Uncertain Futures:
Tracing the Conceptualisations of Uncertainty and the Imaginaries of Futures in the Assessment Reports of the Intergovernmental Panel for Climate Change

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ABSTRACT

By tracing the conceptualisation of uncertainty in the Assessment Reports of the Intergovernmental Panel for Climate Change (IPCC), this thesis explores the imaginaries of the future constructed by the scenario-planning methodology. In its assessments, I argue that the IPCC produces spaces where technical and socioeconomic uncertainty is operationalized to construct interpretations of prescriptive futures wherein it is possible to retain contemporary economic relations *and* effectively mitigate climatic changes. Finally, I explore the temporal displacement that scenario-construction can produce; that is, the imaginaries of the future seek to displace us temporally from the point that effective, political action *must be* taken to one where it is *being taken*.

I argue that engaging with dominant knowledge producing institutions, like the IPCC, is a necessary step in understanding how prescriptions are embedded in climate research; I seek to excavate these prescriptions and understand how contemporary economic relations are being inscribed in the scientific knowledge production of climate change. I problematise the political and economic relations that underscore the scientific knowledge production; to ask why it is, that: "the more knowledge there is of the consequences, the more fossil fuels are burnt"?[1]

[1] Malm, Andreas. *Fossil capital: The rise of steam power and the roots of global warming.* Verso Books, 2016: Chapter 1

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Finally, to all the people who informed my political thinking; your critical work carries this thesis and reminds me of the political stakes inscribed in this kind of work.

[2] Borrowed from Ann Stoler in *Along the Archival Grain*: : "The term "acknowledgment" has always struck me as a misnomer that carries with it more an obligatory recognition of debt than the valued recognition that appreciation implies. How to convey the gratitude that comes from those savored friendships, nourished by trust and care, that in turn enable bolder forays and more engaged critique?"

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Introduction

In 2018, the global atmospheric concentration of carbon dioxide registered at 408.52 parts per million (ppm). This was a 25.2% increase from the early 1970s[3]—the time when the CO_2 concentration had exceeded over 320 ppm; prompting concerns from international organisations, various governments, and scientists that the corresponding carbon emissions were increasing far too quickly. In 1972, after its Environmental Conference in Stockholm, the United Nations established the Environment Programme which would, in 1988, join forces with the World Meteorological Organisation to form the Intergovernmental Panel for Climate Change (IPCC). In the UN General Assembly of December, that year, the IPCC was specifically asked to "delay, limit, or mitigate"[4] climate change, with the recognition that "human-induced climate change can have profound consequences for the world's social, economic and natural systems".[5]

Since then, the IPCC has engaged in endorsing understanding, and mapping historical climatic data to understand what the future trajectories of these extreme changes might be. What is the rate of increase of carbon emissions in the next couple of decades? How does this rate of increase affect atmospheric compositions? The IPCC attempts to understand these questions with the recognition that the rapidly changing climatic conditions are intrinsically linked to the social, economic, and natural conditions of the world, and, in turn, will drastically affect people's livelihoods, health, homes, and societies. Therefore, understanding the atmospheric concentrations of CO_2 requires not just scientific data; but also socioeconomic data which can trace and map how these concentrations *have been changed and will be changed* in the future. Recognising that indicators of climate change go far beyond carbon

[3] Refer to Figure 1; Graph taken from *Our World in Data*: https://ourworldindata.org/atmospheric-concentrations
[4]General Assembly resolution 43/53, *Resolutions Adopted on the Reports of the Second Committee.*
[5] Intergovernmental Panel for Climate Change, Synthesis Report. *First Assessment Report.* Cambridge University Press, 1990

emissions, the IPCC utilises the methodology of scenario-construction—much like contemporary climate, economic, and financial research—to articulate, map, and discuss *possible trajectories* of climate change that might unfold depending on present variables.[6] These 'scenarios', therefore, are articulations of *futures* that are constructed using scientific, social, economic, and environmental modelling systems.

Possibility appears perfectly placed in the epistemological-theoretical discussions in the fields of philosophy and mathematics. It was Gottfried Wilhelm Leibniz who explored the possibility of the existence of other worlds; and propounded a correlation between "creatability of worlds"[7] and the "degrees of possibility in the mind of God."[8] In his work on the philosophical and mathematical possibility of infinity, Georg Cantor proposed the reconceptualisation of the numerical representation of the infinite;[9] a proposal that could contribute to the mathematical understanding of impossibility and possibility.[10] Foundational to any discussion of possibility, however, is the notion of uncertainty—something that has also beleaguered philosophers and mathematicians. Displacing the commonly accepted notions of epistemic uncertainty, David Hume, in his *Treatise of Human Nature*, argued that the certainty with which causation is implied, might be misplaced. The philosophical, scientific, and mathematical conceptualisations of uncertainty are the basis of the "contemporary philosophy of possible worlds" which engages with "the logic of possibility, necessity and contingency"[11]

In this thesis, however, I investigate the epistemological-theoretical foundations of uncertainty, possibility, and futures, not in contemporary philosophical or mathematical fields; rather,

[6] Refer to Figure 2; an example from the IPCC 5th Assessment Report that maps carbon dioxide concentration over the next 480 years depending on various 'scenarios'.
[7] Cooper, Melinda. "Turbulent worlds." *Theory, Culture & Society* 27, no. 2-3 (2010): 173
[8] Ibid. For a detailed discussion of Leibniz's possible worlds, refer to *Turbulent Worlds,* 173-174
[9] Dauben, Joseph Warren. *Georg Cantor: His mathematics and philosophy of the infinite.* Princeton University Press, 2020.
[10] Priest, Graham. "Thinking the impossible." *Philosophical Studies* 173, no. 10 (2016): 2649-2662.
[11] Cooper, Melinda. "Turbulent worlds." *Theory, Culture & Society* 27, no. 2-3 (2010): 174

I argue that these conceptualiations are inextricably interwoven with contemporary, scientific knowledge production of climate change.

Intergovernmental Panel for Climate Change: A Brief Background

The Intergovernmental Panel for Climate Change—with member governments' experts, external scientists, researchers, economists—produces Assessment Reports (AR) and Working Group Reports which utilise existing scientific research on climate change to assess scenarios for the future. The Assessment Reports synthesise the latest scientific, technical, financial, economic, and social datasets to make sense of where carbon emissions might be headed in the next hundred years. What impacts will the emissions have? What are the ways of mitigating these impacts? What are the challenges of mitigation? What are some of the challenges of gathering knowledge about climate change? These are some of the questions these Assessment Reports bring forward and attempt to answer.

"Following a call to governments and IPCC observer organisations for nominations and the submission of detailed CVs, authors are selected on the basis of their expertise"[12] and contribute to the Assessment Cycles with their respective fields of expertise. From the existing scientific literature, these authors collate, manipulate, and endorse climatic and socioeconomic data; this is then mapped onto existing scenario-constructions—also selected from published scientific literature. Over the course of the Assessment Cycle, various teams produce their reports for consideration and review; therefore, much like a reviewed scientific article, these reports are only published after extensive reflective processes.

[12] Intergovernmental Panel For Climate Change. 'IPCC Factsheet: How Does the IPCC Select its Authors?" https://www.ipcc.ch/site/assets/uploads/2018/02/FS_select_authors.pdf

The IPCC is not an insular organsiation, it is a dominant knowledge producing institution that utilises the latest scientific data, manages varying governmental relationships, and engages in multi-level modelling of futures; this makes it an important institution to track. While it does not produce scientific data and models; its endorsement, treatment, and understanding of existing scientific knowledge These reports are significant because IPCC collaborates with governments, researchers, scientists to produce 'acceptable' data and visions of futures for climate change mitigation.

This thesis is grounded in the five Assessment Cycles of the IPCC conducted between 1990 and 2014—with explicit analysis of the shift between the Fourth and Fifth Assessment Cycles. Research for the sixth report is currently underway and will be published in 2022. According to existing scholarship on the IPCC reports, the first four Assessment Reports utilise expertly conducted scientific research and hierarchical modelling systems; however, the fifth reports, as discussed previously in the proposal, relied on a parallel modelling system to map out socio-economic relations with climate change.

The argument of this thesis is structured as follows:

I. Tracing the conceptualisation of epistemic uncertainty in the Assessment Reports
II. Investigating the scenario-construction methodology for the production and endorsement of prescriptive future imaginaries
III. Exploring the imaginaries of the future as logical necessities to understand how they restrict political alternatives.

In order to grasp the potential trajectories of climatic changes over a period of time, it is necessary to engage with the notion of scientific uncertainty—as I will illustrate in the first chapter, uncertainty is a crucial conceptualisation that enables the utilisation of the scenario-construction methodology. Therefore, in the first chapter, I explore the conceptualisation of uncertainty in scientific literature; particularly the distinction between aleatory and epistemic uncertainties. What is the basis of this distinction? Recognising that the IPCC Assessment Cycles utilise complex notions of epistemic uncertainty, I will trace how the concept evolved in their knowledge production not just discursively but also methodologically. Moving through the reports, I locate the distinctions between technical and socioeconomic uncertainty as they appear in the IPCC reports to illustrate how uncertainty is produced in the processing of climatic measurements and socioeconomic data.

Then, I investigate the scenario-construction methodology: what are its uses? On what basis—scientific, philosophical, political, logical—does this methodology hold ground? By illustrating the conceptual and political spaces scenario-thinking delimits, I argue that it produces certain imaginaries of the future; by imaginaries, I refer to the political visions of the future that interpret what the world *might, and should, look like*. constructed scenarios are political tools through which certain *futures* are rendered desirable and *possible*.

Finally, the third chapter explores the temporalisation inscribed in the methodology of scenario-construction and its political consequences. What does the construction of the future reveal, conceal, and obscure about the present? How does an imaginary of the future produce a judgment on contemporary political, social, and economic relations?

Methodology

The methodology of this investigation consisted of three parts: analysing the Working Group and Synthesis Reports; tracing the methodological, conceptual, and discursive shifts between the Assessment reports, particularly between the Fourth and Fifth Assessment Cycles; and investigating the scientific and socioeconomic modelling processes upon which the climate research is constructed.

For the Working Group and Synthesis Reports, I employed techniques from discourse and archival analysis. Particularly, I focused on tracing the conceptualisation of uncertainty in order to locate its operationalisation in the construction of the scenarios. Rather than starting chronologically, I began with the latest IPCC reports (in fact, these reports belong to the Sixth Assessment which is due to be completed in 2022) and moved backwards. I studied the Special Report on the Global Warming of 1.5°C published in October 2018 *and then* began a structured analysis of the Five Assessment Cycles. First, I tackled the Synthesis Reports of all the Cycles starting from the Fifth. Briefly highlighting and mapping the conceptualisations of uncertainty, I then turned towards the three Working Group reports for each assessment and researched the *exact methodology the researchers employed* to make the conclusions I had found earlier in the Synthesis Reports.

For the second step of my analysis, I compared the conceptualisations I had found across the reports and grouped them according to their modelling methodology. While I had noticed a shift between the Fourth and Fifth Cycles earlier, it was at this moment that the shift indicated not only a discursive basis but also a methodological one. Between the Fourth and Fifth Assessment Cycles, the IPCC adopted different modelling processes to construct new scenarios and produce updated climate projections.

While grouping the conceptualisations of uncertainty according to their modelling methodologies, I consulted the work of Akira Kasahara, Akio Arakawa, and Vivian Lamb published in the 'Methods in Computational Physics: Advances in Research and Applications' journal in 1977 to understand the General Circulation Model[13] and other numerical models for climate research.[14] The General Circulation Model is a tool for understanding the impact of different atmospheric concentrations on the "physical processes in the atmosphere, ocean, cryosphere and land surface"[15]. Understanding the modelling techniques was a necessary step *before* commencing a detailed conceptual analysis of uncertainty as it informed my research on the scenario-construction used by the IPCC.

For the analysis of scenario-construction, I moved away from the IPCC documents and traced the methodology back to its origins. Melinda Cooper's *Turbulent Worlds* was my first point of reference. Understanding the method of scenario-construction independently, I revisited the IPCC documents to research how their authors employed this methodology and why.

There were two limitations that I faced during my investigation: analysis of the scientific processes and the vast volume of archival material. My natural sciences background is limited; therefore, the obvious limitation I had to overcome was thoroughly understanding the natural scientific basis of the climate research conducted by the IPCC and other contemporary climate researchers. During the preliminary research stage, I consulted numerous academic resources—particularly, articles published in the 'Earth and Planetary Sciences' section of the *ScienceDirect* journal—to understand the scientific and technical basis of climate research. I also attempted to study how climatic measurements are conducted, their time-frames, and limitations. Furthermore, I studied the glossaries of the IPCC documents, environmental textbooks, and other climate research literature to understand the key concepts like radiative forcing, atmospheric concentrations, lag-times,

To understand the Integrated Assessment Models, and other climate modelling techniques used by the IPCC, I turned to three resources: environmental science textbooks, the Socioeconomic

[13] KasaHara, Akira. "Computational aspects of numerical models for weather prediction and climate simulation." In *Methods in Computational Physics: Advances in Research and Applications*, vol. 17, pp. 1-66. Elsevier, 1977.
[14] Arakawa, Akio, and Vivian R. Lamb. "Computational design of the basic dynamical processes of the UCLA general circulation model." *General circulation models of the atmosphere* 17, no. Supplement C (1977): 173-265.
[15] https://sedac.ciesin.columbia.edu/ddc/ar5_scenario_process/index.html

Data and Applications Center (affiliated with NASA), and the Earth Observing System Data and Information System (also a division of NASA). The two divisions of NASA provided detailed information of the datasets and modelling processes utilised by the IPCC. Understanding this information was more difficult than the textbooks as it is geared towards high level researchers in the field of climate research; however, it provided all the necessary explanations for the modelling processes so that I could conduct my analysis of the changes through the years. Finally, I parsed through the IPCC archives for explanatory documents of their methodology—in a couple of quick searches, I was able to find detailed explanations of their scientific methodology as they often publish special 'Methodology Reports' every couple of years.

