How soon is now?

Exploring mitigation of short-lived greenhouse gases in the landscape of climate risk and policies on metrics

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Abstract

In the collected efforts towards understanding earth's climate system, and acting on climate change, the time dimension is of central importance. When humanity's collected activity is carbon-neutral, and how the trajectory towards such a state might look, is a tough question to answer. One thing which does however stand out clearly is the fact that the common practice of having CO_2-equivalents be based almost exclusively on a 100-year time-frame is not beyond criticism. This can be said both in the light of scientific research and of political goals and demands. If there are motivations for weighing a shorter time-frame into the way we assess climate impact, how should this be achieved? Short lived greenhouse gases like methane look more potent as climate forcers with a shorter time-frame, how ought this be understood in a policy context?

This study is written on behalf of Naturvårdsverket, the Swedish Environmental Protection Agency, and considers various metrics for determining climate impact (CO_2-equivalents) in a context of potentially devastating climate feedback mechanisms in the coming decades. By involving government agency experts and distinguished climate scientists in interviews, the study seeks to understand how we are to view the questions surrounding metric-use, and what new ways of thinking about metrics, time-frames and risk perception seem promising and common among experts. A qualitative analysis is performed using an iterative process of interviews, interpretation and thematization. Possible ways of thinking when designing a policy framework with methane in mind are outlined. The surrounding questions are viewed through the challenging themes of credibility, risk assessments and science-policy interaction, among others. The study shows how one might justify a special focus on methane emissions by highlighting climate risks in the near decades. Given the right circumstances it is deemed plausible that such 'methane strategies' could be effective and help institutions like national environmental agencies as well as smaller actors and specialized organisations in shaping more ambitious mitigation trajectories.

Keywords: *Global warming, GWP, GTP, methane, short-lived greenhouse gases, short-lived climate forcers, climate policy, climate risk, climate crisis, carbon pricing, climate negotiations, technocracy.*

Contents

1 Introduction

1.1 Background and Context of Problem

Anthropogenic climate change caused by increased levels of greenhouses gases in earth's atmosphere is perhaps the most significant and daunting phenomenon faced by contemporary human civilization. As such, it presents us with challenges on a magnitude thus far unseen on a global scale. Climate change is an existential issue that entices and forces us to question human patterns of consumption, distribution of wealth, and our relationship to the rest of nature. Paving the ways needed to get out of fossil dependence and unsustainable practices in the biophysical environment is fraught with a complexity where science, economics and politics intermingle intricately. This complexity puts demands on research, negotiations, planning, transformations of energy systems and the like. Seen from a birds-eye perspective, and due to the complex nature of the field, various efforts and pictures concerning climate- and energy related challenges appear incoherent with one another. Specifically, assessments of when rampant effects on human lives due to large scale climate system perturbations might occur, on the one hand, and on the other, the time-frames of involved political targets and agreements, are not necessarily aligned. That is to say, there is an apparent mismatch between target time-frames relevant in the context of limiting global warming and the metrics guiding and following-up decisions and strategies to fulfil such limiting.

A time-frame used prevalently when assessing anthropogenic effects on the global climate system, sketching roadmaps over future emissions and emission reductions, and the like, is 100 years or in the vicinity thereof. This has been the case at least since the early 1990s. For instance, this time-frame is evident in Representative Concentration Pathways outlined by the Intergovernmental Panel for Climate Change, IPCC (IPCC 2019). It is also evident in the 2°C goal agreed upon in the Paris Agreement (UNFCCC 2020a). In both cases, the end-year is 2100, making the time frame 80-years at the time this study was performed. Important to the forthcoming questions here, the 100-year time-frame is used explicitly in the dominant metric for assessing the climate impact generated by emissions of gases and particles: GWP_{100} (Global Warming Potential, 100 years). This metric has enjoyed the center stage in the meeting of climate science and -policy since IPCC's first assessment report (IPCC 1990, p. 45) and in terms of negotiations since COP1, the first Conference of the Parties hosted by the United Nations Framework Convention on Climate Change (UNFCCC 1995, p. 15). GWP_{100} describes the aggregated warming potential 100 years onwards after a given unit of emissions enters the atmosphere (IPCC 2013, pp. 710-712). Metrics like GWP_{100} are in the vocabulary of the IPCC called 'common metrics' and their purpose is to relate emissions to global warming in a way which makes it possible to relate any amount of any greenhouse gas to other emissions in terms of their contributions to warming (ibid, p. 710). A certain amount of any greenhouse gas is thus 'equivalent' to a certain amount of CO_2 released. Whenever a policymaker, analyst, consumer or voter might encounter carbon footprints expressed in CO_2-equivalents, these are almost unequivocally expressed using GWP_{100} as a basis. GWP_{100}, however, is no natural law. It rests on scientific discernments which are open to debate (ibid, p. 663). Perhaps most crucially, the dominant role of GWP_{100}'s 100-year time-frame is "value based" (ibid, p. 716). In practice, this choice of time-frame turns into a value judgement on the dynamics and risks contained in the potential futures of earth's climate system.

