance, although future-S_i/S_f scenarios may always be contemplated as fictional because their ontological value cannot be firmly established in the present, both past-S_i/S_f and present-S_i/S_f scenarios could have a real or a fictional character depending on whether they represent a past that has occurred or a present situation that is occurring.

Despite the cognitive possibility of creating this wide variety of scenarios, the scope of Future Studies does not usually include all of them. First, in relation to '$\{S_f\}$,' the Futures Studies community –as its name suggests– seems especially interested in the generation of narratives whose T' is in the future (i.e., in future-S_f scenarios). Second, in relation to 'S_i', although it is possible to generate these future-S_f scenarios from past-S_i (fictional or real), present-S_i (fictional or real), or fictional future-S_i situations (T), scenario practitioners who seek to explore the window of future possibilities generally

do not use *fictional* past-S_i or present-S_i scenarios (i.e., counterfactuals or alternative present-worlds) as starting points. This does not imply that there is no need of (historical) retrospection or potential benefits in working with those kinds of "worlds." Indeed, as Booth et al. (2009) recognize, counterfactuals may contain heuristic power similar to future scenarios (e.g., they may be thought-provoking and emphasize contingency). However, as far as counterfactuals point to states of affairs "that were previously possible *but are no longer possible*" (Byrne, 2005: 1, emphasis added) and alternative present-worlds point to unreal present worlds, these narratives seem to have severe limitations as resources for illuminating robust realizable future possibilities. That is, we can hardly explore a robust window of probable, possible, and/or plausible futures *in our actual world* if we start the exploration *into the future* by 'extending' or modelling worlds that we recognize from the beginning as unreal and/or impossible. In the same way, taking future-S_i scenarios as a starting point may be problematic: it seems arduous to assess the credibility of a future-S_f scenario that has been created from a future-S_i scenario whose ontological value –as I mentioned before– cannot be recognized or firmly established in the present (Nordmann, 2013).

Instead, future scenario practitioners may use real past-S_i or present-S_i situations as a starting point in order to create two or more alternative future-S_f scenarios (van der Heijden, 2011). However, if future-S_f scenarios generated from past-S_i situations have to be modeled extremely realistically until they reach the present (in order to maintain credibility and prevent working with counterfactuals or creating alternative presents), then it may be preferable to start the representation process directly from present-S_i situations (i.e., from "now"). This preference does not imply that past data, facts, or narratives are ignored or that the heuristic value of including historical analogies (Schwarz-Plaschg, 2018) in the formation of scenarios is rejected. Indeed, one should always consider in {e} data referring to all the three parts of the timeline as a matter of principle when modeling robust future-S_f scenarios.[2] As Selin (2006: 8) points out, "[g]ood scenarios are typically buttressed with oodles of *quantitative, historical and contextual data. Varied rates of change, demographics, economic trends, statistics and other 'hard' indicators are included* to enhance the overall credibility of the scenarios" (emphasis added). Nevertheless, one should distinguish between the 'temporal location' of some data used for creating S_i (i.e., to which part of the timeline {e} refers) and the 'temporal location' of S_i (T) from which the modeling process of the future scenario starts.

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

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

3. Evaluating future scenarios: Plausibility as an anticipatory-enabling epistemic device and as a methodological-limiting criterion

If future scenarios are not normally created as ways to know or describe *what will happen*, but are intended to explore *what might be* to improve reflexivity in the present (Klein, Snowden, & Pin, 2011; Mietzner & Reger, 2005)*,* then the assessment of future scenarios does not (or should not) rely on epistemic categories such as *truthfulness* or *verisimilitude* (Selin & Guimarães Pereira, 2013; Selin,

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[2] I would like to thank an anonymous reviewer for this helpful remark.

2011; Guimarães Pereira, Von Schomberg, & Funtowicz, 2006). In other words, the classical epistemic criteria used to evaluate the *relationship* between a representation and what it represents should be relinquished for at least two primary reasons. First, it is not always possible to have precise knowledge of the future, and, second, the purpose is not to know the future, but first to open it (i.e., to explore the window of plausible and desirable futures) and then to 'close it down' by guiding the decision-making processes. To determine the specific scenarios worthy of consideration for decision-making, other criteria beyond those linked to the concept of correspondence should be proposed. The burning key questions are which ones and how should they be understood and operationalized.