The second limitation of this investigation is the vast volume of archival material. Every Assessment Cycle produces not just the Working Group and Synthesis Reports, but an array of Special Reports, Explanations, and Refinements. For the scope of this research, I studied the Working Group and Synthesis Reports of the five Assessment Cycles; however, there is more material that *needs to be studied to continue this project*. I remained within the scope of the published reports, but extending this project would require further investigation into unpublished and unofficial information pertaining both to the scientific and socioeconomic data collected by the IPCC.

Chapter I: Tracing the Conceptualisation of Uncertainty

In scientific literature concerning statistical methodologies, uncertainty is differentiated into two types: aleatory and epistemic. Put simply, "aleatory probabilities have to do with the physical state of coins or mortal humans. Epistemic probabilities concern our knowledge."[16]. To understand the first type of uncertainty, we can look to the root of the word itself: the Latin, *aleatorius,* which refers to a gamester, and *alea,* a game with dice;[17] aleatory uncertainty, therefore, is the probabilistic uncertainty of stochastic processes like throwing a die, or flipping a coin. Epistemic uncertainty, however, is the type of unknowns that pertain to our knowledge; that is, our relationality to the scientific object. Uncertainty of the epistemic kind, "generally, but not always, concerns past or present phenomena that we currently don't know but could, at least in theory, know or establish"[18]. We don't *know* something in the present moment, however, with more evidence, *it is possible* to acquire more knowledge and thus, be *more certain* about a scientific object. Furthermore, epistemic uncertainty necessitates the investigation of the origins of our surety: *how* can we be certain that our knowledge of a scientific object is accurate? How can we be certain that it is possible to *even know* the scientific object? Methodologically, apparent patterns in repeated experimentation can limit the degree of epistemic uncertainty but cannot completely erase the margin. This definition of epistemic uncertainty—the incomplete knowledge of the scientific process, event, or object—posits that it is

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[16] Hacking, Ian. *The emergence of probability: A philosophical study of early ideas about probability, induction and statistical inference*. Cambridge University Press, 2006: 147-148

[17] Etymology of Aleatory. From: https://www.etymonline.com/word/aleatory#etymonline_v_8126

[18] Van Der Bles, Anne Marthe, Sander Van Der Linden, Alexandra LJ Freeman, James Mitchell, Ana B. Galvao, Lisa Zaval, and David J. Spiegelhalter. "Communicating uncertainty about facts, numbers and science." *Royal Society open science* 6, no. 5 (2019): 181870: 2

possible to get closer to the state of complete knowledge of a scientific object by gathering more information, seeking patterns, and repeating experimentation.

In *The Emergence of Probability*, Hacking illustrates that aleatory probabilities are quantitative[19] instruments of communication: for every coin flip, die roll, or card draw, we can understand and communicate the probability of its outcomes by quantifying the possible results; however, while we can know all the possible outcomes in cases like die rolls and coin flips, we don't *know what the outcome* will be for a particular coin flip. We can only say that since there are two possibilities, there is always a 50% chance of landing either one. However, as Hacking points out, "epistemic probability is not like this. You can compare the degree to which evidence warrants several propositions without recourse to numbers."[20]. Epistemic probabilities and uncertainties can be communicated without quantification; predominantly through confidence levels, beliefs, and likelihoods. As opposed to stochastic uncertainties, fundamental to the scientific conceptualisation of epistemic uncertainty is that it is reducible; through increasing test repetitions, increasing sample sizes, etc., it is, theoretically, possible to grasp more of the scientific object. The likelihood of reducing epistemic uncertainty is itself something that can be understood through qualitative measurements.

This is precisely the conceptualisation of uncertainty we encounter in the assessment reports of the IPCC: 'epistemic', and specifically, technical. All climate measurements, atmospheric concentrations, sea level rises, carbon emission rates, et cetera are communicated in terms of confidence intervals and likelihoods; that is, uncertainty is itself inscribed in the way these epistemic probabilities are understood. Scientific data pertaining to the object of the 'climate' is collected using various technologies and techniques; there is a whole host of institutions responsible for understanding the meteorological, geological, hydrological, (and so on) cycles independently and

[19] Hacking, Ian. *The emergence of probability: A philosophical study of early ideas about probability, induction and statistical inference*. Cambridge University Press, 2006. 99-100
[20] Ibid: 99

interdependently. Let us take the example of a relatively simple climate measurement like the atmospheric composition. Large institutions like the World Meteorological Organisation have monitoring watches that coordinate with smaller scientific bodies across the world to sample air and measure its composition according to their criteria: radiation, greenhouse gases, et cetera. These measurements will change depending on the location, time of the day, and even presence of other compounds; however, repeated sampling, cross-checking, and comparing measurements has allowed institutions like the WMO, and the scientific bodies associated with the IPCC, to be quite certain of their understanding of the atmospheric composition. Their studies, among others, have repeatedly demonstrated the increasing rate of greenhouse gases in the air composition across the world. However, the raw measurements taken on any given day can be affected by 'sensitivities' to other compounds, and background chemical molecules.[21] That is, the presence of some molecules might highlight the presence of others or, in fact, make it harder to detect. This is the technical uncertainty present in the scientific process.

Technical uncertainty contributes to epistemic probability as it specifies the source of the uncertainty: the level of confidence in technological and scientific objects. Accounting for technical uncertainty means that scientific bodies have to acknowledge and minimise the risks associated with scientific instruments and ensure that measurements can be as accurate as possible. This kind of

[21] For more detailed explanation of sensitivities, refer to: Chapter 16: Measurement of Atmospheric Composition: https://library.wmo.int/?lvl=notice_display&id=19672#.YMNFWqgzaUk

epistemic uncertainty is present throughout the assessment conducted by the IPCC since its conception. Therefore, evidence is presented through qualitative expressions of uncertainty, like:

(*robust evidence, high agreement*)

(*limited evidence, medium agreement*)

(*high confidence*)

These are discursive expressions of scientific probabilities that have become increasingly consolidated through the two decades of IPCC assessment. That is, climate data which was presented with *medium confidence* in the assessments of 2001 is now presented with *very high confidence* in the assessments of 2014. Therefore, while the degree of confidence may have changed, the conceptualisation of uncertainty as a technical, epistemic object remains the same through the assessment reports.

The scientific data presented in the Third Assessment Report is explicitly accompanied by the clarification that, "progress has been made in reducing uncertainty, particularly with respect to distinguishing and quantifying the magnitude of responses to different external influences"[22]. That is, technical uncertainty has been substantially reduced in the measurement of scientific data from the initial reports of the IPCC. Through the working groups' and the synthesising assessment reports, there is a clear understanding of uncertainty as an object of the scientific process that needed to be controlled and reduced. Furthermore, we find clear demarcations between scientific uncertainty and *socioeconomic* uncertainty: "a key uncertainty is the lack of appropriate knowledge on the interactions between climate change and other environmental issues and the related socio-economic

[22] Intergovernmental Panel for Climate Change, Climate Change 2001: *Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, 2001: 158

implications"[23]. Therefore, the focus of the report was predominantly on reducing the technical uncertainty of the scientific measurements of climate data.

Uncertainty, in all of the IPCC reports, is found in the concept of a 'time-lag'. Particularly, at the turn of the century, when the Third Assessment Report was published, the notion of epistemic uncertainty surrounding climate data due to time-lags was an acute problem for different scientific disciplines. Time-lags are essentially temporal sources of uncertainty surrounding climate data: for example, when measuring atmospheric concentrations, the air samples reflect accumulated compositions from the past, that is, it takes a certain amount of time for the emissions to be reflected in the concentrations. This was precisely the concern expressed the third report, specifically referring to the problem of adaptation: "adaptation is affected by the time lags involved in identifying climate change impacts, developing effective adaptation strategies, and implementing adaptive measures"[24]. After recognising that atmospheric concentration, among other climate measurements, actually *lagged* back in time, scientific bodies associated with the IPCC grew increasingly concerned about the time-frame of *any* adaptive measures. This concern was rooted in the uncertainty of temporality of the measurement itself: how can we understand atmospheric concentrations if we are essentially measuring accumulated concentrations? How can we measure, calculate, or model for accumulated concentrations that would reflect the concentration *of contemporary emissions*? This uncertainty was not just of atmospheric concentrations, scientists soon realised that *all* climate measurements were essentially displaced in time and that scientific bodies would have to understand the rate of the time-lag and measure climate data accordingly.

While this uncertainty has not been entirely reduced, various mathematical and statistical models have allowed for the incorporation of this time-lag into climate measurements since the third

[23] Ibid: 145
[24] Intergovernmental Panel for Climate Change, Climate Change 2001: *Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, 2001: 18

assessment report.[25] Similarly, the technical uncertainty encountered in terms of climate sensitivity has also been understood more thoroughly since the early 2000s. In the Third Assessment Report, the authors clearly acknowledge that:

> Because of uncertainty in climate sensitivity, and uncertainty about the geographic and seasonal patterns of changes in temperatures, precipitation, and other climate variables and phenomena, the impacts of climate change cannot be uniquely determined for individual emission scenarios.[26]

This technical uncertainty revolves around understanding the specifics of climate measurements in terms of their impacts in different scenarios of the future: that is, it was difficult to predict the individual climatic changes that different scenarios would entail. For example, if the carbon dioxide concentration exceeded 800 parts per million for some given future year, say 2050, it was difficult to determine scientifically the changes in the different climate variables. It was difficult to model what seasonal changes in temperature would look like; or, what levels of precipitation we should expect, et cetera. The fundamental reasoning behind this was simple recognition that the climatic variables are not insular.

The foundational premise of the IPCC was to acknowledge "human-induced climate change"; however, so far, I have only discussed epistemic and technical uncertainty. I have only outlined what the *scientific* conceptualisations of uncertainty are and how they operate in the early IPCC reports. However, between the third and fifth assessment reports, the conceptualisations of uncertainty underwent a radical transformation: while the conceptualisation of technical uncertainty was itself

[25] For Time-Lag refer to: Hagen, Melanie, W. Daniel Kissling, Claus Rasmussen, Marcus AM De Aguiar, Lee E. Brown, Daniel W. Carstensen, Isabel Alves-Dos-Santos et al. "Biodiversity, species interactions and ecological networks in a fragmented world." *Advances in ecological research* 46 (2012): 89-210.

[26] Intergovernmental Panel for Climate Change, Climate Change 2001: *Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, 2001: 104

retained, the fourth and fifth assessment cycles identified and worked towards the thorough characterisation of *socioeconomic uncertainty*.

In terms of technical uncertainty, the authors of the Fourth Assessment Report clearly state that "the range of projections [of emissions are] broadly consistent with the [third assessment report]"[27]; however, "uncertainties and upper ranges for temperature are larger mainly because the broader range of available models suggests stronger climate-carbon cycle feedbacks.[...] The strength of this feedback effect varies markedly among models"[28]. Through the extensive use of advanced measurement and modelling technologies, the fourth report actually indicates *an increase* in the margin of the upper temperature uncertainty precisely because of innovative feedback models developed between the two assessment reports. Let us just grapple with this complex notion of uncertainty: the epistemic claim here is that *because* of advanced modelling systems, we can actually see that climate feedback cycles will be stronger, but this actually causes an increase in the uncertainty of ascertaining the precise range of high temperatures. While technical uncertainty might have decreased, the larger, epistemic uncertainty *actually increases* as we know that there are stronger feedback mechanisms, but we don't know *how strong*.

In the Fourth Assessment Report, there are indications of a more consolidated conceptualisation of technical uncertainty and its relationality to epistemic claims. There have been numerous modelling, measurement, and procedural improvements between 2001 and 2007 that have allowed for a clearer grasp of the uncertain scientific object. Inherent in the claim of epistemic probability and uncertainty is, therefore, the notion that it can be reduced. However, the object of *socioeconomic uncertainty* is not so thoroughly conceptualised at this juncture; the fourth assessment still

[27] Intergovernmental Panel for Climate Change: Climate Change 2007: *Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. Geneva, Switzerland, 2007: 7
[28] Ibid: 7

characterised the non-technical uncertainties in an ambiguous and constantly changing manner. For example, when discussing the socioeconomic elements of climate change, the authors wrote that the, "barriers, limits and costs of adaptation are not fully understood, partly because effective adaptation measures are highly dependent on specific geographical and climate risk factors as well as institutional, political and financial constraints"[29]. At this point, there was a stark imbalance in how socioeconomic uncertainties and risks were being handled in comparison to the technical uncertainties.

