Scenarios as tools of the scientific imagination: The case of climate projections[1]

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Abstract:

Climatologists have recently introduced a distinction between projections as scenario-based model results on the one hand and predictions on the other hand. The interpretation and usage of both terms is, however, not univocal. It is stated that the ambiguities of the interpretations may cause problems in the communication of climate science within the scientific community and to the public realm. This paper suggests an account of scenarios as props in games of make-belive. With this account, we explain the difference between projections that should be make-believed and other model results that should be believed.

Keywords:

Climate Models, Scenarios, Uncertainties, Make-Believe, Fictional Propositions

1 Introduction

Scenario-based reasoning plays an increasing role in many fields of (applied) sciences. After Herman Kahn introduced the scenario approaches into strategic reasoning on nuclear warfare early on during the Cold War period (cf. Schwartz 1991), with the first Report to the Club of Rome in the 1970s (Meadows et al. 1972), scenario-based reasoning took center stage in models that are used to inform decision-makers in the

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area of environmental policy. Via technology assessment, scenario-based thinking has also entered the engineering sciences (e.g. Carroll 1995) and takes central stage in foresight practices (Mietzner and Reger 2005). Today, particularly in the field of sustainability and energy supply (World Energy Council 2013), scenarios provide the basis for strategic decisions both in companies and on the policy level. Common to all scenario-based reasoning is that scenarios provide means to make uncertainties manageable. The following quote from the supporting material of the fifth report of the Intergovernmental Panel on Climate Change expresses this clearly: "The goal of working with scenarios is *not to predict* the future but to better *understand uncertainties* and alternative futures, in order to consider how robust different decisions or options may be under a wide range of possible futures" (our emphasis).[2] Note that there is a plethora of uncertainties that climate modeling has to address and addresses. These include uncertainties due to natural variability of the climate system (which for long-term projections only plays a minor role) as well as uncertainties in the models. The latter are commonly distinguished in the literature (sometimes using different terms) into uncertainties that arise due to the fact that not all parameters, including boundary and initial conditions, are known with the required precision, and conceptual or structural uncertainties that arise because not all parts of the climate system are known in a comprehensive way (cf. Hillerbrand 2010). In this paper we focus on scenario uncertainties only as we think that this topic has received significantly less coverage in the philosophical literature. These uncertainties are peculiar to long-term projections that sensitively hinge on political and societal decisions.

[2] http://sedac.ipcc-data.org/ddc/ar5_scenario_process/. Accessed 6 May 2019.

Scenarios often provide the input for computational models. In order to distinguish such scenarios from scenarios that are generated with the help of models (so called "calculated" scenarios; cf. Dieckhoff and Grunwald forthcoming), they are commonly referred to as *input* scenarios. If not stated otherwise, we use the term "scenario" synonymously with "input scenario." Examples range from applied science for policy advice such as estimating the feasibility or the impact of future smart vehicles (cf. Schippl and Truffer 2018) or the feasibility of renewable electricity scenarios (cf. Balta-Ozkan et al. 2014) to more fundamental sciences such as climate science. The Intergovernmental Panel on Climate Change (IPCC) provides the most sophisticated uses of these input scenarios for climate modeling as summarized in their reports. The IPCC explicitly differentiates the output of climate simulations that involve scenarios from results that do not depend on scenarios. In order to name outputs that depend on scenarios the authors of the IPCC coined the term "projections" to distinguish scenario-based model results from "predictions" or "prognoses" (cf. Nakicenovic et al. 2000). In medicine, for example, predictions refer to the likely course of a disease in an individual, while prognoses refer to subpopulations of people that most likely develop a certain disease or react to a certain treatment (cf. Brünner 2009). Coining a new term for scenario-based model results emphasizes the intuition that the involvement of scenarios is more than an extension or sophistication of exiting methods, but something really new. But what exactly distinguishes projections, besides the involvement of scenarios, remains an open question.

Dennis Bray and Hans von Storch write that

> [b]oth terms, prediction and projections, […] are subject to different interpretations and connotations. Thus, the use, if not explicitly specified, has

> the potential to cause problems not only in the communication of climate science in the broader scientific realm but also in the understanding by the public at large, potentially influencing policy decisions, policy design, and policy implementation and public perceptions of climate change. (2009, pp. 534f.)

According to the IPCC, the very idea to use scenarios is to get a better grasp on uncertainties instead of reaching predictions in the first place. Taken this contention expressed in the above citation seriously, we see a potential danger that the aim to better understand uncertainties gets threatened by an unclear or vague terminology. As Bray and von Storch seem to imply, the use of scenarios may give rise to more problems than it was about to resolve.

Methodological reflections on scenario development and use have increased during the last decade and these debates address predominately the modelers. In this paper we address the issue from a different perspective and ask as to how to interpret scenario-based model results. We aim to do so by spelling out the difference between projections and predictions as specified by the IPCC. With this, we want to address not only modelers but also many different people who make use of the scenario-based model results like politicians, CEOs, scholars and engaged citizens.

The paper is structured as follows. The first part of the paper introduces the theory of make-believe as it was originally suggested by Kendall Walton (1990) as an account of the notion of fiction in the arts. This provides the basis for fictionalism about models (Section 2). With the help of this groundwork, we look into scientists' uses of scenarios and offer an interpretation of the notion of projection in the following sections. As a case study, we take a closer look at the so-called "emissions scenarios" that provide the input for climate models (Section 3) and give our philosophical interpretation of them (in Section 4). Before we conclude, we discuss an objection to our proposal (Section 5) and, finally, summarize the results of the paper with a discussion (Section 6).