The choice of metric may seem like a detail from scientific and bureaucratic discourse, but it has important ramifications. Consider carbon dioxide, CO_2, and methane, CH_4. In terms of warming from direct anthropogenic emissions, CO_2 is by far the dominant long-lived greenhouse gas, and methane the dominant short-lived greenhouse gas.[1] But what are their respective contributions to global warming, how do they compare? Using GWP_{100} the CO_2-equivalent of methane is 28 and looking at Swedish emissions year 2017, ~85% of anthropogenic warming stemmed from CO_2 and ~8% from methane (IPCC 2013, p. 731; SCB 2019).[2]

Two competing metrics for comparing the climate forcing effect of emissions are GWP_{20} and GTP_{100} (Global Temperature-Change Potential, 100 years). GWP_{20} is the 20-year analogue of GWP_{100} and GTP is a type of metric looking at temperature change at earth's surface for a target year (IPCC 2013, pp. 710-712). Arguments for using these metrics have been put forth, for instance in the case of GWP_{20} by Ocko et. al. in 2017 and in the case of GTP by Tol et. al. in 2012. The CO_2-equivalent for

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[1] Water vapour is the strongest component in earth's greenhouse effect, but to the extent that human activities generate significant amounts of water vapour this is a secondary effect of warming and water vapour is considered "*a feedback agent, rather than a forcing to climate change*" (IPCC 2013, p. 666).

[2] Statistics used here are excluding the LULUCF sector (which acts, by way of growing forests, as a large source of CO_2-uptake in Sweden) and including Swedish-tied transports to and in other countries.

methane using GWP_{20} is 84 and using GTP_{100} only 4 (IPCC 2013, p. 731). Using these numbers, Swedish emission footprints arrives at ~73% for CO_2, ~21% for methane using GWP_{20} and ~92% for CO_2, ~1% for methane using GTP_{100} (SCB 2019). Such vast differences suggest that decisions on metric choice formed in a strategic milieu of science, economic interests and international relations may affect concrete climate policy significantly, since the metrics value different gases and thereby different sources differently.[3]

While the technical questions of how metrics such as GWP_{100} reflect or manifest value judgements on the importance of different gases may be a fringe phenomenon in the eye of the public, there is a lively scientific, political and public debate around the urgency of mitigation efforts at the epicenter of contemporary political and medial discourse. This heated debate reflects, among other things, the dreaded consequences on capabilities for sustaining human lives and communities, stemming from dramatic emergent climate system phenomena as identified through natural science. The climate system is complex and showcases, as many complex systems do, self-amplifying chain reactions, or 'positive feedback' (IPCC 2013, p. 57). In their most severe form these positive feedback mechanisms are labeled 'tipping points' (Lenton et. al. 2019). Significant portions of the scientific community involved in arguing for urgency in light of the existence of tipping points call for radical transitions of infrastructure, public awareness and behavioral change on time-frames much shorter than 100 years. As a manifestation of this, the IPCC 1.5 °C special report advocates for a 45% reduction in global emissions by 2030 from the 2010 levels, to meet the goal of limiting global warming to 1.5 °C from pre-industrial levels (IPCC 2018, p. 12). This is certainly a mitigation pace so rapid that there is a clear mismatch with the 100-year perspective. Politically, a concept gaining traction in 2019 is public bodies declaring 'climate emergency', famously so the European Parliament in late November (EP 2019). As of the end of 2019 climate emergency declarations had been issued in over 1,200 jurisdictions and local governments covering around 800 million citizens (Climate Emergency Mobilisation 2019). In the case of the European Parliament, the declaration included a target of a 55% reduction in emissions by 2030 compared to 1990 levels, net-zero emissions by 2050 and demanding all proposals by the European Commission to be in line with the 1.5 °C-goal (EP 2019). At the grassroots political level, an eye-catching example of reactions to the most severe risks inherent in climate change is the activist group