Reading the documents from the Fifth Assessment Cycle is an intriguing exercise: on one hand, so much of the scientific material is similar to previous findings, measurements, and foci; yet, it also reflects a drastic change in the urgency and methodologies of the scientific, political, and economic bodies tasked with the research. Something shifted; uncertainty was itself subjected to scientific experimentation and philosophical consideration. In addition to conceptualising uncertainty as technical and a part of the scientific process, there was an acknowledgement that climate research cannot solely focus on climatic measurement because it is, fundamentally, *not only* a scientific issue, but a social-political-economic one. There was an acknowledgement that, "climate change exposes people, societies, economic sectors and ecosystems to risk. Risk is the potential for consequences when something of value is at stake and the outcome is uncertain, recognizing the diversity of values"[30]. The authors highlighted the necessity of understanding uncertainty itself as an expanded concept:

> Uncertainties in the past and present are the result of limitations of available measurements, especially for rare events, and the challenges of evaluating causation in complex or multi-component processes that can span physical, biological and human systems. For the future, climate change involves changing likelihoods of diverse outcomes. Many processes and mechanisms are well understood, but others are not. Complex interactions among multiple climatic and non-climatic influences changing

[29] Intergovernmental Panel for Climate Change: Climate Change 2007: *Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. Geneva, Switzerland, 2007: 73, 74

[30] Intergovernmental Panel for Climate Change: Climate Change 2014: *Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer. (eds.)]. Geneva, Switzerland, 2014: 36

over time lead to persistent uncertainties, which in turn lead to the possibility of surprises.[31]

The reason for understanding uncertainty as an expanded concept comes directly from the acknowledgement that climate change is not purely a scientific or natural phenomenon to be observed, but a larger issue. The interactions between 'climatic' and 'non-climatic' influences, which were not well understood over a decade before the fifth assessment, were now the center of the scientific inquiry; the uncertainties pertaining to the social and economic conditions were explored just as much as the 'scientific' basis of climate change.

The expanded notion of uncertainty in the Fifth Assessment Cycle is intriguing for many reasons, the fundamental one being that it defines uncertainty not simply as a scientific, epistemic disagreement between different expert claims; rather, it politicises the notion of epistemic uncertainty itself and concedes that, often, epistemic uncertainty can arise from the moral and political disagreements between experts. Thus, it incorporates into the philosophical conceptualisation of epistemic uncertainty the notion of political disagreements—what *is* the problem, what *should* be done about it, *how long* can we go without actually reducing fossil fuel emissions, et cetera. One doesn't have to venture far into the IPCC discourse to understand what 'political disagreements', or simply, non-technical disagreements might be: looking at the glossary itself, the expanded definition included "ambiguously defined concepts or terminology"[32], or "uncertain projections of human behaviour"[33]. Ambiguity, here, pertains predominantly to the non-climatic conceptual apparatus; that is, the economic, political, and social dimensions. In the imagination of the IPCC, these 'non-climatic' elements include fossil fuel consumption, historic carbon emissions, contemporary 'green' technologies, human population rates, 'economic growth', et cetera. By incorporating 'disagreements'

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[31] Ibid: 37

[32] Intergovernmental Panel for Climate Change: Climate Change 2014: *Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer. (eds.)]. Geneva, Switzerland, 2014: 128

[33] Ibid.

into the definition of uncertainty, their own notion of a scientific, epistemic uncertainty begins to disintegrate. This incorporation illustrates that the space of what is called a 'scientific epistemic uncertainty' itself is changing.

This is not purely a discursive move; the point here is to understand the underlying processes of this shift and their consequences. I turned to the modelling softwares themselves: were the socioeconomic conditions being centered merely discursively in these reports? Or, was that an indication that the conceptualisation of climate change is undergoing a radical shift, and the consideration of the expanded notion of uncertainty might tell us something about it? Was it the case that the authors of the fifth report simply decided that there should be increased focus on the 'non-climatic' aspects of climate change in the newer reports? Or, was there a methodological shift in the knowledge production? Indeed, there was a radical change in the methodology of modelling used for the fifth assessment as opposed to the previous ones: rather than the linear modelling process used previously, a parallel, integrated modelling system was utilised to process climatic, social, and economic data.

The foundational modelling methodology utilised by scientific institutions and researchers to process climatic and its corresponding data is the Integrated Assessment Model. These are methodologies of analysis, data collection, and assessment portfolios which combine different disciplinary models of climate, social, and economic measurements; the IAM attempts to model the complex relationships between 'natural' and 'social' (read: economic) conditions to understand the range of impacts changing climates can have.

As van Beeck et al. explain, "IAMs are in essence computer simulations that represent complex interactions and feedbacks on a long time scale between the socioeconomic system (including climate policies) and the natural system, which are explicitly designed to inform climate policy-making"[34]. These assessment models can account for complex feedback mechanisms and sensitivities *over a particular period of time*; that is, these models can process socioeconomic and climate data simultaneously over a chosen time-period and see how initial interactions impact the subsequent ones.

The Integrated Assessment Models, along with other modelling systems, were utilised to understand how different 'human actions' interact with the changing climatic conditions. In the earlier reports, the IPCC would utilise socioeconomic data to understand its effects on climatic elements individually; then, would "assess the implications of those climate changes, along with differing socio-economic futures and other environmental changes, on natural and human systems"[35]. The methodology, known as the linear modelling process, involved prioritising socioeconomic data (like, consumption rates, population rates, growth, and other economic indicators) to understand the impact on other variables like emission rates. Using *existing socioeconomic scenarios* produced by the scientific and economic community, this process would try to understand what kind of emissions, fossil fuel consumption rates, etc. could we expect over a set period. Then, the climate modelling process would develop these scenarios further and provide more detailed projections that would be used to understand the scenarios further.

This modelling process, according to the authors of the Fourth Assessment Report, required the management of uncertainty. In the Working Group report of this assessment cycle, the authors mention that integrated models have a trade-off "between realism and flexibility, where simple models are more flexible but less detailed, and complex models offer more detail and a greater range of

[34] van Beek, Lisette, Maarten Hajer, Peter Pelzer, Detlef van Vuuren, and Christophe Cassen. "Anticipating futures through models: the rise of Integrated Assessment Modelling in the climate science-policy interface since 1970." *Global Environmental Change* 65 (2020): 102191: 2

[35] "SCENARIO PROCESS FOR AR5." Socio-Economic Data and Scenarios. https://sedac.ciesin.columbia.edu/ddc/ar5_scenario_process/index.html.

output"[36]. The implication here is that complex models do not offer the opportunity for flexibility. There is a *choice*, therefore, in what type of models are utilised to map and project both 'climatic' and 'non-climatic' elements; even more so, there is a choice in the employment of models to manage uncertainty. The expert, in that moment, chooses what sort of 'uncertainty' needs to be minimised; further indicating that the scientific object of epistemic uncertainty put forward by the earlier IPCC reports now included definitions of 'choice', and 'trade-off'.

At this point, however, the notion of expert disagreements had not appeared in the IPCC reports explicitly. But the modelling process was already changing. As Low and Schäfer discuss in relation to bio-energy capture, "since 2006 (for eventual incorporation into AR5), IAM work has undergone a community-wide shift to a 'matrix architecture', where scenarios are developed by varying three kinds of parameters: radiative forcing, socio economic development, and policy"[37]. These parameters, rather than being developed linearly as discussed above, were being developed by different working groups parallelly. Thus, in the Fifth Assessment Report, the social and economic conditions were not *assumed* to construct existing scenarios for the climate modelling process and further scenario developments but were brought *into the matrix of the modelling processes*. By concurrently developing socioeconomic and climate models, the scientific institutions which contribute to the latest IPCC assessment cycles have the opportunity to theoretically grasp the object of socio-economic uncertainty in terms of climate research. Rather than processing socioeconomic data *in order to* construct climate models, for the fifth assessment report, climatic and socioeconomic data was processed

[36] Intergovernmental Panel for Climate Change. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press. 2007: 139
[37] Low, Sean, and Stefan Schäfer. "Is bio-energy carbon capture and storage (BECCS) feasible? The contested authority of integrated assessment modeling." *Energy Research & Social Science* 60 (2020): 101326.2

simultaneously; therefore, contributing to an 'expanded' conceptualisation of technical and socioeconomic uncertainties evident in the fifth assessment cycle.

In the Working Group report of the fifth assessment cycle, there is a systematic and meticulous treatment of uncertainty; in fact, in a particularly entertaining passage, the authors declare that "natural language is not adequate for propagating and communicating uncertainty"[38] Therefore, an amalgamation of qualitative and quantitative representations are justified not just in the report, but in the modelling process itself. By incorporating a particular set of 'socioeconomic' conditions into the modelling process through the Integrated Assessment Models, these conditions and their perceived uncertainties can be theorised and *understood*; they were no longer assumed at the beginning of the process; but, were instead treated as dynamic conditions that required scientific attention.

Furthermore, in comparison to earlier reports, where social and economic "judgment and choice were primarily framed in rational-economic terms"[39], the recent assessment cycle "reviews the psychological and behavioural literature on perceptions and responses to risk and uncertainty."[40] Thus, in addition to shortening the modelling time, the fifth assessment cycle attempted to consolidate a holistic understanding of what they previously called 'non-climatic' elements. Therefore, the incorporation of socioeconomic conditions into the modelling process also allowed the authors and

[38] Intergovernmental Panel for Climate Change. Climate Change 2014: *Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press. 2014: 174

[39] Intergovernmental Panel for Climate Change. Climate Change 2014: *Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press. 2014: 159-160

[40] Ibid.

other contributors of the IPCC to attempt to grasp other kinds of uncertainty inherent in the problem of climate change.

This shift in the modelling process and the conceptualisation of uncertainty, however, allows for something else to happen: the *assumptions* underlying the 'non-climatic' elements—that is, the political, economic, historical, and social—*became one of the central parts of the scientific understanding of climate change*. In turn, a whole new range of uncertainties entered the calculus of climate change. By parallelly developing socioeconomic and climate models, the IPCC attempted to grasp the undeniable aspect of climate change: the historical and contemporary impact of 'human' actions. The phrase "impact of human actions" is increasingly mentioned both in the methodological and assessment reports of the IPCC; again, this isn't a discursive move. As illustrated earlier, the shift in the methodological approach *and* the focus on 'non-climatic' elements in the recent assessment cycles highlight the commitment to acknowledge the anthropogenic account of climate change; this, however, is by no means a critical commitment. In the following chapter, while discussing the production of futures and restriction of possibilities, I demonstrate the ways in which the IPCC preempts ecological critique and has incorporated the anthropogenic account of climate change

Coming back to the question of social, economic, and political assumptions: the recognition that the purely scientific understanding of climate change is inadequate, the IPCC turned towards other conditions and incorporated them into the modelling process. What are the assumptions of the modelling inputs? In the initial development of IAM, classical economic theory was the basis of 'socioeconomic' inputs of the models; that is, the fundamental belief in the optimisation of markets; belief in 'economic growth'; and other tenets of economic theory.[41] This, in many ways, remains the terrain upon which contemporary assessment models run their processes. In the Working Group

[41] "Q&A: How 'Integrated Assessment Models' Are Used to Study Climate Change." Carbon Brief, April 26, 2021. https://www.carbonbrief.org/qa-how-integrated-assessment-models-are-used-to-study-climate-change.

Reports of the Fifth Assessment, the assumptions of complex IAMS are revealed: "IAMs designed for cost-benefit analysis typically simulate the choices of an idealized 'social planner"[42] which means that IAMs need to conceptualise the "highest social welfare"[43] to understand the range of mitigation scenarios. Whereas, "IAMs designed for cost-effectiveness analysis"[44] assume that society will want to achieve a "pre-defined climate goal"[45] at the lowest possible social and economic 'cost'.

In either type of complex assessment model, there is a plethora of assumptions that form the basis of socioeconomic inputs: assumptions about what the highest social welfare is; about what mitigation options a *perfectly optimised* society would desire; about what a *perfectly optimised society* is; about the desirability of the cost-benefit analysis; and so on. These range of assumptions reflect the complicated and dynamic nature of 'epistemic uncertainty' underlying the socioeconomic inputs of the assessment models. In the Working Group Report of the Fifth Assessment, the authors conceded that it is precisely due to the "simplifications and differences in [socioeconomic] assumptions [that] are the reason why output generated from different models, or versions of the same model, can differ..."[46]. In the earlier reports, while simplifications of socioeconomic assumptions existed, the 'differences' and disagreements were not explicitly explored as sources of uncertainty; however, this has radically changed between the two assessment cycles.

The incorporation of these expert disagreements, differences, and assumptions might, at first, indicate that the conceptualisation of uncertainty has expanded not just on the discursive level in the

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42 Intergovernmental Panel for Climate Change. Climate Change 2014: *Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press. 2014. 178
43 Ibid.
44 Ibid.
45 Ibid.
46 Intergovernmental Panel for Climate Change. Climate Change 2014: *Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press. 2014 10

reports, but in the *actual methodological assessment of climate change* by the IPCC. This reading of the shift is absolutely necessary. As the modelling process of the assessment cycles evolved, 'technical uncertainty' *was decreased* by more accurate measurements, better grasp of the climatic feedback loops, and shorter modelling times which allowed the scientists, and other contributors to the IPCC to understand real-time impact of these climatic elements on human society. On the other hand, the scientific object of *socioeconomic* uncertainty entered the picture immediately after the fourth assessment cycle: acknowledging that climate change is, indeed, a complex economic and social problem, scientists and authors of the IPCC needed to grasp this interaction. Therefore, socioeconomic simplifications, assumptions, and, most importantly, expert (read: economic) disagreements needed to be encapsulated in the scientific process of understanding climate change itself.

This, however, is only the first step in grappling with the object of *uncertainty* in the assessment reports. Taking their earlier logic of scientific epistemic uncertainty, and reading the recent expansion of the concept, we can observe that the seemingly sterile space of epistemic *uncertainty* in the IPCC reports is not so clean; the treatment of uncertainty in the reports and methodological process highlights that the contours of this space are malleable. When the object of 'uncertainty' encapsulates disagreement and different forms of risk assessment, it indicates that the earlier 'scientific' definitions of uncertainty that the IPCC reports are grounded in are not so naturally defined. The fact that *we cannot know everything* carries through all of the assessment reports; however, through the years, the notion that we cannot know everything *because we disagree* became consolidated. This malleability of the conceptualisation of uncertainty—discursively, theoretically, and methodologically—demonstrates that the space of uncertainty is not *natural*, but produced. Despite the increasingly accurate scientific measurements of the rapidly changing climatic elements, the socioeconomic modelling allows for an active negotiation of uncertainty; that is, it allows for assumptions and other *choices* to be presented as uncertainty, denying the opportunity for any public contestation of these assumptions.