Before we begin our analysis, let us express some word of caution. Generally speaking, while proponents of scientific fictionalism do use the notion of fiction, they usually do not want to downplay scientific findings as material that is simply made up. When models are compared to fictions, this is not meant to decry them as stories that are arbitrarily invented. No fictionalists' claim should be interpreted as a postmodernist claim that equates fiction and science (cf. Frigg 2010c, p. 247). Comparing models to fictions is sometimes criticized as grist for the mills of anti-scientists. For example, Ron Giere points to the danger of playing into the hands of the followers of "creation science," who try to argue against evolutionary theory (cf. 2009, p. 257). Relatedly, one might fear that interpreting the scenario-based results of climate simulations as fictional propositions will encourage climate skeptics. This fear, however, is not justified and misses the point that climate modeling obeys certain scientific standards, e.g., it is derived from corroborated, well-tested theories such as thermodynamics. Rather, we believe that our analysis helps to produce adequate interpretations of scenario-based modeling results and explains how they differ from model results that do not use scenarios as an input. Roman Frigg makes a distinction that is very helpful in this context: he draws a line between fiction as falsity or non-existence and fiction as imagination (cf. 2010c, pp. 248f.). Scientific fictionalists primarily use the latter notion of fiction, and the theory of make-believe grounds their interpretation of fiction as imagination. In particular, they build on the work of Walton (1990), which also provides the starting point for our analysis of scenario-based reasoning. Thus, we begin with a discussion of Walton's theory in the following section.

2 Objective Imagination and Make-Believe

According to Walton, studying games of make-believe is the first step toward understanding any kind of fictional art, such as literature, film, theater, or painting. Games of make-believe are fundamentally about imaginings that are constrained by certain rules. Such games vary widely. They range from games with linguistic material such as novels, to games with concrete objects such as playing "house" with dolls, to games with works of program music and to games with works of cinema such as Hollywood films. The notion of make-believe, on which Walton's theory is founded, springs from observation of the universal phenomenon that children play games, in which they imagine things that do not have to be real. Human beings at the youngest age can and regularly do engage in such games, which involve pretense without the intention of deceiving other players.[3] Children playing in a wood who agree to imagine that tree stumps are bears illustrate a simple form of a game of make-believe. Suppose that in the game there is a prescription that all participants should imagine a bear when they notice a tree stump. The stumps are "props" in this game of make-believe (cf. Walton 1990, p. 37). In general, in any game of make-believe, a prop acts as a crucial aid to the required imagining. Together with certain rules, in this case the above-mentioned prescription plus further principles of inference, the props prescribe

[3] Accordingly, the theory of make-believe is often referred to as "pretense theory." We will use "make-believe" and "pretense" synonymously. Walton himself, however, is ambivalent about the use of the latter term (cf. 1990, pp. 81f., pp. 391f., pp. 400-405).

propositions that the players are supposed to imagine. These propositions that ought to be imagined are called "fictional propositions." A fundamental statement of the theory is that props "generate" fictional propositions. For example, five tree stumps in a part of the wood generate the fictional proposition that in this part of the wood there are five bears. Fictionally there are five bears, while actually there are only five tree stumps. The rules of the game are called "principles of generation" (cf. Walton 1990, p. 38).

Fictional propositions can be regarded as "fictional truths"; in other words, the fact that a certain proposition is fictional constitutes a fictional truth. This should not be conflated with truth *simpliciter*, because in the example it is not true that there are five bears in the wood; it is true that there are five tree stumps. The prop and the direct principle generate the primary fictional truth that there are five bears. The primary fictional truth and the indirect principle generate the implied fictional truth that there are five dangerous bears (Walton 1990, p. 140).

To say that it is fictional that there are five dangerous bears means that there is a prescription for imagining this proposition. From this it follows that what participants should imagine in this game is not arbitrary. In general, the props and principles of generation ensure that there are accepted standards for what is fictionally the case in such a game. If a participant were to imagine that there were only four bears in the wood if there are in fact five tree stumps, she could be corrected and told that fictionally there are five bears. So participants can make mistakes in games of make-believe. Props and principles guarantee that there is something to discover in games of make-believe, because these props and principles deliver criteria for appropriate imaginings within such games.

Walton develops the theory of make-believe by applying it to representational arts more generally. Works of fiction such as novels or paintings are props in games of make-believe, much like the tree stumps in the children's game. Novels, paintings, and other props generate fictional truths; engagement with art is therefore continuous with games such as the one the children play in the wood. Appreciators of art should, according to specific rules, imagine certain propositions in order to understand a given artwork correctly. However, the status of the principles of generation in the children's game is different from the status of those principles in most games involving works of art. The rules in the children's game are ad hoc. They are not stable and are not widely shared in a community beyond the few players in that particular game. The rules of games involving works of art, however, are mostly stable and widely shared. These games are "authorized" games (cf. Walton 1990, p. 51). Unlike the tree stumps that only happen to be used by children as props for the game of hunting bears, the props in authorized games are designed to be used as props; moreover, there is agreement regarding the use of these props because of stable and widely-shared principles of generation. In the Middle Ages, for example, everyone in Europe was aware of the convention that the colors of the Virgin Mary in paintings were blue and white. The game of make-believe involving paintings in the Middle Ages included the principle that one should imagine the Virgin Mary when seeing a woman dressed in blue and white clothes in a painting. Arthur Conan Doyle's Sherlock Homes stories provide another example. These stories make it fictional that there is a detective living at 221B Baker Street in Victorian London. Such paintings and works of literature are not ad hoc props. It is their function to serve as props, and they are specifically made for this purpose. For this reason, most games of make-believe that require participants to engage with representational artworks are authorized games. In most cases, members of a society therefore agree in judging certain statements about works of art to be correct or incorrect. For example, every knowledgeable person will agree that it is correct that

Sherlock Holmes lives at 221B Baker Street. This is a fictional truth, while the proposition that Holmes lives at 221B Paddington Street is not. Importantly, one should have the attitude to make-believe toward the proposition about Holmes living at 221B Baker Street, rather than the attitude of belief. Appreciators of artworks, then, are invited to imagine fictional propositions that are constrained by the works as props and by stable and shared principles of generation.[4]