3.1. Plausibility in "the jungle of qualifiers"

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

In this "jungle of scenario qualifiers," at least two major groups of indicators can be distinguished: those that are focused on evaluating the robustness of the scenarios as *products* (i.e., focused on S_f) (identified herein as "1") (e.g. Amer, Daim, & Jetter, 2013), and those that are focused on evaluating the scenario creation *processes* (i.e., focused on "$(S_i + \{e\}) \rightarrow \{S_f\}$" situated in a broad context of action) (identified herein as "2"). Moreover, among the indicators focused on evaluating the representational products $\{S_f\}$, it is possible to find indicators that evaluate $\{S_f\}$'s internal (identified herein as "1a") and external (identified herein as "1b") relationships (Amer, Daim, & Jetter, 2013: 36, Table 7). Both general approaches are compatible and might complement each other, but it is theoretically interesting to note that each focuses on different dimensions of the scenario formation scheme "$(S_i + \{e\}) \rightarrow \{S_f\}$" and its implementation.

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

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

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

- Consistency: Some scenarios contained in $\{S_f\}$ could be integrated or combined
- Possibility: S_f or $\{S_f\}$ are theoretically able to come into existence (i.e., there are no known primitive or elemental physical and/or technical constraints of S_i that may contradict S_f/$\{S_f\}$'s potential occurrence)
- Probability: From certain initial conditions 'S_i' and our knowledge and expectations (included in $\{e\}$) about how that S_i will evolve and what of S_i will or will not change and remain constant, S_f/$\{S_f\}$ are objectively/subjectively likely to happen

- Feasibility: S_f or $\{S_f\}$ are achievable (i.e., there are no known or expected contingent, and specific social, legal, economic and/or political conditions of S_i included in $\{e\}$ that could hamper $S_f/\{S_f\}$'s realization)
- Plausibility: S_f or $\{S_f\}$ are derivable or can be arguably inferred or concluded from the initial conditions $(S_i + \{e\})$; i.e., if we agree that $(S_i + \{e\})$, then…
  - *it is reasonable to believe* that S_f or $\{S_f\}$ *could happen* (Wilson, 1998)
  - S_f or $\{S_f\}$ are *trustworthy* (Selin, 2006)
  - S_f or $\{S_f\}$ are *credible* (Nordmann, 2013; van der Helm, 2006)

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

The following are examples among the indicators of "2," which are focused on evaluating the representational quality of the scenario generation *processes* (i.e., "How well does the exploration of the future, $(S_i + \{e\}) \rightarrow \{S_f\}$, perform/shape the practices or help to achieve an objective?").
- Utility/Pertinence/Relevance: Scenario-making process is useful to achieve an objective (e.g., contributes to decision-making processes, and enables anticipatory abilities)
- Creativity/Novelty: Scenario-making process challenges the 'mainstream' vision(s) of the future

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

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

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

3.2. Plausibility as a methodological-limiting criterion

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

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

According to the definitions provided above, one of the most basic characteristics that possibility, probability, and plausibility seem to share is that they all limit '$\{S_f\}$' in relation to certain information contained in '$(S_i + \{e\})$'. However, the differences between them could be determined by the kind of reasoning ('→') on which they are based (see Nordmann, 2013: 127) and the elements of '$(S_i + \{e\})$' that count as 'relevant' during that reasoning process (see Table 2).

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

Table 2. Type of reasoning and $(S_i + \{e\})$ elements considered relevant for possible, plausible, and probable qualifiers

Against the background shown in Table 2, we may note that "the possible" subsumes "the plausible" and "the probable," and that "the plausible" subsumes "the probable" (i.e., probable ⊂ plausible ⊂ possible). A plausible scenario in a given world is presupposed to be possible in the same world. In the same way, a probable future scenario in a given world is presupposed to be plausible (and, therefore, also possible) in the same world.