[3] None of the CO_2-equivalents above include what's called "climate carbon feedback", cc fb. There are statistics available which include cc fb, but these are, at the time of writing, rarer in practical gas comparisons.

Extinction Rebellion which demands net-zero emissions in the UK by 2025, six years from its formulation (Extinction Rebellion 2019).

How do metrics appearing to be dry technical jargon fit into the context of worries surrounding cataclysmic climate feedbacks, mass extinction, and the politics of the streets? Inherently and mathematically, GWP_{100} takes into account decades of global warming, decades at the *end* of these 100 years, which from a certain angle appear irrelevant *if the coming decades really are make-or-break*. That is, if we are to take the most dire predictions of climate collapse seriously then should we adopt a time frame where metrics guiding our assessment of the problem with the time-frames deemed absolutely necessary to solve the problem itself? This also begs questions concerning what an updated practical mitigation strategy could look like if we are to factor in such near-term risks of climate collapse. One thing seems evident as we enter the 2020s: A substantial part of the public and its institutions demand action **now**. Since this is not simply a testament as to *when* to start acting, but also mirrors a desired albeit sometimes vague rate of change, one might ask: **How soon is "now"?** If "now" is much sooner than 100 years, does this alter the way we ought to view, and mitigate, emissions of short-lived greenhouses gases and specifically methane?

1.2 Purpose

The aim of this master's thesis project is to investigate whether short-lived greenhouse gases (SLGHGs) are underestimated as radiative forcers in our contemporary understanding of the climate system. If there exists evidence or rigorous reasoning for claiming so, then what is the nature of such evidence or reasoning? And if so, what could be the practical implications and possibilities when trying to design new policy frameworks in light of this evidence? The study aims, using predominantly qualitative methodology, to cast a vast and nuanced net over questions on risk assessments and -perceptions, management of metrics and policy-pragmatic considerations for an improved and better-informed momentum in the sphere of climate ambitions. The purpose is further to contribute to the realm of cross-disciplinarity within climate science by viewing quantitative questions such as risk assessments through more of a qualitative lens, as well as applying non-partisan, evidence-based reasoning and interpretation in domains relating to energy infrastructure and the like which are prone to subjectivity and conflicts of interest.

This study is conducted on behalf of Naturvårdsverket, the Swedish Environmental Protection Agency (S-EPA), and aims to contribute to the knowledge and toolbox available to the S-EPA's Climate Policy Unit. As such, the aim is to inform concrete future models and analyses concerning the mitigation of short-lived greenhouse gas emissions.

1.3 Hypothesis and Research Questions

Given the purpose of the study, it is deemed fruitful to explore, broadly, a set of multi-faceted and intertwined research questions. These questions are allowed to evolve, change, merge and replace one another as work progresses, a process which will be elaborated upon in Methods & Materials, section 3, with support in an analytic framework found in the Theory section, 2. Below we find the questions the study finally aims at answering.

Research questions:

1) What can the history of and current debate surrounding 'common metrics' tell us about the feasibility of a changed policy for metric use and consequences for practitioners in the field?
2) What are the strengths and weaknesses inherent in different metrics, or combinations of metrics?
3) How does the contemporary understanding on climate risk, specifically surrounding tipping-points, manifest itself in its relation to a change in metric use?
4) How can a metric well-suited for guiding policy surrounding SLGHGs be designed?