Philosophers of science have recently transferred pretense theory from the fine arts to the sciences (cf. Godfrey-Smith 2009; Frigg 2010a, 2010b, 2010c; Toon 2012; Levy 2015; Frigg and Nguyen 2016, 2019). Scientific modeling often involves descriptions that refer to hypothetical entities rather than actual entities. Examples include the description of atoms or molecules as point particles in statistical mechanics, a frictionless plane on which a solid body glides in classical mechanics, stellar bodies with perfectly homogenous mass distributions, perfectly rational agents, and instantaneous access to information in economic theory. Indeed, such "hypothetical systems" (Frigg 2010a) or "missing systems" (Thomson-Jones 2010) are part and parcel of many scientific models.[5] According to scientific fictionalists, modelers do not believe

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[4] These games of make-believe are not resricted to only prescribe imagings about past or present things. Utopian or dystopian works of fiction are also props in such games. The paradigmatic example of such a dystopian work is George Orwell's novel *Ninenteen Eighty-Four*. It can be reconstructed as a prop that generates fictional proposition about a future society, in which a perfect surveillance system is installed, and it also generates fictional propositions about the character Big Brother that one should imagine being the political leader of this society.

[5] Peter Godfrey-Smith characterizes such missing systems as entities that do not exist but that might have existed, and that in such a case "would have been concrete, physical things, located in space and time and engaging in causal relations" (2009, p. 101).

that these hypothetical entities exist, but they have the attitude to make-believe toward propositions about these entities.

As mentioned, scientific models often involve descriptions that do not refer to any actual entity. Although it is clear that perfectly homogenous mass distributions are not part of our world, scientists speak of such things as if they were. Consider as an example the two-body model of the earth's motion around the sun. Here scientists model the world in terms of hypothetical entities; two perfectly spherical bodies that have a homogenous mass-distribution are used as "stand-ins" for the earth and the sun of our solar system.

One can use this example of the model of sun and earth to apply the theory of make-believe to the sciences. Modelers consider model descriptions, i.e. sentences such as "There are two gravitationally interacting bodies of homogeneous mass distribution, located from each other at a certain distance and interacting only gravitationally," in order to imagine a hypothetical model system. In this case, we have the system of two hypothetical bodies governed by Newton's theory of gravitation. As discussed at the beginning of this section, a prop in an authorized game of pretense generates fictional propositions. According to fictionalism one can interpret the model description about the gravitationally interacting bodies as just such a prop. Make-believe theory requires that model descriptions as props should be used to imagine propositions that characterize a hypothetical object, the "model system" (cf. Frigg 2010c).

Using a model description to imagine a corresponding model system, it is possible to make several inferences. For a fixed position of the model sun, one particular inference is that the model earth moves around the model sun in an elliptical orbit with certain properties. The exact determination of the orbit of the model earth around the model sun is an implied fictional truth if the modeling is interpreted as a game of make-believe. First, the props and principles of direct generation produce the primary fictional truths of the modeling; for example, it is generated that the model earth and the model sun are spherical bodies. Second, the implied fictional truths follow from the primary fictional truths and from principles of indirect generation. These principles are more complex than in the example of the children's game, as they are in this case the laws of classical mechanics.

So, the activity of modeling is reconstructed as an act of imagination in a game of make-believe. The model description of the model sun and the model earth functions as the prop in this game. The background theory, including laws and general principles, aligns with linguistic conventions to constitute the game's principles of generation. And the proposition that the orbit of the perfectly spherical planet around the model sun is an ellipse is an implied fictional truth in the game (cf. Frigg 2010a, 2010b, 2010c).[6]

The target of the modeling is our earth's movement around the sun. In order to learn something from the model about the target system, a further step is needed. The fictional truth that the model earth moves in an elliptical orbit around the model sun must be translated into a claim about the target, our earth orbiting around the sun. The claim that is the result of the modeling is that our earth moves in an elliptical orbit around our sun, at least to a certain degree of approximation.[7]

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[6] Here, imaginings about the future are also easily at hand. One can imagine that, for example, given a particular season of the year the model sun will move in such a way that the distance between model earth and model sun will increase and, so, the change of seasons will have to be expected according to this game of make-believe.

[7] What licenses this translation of fictional truths into claims about the target can be accounted for with different justifications. One option is to postulate a key of modeling that is analogous to a key of a map

The theory of make-believe offers an explanation for the “face value practice” (Thomson-Jones 2010) of speaking of apparently non-actual things as if they were part of our world: scientists engage in games of make-believe when they use model descriptions in order to imagine model systems. So model descriptions can be regarded as props in games of make-believe. Unlike the tree stumps in the children’s game, but like artworks in authorized games, the props are meant as props. And, as in the children’s game, what the scientists are to imagine is not arbitrary. It is constrained by principles of generation. In the case of the model of the earth’s movement around the sun, these principles are Newton’s laws. In general, there are shared and stable principles in science that are missing in the children’s game. Each discipline has its own principles of generation that allow only restricted inferences from model descriptions of specific modeling tasks. The principles of generation, together with the props, constrain what should be imagined. With the help of principles and props, then, one can derive the fictional truths of a particular modeling.

In the following sections, we will apply pretense theory to scenario-based modeling. We will argue that not only model descriptions but also scenarios may act as props in games of make-believe. In order to produce model results, the modeler has to imagine certain propositions that are constrained by different scenarios and by the principles of the model in question. Before we continue, let us first discuss one issue that may be raised by skeptics about the Waltonian approach who rather would like to

(cf. Frigg 2010a, 2010b, 2010c). A refined version of this justification involves a prior step of exemplification of properties by the model and a later step of imputation of properties to the target that have to be transformed through a process of involving a key (cf. Frigg and Nguyen 2016). A further option is to utilize the notion of partial truth (Levy 2015).

use the language of possible worlds in order to analyze scenarios (i), and we also want to discuss another issue that fictionalists about models may raise (ii).