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

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

(i).   a more or less robust characterization of S_i
(ii).   experience and empirical evidence about past and present (e.g., trends), and

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

The type of reasoning is what makes the essential difference here. On the one hand, the probabilistic inductive reasoning by which probability is guided requires limiting and specifying the information of that set beforehand in terms of their –objective or subjective– statistical significance (i.e., it works by statistical background information; Jaeger, 2005). Before inferring probable futures there is the need to establish what variables we expect that will remain constant or change and to what extent. In other words, although both plausibility and probability may share '(S_i + {e})', probability requires dealing with the '(S_i + {e})' background information in a specific way: it adjusts '(iii)' in the light of '(ii)' to extrapolate the resulting information on '(i)' in order to obtain a future scenario to which is assigned a certain *degree of belief in its realization*. Plausibility, on the other hand, does not *require* necessarily this prior adjustment of '(S_i + {e}),' nor is it intended to assign a degree of belief in the realization of a future – although probable futures may also be generated or considered plausible following an abductive process (probable ⊂ plausible). Instead, what plausibility offers is far humbler: to assess if a future scenario can be reasonably concluded or derived from '(S_i + {e}).' In other words, plausibility merely assesses whether '(S_i + {e})' has enough *argumentative force* for seriously considering S_f, and thus establishing a pragmatic relationship based on agreement and/or trust on the premises, values, and processes through which S_f was epistemically constructed (Josephson & Josephson, 1994: 265-272; Rescher, 1976: 30-21). Thus, plausibility "has much to do with how we reason and how we construct a convincing argument" (van der Helm, 2006: 24): the focus of attention is more on the validity of the premises and the argumentation process that support the conclusion (i.e., on '(S_i + {e})' and '→'), rather than on the conclusion itself (i.e., on {S_f}).

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

The variability and imaginative freedom that the plausible reasoning allows could lead to several critical considerations. For example, one might think that this criterion is insufficient to constrain the set of future scenarios for decision-making purposes.[3] Certainly, even if a specific set of input data (S_i + {e}) is established, the abductive or imaginative inferential process may theoretically produce a large number of plausible scenarios. However, when scenario building is intended to support decision-making processes, we should understand that plausibility is a necessary but *not sufficient* methodological-limiting criterion.

[3] I would like to thank an anonymous reviewer for this helpful remark.

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

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

3.3. Plausibility as 'an epistemic device' for the anticipatory heuristics of future scenarios

However, as we are not just working with past and present facts, but also with uncertainties, expectations, claims, and speculations referring to the unknown and undetermined future, it is not always easy to develop and implement the previous strategy (Michelson, 2013: 193-194). In this regard, some scenario practitioners appeal –resembling the post-normal science framework– to the need to form an extended and inclusive peer community in which the voices of a broad range of disciplines and social actors (with their respective expertise, expectations, beliefs, feelings, and values) are welcome and encouraged to participate. For these authors, strengthening the information included in '$(S_i + \{e\})$' and the inferential process '$\rightarrow$' "requires negotiation with multiple stakeholders, from scientist and engineers to policymakers, journalist, and the lay public. In short, generating plausible foresight inevitably involves a strong social component and cross-disciplinary negotiation" (Michelson, 2013: 194).

In this post-normal context in which the plausibility of a scenario is considered a matter of social scrutiny and inclusive deliberation (Selin, 2011; Guimarães Pereira, von Schomberg, & Funtowicz, 2006), a variety of future horizons and perspectives (and reasons to support them) are expected to emerge, enriching the elements that comprise '$(S_i + \{e\})$' and strengthening the viewpoint about the present and the tacit/explicit cognitive, affective, and normative knowledge and assumptions.
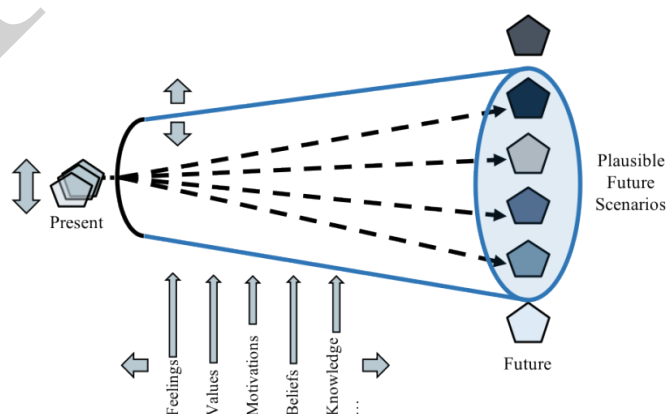
Fig. 2. Negotiation of plausibility.