2 Theory

This section includes, first, a little information on established 'common metrics' available for inter-gas comparison and a limitation as to which of these will be primarily considered here. Subsequently, theoretical perspectives are presented which aid the analysis, as well serving as justification for the methodology employed (section 3). Lastly, an analytic framework is introduced with its initial six starting-point criteria. This framework will develop over time during the course of gathering data and continuously evaluating the findings. (see Figure 2, section 3)

2.1 Common Metrics in Short

Central to this study are the 'common metrics' of which a couple were used as examples in the Introduction. The GWP and GTP concepts are described in short in Figure 1, GWP will be the most important metric for the reader to keep in mind in the continuation.

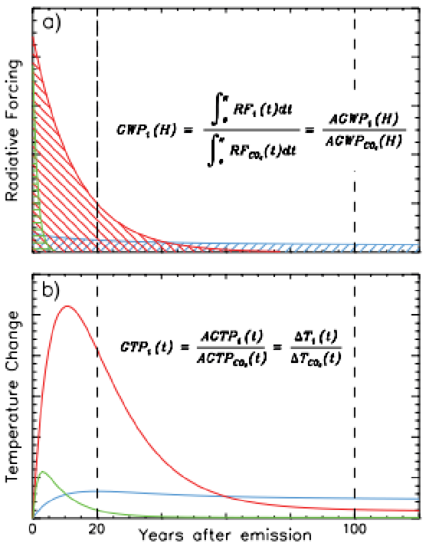

Figure 1: GWP and GTP

GWP (a) can be understood as the integrated product of the radiative forcing (i.e. the net greenhouse effect as determined by the spectra of light-matter interaction of the specific substance) of the studied gas/molecule/particle and its projected life-time in the atmosphere as determined by its interaction with other substances and the biosphere. GWP thus captures the amount of heat energy trapped by a distinct pulse emission from some given source. GTP (b) looks instead at the atmospheric temperature rising effect at a certain time t after the pulse emission is released, and ignored heat trapped in other matter of the bio-geo-physical than the atmosphere itself. GWP and GTP can be computed at any time *t*, the two most used such times *t* are 20 and 100 years, as shown in the figure and as discussed in the Introduction.

Image source (IPCC 2013, p. 711).

As it turns out, most of the analysis conducted here will revolve around the GWP metric. Besides GWP and GTP a wide array of metrics exists, many of which add other physical factors such as land use into the metric, while others add economic factors such as cost of emission reductions. To name a few, these bear names, and concepts, such GDP (Global Damage Potential), GCP (Global Cost Potential) and CETP (Cost-Effective Temperature-change Potential).[4] Another metric which turns up in the professional debate around CO_2-equivalents is GWP* (Allen et. al. 2018a). This is a metric which captures the different dynamics of different gases by modelling added warming potential as a function of *cumulative* CO_2-emsission and emissions *for the last year* for short-lived gases such as methane (ibid, p. 3).

2.2 An Undercurrent of Policy-Science Interaction

There may be many ways if of drawing upon distinctions and interactions between the political life on the one hand and the scientific life on the other. As anthropogenic climate change is better understood, with advancements in relevant scientific fields, it becomes simultaneously a clearer and more urgent political issue. How science and politics interact thus becomes pertinent for scientists and policymakers alike to understand. To add a meta-layer to this fact, we may need to learn (*scientifically*) about this (politics-science) interaction in order to bridge it (by means of *politics/strategy*(?)). As was partially touched upon in the introduction, it is not difficult to see how

i. Science may become 'politicized'.
ii. Politics may become reduced (perhaps via 'scientism'?) to 'technocracy'.