(i) Bray and von Storch assume that the difference between projections and predictions is that the former are descriptions of *possible* outcomes whereas the latter are descriptions of *probable* outcomes (cf. Bray and von Storch 2009, p. 537). This characterization seems to be in line with the following quote. “Essentially, a projection of climate change differs from a prediction in that a scenario of future emissions is assumed without giving it any specific likelihood of occurrence” (Giorgi 2005, pp. 252f.). Given that projections as scenario-based results are descriptions of possible results, to use the notion of possibility may be a first step in explaining what scenarios and scenario-based model results are. An intuitively appealing approach might be to invoke the language of possible worlds. However, the metaphysical extravagance of the possible worlds framework is undesirable. We will take an alternative route in this paper.[8]

The theory of make-believe, in contrast, is ontologically parsimonious and only rests on the activity of imagining and corresponding attitudes of those who participate in games of make-believe. In offering an interpretation of the notion of projection we build on the work of scientific fictionalists and on the theory of make-believe. With this interpretation we aim not only to improve the understanding of scenario-based reasoning for policy makers and modelers, but also to supplement current debates on

[8] There are also other approaches that want to apply the notion of a *credible* world to climate modeling. Betz (2015), for example argues that climate models can be interpreted as credible worlds. This approach might be fruitful but in this paper we focus on scenarios and do not want to presuppose a particular view about the ontology of models.

climate models, for example those focusing on "serious" or "real" possibilities (cf. Katzav 2014; Betz 2015). Joel Katzav, for example, discusses a possibilist view of climate models according to which "useful climate model assessment does not primarily aim to teach us something about how the climate system actually is but, rather, primarily aims to teach us something about how it might be" (2014, p. 229). We do not aim to discard the possibilist views by Betz and Katzav; the goal of this paper is rather to explore an alternative view on scenario-based research that utilizes the concept of a game of make-believe. Despite the burgeoning study of climate models within philosophy of science (e.g. Winsberg 2012; Parker 2014; Katzav 2014; Betz 2015; Frigg, Smith, and Stainforth 2015; Frisch 2015) and the dependence of most climate models on scenarios, so far scenario-based reasoning in the sciences has rarely been discussed in philosophy.[9]

(ii) Following the views of climate scientists who see scenarios as characterized either by "storylines" or "narratives," and following debates in philosophy of science that compare models to "fictions" (cf. Godfrey-Smith 2009; Frigg 2010a; Toon 2012; Frigg and Nguyen 2016), we study the role of make-believe and the imagination in scenario-based reasoning. In the following sections, we argue that scenario-based modeling results can be interpreted as propositions to which one should have the attitude to make-believe instead of the attitude to believe.[10] Borrowing the terminology from Walton and fictionalist approaches in philosophy of science, scenario-based

[9] For notable exceptions see, for example, Betz (2009), Lloyd and Schweizer (2014) and Dieckhoff and Grunwald (forthcoming).

[10] We use the expression "attitude to believe" to refer to an attitude toward propositions that takes them to be true simpliciter, probably true or empirically adequate.

modeling generates model results that we interpret as implied fictional truths because scenarios function as props in authorized games of make-believe. While for some only the specification of model systems involves a form of make-believe, we contend that the propositions generated by scenarios about the evolution of the earth's climate also involve a form of make-believe. Moreover, in contrast to scientific fictionalists, we argue that the "scientific fictions" of the modeling are the scenarios and not the models as such because scenarios function as props in games of make-believe. Whether or not the models themselves – understood as model descriptions or model systems or both – are to be interpreted as fictions in the sense of props, and whether or not the models do contain fictional elements, our analysis leaves open.[11] Just as we want to stay uncommitted about a particular metaphysical view on possibility we also do not commit ourselves to a view about the ontology of models. Whether models are abstract objects, sets of propositions, fictional or hypothetical objects etc. we leave open for the purpose of this paper. Consequently, our analysis of scenario-based reasoning should not presuppose one of these particular views on the ontology of models. One may argue that we already embrace fictionalism about scenarios and, so, we may also want to embrace fictionalism about models in general. As it will become clear later on, statements such as claims about the cause of global warming require a different attitude than the attidude to make-believe that fictionalism about models would requires for all results of modelling practices. We argue that the proper attitude to some result is belief, though.

[11] In particular, Frigg's (2010a, 2010b, 2010c) and Toon's (2012) fictionalists accounts are subject of criticism (cf. Weisberg 2013; Poznic 2016) and the generic comparison of models with works of fiction is called into question (cf. Giere 2009). Because of these arguments we want to stay uncommitted concerning these views about models being scientific fictions.

Therefore, fictionalism about models in general is not a position that we want to defend, here.

3 Emissions Scenarios in Climate Modeling

Particularly when analyzing large-scale environmental issues such as those associated with global warming and greenhouse gas emissions, scenarios provide the input for complex simulation models. Because of their dependence on scenarios, physical climate models are particularly well-suited for our analysis. We therefore focus in the following pages on scenarios used in physical climate modeling. Here, the IPCC provides standard sets of scenarios for climatologists. As climate modeling consumes time and money and it is very complex, standardized scenarios are helpful tools. Sets of standardized scenarios provide a database for the models; they enable climatologists to compare different climate model runs. So-called "emissions scenarios" help to estimate climate-relevant factors that are needed as input in climate models. The scenarios parameterize assumptions about the future development of energy demand and supply over the course of the twenty-first century, such as those regarding the growth of the global population or economic growth. These parameters determine the temporal evolution of greenhouse gas concentrations, as well as other climate-relevant factors such as aerosol concentration and changes in albedo, over the course of the century (van Vuuren et al. 2011). Emissions scenarios are special socio-economic images, understood as a synthesis of quantitative statements and qualitative information that characterize a plausible future (cf. Kriegler et al. 2012, p. 808). In the following, we take a closer look at the scenarios used for modeling the climate that are called SRE scenarios, RCP scenarios, and SPP scenarios.