In Timothy Mitchell's *Carbon Democracy,* uncertainty, pertaining to [ecology economy], is theorised as a produced object. Specifically considering the technical uncertainty surrounding the extraction, distribution, and exploration of oil resources, Mitchell predominantly discusses the production of uncertainty around oil in terms of technical and political knowledge: it is something that can be created, manipulated, and understood in different ways. The production of uncertainty does not simply mean the production of probability; rather, following from Mitchell, "technical uncertainty [] allows a certain form of reasoning—that of economic calculation"[47] to form. Mitchell argues that technical uncertainty—scientific, financial, economic—is the space wherein other forms of reasoning can negotiate with empirical fact. According to Mitchell, historically, uncertainty has been easier to produce with the measurement of oil.[48] The nature of oil explorations, geophysical assessments, and volatile financial markets have made it possible for oil corporations and governments to *produce* uncertainty around oil that makes political contestation over extraction, exploration, and utilisation of fossil fuels impossible.

However, with the technical knowledge of climate change—atmospheric measurements, precipitation levels, sea level changes, biophysical changes, et cetera—uncertainty is difficult to produce.[49] Technical advancement, in addition to scientific concern over anthropogenic climate change, has yielded extremely accurate, and concerning, measurements of the Earth's rapidly changing climate. While agreeing with Mitchell's point of comparison, and even his conclusion, I have attempted to illustrate that, while technical uncertainty is difficult to produce with measurements of climate; institutions like the IPCC produce sophisticated *socioeconomic uncertainties,* whose fundamental

[47] Mitchell, Timothy. *Carbon democracy: Political power in the age of oil*. Verso Books, 2011, 11
[48] Ibid: 242.
[49] Mitchell, Timothy. *Carbon democracy: Political power in the age of oil*. Verso Books, 2011: 242

conceptual crux is a mix of prescriptions, assumptions, and 'disagreements'. As the economic and social conditions are incorporated into the modelling process, the range of expert disagreement increases and interacts with the scientific data acquisition of climate measurements which has a smaller margin of technical uncertainty. Therefore, even *with accurate measurements*, the large margin of uncertainty is produced around the questions of climate change and *any potent political action*.

Chapter II: Scenario Construction and Imaginaries of the Future

Using General Circulation Models and paleoanalogs,[50] the First Assessment Report constructed a set of four narratives of climate projections: each describing a future with a particular temperature increase and corresponding climatic consequences. Its task was to understand 'human-induced' climate change and establish immediate solutions gathered from the scientific and economic community. The mathematical description of the climatic elements, combined with a set of agricultural, land, water, and livestock data provided the terrain upon which climatic projections could be mapped. The point of the exercise was to consider: If the temperature increases by 1.5 degrees Celsius by 2030, what will the corresponding effects be on human activities? If it increases by that amount much earlier, would the effects be amplified? How do different temperature increases impact the ability to understand other climatic change? Moreover, how far into the future will these climatic projections hold true? The scientists and authors of the IPCC, in the early stages of their Assessment Cycles, had to contend with not just scientific, but also methodological obstructions to understanding climate change. To answer these questions, they decided to adopt a methodology developed much earlier—scenario-planning.

Etymologically, the word scenario comes from the Latin *scena,* meaning , 'scene' and the Italian, *scenario* meaning the "sketch of the plot of a play"[51] A 'scenario' was, in fact, like a story set far into the future, but extrapolated from contemporary conditions. So, what was the methodology of scenario-planning and why was it useful for climate scientists? What place did it have in climate science and, particularly, in ascertaining climate projections?

Accenture, a large business management and consulting company, offers some insight into what exactly scenarios might be: on their seemingly stylish, but ultimately confusing website, they

[50] Intergovernmental Panel on Climate Change, *First Assessment Report*, 1990: 91
[51] Etymology of 'Scenario', from: https://www.etymonline.com/word/scenario#etymonline_v_22868

highlight that "for decades [they] have been able to predict business outcomes based on statistical probability"[52]. The knowledge of the past and present risks has allowed consulting companies like Accenture the ability to understand future business and financial trends, thereby offering advice to their Fortune 500 clients. However, they realise that the "extrapolation of the past no longer allows us to predict the future"[53]. Simply taking statistical measures no longer allows consulting firms the opportunity to predict future trends and risks; therefore, they have turned to an approach called 'scenario-based planning'. Another consulting company based in North America, the Futures Strategy Group, promises that they "help [their] clients forge winning strategies by *anticipating change*, and not merely reacting to it."[54]. Scenario-based planning helps consulting firms like Accenture and Futures Strategy Group not just to *predict statistical future trends*, but to conceive and imagine *scenarios* that *plausibly might unfold* given the fulfillment of certain events.

These consulting firms, however, are not the pioneers in devising what is called 'scenario-based planning'. In *Turbulent Worlds,* Melinda Coopers introduces us to: "the context of the first oil crisis [wherein] strategists associated with French petroleum companies Shell and ELF began experimenting with new forecasting techniques designed to register the essentially uncertain nature of the future"[55]. In the late 1960s, the Royal Dutch Shell implemented a Unified Planning Machinery which allowed the company to plan, understand, and quantify the process of extraction, distribution, and consumption of oil; "from the oil in the ground through to its sale at petrol stations, with a horizon of six years"[56]. When this planning methodology collapsed a couple of years later, the company utilised scenario-planning to think about the possible futures and plan their extractive and distributive process

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52 "Scenario-Based Planning, Exploring the Best Chance." WordPressBlog. Accenture, March 12, 2020. Available at: https://www.accenture.com/nl-en/blogs/insights/scenario-based-planning-exploring-the-best-chance-on-success.
53 Ibid.
54 "About", Futures Strategy Group. Available at: https://www.futuresstrategygroup.com/content/about
55 Cooper, Melinda. "Turbulent worlds." *Theory, Culture & Society* 27, no. 2-3 (2010):171
56Ringland, Gill, and Laurie Young. "Scenarios in marketing." *John Wily and Sons* (2006).207

accordingly.[57] In fact, in a piece discussing Shell's scenario-planning, the Harvard Business Review reports that, "the very first oil-price scenarios prepared by this duo [Newland and Davidson] were sent to senior executives by mid-1971"[58]. These scenarios allowed the company to utilise the data they had collected to map out future trajectories of the oil-prices, risks, and possible mitigation attempts. Therefore, instead of utilising purely statistical data to infer probabilistic trends, the Royal Dutch Shell decided to incorporate *types of data*—demographic, supply, demand—into a singular system.

In the literature discussing the history of scenario-based planning, its conception, development, and refinement is often traced back to a particular name: Herman Kahn. Working for the RAND institution in the 1950s, Khan is particularly famous for utilising "game theory in nuclear warfare strategies"[59]; however, soon after leaving the RAND institute,[60] Kahn founded the Hudson Institute where he encouraged futuristic planning methodologies that *went beyond statistical probabilities*. Cooper defines Kahn's scenario-based planning as "as a collective thought-experiment in which specialists from different disciplines are asked to imagine and unfold a series of alternative futures from a position of present uncertainty."[61] The Hudson Institute, therefore, comprised of different disciplinary expertise that would attempt to advise and manage "strategic transitions to the future"[62] by constructing thought experiments about the future from a particular position. This position, as Cooper points out, is characterised by the notion of *uncertainty*.

Scenario-based planning, therefore, was conceived as a methodology of conceptualising the future that allowed for *a move beyond statistical probability*. By 'collectively' discovering positions of uncertainty in any given system, identifying key variables in that system, and "by stretching these

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[57]Wilkinson, Angela, and Roland Kupers. "Living in the futures." *Harvard business review* 91, no. 5 (2013): 118-127.
[58] Ibid.
[59] "Herman Kahn (1922-1983)." atomicarchive.com: Exploring the History, Science, and Consequences of the Atomic Bomb. Accessed June 10, 2021. https://atomicarchive.com/resources/biographies/kahn.html.
[60] "Herman Kahn (1922-1983)." atomicarchive.com: Exploring the History, Science, and Consequences of the Atomic Bomb. Accessed June 10, 2021. https://atomicarchive.com/resources/biographies/kahn.html.
[61] Cooper, Melinda. "Turbulent worlds." *Theory, Culture & Society* 27, no. 2-3 (2010): 171
[62] About - Hudson Institute. Accessed June 10, 2021. https://www.hudson.org/about.

variables to their limits of credibility, the group tries to create a number of possible futures which, while plausible, are significantly different from "business as usual."[63] Therefore, the construction of possible futures, requires a reference point of the present, which will then be featured in the scenario-planning as the business-as-usual. That is, the control variable which, in traditional scientific experimental practice doesn't change, however, the control in the scenario-based planning changes as it refers to the transition from the present moment to a particular future wherein there is no action taken against that variable. As Paul J. H. Schoemaker, an academic in the fields of decision-making and strategy, points out, "the aim of scenarios is not probabilistic forecasting nor to characterize a few uncertainties in terms of their possible outcomes and likelihoods."[64]; rather, it is to delineate possible futures that could unfold *if certain interventions take place*.

In the case of the Royal Dutch Shell, scenario-based planning was employed to resolve what the Unified Planning Machinery could not: establishing multiple futures based on a set of collectively decided uncertainties that not only incorporated social, economic, and political variables but also mapped these futures *over a long period of time*. Paul Dragos Aligica, formerly part of the Hudson Institute, describes the methodology of constructing scenarios as "part of a broader propaedeutic and heuristic methodology."[65] which allows for, according to other proponents of scenario construction, the production of solutions to large-scale, systemic problems through more short-term methods. According to these early scholars behind scenario-based planning, the reduction of complexity is a necessary step to imagine these solutions:

> Paradoxically, building scenarios can simplify things, in spite of introducing multiple futures. The multiple causal and narrative accounts operate in this case as a complexity-

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[63] Van Der Heijden, Kees. "Scenarios and forecasting: two perspectives." *Technological forecasting and social change*65, no. 1 (2000): 33

[64] Schoemaker, Paul JH. "How historical analysis can enrich scenario planning." *Futures & Foresight Science* 2, no. 3-4 (2020): 13

[65] Aligica, Paul Dragos. "Scenarios and the growth of knowledge: Notes on the epistemic element in scenario building." *Technological Forecasting and Social Change* 72, no. 7 (2005): 819

> reduction device. The segmentation of complexity reflects an adaptation to the human mind, which can handle only a limited amount of complexity[66]

Aligica, here, refers to the process in scenario construction which involves identifying variables that will form the foundation of the futures. For example, for scenario-based planning for climate change, one of the key variables would be greenhouse emissions, or atmospheric concentrations, or even another key indicator of warming trends. Based on this variable, among others, multiple scenarios can be constructed.[67] The first might be the 'business-as-usual', or the control scenario, wherein the atmospheric concentration is mapped out according to the way it has been increasing in the recent past. Another scenario could be the worst possible one where the concentration exceeds, perhaps, a thousand parts per million; some more scenarios could be mapped out somewhere between these two. Despite introducing a level of complexity by constructing various scenarios, this particular scenario-construction has, according to proponents of scenario-based thinking, simplified the problem of increasing atmospheric concentration of greenhouse gases; simply due to the fact that we can conceive of these drastic scenarios while removing other variables from the equation.

Another important characterisation of scenario-construction is the spaces it delimits: that is, how it chooses to assign value to different variables. Returning to Schoemaker's characterisation: "a distinction is usually drawn in business applications between the exogenous part of the world which the scenarios examine and the endogenous part of strategy formulation that is under leaders' control or influence."[68] That is, scenario construction requires delimiting externalities and what scholars like Schoemaker call 'endogenous' aspects, such as political or economic responses to these externalities.

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[66]Aligica, Paul Dragos. "Scenarios and the growth of knowledge: Notes on the epistemic element in scenario building." *Technological Forecasting and Social Change* 72, no. 7 (2005) 819

[67] My example is, itself, a case of simplification in order to illustrate the larger point.

[68] Schoemaker, Paul JH. "How historical analysis can enrich scenario planning." *Futures & Foresight Science* 2, no. 3-4 (2020) 13

Therefore, a scenario is not only a simplified construction of imaginaries, but also, a strategy to delineate potential actions from externalities wherein uncertainties lie.

Following Cooper's argument: "when the convertibility of the dollar against gold was replaced by floating and volatile exchange rates, the unpredictable was, of necessity, factored into the calculus of world economic futures"[69]; we see that uncertainty, unpredictability, and the unknown are fundamentally intertwined with scenario-construction. Thinking about unpredictability, and in turn, uncertainty, was an inevitable aspect of scenario-construction—whether one was a fellow at the Hudson Institute, worked with Newland and Davidson at Royal Dutch Shell, or currently works for consulting firms like Accenture; the construction of scenarios imaginaries of the future required an unmoderated confrontation with the notion of uncertainty.

The Swiss Reinsurance Company, one of the largest reinsurance companies, recently produced a model for analysing over 50,000 pandemic scenarios on different financial portfolios;[70] While they can calculate "potential financial exposure in [their] mortality book"[71], every variable in their model is underlined with a particular quantification of uncertainty. For example, with variables such as medical interventions, the geopolitical uncertainties of vaccine approvals heavily impacts the ability of the population to receive *both* doses of their vaccines. So, for every variable, the modellers have to identify and locate certain uncertainties. Another set of modellers, this time working for another large consulting firm, McKinsey & Company, not only identified the key uncertainties for their scenario-construction, but also developed a four-level framework of managing the subsequent uncertainty. The point of these examples is to illustrate that the management of uncertainty exists on multiple levels of

[69] Cooper, Melinda. "Turbulent worlds." *Theory, Culture & Society* 27, no. 2-3 (2010): 167
[70] "An Insight into Swiss Re's Pandemic Modelling: Swiss Re." [ALT + 2]. Swiss Re Group, April 9, 2020. https://www.swissre.com/risk-knowledge/risk-perspectives-blog/insight-into-swiss-res-pandemic-modelling.html.
[71] Ibid.

the scenario construction process; and that every consulting, risk management, or governmental institution seems to have their own framework, or understanding of this uncertainty.