This enrichment, beyond promoting the inclusion of a greater number of voices and increasing the social legitimacy of the process, is what is expected to epistemically enable the anticipatory heuristics of scenario building practices (i.e., promote the identification of alternative futures that might otherwise go unnoticed, and to avoid the uncritical reification of some futures). If the creation of alternative futures fundamentally depends on enrichening '(S_i + {e}),' and the negotiation of plausibility requires (i) diversifying, scrutinizing, and problematizing what can or must be accounted for '(S_i + {e})', and (ii) discussing what would be reasonable to derive from it, we may theoretically determine that "plausibility" serves here as a 'socio-epistemic tool' whose function is to enable the anticipatory heuristics (*see* Fig. 2).

Situated within this deliberative context, plausibility is above all an epistemic device that demands collective inquiry and reflection upon the foundations of the ways in which we think, project, use, and construct our representations of the future. If scenarios can be conceptualized as "perception devices" (van der Heijden, 1996: 29), plausibility may be theoretically understood as the socio-epistemic tool that enables the creation of anticipatory knowledge through opening up the range of diverse alternative pathways that might be included within our range of visions. Plausibility, understood as an epistemic device, aims to underline the existence of multiple action pathways, reinforcing the contingency of the future, and thus serving as an antidote against deterministic and reifying visions.

At this point, it is interesting to note that the object of this deliberation is not the future *per se,* but rather *how we think about it here-and-now*. The debate focuses more on reflecting on the (performative) representations we currently have about what might happen (what we know about the future, why we think we know it, and what this knowledge implies – {e}), rather than trying to guess what is going to happen (i.e., if S_f will or will not be the case). Discussing on plausibility entails to collectively identify and embrace the uncertainties, assumptions, expectations, and hopes about the future that we actually have, and reflect on the robustness of the reasons that support them.

As may be evident, this deliberative process may encounter limitations and tensions in the practical arena that could undermine its expected theoretical effectiveness. Indeed, power relations may shape the negotiation dynamics about what should count as '(S_i + {e})' and what is potentially derivable from there, thus conditioning the results. In a context in which "actors are trying to persuade each other of what to take seriously" (Nordmann, 2013: 130), perhaps some have more argumentative authority and resources to assert their voices. In this sense, an important element that scenario practitioners should consider when carrying out plausibility negotiation processes is creating the best possible conditions to ensure not only the diversity and quality of the participants, but also the robustness of their interventions and interactions (e.g., trying to minimize or avoid cases of epistemic and hermeneutic injustice; *see* Fricker, 2007). The quality of the deliberative process and outcomes will not only depend on the diversity of participants that are involved, but also on the quality of the dynamics and relationships that they establish, as well as on their responsiveness towards the available evidence and empathy with the viewpoint of others.

In this regard, it would be of great importance to support the rationale of plausibility negotiation providing empirical data on how plausibility negotiation dynamics unfold and how the tensions that may emerge in that process are exploited, shaped, contested, and/or controlled. Furthermore, it would be interesting to empirically assess the impact of this process on the different participants (e.g., how it enriches or helps to change their perspectives, develop anticipation skills, or appeal to action). These issues are of critical importance insofar as the deliberation processes on plausibility are intended to be a space for collective learning, and very often its outcomes are intended not only to assist the training of anticipatory capacities but also to influence decision-making processes.

3.4. Final remarks on the double role of plausibility: between opening up and closing down the future

After addressing the twofold nature of plausibility, two key questions remain open: What is the relationship between these roles, and why is the differentiation of them important?

Firstly, it should be noted that (i) these two roles do not have to necessarily be connected in the order in which they were previously presented (i.e., first methodological-limiting and then the anticipatory enabling), and that (ii) plausibility does not necessarily have to fulfill both roles. Although plausibility always plays its methodological-limiting role, it is not the same with the anticipatory-enabling one. In scenario practices which only aim to *project* a prefixed '$(S_i + \{e\})$' for exploring the set of plausible futures that might be derivable from there, plausibility merely functions as a limiting criterion. However, in scenario practices in which plausibility also plays the anticipatory-enabling role the methodological-delimiting role can be understood as an outcome of the former. In other words, "plausibility" functions *within* the deliberative process as an epistemic device (e.g., envisioning alternative futures and reflecting upon our assumptions, values, and uncertainties regarding the issue at stake). But once this deliberative process is concluded, "plausibility" acts as a criterion that closes down the area of future alternatives on the basis of the negotiated '$(S_i + \{e\})$'.[4]