The third and the fourth IPCC reports consider as many as 40 individual scenarios (cf. Nakicenovic et al. 2000, p. 4). These scenarios were first published in the *Special Report on Emissions Scenarios* in 2000 (Nakicenovic et al. 2000). Accordingly, they are labeled "SRE" scenarios. In every SRE scenario, different assumptions are made about technological and economic development. Some scenarios consider a more environmentally friendly future than others; however, none of them consider deliberate political measures to limit greenhouse gas emissions (such as, for example, declared in the Kyoto Protocol).[12]

The fourth assessment report classifies the 40 SRE scenarios into four families, with different outlooks on socio-economic development. The descriptions of these different socio-economic developments are called "storylines." The four families that are labeled *A1*, *A2*, *B1*, and *B2* can be characterized with the following four descriptions or "storylines":

- The *A1* scenario family assumes quick economic growth and a world population that peaks at 9 billion in 2050, gradually declining afterwards. New and efficient energy technologies spread quickly all over the globe, and income and wealth disparities among various regions begin to even out. Different scenarios in this family emphasize the use and development of different technologies: one scenario is fossil-intensive, while another focuses on non-fossil sources.
- *A2* scenarios share with those from the *A1* family the assumption that economic growth correlates with more energy demand; however, the world is now imagined as less integrated, as economic growth differs from region to region. Moreover, the world

[12] Implemented around the time of the third and fourth IPCC reports, the Kyoto Protocol was the United Nations' international treaty regarding greenhouse gas emissions. It was adopted in December of 1997 and was signed by many states – except for the U.S. and China as notable exceptions.

population continuously increases even after 2050.

- *B1* scenarios, like *A1*, consider a more integrated world with the same population dynamics – but one in which economic growth yields less greenhouse gas emission due to the introduction of green and efficient technologies.
- The *B2* scenario family resembles the less integrated world in *A2*, in which economic and technological development is very fragmented. Like *B1*, it is more ecologically friendly than *A2*. But in contrast to *B1*, environmentally friendly solutions are local rather than global (cf. Solomon et al. 2007, 18).

As regards future greenhouse gas emissions, the projected atmospheric concentration in the four scenario families ranges from 490 to 1260 ppm. The significance of the projected range become clear when one compares it to the pre-industrial level of about 280 ppm in 1750 and to the concentration of 368 ppm in 2000. Of course, though this spans a wide range of emission futures, the real course of events may well be very different, and real emissions may be well outside the projected range (cf. Hillerbrand 2014).[13]

The information provided by emissions scenarios is extremely complex. Climate models have different resolutions; the scenarios offer high-resolution input data for numerical climate models that divide the world into grids.[14] Moreover, all climate scenarios incorporate knowledge from very different fields: from physical climate models, impact models, ecosystem models, and others. They are not dreamed up in the

[13] This is related to the discussion of the difference between scenarios and initial conditions in Section 5. The scenarios are not descriptions of an actual future. They are first of all about potential futures.

[14] For example, the scenarios in the fifth IPCC report provide the input data for a spatial grid with cells measuring half a degree of latitude and longitude, resulting in 518,400 cells in total.

lab or constructed out of thin air; they are gauged against scientific background knowledge. Consequently, new research delivers an update to these scenarios from time to time, as detailed in the supporting material prepared in anticipation of the fifth IPCC assessment report:

> New sets of scenarios for climate change research are needed periodically to take into account scientific advances in understanding of the climate system as well as to incorporate updated data on recent historical emissions, climate change mitigation, and impacts, adaption and vulnerability.[15]

The fifth IPCC report considers new scenarios with a change in their underlying storylines. Instead of clustering a large group of scenarios into families as in the fourth report, now only four so-called representative scenarios are considered. The four scenarios are characterized as

> alternative pathways (trajectories over time) of radiative forcing levels (or CO2-equivalent concentrations) that are both representative of the emissions scenario literature and span a wide space of resulting greenhouse gas concentrations that lead to clearly distinguishable climate futures.[16]

These radiative forcing trajectories are termed "Representative Concentration Pathways" or "RCP" scenarios. The four representative scenarios are called *RCP8.5*,

[15] http://sedac.ipcc-data.org/ddc/ar5_scenario_process/scenario_overview.html. Accessed 6 May 2019.

[16] See previous footnote.

RCP6, *RCP4.5*, and *RCP2.6*, where the numbers refer to radiative forcings (measured in watts per square meter) by the year 2100.[17]

Each RCP scenario was developed by a different research group. These research teams reviewed the existing literature and synthesized values for a wide range of scientific and socio-economic data such as population growth, air pollution, land use, and energy sources. But unlike the SRE scenarios, this database contains climate-relevant parameters only and does not include socio-economic data. Researchers can instead test various social, technological, and economic circumstances that are compatible with the various RCP scenarios. The descriptions of these circumstances are called "narratives," and are in a sense similar to the descriptions of the SRE scenarios. The descriptions of the RCP scenarios are provided by so-called "shared socio-economic reference pathways," which are defined as "parsimonious narrative[s] capturing the key dimensions of the underlying global scale socio-economic development" (Kriegler et al. 2012, p. 808). However, the new scenarios also differ from the SRE scenarios in other respects. For example, the RCP scenarios can account for political measures to counterbalance climate change, such as the two-degree goal or possibly geo-engineering. Though these scenarios span a broad range of potential futures, it is conceivable – i.e. in accordance with the laws of nature – that the actual future lies outside the range spanned by the RCP scenarios used in the fifth report.