While Cooper's work predominantly revolves around scenario-construction and financial markets of the United States of America, she highlights that:

> The applications of scenario planning are not limited to the global capital markets however. As the natural sciences adopt the framework of complex adaptive systems to model the dynamics of ocean currents, atmospheric turbulence and the hydrological cycle, scenario planning provides an insight into the multiple and uncertain futures engendered by their interactions[72]

As the urgency of extensive climatic change became apparent, various scientific and governmental institutions, the Intergovernmental Panel for Climate Change being one of them, turned to scenario-based planning. As the Assessment Cycles have evolved, the IPCC has utilised the methodology of scenario-construction to produce certain imaginaries of the possible future.

Before the Fifth Assessment Report, the development and application of the scenarios was linear.[73] That is, the Integrated Assessment Models produced emissions and socioeconomic scenarios which were applied and further developed for different climate projections. As discussed in the previous chapter, this linear process began with constructing new, or endorsing existing, socioeconomic scenarios—the existing scenarios could be borrowed from other studies of the United Nations or the World Bank—[74] and *only then*, were the climatic scenarios constructed to produce climate projections for the next century or so. At the very end, these scenarios were revisited and utilised to conduct what the IPCC calls the 'Impact, Adaption, and Vulnerability' study which involves the application of these scenarios to different regions and socioeconomic contexts.[75] Between the

[72] Cooper, Melinda. "Turbulent worlds." *Theory, Culture & Society* 27, no. 2-3 (2010): 172
[73] "SCENARIO PROCESS FOR AR5." Socio-Economic Data and Scenarios. Accessed June 10, 2021. https://sedac.ciesin.columbia.edu/ddc/ar5_scenario_process/parallel_IAV_research.html.
[74] Data Usage Guidance of the IPCC: Available at: http://www.ipcc-data.org/guidelines/TGICA_guidance_sdciaa_v2_final.pdf,
[75] "SCENARIO PROCESS FOR AR5." Socio-Economic Data and Scenarios. Accessed June 10, 2021. https://sedac.ciesin.columbia.edu/ddc/ar5_scenario_process/parallel_IAV_research.html.

earlier reports and the Fifth Assessment Cycle, the methodology was not the only element that underwent a transformation: the scenario construction itself changed. Since its conception, the IPCC has developed and endorsed multiple scenario sets: SA90, IS92, SRES, and RCPs.

One of the most striking elements of the changes between the scenarios is their number: in SA90 had 4 scenarios; IS92 had 6; SRES had 40 and 6 of these were used to illustrates the general trends;[76] Finally, RCP had over a thousand scenarios and four 'pathways' were chosen to represent these scenarios.[77] In a detailed study of the subsequent changes between these scenarios, the authors of 'The Evolution of the IPCC's Emissions Scenarios' identify the structural changes between the first three sets of scenarios:

> The SA90 series provided more detailed emissions profiles to assess future climate change, which replaced the former and often used simple doubling assumption for CO2 emissions (WMO/UNEP, 1988). The IS92 series was intended to update the SA90 series in the light of "recent developments and newly adopted policies" (IPCC, 1992a). The SRES series was not only conducted to update the IS92 series, but also to consider procedural and structural recommendations advocated by the IPCC's evaluation of the IS92 series.[78]

The scenario-construction had to reflect the structural policy changes, financial fluctuations, and other institutional responses to climate change. In the SRES scenarios, used for the Third and Fourth Assessment Reports, the IPCC had to reconsider its own policy recommendations and treatment of variables used in the previous sets of scenarios. The authors also identify "the main triggers for updating the IPCC emissions scenarios were the need to consider more complex dynamics and new uncertainties, as well as methodological improvements in the construction procedure."[79] Scenario-based thinking, as discussed earlier, is fundamentally rooted in the consideration of uncertainty;

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76 Girod, Bastien, Arnim Wiek, Harald Mieg, and Mike Hulme. "The evolution of the IPCC's emissions scenarios." *Environmental science & policy* 12, no. 2 (2009): 3

77 https://iiasa.ac.at/web/home/research/researchPrograms/Energy/IPCC_AR5_Database.html

78 Girod, Bastien, Arnim Wiek, Harald Mieg, and Mike Hulme. "The evolution of the IPCC's emissions scenarios." *Environmental science & policy* 12, no. 2 (2009): [5

79 Girod, Bastien, Arnim Wiek, Harald Mieg, and Mike Hulme. "The evolution of the IPCC's emissions scenarios." *Environmental science & policy* 12, no. 2 (2009): 10

therefore, the IPCC, with the evolving conceptualisation of uncertainties, needed to construct scenarios that would be able to reflect these variables.

In the Fourth Assessment Report, there were four storylines that the scenarios were grouped under: (unfortunately, they were named in an incredibly dry and confusing manner) A1, A2, B1, and B2. These scenarios, produced from the integrated assessment models, represented constructions of the future based on a set of socioeconomic assumptions like population rates, land use, fossil fuel emissions per capita, and so on. In the set A1, the scenario consisted of a future where there is "very rapid economic growth, a global population that peaks in mid-century and rapid introduction of new and more efficient technologies."[80]. As discussed in the earlier chapter, it is important to remember that the set of economic assumptions remains similar to the very first Assessment Report; that is, to provide an example, the belief and agreement in the definition of economic growth as a positive process. This set of scenarios are further divided according to their set of assumptions: A1F1 indicates what is called a fossil-intensive scenario; A1T consists of non-fossil resources, and finally there is a subset that consists of a balance between the two.[81] A2, consists of a world which is "heterogenous" with "with high population growth, slow economic development and slow technological change"[82]; it is necessary to note the fundamental assumption here that technological change, defined as mitigation and adaptation-oriented technologies, is assumed to be universally positive development. The second type of scenario, that is the 'B', also is divided into two types: B1 and B2. Much like A2, B2 describes a heterogeneous world "with intermediate population and economic growth, emphasising local solutions to economic, social, and environmental sustainability"[83] whereas B1 is a "B1 describes a convergent world, with the same global population as A1, but with more rapid changes in economic

80 Intergovernmental Panel for Climate Change: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. Geneva, Switzerland, 2007 44

81 Ibid.

82 Ibid.

83 Ibid.

structures toward a service and information economy."[84] These scenarios were utilised to model different rates of radiative forcing. The IPCC defines radiative forcing as "a change in energy flux caused by a driver and is calculated at the tropopause or at the top of the atmosphere"[85]; essentially, the concept is a measure of the imbalance of the "Earth's energy budget."[86] Using these scenarios and applying them to different levels of radiative forcing, the IPCC constructed various climate projections to understand how major climatic elements can change over a set period of time.

Between the Fourth and Fifth Assessment Cycles, there was another fundamental change in the methodology of producing and applying scenarios: instead of the construction of emissions and socioeconomic scenarios, as was the case with SRES, the parallel modelling methodology began with assuming particular levels of radiative forcing *alongside the construction of the scenarios*. This was, then, termed the 'Representative Concentration Pathway'; the four pathways are characterised by the following radiative forcing levels:

"RCP2.6

One pathway where radiative forcing peaks at approximately 3 W/m2 before 2100 and then declines (the corresponding ECP assuming constant emissions after 2100).

RCP4.5 and RCP6.0

Two intermediate stabilization pathways in which radiative forcing is stabilized at approximately 4.5 W/m2 and 6.0 W/m2 after 2100 (the corresponding ECPs assuming constant concentrations after 2150).

RCP8.5

[84] Intergovernmental Panel on Climate Change, Fourth Assessment Report, 2007, available at www.ipcc.ch., 44

[85] Intergovernmental Panel for Climate Change: Climate Change 2014: *Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer. (eds.)]. Geneva, Switzerland, 2014:126

[86] Chandler, David L. "Explained: Radiative Forcing." MIT News | Massachusetts Institute of Technology. Accessed June 10, 2021. https://news.mit.edu/2010/explained-radforce-0309.

One high pathway for which radiative forcing reaches >8.5 W/m2 by 2100 and continues to rise for some amount of time (the corresponding ECP assuming constant emissions after 2100 and con- stant concentrations after 2250)."[87]

Unlike the previous scenarios-constructions, where the socioeconomic scenarios predated the radiative forcing levels and climate models, the Fifth Assessment Cycle *began* with defined levels of radiative forcings that the scenarios could initially be grouped under; thus, "each RCP provides only one of many possible pathways to that level of radiative forcing."[88] The SRES scenarios, particularly, have internal economic and technological assumptions that render the *entire set of scenarios as internally consistent*; however, "the RCPs are not associated with unique socioeconomic assumptions or emissions scenarios but can result from different combinations of economic, technological, demographic, policy, and institutional futures."[89] Thus, the scenario-construction in the Fifth Assessment Cycle produced levels of radiative forcing that an amalgamation of social, political, and economic structures could *aim to achieve*.

This separation was possible through the production of *socioeconomic uncertainty*; this production allowed for economic assumptions and conceptual ambiguity to enter the modelling and application process of the RCP scenarios. In the Fifth Synthesis Report, the authors clearly note that the "cost-effective"[90] scenarios utilised contain the following assumptions: "that all countries of the world begin mitigation immediately, there is a single global carbon price applied to well-functioning markets, and

[87] Intergovernmental Panel for Climate Change: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer. (eds.)]. Geneva, Switzerland, 2014 127

[88] "Explainer: The High-Emissions 'RCP8.5' Global Warming Scenario." Carbon Brief, August 22, 2019. https://www.carbonbrief.org/explainer-the-high-emissions-rcp8-5-global-warming-scenario.

[89] "SCENARIO PROCESS FOR AR5." Socio-Economic Data and Scenarios. Accessed June 10, 2021. https://sedac.ciesin.columbia.edu/ddc/ar5_scenario_process/parallel_IAV_research.html.

[90] Intergovernmental Panel for Climate Change. Climate Change 2014: *Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press. 2014: 57

key technologies are available."[91] The first assumption here is that carbon pricing, in itself, is a key mitigation measure. Even if we concede that singular carbon pricing in global markets is *the* mitigation measure; this claim still raises several questions: what are key technologies? What does uniform mitigation look like? What *is* mitigation? These conceptual ambiguities, which are now defined as 'uncertainties' allow the IPCC to produce and apply scenarios based on uncontested economic assumptions. As Figure _ demonstrates,[92] The highest and lowest RCP are utilised to produce a range of climate projections that *are based on socioeconomic assumptions about contemporary economic conditions.*

This conceptual ambiguity, as in the case with 'uncertainty', is not discursively established in the reports; rather, it is methodologically inscribed in the structure of scenario-construction itself. By delineating a 'baseline' scenario, the IPCC establishes a simple yet ambiguous definition of what a 'no-policy' future looks like. That is, this scenario is "based on the assumption that no *mitigation* policies or measures will be implemented beyond those that are already in force and/or are legislated or planned to be adopted."[93] The construction and separation of 'baseline' and 'mitigation' scenarios is itself an exercise in economic and political prescription as a status-quo or 'business-as-usual' is *defined in the modelling process*. This definition is highly political: it assumes high efficiency and efficacy of existing mitigation measures; it produces a business-as-usual scenario that looks substantially different from contemporary environmental, economic, and political conditions as it assumes *no policy measures*; and finally, the baseline scenarios are then "compared to *mitigation scenarios* that are constructed to meet different goals for greenhouse gas (GHG) emissions, atmospheric concentrations or temperature

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[91] Intergovernmental Panel for Climate Change: Climate Change 2014: *Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer. (eds.)]. Geneva, Switzerland, 2014: 57

[92] Assessment Report 5 Scenario Database: https://secure.iiasa.ac.at/web-apps/ene/AR5DB/dsd?Action=htmlpage&page=about#

[93] Intergovernmental Panel for Climate Change: Climate Change 2014: *Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer. (eds.)]. Geneva, Switzerland, 2014: 119

change"[94] which necessarily produces inaccurate reflections of needed mitigation measures as these measures are modelled *both from contemporary conditions and a fictitious baseline scenario*.

In the Fourth Assessment Cycle, uncertainty surrounding the socioeconomic variables disallowed the scenario-construction to incorporate a consolidated conception of mitigation *into its modelling and application process*: in the Synthesis Report, which details the mitigation recommendations, the authors state that "uncertainty arises in particular from assumptions regarding the drivers of technology diffusion and the potential of long-term technology performance and cost improvements" {WGIII 3.3, 3.4, 11.3}[95]; however, this uncertainty was not incorporated into the scientific process the way it would later come to be. Here, the IPCC still retained its original definitions of epistemic uncertainty. Only when socioeconomic uncertainty was *itself subjected to scientific inquiry and incorporated into the modelling process by producing parallel scenarios,* the IPCC operationalised a set of sophisticated scenarios that indicated not only the aspirational radiative levels but also produced *an independent space wherein economic and social conditions could be negotiated to meet the radiative forcing levels*.