Secondly, it is important to note that although both roles are involved in the dialectics of opening up and closing down the future, each does this in relation to different aspects. On the one hand, plausibility as a methodological-limiting criterion *opens up the space of future scenarios worthy of consideration beyond "the probable"* (see Section 3.2) and closes them down on the basis of a prefixed '$(S_i + \{e\})$'. On the other hand, the anticipatory-enabling role has the potential to open up the space of future scenarios not only beyond "the probable," but also in more radical terms. It is in the anticipatory-enabling role where '$(S_i + \{e\})$' and '$\rightarrow$' are problematized, and thus where "[p]lausibility sparks questions about anticipatory knowledge and even reaches more fundamentally into what we know and how we know it. The very (un)knowability of the future is illuminated in such a way that we can begin to unravel the norms, values, methods, cultures and logics that give rise to a variety of future-oriented practices" (Selin & Guimarães Pereira, 2013: 100-101).

The significance of the theoretical distinction between these two roles lies within the fact that although many scenario practices call for "plausibility," not all of them do so in order to enable the anticipatory heuristics that this epistemological tool can provide.

4. Implications: Future scenarios and the quest for plausibility in the making of technology

After previously analyzing the possible roles that "plausibility" may play, it is now necessary to reflect specifically upon the implications that this analysis could have when assessing the plausibility of future scenarios for technological governance.

One important lesson learned over the last 50 years is that the technological innovation process is indeed (partially) shaped by our visions, expectations, and hopes (i.e., anticipations). The interest aroused in the performative role of anticipations is understood in a double sense: as a sociological fact that affects the way in which we understand the technological phenomenon, and as a resource to promote the governance of emerging technologies (Konrad et al., 2016).

Despite the criticism that the "future talk" has received when applied to the governance of technologies (Nordmann, 2014, 2013, 2010, 2007; Nordmann & Schwarz, 2010), some authors continue to defend potential benefits that creating future scenarios may have for the governance of emerging technologies (Boenink, 2013; Selin, 2014, 2011). These authors consider the creation of

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[4] In this regard, several critical questions may arise. For example, an elementary but extremely important issue that has not been sufficiently and explicitly articulated in the specialized literature is how the space of "the plausible" is finally defined and closed. Although it may not be problematic to reach a minimum agreement about what delimits the space of "the possible" in contexts in which the multiple actors involved share alternative but potentially compatible objectives, knowledge, and/or assumptions, this can be problematic in situations where incommensurability between these elements exists.

scenarios as a central political-epistemological tool for increasing resilience, preventing potential problems, assessing the suitability of visions for future innovations (Ferrari, Coenen, & Grunwald, 2012), and, ultimately, for strengthening decision-making processes through multiple deliberative methodologies in contexts of uncertainty (Selin, 2011). In this context, anticipation implies not only exposing the performativity of technological expectations and the so-called "present futures" (Alvial-Palavicino, 2016; Brown, Rappert, & Webster, 2000), but also considering their heuristic characters in order to better understand our present (Miller, 2018) and promote a more reflective governance of emerging technologies (Guston, 2014).

How can we understand and contextualize the concept of plausibility within this rationale? The previous sections attempted to highlight the enabling and limiting functions that plausibility could have for scenario building and assessment practices. Since future socio-technical scenarios are a specific type of scenarios that aim to explore the co-evolution and co-production between science, technology, and society, the previous findings are equally applicable to them as well. In this sense, plausibility also may play in this context two roles: as a methodological-limiting criterion and as an anticipatory-enabling "epistemic device." On the one hand, its limiting role refers to the need to create a filter when opening up the future because not every "socio-technical world" can happen according to the current situation (S_i) and the actual set of knowledges, beliefs, feelings and so on ($\{e\}$). On the other hand, its enabling role refers to the need to problematize what should count as '($S_i + \{e\}$)' opening it up to public scrutiny (Selin, 2011).