Like the SRE scenarios, the RCP scenarios consider fairly different climate futures. Because the real course of events may well be outside the range spanned by the

[17] The last scenario is also referred to as *RCP3PD*, where "PD" stands for Peak and Decline – meaning that the radiative forcing peaks in the twenty-first century and then declines to the level of 2.6 watts per square meter.

representative pathways, scientists do not believe that all the outputs of climate models will be realized. Therefore, there is some danger of conflating them with realistic descriptions of an actual future in case that one is not carefully reflecting on the difference between predicting something and developing projections about the future. In fact, scientists frequently assert that the outputs of the climate models are highly uncertain. They rarely quantify this uncertainty in terms of probabilities (cf. Hillerbrand 2010). Rather, the significance of the utilization of SRE and RCP scenarios is that these scenarios are used in situations where we face high uncertainty. This is true for scenario analysis more generally, and is also highlighted in the supporting material for the fifth IPCC assessment report cited above.

While the climate outcomes, represented by the four alternative RCPs provide but one aspect of key determinants of uncertainty in outcomes, a more elaborate framework considers these as only one axis of a matrix (O'Neill et al. 2014). A second determinant of uncertainty in outcomes is socioeconomic development. Different "development pathways can lead to societies that vary widely in drivers of emissions and land use as well as in their capacities to mitigate emissions or undertake adaptation measures" (ibid., p. 388). These different development trajectories are represented by "a set of alternative reference assumptions about future socioeconomic development in the absence of climate policies or climate change, the Shared Socioeconomic Pathways (SSPs)" (ibid.). The five SSPs referred to as SSP1, "Sustainability" or "Taking the Green Road," SSP2, "Middle of the Road," SSP3, "Regional Rivalry" or "A Rocky Road," SSP4, "Inequality" or "A Road divided," and SSP5, "Fossil-fueled

Development" or "Taking the Highway" will be used in the upcoming 6th IPCC Asessement report in 2021 (cf. Rihahi et al. 2017).[18]

Next to RCPs and SSPs there is a third key determinant of uncertainty in outcomes: The so-called Shared climate Policy Assumptions (SPAs). Elmar Kriegler et al. (2014) define policies for carbon and other greenhouse gas emissions and mitigation and adaption measures more generally that link socioeconomic futures with forcing and climate outcomes. All these scenarios aim to provide shared and in some sense "standardized" assumptions as an input of the plentiful climate models.

The IPCC purposely introduced the novel term "projection" in order to distinguish scenario-based model results from prognoses or predictions. We will provide an interpretation of this term in which we contend that the correct attitude toward the scenario-based output of a climate model is not to believe but to make-believe. However, this claim does not mean that the output is arbitrary. Predicated on a scenario that contains information about factors such as future greenhouse gas concentration, the projection of a particular model run is an outcome that is scientifically constrained. As shown in the previous sections, the make-believe in a game is constrained by props and principles of generation.

Important for the purposes of this paper is that the scenarios are most often associated with climate futures that are described in the SREs, RCPs or SSPs. These so-called narratives or storylines regulate the way input from a scenario can be used as a

[18] See also https://www.unece.org/fileadmin/DAM/energy/se/pdfs/CSE/PATHWAYS/2019/ws_Consult_14_15.May.2019/supp_doc/SSP2_Overview.pdf. Accessed 15 July 2020.

special tool in climate modeling.[19] In the next section we will apply the fictionalist concept of a prop in order to explain this special functioning of scenarios in climate models.

4 Scenarios as Props in Games of Make-Believe

As discussed in the previous section, the scenarios that the IPCC considers yield quantitative information about climate-relevant parameters such as greenhouse gas and aerosol concentration in the atmosphere. Each scenario can be characterized by values of future forcing, emission concentrations, and emission rates and these may differ vastly. For the purpose of this paper it is important that both quantitative and qualitative model results generated with the help of scenarios can be characterized by propositions.

The scenarios are a way to deal with uncertainties about the three mentioned values of future forcing, emission concentrations and emission rates. The climate projections are, however, fraught with additional uncertainties that are a central point of research in the climate sciences. The IPCC has chosen to communicate these uncertainties in the final projections with two metrics, namely *confidence* and *likelihood*. The former takes into account the validity of the finding. This includes the validity of the empirical data it builds upon and the validity of the models used, among others. The latter quantity expresses measured uncertainty probabilistically and

[19] Our use of these terms is just mirroring the use of the IPCC. We do not aim to make a direct contribution to discourses in the scholarly literature where narratives and storylines are at the center of interst. In history, for example, the term "narrative" is considered as a central concept to denote a particular type of explanation. Thanks to an anonymous reviewer for pointing this out and pressing us on being clearer about our stance toward this issue.

expresses it in a quantitative way.[20] In contrast, the last IPCC reports take confidence as a qualitative measure. The reason for this qualitative uncertainty is that some parameters cannot be modeled endogenously. In the following, we will take the qualitative confidence level to be indicative for games that are authorized in the sense explained in Section 2. To be precise, only results that are assessed to come with "high confidence," we want to accommodate into authorized games of make-believe. The community of researchers agrees that results that are assessed to be accepted with "high confidence" are among the best results one can get. The results are fraught with uncertainties, still, but the confidence is high, nevertheless.

With this in mind, let us consider in the following some model results generated by climate models. Firstly, consider this quotation from the Summary for Policymakers of the Working Group I Contribution to the fifth IPCC report:

> Relative to the average from year 1850 to 1900, global surface temperature change by the end of the 21st century is projected to *likely* exceed 1.5°C for RCP4.5, RCP6.0 and RCP8.5 (*high confidence*). Warming is *likely* to exceed 2°C for RCP6.0 and RCP8.5 (*high confidence*), *more likely than not* to exceed 2°C for RCP4.5 (*high confide*nce), but *unlikely* to exceed 2°C for RCP2.6 (*medium confidence*). Warming is *unlikely* to exceed 4°C for RCP2.6, RCP4.5 and RCP6.0 (*high confidence*) and is *about as likely as not* to exceed 4°C for RCP8.5 (*medium confidence*). (Stocker et al. 2013, p. 20; emphasis in original)

[20] For the fifth assessment report, see https://wg1.ipcc.ch/AR6/documents/AR5_Uncertainty_Guidance_Note.pdf or http://ipcc-wg2.awi.de/guidancepaper/ar5_uncertainty-guidance-note.pdf. Accessed 6 May 2019.