For example, let us consider the clear economic prescription in the Fifth Assessment Report: the authors highlight the need to recommend solutions that allow 'policymakers' and other institutional leadership to make necessary decisions under *uncertain conditions*. The whole point of the Representative Concentration Pathways is to group a set of existing scenarios that *could possibly achieve the desired* radiative forcing level and then produce climate projections based on these scenarios. However, "the scenarios are [also] used to assess the costs associated with emission reductions

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[94] Intergovernmental Panel for Climate Change: Climate Change 2014: *Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer. (eds.)]. Geneva, Switzerland, 2014: 119

[95] Intergovernmental Panel for Climate Change: Climate Change 2007: *Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. Geneva, Switzerland, 2007:73, 74

consistent with particular concentration pathways."[96] So, the scenarios account for the economic rationality of cost-effectiveness and are applied to climate projections to assess what sorts of mitigation measures are the most appropriate. Their conclusion being that the scenarios which will successfully maintain the temperature increase below 2°C will "include more rapid improvements in energy efficiency and a tripling to nearly a quadrupling of the share of zero- and low-carbon energy supply from renewable energy, nuclear energy, and fossil energy with carbon dioxide capture and storage (CCS) or BECCS by the year 2050."[97] Thus, under the prescriptions of cost-effective mitigation measures, IPCC considers the continued use of fossil fuels appropriate insofar as technologies of carbon capture and storage are implemented simultaneously.

In a recent publication, Andreas Malm and Wim Carton pointed out that direct carbon capture technology "holds out a promise of almost irresistible allure: to undo the damage fossil-fuel combustion has inflicted on this planet,"[98]; by incorporating this technology, without significant discussion of its drawbacks, the IPCC endorses scenarios wherein it is acceptable to continue fossil fuel combustion insofar as there is carbon capture technology to save the day. It is not just the encouragement of continued fossil-fuel combustion, however; as Malm and Carton point out, direct carbon capture "offers capital near-total control over the conditions of carbon removal"[99] as "fossil capital deploys them to reproduce itself"[100]. Thus, the inclusion of technologies such as direct carbon capture *in their existing socioeconomic conditions*—that is, as Malm and Carton highlight, to facilitate the reproduction of the fossil fuel industry itself—is a commitment to prescribe imaginaries of the future

96 Intergovernmental Panel for Climate Change: Climate Change 2014: *Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer. (eds.)]. Geneva, Switzerland, 2014: 57

97 Intergovernmental Panel for Climate Change: Climate Change 2014: *Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer. (eds.)]. Geneva, Switzerland, 2014, 82-83

98 Malm, Andreas, and Wim Carton. "Seize the Means of Carbon Removal: The Political Economy of Direct Air Capture." *Historical Materialism* 29, no. 1 (2021): 11

99 Ibid: 26

100 Ibid: 34

which keeps the economic conditions of these technologies intact. Before the Fifth Assessment Cycle, these scenarios were still a methodology to produce imaginaries of different futures; however, with between the Fourth and Fifth Cycles, the shift in methodology also contributed to a *more thorough grasping of uncertainties* which allowed for directly prescriptive futures as the one illustrated above.

Following the Fifth Synthesis and Working Group Reports to their conclusions, it becomes evident that the IPCC does, in fact, attempt to provide imaginaries of the ideal future wherein mitigation is effectively managed by the unit of the nation-state and the desired levels of radiative forcing. In one such imaginary, the report concludes that is we want to see mitigation scenarios "in which policies stabilize atmospheric concentrations (without overshoot) in the range from 430 to 530 ppm CO2-eq by 2100 [note: this atmospheric concentration level falls under the scenarios represented by the range between the RCP 2.6 and 4.5] lead to substantial shifts in annual investment flows during the period 2010–2029 compared to baseline scenarios."[101] As I discussed earlier in the chapter, the construction of a scenario necessitates delineating the externalities from the 'actors' ; that is, pointing to a group of variable (in this case they would be the atmospheric concentration, radiative levels, and emission rates) and defining the *actors* that would be able to effectively intervene. In this case, the actor turns out to be the set of institutions and individuals that would provide increased investment to the climate finance industry, renewables, and other mitigation technologies. The scenario-construction here provides indications of *who* the actors would be and *what* effective mitigation looks like; this is a consequential point because it is presented as a scientifically-coherent scenario *which prescribed changes in investment flows.*

Applying this scenario construction, the authors recommend that technologies and instruments like "credit insurance, feed-in tariffs, concessional finance or rebates [could] provide an

[101] Intergovernmental Panel for Climate Change: Climate Change 2014: *Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer. (eds.)]. Geneva, Switzerland, 2014: 110

incentive for mitigation investment by improving the return adjusted for the risk for private actors."[102] It is useful to return to Cooper's work here in order to understand that the imaginary of the future being constructed here relies heavily on the fundamental beliefs of individuals and firms working in climate finance. That is, Cooper highlights that the production of financial instruments to incentivise mitigation for and combat climate change rests on insuring, protecting, and valuing risk of the *unknown*; she explains that:

> "What if we correlated unknowable value to unpredictable nature and priced these in affective terms –in the language of confidence, trust and degrees of belief? This is in fact the solution that has been offered by the invention of environmental derivatives, financial instruments designed to price and trade both in the uncertainties of the weather and our own uncertainties about the future of climate change"[103]

Mitigation incentives, too, follow this logic: credit insurance, tariffs, and rebates are instruments through which climatic risk and uncertainty are redefined as a financial relationship between institutions, the economy, and the unknown. Therefore, IPCC's application of the set of desired scenarios to produce mitigation measures encourages the same transformation of uncertainty that is embedded in contemporary financial instruments which Cooper illustrates in her analysis of weather derivatives.

Put simply, the construction, management, and application of scenarios in the IPCC reports are an exercise in producing different imaginaries of the future. The change in methodology meant that instead of asking: what sorts of conditions would change the climate, they now ask, if we want the climate to change *up to a particular degree*, what kind of conditions should institutions, individuals, and other units in the IPCC's analysis, aspire to? Therefore, by grasping and producing socio-economic uncertainty, authors and contributors of the IPCC constructed more consolidated scenarios

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102 Intergovernmental Panel for Climate Change: Climate Change 2014: *Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer. (eds.)]. Geneva, Switzerland, 2014:, 111

103 Cooper, Melinda. "Turbulent worlds." *Theory, Culture & Society* 27, no. 2-3 (2010): 178

that can *account for economic and technological solutions to the problem of climate change* in their modelling process. By constructing these imaginaries of the future, the IPCC proposes potentialities wherein financial and technological solutions to the climate problem conceal the necessity of any economic change. In terms of economic conditions, while the IPCC acknowledges that the current rate of fossil fuel consumption is unsustainable in the long-term, its scenarios and models suggest that redirecting investment flows and introducing new financial instruments can adequately help us in reaching the set of scenarios where the warming remains under 2oC.

By operationalising scenarios, complex imaginaries are constructed which can account for a range of technical *and* socioeconomic uncertainties that other economic, social, and climate forecasting tools cannot. Recapitulating Mitchell's characterisation of technical uncertainty as a space where the reasoning and logic of economic calculation can enter the scientific debate; I propose that we consider a similar interaction happening in the scientific research surrounding climate change: with more sophisticated conceptualisation of technical and socioeconomic uncertainty, the methodology of scenario-construction produces a space wherein scientific fact and economic reasoning can freely confront each other. That is, the IPCC research produced a space wherein economic reasoning could negotiate with scientific, climatic measurements *on different levels of the modelling process* to prescribe potential futures where contemporary economic conditions could be retained, more or less, and the desired radiative forcing level achieved. Moreover, these scenarios not only *prescribe* the contours of the future, but also *work to restrict* other imaginaries.

Chapter III: Restriction of Alternative Imaginaries

Direct Carbon Capture is just one of the technologies contained in the economic prescription of the IPCC. As discussed in the previous chapter, the scenario-construction methodology, particularly with the Fifth Assessment Cycle, produces an imaginary of the future wherein turbulent climatic change can be mitigated while retaining existing socioeconomic conditions. This is, itself, made possible by the production and negotiation of uncertainty where, scientific fact can confront "economic calculation"[104]. Speaking specifically about energy-system modellers of the 1980s and 1990s, Malm and Carton highlight that their systems seemed to be oriented not toward understanding reduction of emissions, "but to help compensate for locked-in or supposedly unavoidable *future* emissions—taking back what the world cannot help but continue to let out."[105] Therefore, this idea—*that we will continue to emit, and these emissions are, after all, unavoidable*—was present at the very beginning of climate modelling. How should one calculate future emissions? How should energy and climate modellers project future emissions and subsequent atmospheric concentrations? Since we have an arsenal of scientific methods and apparatus, the answer might seem obvious: *just measure it!*

However, my task has been to illustrate that, in terms of climate modelling and scenario-construction, there is an inherent assumption that the rate of continued emissions remains the same for the foreseeable future. Let us consider the Rasmussen Report, cited in the Fifth Assessment Report, for further illustration. This was a 'Reactor Safety Study' conducted for the Nuclear Regulatory Commission for the United States of America in 1975; the point of this study was to assess the risk involved in the case of a nuclear plant accident. The conclusion of the report was that the risk involved in the nuclear accident is *very low*.[106] Four years later, the Australian Atomic Energy Commission

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[104] Mitchell, Timothy. *Carbon democracy: Political power in the age of oil*. Verso Books, 2011, 11

[105] Malm, Andreas, and Wim Carton. "Seize the Means of Carbon Removal: The Political Economy of Direct Air Capture." *Historical Materialism* 29, no. 1 (2021): 5

[106] US Nuclear Regulatory Commission. *Reactor safety study: An assessment of accident risks in US commercial nuclear power plants*. Vol. 2. US Nuclear Regulatory Commission, 1975.

published a review paper, and contained in it, a critical question: "what are the chances of RSS [the Rasmussen Report] being too optimistic by a very large factor?"[107] This review contained a section wherein it considered the 'delayed deaths' by cancer and other consequences of excessive radioactive exposure; something that the Rasmussen report did not. The point of the example is to illustrate that, even though, *scientifically*, the Rasmussen report considered the necessary variables and calculated risk through statistical methods, *the researchers made a choice to include certain deaths but not others*.

Coming back to the IPCC reports, we find similar *decisions* interwoven with the scientific method of measuring climatic changes. I problematise *these decisions*; not their scientific basis. "Building on an initiative by the Intergovernmental Panel on Climate Change (IPCC)"[108], the *Centre d'Études Prospectives et d'Informations Internationales* (CEPII) published a research report outlining the scenarios that emerged out of the Representative Concentration Pathways. I use this singular report to illustrate the economic prescriptions of the IPCC in practice; however, there are countless others which highlight the underlying assumptions and prescriptions of the IPCC. In the process of outlining the scenarios, the authors provide descriptions of the types of future that might be the most prevalent: one is a 'sustainable' imaginary and the other is one with high inequality. They conclude that the sustainable scenario includes, "Rapid economic growth in low-income countries [which] reduces the number of people below the poverty line. The world is characterized by an open, globalized economy, with relatively rapid technological change directed toward environmentally friendly processes"[109]; this scenario, for these authors *and* in the scenario-construction of the IPCC, stand starkly in contrast to "a highly unequal world both within and across countries. A relatively small, rich global elite is responsible for much of the emissions, while a larger, poorer group contributes little to emissions and

[107] Gilbert, C. P. *Nuclear reactor safety-a review of the Rasmussen Report (WASH-1400).* Australian Atomic Energy Commission, 1979: 16

[108] Fouré, Jean, and Lionel Fontagné. *Long term socio-economic scenarios for Representative Concentration Pathways defining alternative CO2 emission trajectories*. Vol. 1. CEPII Research Report, 2016, 4

[109] Fouré, Jean, and Lionel Fontagné. *Long term socio-economic scenarios for Representative Concentration Pathways defining alternative CO2 emission trajectories*. Vol. 1. CEPII Research Report, 2016, 9

is vulnerable to impacts of climate change."[110] The imaginaries of the future, in the IPCC and subsequent research, are constructed according to prescriptive assumptions upon which climate modelling is itself conducted. There is, therefore, the *choice* to model emissions according to an imaginary of the future wherein emissions *inevitably continue to rise*; with technological machinery to salvage the conditions; and economic growth is divorced from questions of inequality.

These scenarios, as Cooper posits are perhaps, "the most consequential of epistemologies of contemporary politics,"[111] as they *anticipate* solutions that remain in service of, in Malm's words, "fossil capital".[112] By anticipating technological solutions, the construction and application of these scenarios work to conceal the temporality of climate change itself. In *Fossil Capital*, Malm discusses the linear flow of time to conclude that, as time passes, certain events fade or we lose track of their details.[113] However, in an increasingly warming world, "iron laws of economics and geophysics boost the past from behind"[114] forcing us to confront the grip of the physical changes of the planet we are standing on. The IPCC scenarios, particularly from the Fifth Cycle, seek to displace us temporally from the point that effective, political action *must be* taken to one where it is *being taken*. Scenario-construction is precisely predicated on this temporal displacement: it not only produces possible futures, but it also restricts *other* imaginaries by capturing the present moment *in relation to this future*.

To investigate the process of temporalisation and the restriction of imaginaries of the futures, it is necessary to turn to the works of Reinhart Koselleck and Janet Roitman. Reinhart Koselleck, in *Critique and Crisis*, traced the emergence of *crisis* as a historical concept; which, in turn, demarcated the notion of *historicity* wherein the concepts of progress, science, politics, and economics would be

110 Ibid.
111 Ibid. 171
112 Malm, Andreas. *Fossil capital: The rise of steam power and the roots of global warming*. Verso Books, 2016, or Malm, Andreas, and Wim Carton. "Seize the Means of Carbon Removal: The Political Economy of Direct Air Capture." *Historical Materialism* 29, no. 1 (2021): 3-48.
113 Malm, Andreas. *Fossil capital: The rise of steam power and the roots of global warming*. Verso Books, 2016. 9
114 Ibid.

inscribed.[115] He proposed: "It is only as a reaction to Absolutist policies that—intentionally or not—Enlighteners' historico-philosophical self-consciousness makes political sense."[116] Janet Roitman, in *Anti-Crisis*, illustrates that, abstracted from the struggle between Absolutism and the Enlightenment, the historical and philosophical concept of *crisis* could be politically mobilised to categorise time: and, it is "Reinhart Koselleck [who] provides a remarkable inquiry into the process of temporalization".[117] Furthermore, "Koselleck likewise maintains that both this claim and this judgment entail a specific historical consciousness—*a consciousness that posits history as a temporality upon which one can act*"[118] It is precisely this process of temporalisation that is of interest to the inquiry of scenario-construction and its ability to propose and restrict imaginaries of the future.