The quest for plausibility not only appeals to the need to find a comprehensive (not so restrictive, not so speculative) methodological criterion for delimiting the scenarios worthy of consideration in decision-making processes. First and foremost, this quest appeals to the need to increase reflection on the eminently socio-political character of technological co-production. Given that the concept of plausibility "cannot be established beyond a personal or social process of negotiation" (van der Helm, 2006: 26), the deliberative process around "the plausible" can serve as a resource to foster awareness of the contingent, intentional, and malleable nature of socio-technical systems. The diversity of perspectives of the actors potentially involved in negotiating the plausibility of the scenarios could thus enrich the perspectives from which S_i (different perspectives about our present) and $\{e\}$ (knowledges, feelings, values, and so on) are interpreted and the elements that constitute them, thus enlightening and opening the present pragmatic field of plausible actions.

In this way, the discussion on the plausibility of future socio-technical scenarios aims to show that technological development is a socio-political project—it is not possible to completely control and predict its evolution, but it is possible to shape its development. In other words, the negotiation on the plausibility of future socio-technical scenarios is a clear resource for the *Anticipatory Governance* of emerging technologies (Barben et al., 2007) and the promotion of a *Responsible Innovation* (Lösch, Heil, & Schneider, 2017; Stilgoe, Owen, & Macnaghten, 2013).

Nevertheless, and despite the potentially helpful theoretical and practical virtues that scenario creation may have for anticipatory governance of technologies, it should not be forgotten that the plausibility negotiation processes may be subject to the power tensions and disagreements typical of any other socio-political process (van Oudheusden, 2014). The empirical study of these processes and how their results are ultimately "created" and "translated" into truly effective political decision-making is (and hopefully will be) particularly relevant for this promising (and sometimes promissory) field.

5. Conclusions

In this paper, future scenarios were theoretically characterized as representations "($S_i + \{e\}$) → $\{S_f\}$" where S_i should be preferably a real situation set in the present, and $\{S_f\}$ must be understood as –more or less robust– hypothetical narratives set is in the future. Furthermore, the set of assumptions, beliefs, ideas, feelings, and values $\{e\}$ that modulates S_i could refer to all the three parts of the timeline:

the past (e.g., historical data, analogies, past trends…), the present (e.g., present trends) or the future (e.g., assumptions, visions about what might happen).

This characterization was used as a formal tool to explore and clarify the meaning of the term "plausibility" and how it may be applied (Section 3). Analyzing the possibilities for applying the concept of "plausibility" from a relational perspective, I defended that it can play at least two main roles. On the one hand, "plausibility" can be considered as a methodological criterion with a demarcative role for determining the scenario narratives to be considered in decision-making processes. In this first role, plausibility is considered a limiting criterion because scenarios that arguably cannot be derived from a prefixed '(S_i + {e})' are discarded (Section 3.2). On the other hand, "plausibility" can also be regarded as an "epistemic device" for enabling the anticipatory heuristics of future scenarios. In this second role, the concept of "plausibility" is conceived as a socio-epistemic tool for promoting anticipatory heuristics. This second perspective recognizes the negotiation of (S_i + {e}) and what may be derived from it as practice to increase awareness of the openness of the future and to promote anticipatory capabilities (Section 3.3).

Finally, I have examined some of the more direct theoretical implications of the dual role of plausibility for scenario-building processes which aim to promote the anticipatory governance of emerging technologies (Section 4). On the one hand, the limiting role invites us to analyze whether the future socio-technical scenarios are robust enough (i.e., if they follow (S_i + {e})) to be used as resources for decision-making. On the other hand, its enabling role stimulates problematizing which elements count as S_i and {e}. In this second facet, plausibility seems to be an extraordinary resource to introduce a critical look at how we think and build our present socio-technical systems by looking to the future. In times that speculative visions and other socio-technical imaginaries are at the center of the social agenda and in many cases act as one of the diverse legitimating elements of scientific-technological policies, plausibility could serve to problematize them, to visualize the role of technology in our societies, and how we can or cannot influence their development.

Beyond the theoretical virtues that plausibility as an epistemic tool might have, there is an evident need to deepen both in the constitutive elements of the scenarios and the way in which plausibility is empirically operationalized. In this regard, it would be particularly important for the field to pay special attention to the conditions and dynamics that shape and transform the plausibility negotiation processes, how these processes influence the different participants, and how their results are concretized in decision-making.

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