From this we extract the proposition that warming is more likely than not to exceed 2°C. This is, however, not a claim that a scientist believes; instead it has to be conditionalized on a specific scenario, here the scenario RCP4.5. This proposition is only valid in connection with the mentioned scenario. The proposition that warming is more likely than not to exceed 2°C is to be accepted "for RCP4.5" with high confidence. We propose to regard such an apparent claim as a fictional proposition that is generated by the specific scenario. The climate scientist does not believe the proposition that warming is more likely than not to exceed 2°C. Rather, the scientist make-believes the proposition that warming is more likely than not to exceed 2°C given a specific emissions scenario. Conditional on the RCP4.5 scenario, the content of the proposition is something that it is appropriate to imagine. When considering the descriptions of the RCP4.5 scenario, a user of the scenario should imagine the proposition that warming is more likely than not to exceed 2°C. Using the terminology of scientific fictionalism, the scenario RCP4.5 generates the fictional proposition that warming is more likely than not to exceed 2°C.

This passage also contains the statement that warming is unlikely to exceed 4°C. Like the statement that warming is more likely than not to exceed 2°C, this statement is dependent on particular scenarios, here the three scenarios RCP2.6, RCP4.5 and RCP6.0. Expressed with the language of make-believe theory, the scenario RCP4.5 generates both the proposition that warming is more likely than not to exceed 2°C and the proposition that warming is unlikely to exceed 4°C. This second proposition is also something that one should not *believe.* This is because, if there are no measures to mitigate the emissions of greenhouse gasses in the near future, then warming may easily exceed 4°C. Thus the proposition that warming is unlikely to exceed 4°C might be false, and so one should not believe it. The proper attitude toward this proposition is to make-believe it as well. What is more, both propositions are constrained by the same scenario in the sense that the scenario generates both propositions or one could also say that scenario generates the proposition that is constituted by the conjunction of the two propositions. Given the RCP4.5 scenario, the respective climate model mandates that we should imagine that warming is more likely than not to exceed 2°C and that warming is unlikely to exceed 4°C.

Note that we considered only propositions from the quoted summary for policy makers that were attributed a “high confidence.” In line with the concept of an authorized game of make-believe, we interpret these propositions to be imagined in an authorized way.

Secondly, consider the following quotation from another Summary for Policymakers:

> The evidence for human influence on the climate system has grown since the IPCC Fourth Assessment Report (AR4). It is extremely likely that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in GHG concentrations and other anthropogenic forcings together. (Pachauri et al. 2014, p. 5)

The statement in the last sentence of the quotation is not dependent on one or more emissions scenarios. It is a claim about the cause of warming over the last sixty years. The reader, like the scientists, should have the attitude of belief toward this statement. This statement only involves one of the mentioned measures of uncertainty. It expresses uncerntainty in terms of likelihood that can be translated into a quantitative measure. In contrast, the first IPCC quotation provides typical examples of projections that involve not only a dependence on scenarios but also quantitative *and* qualitative uncertainty measures: likelihood and confidence. Because of the result of the central involvement of qualitative measures of uncertainty we argue that these results should be make-believed. Hence, we argue that projections as model results can be interpreted as fictional propositions toward which one should have the attitude of make-believe rather than the attitude of belief. But other propositions, such as the cited causal claim, are instead to be interpreted as claims that express beliefs.[21] Likewise, claims that express predictions or prognoses require the attitude of belief as well.

So what makes this interpretation of scenarios as props in games of make believe more than a mere theoretical reflection on scientific ficitionalism and climate science without any relevance to concrete problems? In order to get a better grasp of the multifaceted uncertainties associated with climate projections, the fourth IPCC report introduces subjective probabilities in the form of degrees of confidence (cf. Parry et al. 2007). As stressed explicitly by the IPCC, low and very low confidence are only used to depict areas of major concern. The introduction of degrees of confidence is greeted with some skepticism amongst climate scientists as in the physical sciences an objective frequentist account to probability seems to dominate. Furthermore, the numerical interpretation of subjective probabilities in terms of degrees of belief as given by the IPCC report is not justified in an optimal way. Moreover, and arguably more important,

[21] Here, fictionalism about models in general might be leading to a different result. If model results according to particular fictionalist views should all be regarded as fictioanal truths, then this result about the cause of warming would also fall under this recommendation. Because we don't want to claim that such a result shoul be make-believed and rather think that one should believe the statement, we prefer to not embrace fictionalism about models in general.

the explicit introduction of degrees of confidence faces the danger of blurring existing consensus amongst scientists and there is a problem with communicating disputes that are only accessible and understandable to experts but not to a greater public. The IPCC is an intergovernmental body under the auspices of the United Nations and was set up at the request of the governments of its members. It collects scientific information for a varied audience, and one central part of this audience is constituted by policy makers and non-climate experts. Hence, addressing issues of confidence without communicating much more, for example, how the degrees of confidence would look like in other areas of (applied) science we use daily may have detrimental effects.

The fictionalist framework is able to account for the uncertainties that climate modeling and input scenarios bring about without a need to quantify or even express subjective degrees of confidence or degrees of belief. In this framework the principles of generation are responsible for a shared understanding of particular propositions and accepted games are only those with shared principles of generation. As detailed above, we suggest that only the high confidence degrees of the IPCC report are associated with authorized games, which have principles of generation being widely shared. For these authorized games it is the case that one is obliged to have an attitude to make-believe toward the respective fictional propositions.