A site of political disagreement, anxiety, and contestation, the declaration of a *crisis* is an act of temporalisation in a *seeming* "epistemological impasse, [it] is claimed to [have] found the possibility for other historical trajectories or even for a (new) future."[119] Roitman, here, argues that the declaration of crisis—that is, the process of temporalisation—presents a moment in time as an impasse; it is here that the institution, authority, or person making the declaration posits a solution, and even a potential future. The IPCC's declaration, in the process of scenario-construction, performs a similar action: it welds together scientific expertise and political disagreements to present possible imaginaries of the future. However, their incorporation of existing economic conditions *into the very modelling methodology* allows for a construction of a seemingly *scientific future* wherein it is possible to exist in a world very much like our own but *without climate change.* While the IPCC does not attempt to produce novel temporalisations, like Roitman argues certain crisis-decorations do, its Assessment Cycles indicate an

115 Koselleck, Reinhart. *Critique and crisis: Enlightenment and the pathogenesis of modern society*. MIT Press, 2000, 174
116 Ibid. 7
117 Ibid. 30
118 Roitman, Janet. *Anti-crisis*. Duke University Press, 2013, 7
119 Ibid: 4

effort to legitimise contemporary mitigation efforts, like carbon capture, in order to posit the *possibility of living the way we currently do, but without the impending ecological crises*.

Just as the process of temporalisation is the outcome of a "moral judiciary against history"[120], the imaginaries of the future are moral judgments of the present: when socioeconomic scenarios are constructed and mitigation technologies like carbon capture are inscribed within these constructions in their existing economic relations, the imaginaries of the future provide legitimisation of the present moment. As Malm and Carton point out, there are already extensive utilisation of the carbon capture technology in countries like Switzerland and the United States. Therefore, in the narratives and scientific methodology of the IPCC, the present moment is temporally displaced and placed in the moment where '*effective action*' is already modelled into the projections of climate change; that is, we are placed at the point where the *action that ought to be taken is already being taken*. By positioning these imaginaries to the present moment, the scenario-construction allows for the political judgment of what effective action is and ought to be, on the basis of scientific fact—however, it is important to note that these imaginaries are constructed *before* the modelling stages. As Franco Berardi states,

> These consequences are implicit in the technical machine, as if they were logico-mathematical necessities. They are not, but the linguistic machine records behaviour and translates it into consequences: real events are activators of mathematical functions inscribed in the machine as logical necessities.[121]

In the case of the IPCC, the technical machine encompasses the process of collecting climatic measurements, constructing scenarios, and producing scientific, social, and economic expertise; this process inscribes political choice into itself as if it were a logical necessity—as something evident and incontestable. However, the measurement and projections of emissions to calculate the required carbon capture rate *is a choice*. There is an alternative method of calculating the necessary rate which begins

[120] Koselleck, Reinhart. *Critique and crisis: Enlightenment and the pathogenesis of modern society*. MIT Press, 2000, 174
[121] Berardi, Franco. *Futurability: The age of impotence and the horizon of possibility*. Verso Books, 2017: 28

with "zero-emissions, [after which] this process [of carbon capture] can start lifting the burden, stone after incremental stone".[122]

Presenting the retention of current socioeconomic conditions as a logical necessity is a requirement for the restriction of *other imaginaries of the future*; moreover, it produces politically moderated and mediated scientific knowledge of climate change. By relating the imaginary of the future wherein the world successfully mitigates climate change and socioeconomic conditions develop on the current trajectory, to the present moment, the IPCC's scientific, economic, and political research attempts to excavate a future from the present conditions. It posits that we are *already* on our way to this imaginary; however, it is not a deterministic prescription; nor is it a prophecy. It is an attempt to present contemporary conditions as logical necessities—even in the face of devastating ecological crises. Since these futures are inscribed in the technical processes of the IPCC as logical necessity, they restrict other imaginaries. This restriction is necessary for the IPCC's political project as, "futures are inscribed in the present as immanent possibilities, not as necessary developments of a code,"[123]; Therefore, capturing and developing imaginaries of the future that *appear as logical necessity* is a crucial practice disallowing *other political alternatives* and demonstrating that the proposed future is scientifically possible.

Projecting and mapping climatic measurements on these imaginaries—that is, the scenario-construction—also produces a body of politically moderated scientific knowledge. As discussed in the previous chapter, IPCC's methodology of scenario-construction changed substantially between the Fourth and Fifth Assessment Cycles. Climatic projections were mapped *onto* the Representative Concentration Pathways and then these were analysed in terms of their social, economic, physical, and systemic consequences. While this methodology *appears* to take place as a progression; upon further

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[122] Malm, Andreas, and Wim Carton. "Seize the Means of Carbon Removal: The Political Economy of Direct Air Capture." *Historical Materialism* 29, no. 1 (2021): 38
[123] Berardi, Franco. *Futurability: The age of impotence and the horizon of possibility*. Verso Books, 2017, 41

analysis, we see that these analyses happen parallely and in a fragmented manner. McKenzie Wark, in *Molecular Red*, discusses the repercussions of fragmented knowledge production in contemporary scientific fields:

> "Specialisation [of the scientific fields] stands in contradiction to the tendency toward the unity of knowledge. It breaks up experience into pieces so that each is organised independently. As a result, two hugely important negative phenomena characteristic of contemporary science come about: an excessive accumulation of material and heterogeneous methods of cognition."[124]

The scenario-construction and subsequent climate projections of the IPCC are *not only political tools* but they also contribute to a 'heterogenous cognition' of the climate problem. That is, the heavily moderated, specialised scientific knowledge itself produces the possibility of cognising the climate problem in multiple ways: on one side, there is the 'natural' problem of the ecosystems being out of balance; then, there is the population problem which can be grouped under demographic and social labels; moreover, the economic 'cost of climate mitigation', as it is commonly referred to in the IPCC literature; and so on. The independent organisation of experience, as Wark suggests, is what allows IPCC to suggest that it is possible to retain socioeconomic conditions while effectively dealing with the exponentially warming planet.

[124] Wark, McKenzie. *Molecular red: Theory for the Anthropocene*. Verso Books, 2015. 14

Conclusion

> And what is needed today, if not some global edition of the Plug Plot Riots? Go and stop the smoke! That might seem like an exceedingly improbable event, but political action can never be based on probability calculations – that would be swimming with the tide or sailing with the storm
>
> - Andreas Malm, *Fossil Capital*

In *The Climate of History*, Dipesh Chakrabarty concludes that unlike other crises, "climate change poses for us a question of a human collectivity, an us, pointing to a figure of the universal that escapes our capacity to experience the world."[125] According to Chakrabarty, the problem of climate change is an inescapable phenomenon that is the product of irreversible changes of human beings' parametric conditions. Over the course of history, human beings have altered these parametric conditions; however, the present moment is unique insofar as these changes are irreversible. The present ecological crisis "is an unintended consequence of human actions and shows, only through scientific analysis, the effects of our actions as a species."[126] Therefore, for Chakrabarty, the resolution of the climate crisis necessarily lies in scientifically understanding the ecological crisis, mapping the point of irreversibility, and *finding a distinctly ecological solution to the crisis*.

By distinguishing technical and socioeconomic uncertainty; producing scenarios as distinct imaginaries of the future; and restricting alternative futures, the Intergovernmental Panel for Climate Change, too, proposes distinctly 'ecological' solutions to the climate crisis which have contemporary economic conditions inscribed in them. Responding to Chakrabarty's proposal of a distinctly ecological solutions, Slavoj Zizek states:

> This is why we have to accept the paradox that, in the relation between the universal antagonism (the threatened parameters of the conditions for life) and the particular antagonism (the deadlock of capitalism), the key struggle is the particular one: one can solve the universal problem (of the survival of the human species) only by first resolving the particular deadlock of the capitalist mode of production. In other words, the commonsense reasoning which tells us that, independently of our class position or

[125] Chakrabarty, Dipesh. "The climate of history: Four theses." *Critical inquiry* 35, no. 2 (2009): 222
[126] Chakrabarty, Dipesh. "The climate of history: Four theses." *Critical inquiry* 35, no. 2 (2009): 201

> our political orientation, we will all have to tackle the ecological crisis if we are to survive, is deeply misleading: the key to the ecological crisis does not reside in ecology as such"
>
> Zizek, *Living in End Times*[127]

The impending global warming, sea-level rise, and other ecological crises are the parametric conditions which deeply threaten human lives; however, Zizek demonstrates that a distinctly ecological solution for the climate crisis is not such an obvious position; rather a political one. It is not a logical necessity out of which solutions like carbon capture are proposed, but rather, they conceal the underlying decisions and economic calculation.

This thesis contributed to this debate by investigating the conceptualisation of uncertainty in a dominant knowledge producing institution like the IPCC; analysed the scenario-construction adopted by this institution; and suggested how positing the imaginary of a future wherein socioeconomic conditions are perfectly retained necessarily restricts others. In the first chapter, I investigated the conceptualisation of epistemic uncertainty through the evolution of the IPCC Assessment Reports to demonstrate that the production, negotiation, and treatment of uncertainty allows for scientific fact to freely confront political judgments. Thus, contrary to Timothy Mitchell's assertion that it is difficult to produce uncertainty around climatic measurements, I illustrated how the category of socioeconomic uncertainty is produced and juxtaposed with technical uncertainty. In the second chapter, I demonstrated how the management of uncertainty allows for the adoption and development of scenario-constructions which produce imaginaries of the possible future; that is, by allowing scientific fact to confront political and economic calculation, the IPCC incorporates the imaginary of a future wherein contemporary economic relations are retained *and* the climate problem can be technologically resolved. Finally, in the third chapter, I discussed how this incorporation follows through into the modelling process wherein further climate projections are constructed; therefore, the retention of these conditions seems not only as a possibility but one which has been

[127] Zizek, Slavoj. *Living in the end times*. Verso, 2011: 333-334

discovered out of logical necessity. Following the work of Koselleck and Roitman, I explored how the methodology of scenario-construction attempts to displace the present moment temporally; that is, by positing a relation of the imagined future to the present, the method of scenario-construction suggests that we are already taking effective action.

The conclusions and findings of this research are the first step of a continued investigation into the scientific knowledge production of climate change. By exploring the processes of dominant institutions like the Intergovernmental Panel for Climate Change, I seek to understand how scientific fact encounters economic rationality; in turn, the future direction of this work will lead to theoretical explorations of futures, forecasting, and their inextricable role in the history of capitalist development. By investigating how economic relations are actively inscribed into contemporary scientific processes, this work will develop into avenues for research of contemporary climate politics.

Appendix

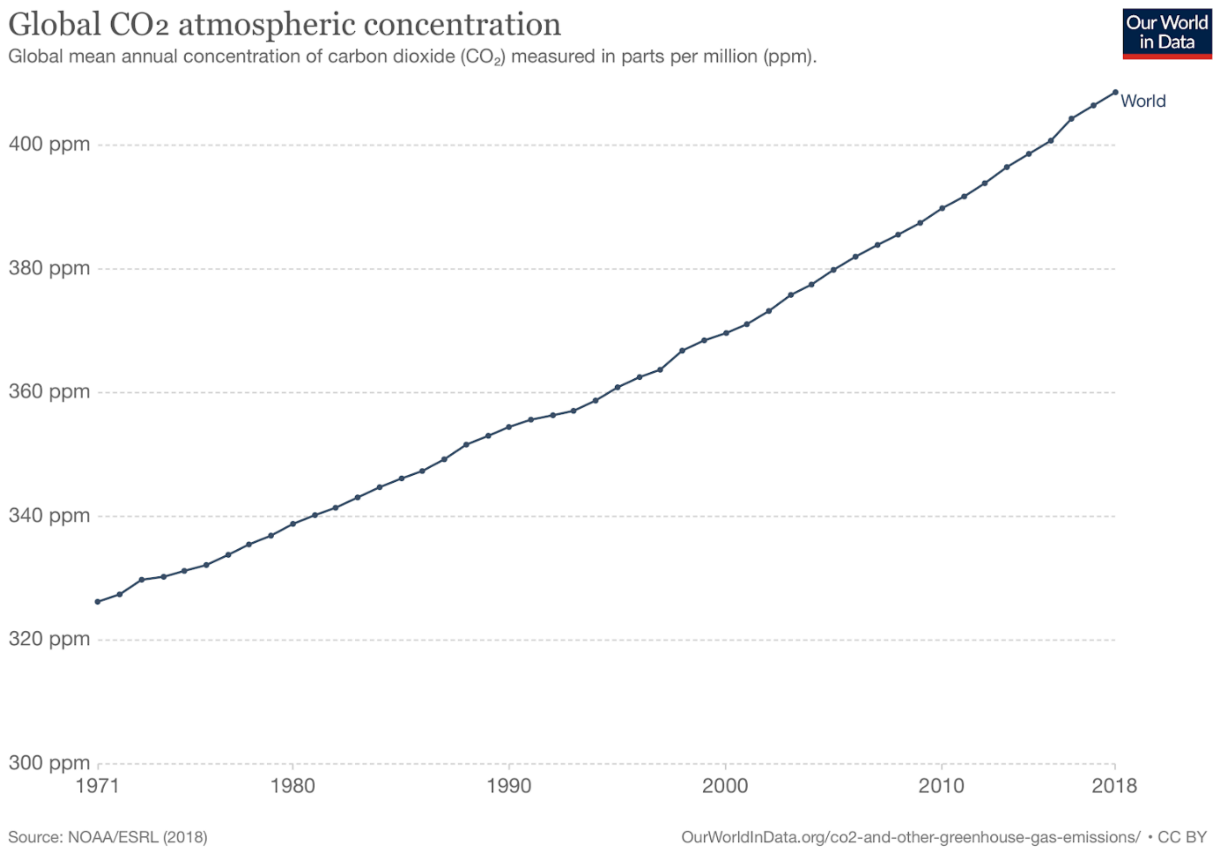

Figure 1:Increase in the atmospheric concentration of carbon dioxide from the 1970s to 2018

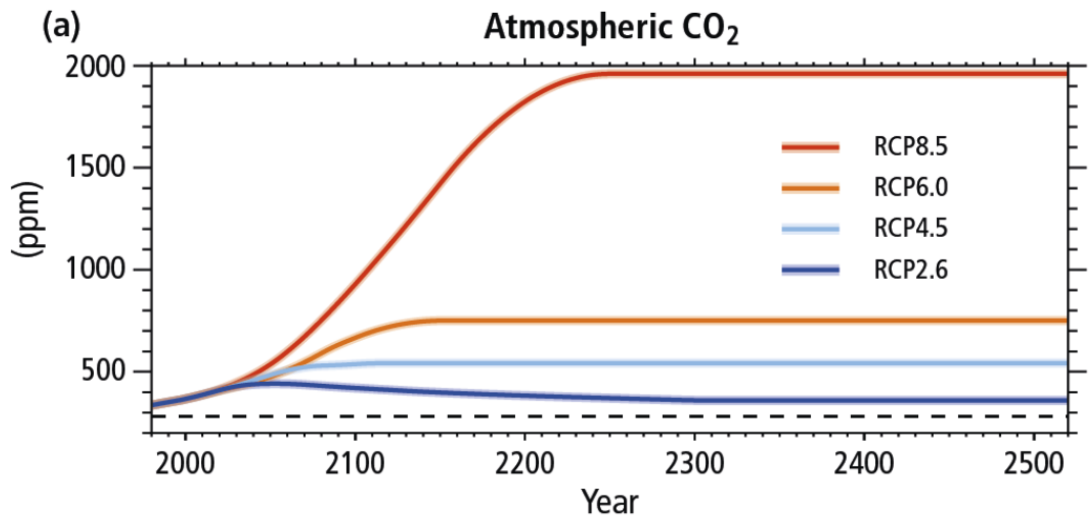

Figure 2: Atmospheric Carbon Dioxide Projections for RCPs

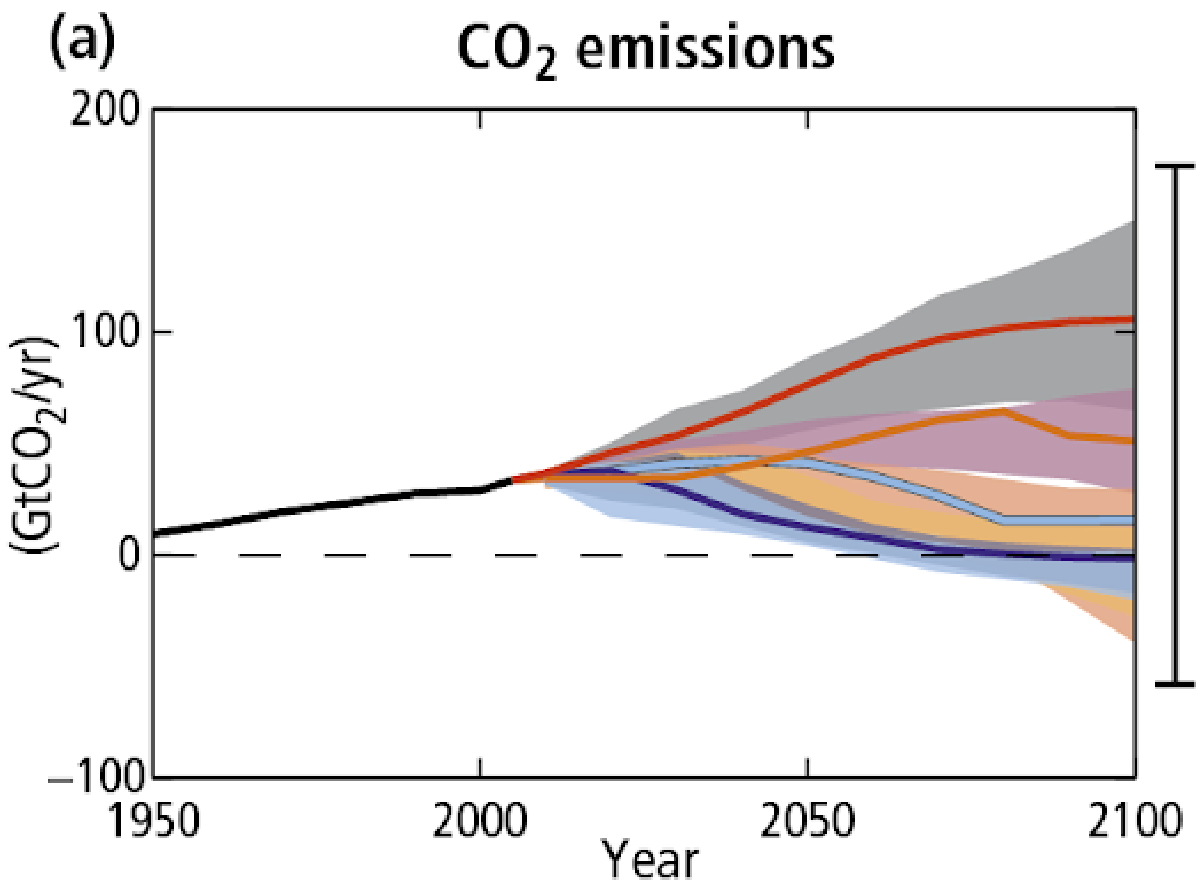

Figure 3: Carbon Dioxide Emissions for All RCP Scenarios

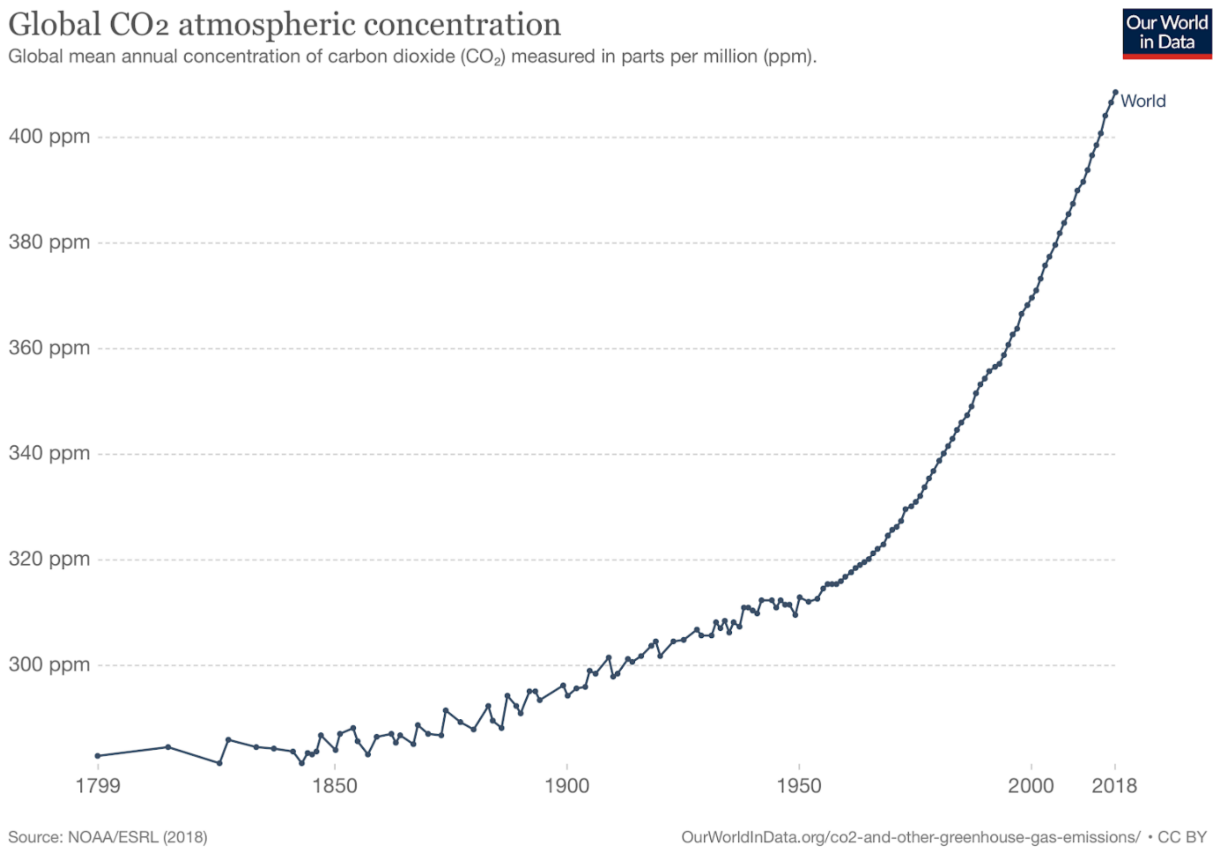

Figure 4: Increase in the atmospheric concentration of carbon dioxide from 1799-2018

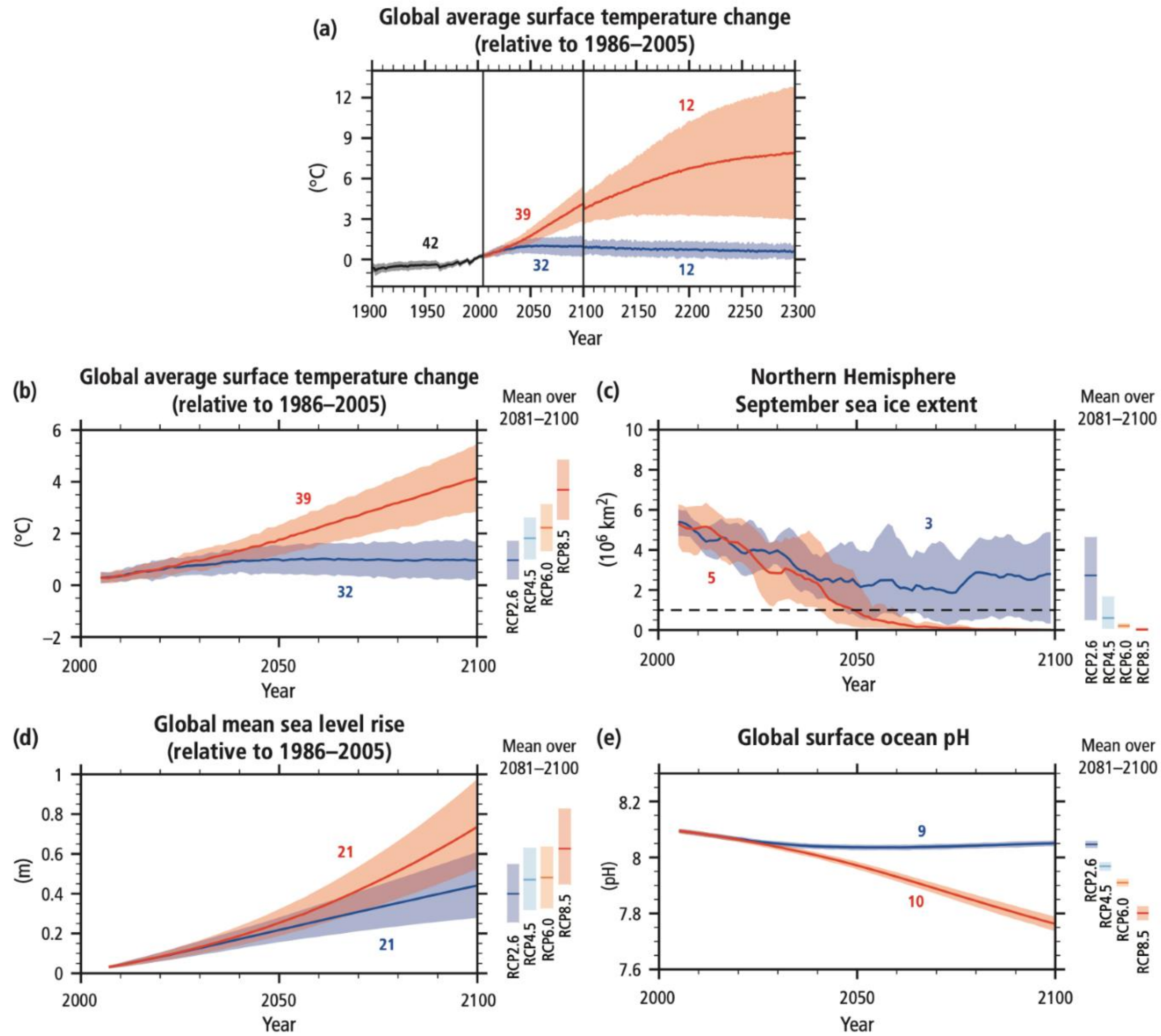

Figure 5: Range of Climatic Changes for RCP

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