The attitude to make-believe is not aimed at true beliefs; to make-believe involves imagining something according to specific rules. The content of certain propositions to be imagined may be true, yet it is often not literally true. In an authorized game of make-believe, there are shared and stable rules or principles. For this reason, an authorized game of make-believe is not a freely floating form of imagining, like dreaming up which figures one can see in a cloud. Although propositions that should be make-believed are not always true, they nevertheless have certain correctness conditions; fictional truths therefore have the status of objective imaginings. The propositions generated by scenario-based models can be regarded as forms of fictional truths. As detailed in section 2, such truths are not to be conflated with propositions that are to be believed because one should not unconditionally believe that global warming is unlikely to exceed 4°C; rather this proposition should be make-believed. It is the case that, under certain assumptions detailed in a specific scenario, the model projections state that this is unlikely. The scenario acts as a prop. Together with the principles, the scenario generates the *fictional* truth that the warming is unlikely to exceed 4°C. Like the modeling discussed in Section 2, the principles of generation encompass physical laws. In the case of climate modeling, these are most notably the laws of thermodynamics and fluid dynamics. Beyond that, a whole range of (explicit as well as tacit) knowledge is part of the required competence of a climate modeler. It ranges from knowledge of atmospheric chemistry, to knowledge of modeling cloud formations and their interaction in the atmosphere, to knowledge how to model and parameterize subgrid processes that are too small to be modeled directly on the numerical grids used to implement the climate models (Hillerbrand 2014). The incorporation of this and other knowledge that is both empirically testable and tested makes climate projections a part of scientific inquiry to be distinguished from "mere fiction."[22] Even though the fictionalist account we are employing is motivated by comparisons to fictional works it does not compare results of science with fictional works. One can even state the result without using the term 'fiction': The theory of make-believe offers an account of the difference between propositions that are mandated by props and principles and propositions that are not mandated. And it

[22] Here we use the term "fiction" in the dismissive way that a climate skeptic might employ it.

thereby accounts for a difference between propositions that should be make-believed and propositions that should be believed.

5 Scenarios and Initial Conditions

One question that arises is as to whether scenarios are not just simply sophisticated initial conditions and whether the presented analysis implies that all initial conditions are to be treated as props in games of make believe. This would contradict the realist intuition that model results should ideally be something stronger than just fictional truths, namely propositions that are to be believed. Our answer in nuce is that scenarios are not simply initial conditions. Both deliver input to climate models, however, their functions and uses differ as we will outline in more detail hereafter.

Both scenarios and initial conditions deliver input to climate models. (Quantitative) scenarios and initial conditions both encompass a set of valued parameters. Climatologists distinguish between scenario input and initial conditions, though. In the case of the IPCC climate models the scenarios provide the height of future climate forcing, i.e. the evolution of greenhouse gas concentration in the atmosphere. They relate to energy demand and the economic growth of a society which are both related to the growth of the population. The first difference is while initial conditions in climate models describe the state of the atmo-, hydro- or kryosphere at the present or at some point in the past, scenarios determine the *evolution* of the climate forcing throughout the time period to be modeled, which can be as long as a century.

A second difference is that initial conditions are mostly not hypothetical. Scenarios on the other hand are about the future and are mostly hypothetical; they are not about factual states of affaires, but about potential ones.

Another difference between scenarios and initial conditions is that climatologists deal with the uncertainties arising from initial conditions and uncertainties arising from scenario input in very different ways. While initial conditions such as the present state of the atmosphere are taken from measurements with rather specific uncertainties associated with them, scenarios are very sophisticated estimates about the future course of events when it comes to climate variables such as greenhouse gas emissions. The quantitative scenario input for climate models comes from rather complex, though much less formalized mathematical models (cf. Hillerbrand 2014). While the initial state is known within some bounds, the scenario can be associated with high uncertainties that are hard to quantify; scenarios as potential future emission pathways are not assigned a specific likelihood or probability of occurrence (cf. Bray and van Storch 2009; Hillerbrand 2014). This is the central reason as to why the IPCC suggests the differentiation between predictions and projections as introduced above. Despite the high uncertainties associated with scenario input, it needs to be kept in mind that complex model-based reasoning underlies the creation of scenarios. Scenarios are not simple guesses about the possible future world we live in with respect to climatic relevant parameters. Rather scenarios derive from sophisticated estimates about potential emission futures and the underlying economic, ecological and political changes.

The last difference between scenarios and initial conditions is that while there is often only one set of initial conditions, there is usually a multitude of scenarios. Scenarios operate in a holistic way in the sense that their function can only be understood in comparison to other scenarios within a group of scenarios, often called a *family* of scenarios. Someone working with scenarios needs many of them to compare model runs with respect to these different scenarios.

6 Concluding Discussion

According to scientific fictionalism, the theory of make-believe can explain the face value practice of talking and thinking about apparently non-actual things as if they were part of our world. Model descriptions as props in games of make-believe generate fictional propositions that have an objective status even though they may not be true. In this paper, we showed that the theory of make-believe can shed new light on the use of scenarios in climate modeling. We used emissions scenarios to demonstrate that in climate modeling, scenarios can also be reconstructed as props in games of make-believe. We argued that in climate modeling the scenarios and not the model descriptions comprise the function of props. Along with this reconstruction, we offered an interpretation of the notion of projection as used by the IPCC; our interpretation explained the difference between projections and both predictions and prognoses by scrutinizing the required attitude toward these different model results. Just as props generate propositions that are to be imagined according to certain games of make-believe, so the scenarios of climate models generate projections as model results that are to be imagined by users of these models. The appropriate attitude toward scenario-based model results that are generated in this specific way is therefore not to believe but to make-believe these results.

As noted above, however, using Walton's theory of make-believe to analyze scientific modeling does not undermine the trustworthiness and reliability of scientific modeling in the slightest. According to pretense theory, the scientifically justified methodology of modeling is part of the principles of generation. The virtue of scientific fictionalism applied to scenario-based models is that it helps to differentiate the specific attitude toward model-based results that rely on scenarios. Moreover, we hope that our interpretation will help the users of scenario-based model results, scientists as well as laypeople and policymakers, to better understand these results and to integrate them into their knowledge systems.

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