Many citizens may, at face value, crave a more socially conscious science community and a more evidence-based society. However, how is one to understand such seemingly beneficial enterprises in light of their more darkly tainted mirror images (i) and (ii)? As some theoretical groundwork aiding analysis in this study, consider the work of 20th century political theorist Hannah Arendt, on the topic, as portrayed contemporarily in *Green Populism?—Action and mortality in the Anthropocene* (Davies 2019). According to Davies:

[4] One can argue that GWP is a special case of the GDP, and GTP a special case of the GCP. (Tol et. al. 2012)

> *"In Arendt's account, Western philosophy and science is predicated on a rejection of the mortal realm of politics, in search of eternal laws of nature."* (Davies 2019, p. 6)

However, the world in which politics and science resides is changing. Davies writes:

> *"What has changed ontologically in the Anthropocene is that the mortality and agency of the natural world has come to the fore, in contrast to the eternal, universal and mechanical laws of nature that were the original concern of modern science."* (ibid)

Not only must politics, at every level, more than ever deal with large scale questions about our physical environment. Additionally, much of our predicament is due to our scientific and technological sophistication which has been, to a large extent, implemented in "*search of eternal laws of nature"* with little regard for "*the mortal realm of politics"* as quoted from Arendt, via Davies, above. Further:

> *"Modern science may be blind to the value of particular human lives, but can it still be blind to the necessary conditions of human life? Arendt argued that it can: 'The simple fact that physicists split the atom without any hesitations the very moment they knew how to do it, although they realized full well the enormous destructive potentialities of their operation, demonstrates that the scientist qua scientist does not even care about the survival of the human race on earth or, for that matter, about the survival of the planet itself.'"* (ibid, p. 7)

Much can be said, in challenge or in defence, of hostility to science and technology existing in parts of the environmental movement. Questions of science, risk and the dichotomy of the (populist) response to technology on the one hand and expert judgment on the other is widely covered in risk assessment literature, e.g. by Shrader-Frechette (1991). Among other things, a central emerging tension here is that the very fact that experts often look at probabilities when assessing risks while ignoring ethics and political concerns, they do not address the (political) processes, involving human agents, by which decisions on risks are typically made (ibid, p. 98). The larger questions around (popularly driven) policy and (expert driven) science are complex, difficult to contribute to empirically and outside the scope here. Also, as will be covered in the next section, the goal here is only to investigate into sentiments held by experts, leaving out the laypersons. Nonetheless, Arendt's reasoning must strike us as worthwhile to take into consideration as a theoretical perspective. Climate change is no splitting of the atom; it is not an instantaneous risk undertaken by maverick scientists. It is however a problem associated with a varying degree of apocalyptic labels (both in discourse and in future scenarios which must be accepted as scientifically feasible): crisis, collapse, breakdown and so forth. Has modern western politics, including its individual subjects, wholeheartedly accepted the scientific concept of continuous progress towards the eternal truth of nature and is this one reason behind climate inaction? When we examine *metrics* encapsulating phenomena of global warming and the qualities of such metrics, are we then ignoring the higher question of whether this is a technocratic endeavour unlikely to be part of, justified, radical change? This study does not seek to dig deeper into theory on technocracy (or governing by empirical data) than this. However, the words of Arendt and what they might reflects about the mutual and competitive interaction between science and politics will here serve as a backdrop for reading and analysing empirical material on perceptions of risk and the role of common metrics.

2.3 Epistemological Anarchy and Testing the Waters of Science Qualitatively

The natural sciences are perceived not to rely on neither qualitative methods nor iterative or irregular modes of structuring the scientific process. The case of the former is almost a tautology. Natural science inherently operates in a tradition that scholars active long after the scientific revolution would label 'positivist'; it is the practice of discovering and quantifying patterns inherent in nature with human subjectivity treated as noise to be minimized. The latter perception, natural science being largely void of more complex methodologies than the rather clear-cut dual pair of empiric testing and deductive reasoning, is more questionable. Feyerabend argues in his *Against Method: Outline of an Anarchistic Theory of Knowledge* (1970) that advancements typically come about as a result of highly chaotic processes. The central thesis of *Against method* is 'epistemological anarchy', which could be said to be a transgressing of formalized methods of scientific inquiry, specifically within the frame of the traditional natural sciences. This transgression is both sensible and necessary and does not negate concepts such as physicality or evidence but rather introduces the notion that less stringent patters of thought are precursors to verifiable theories about the physical universe, or indeed an integral part (albeit hidden) in every case of substantial discovery of a pattern in the natural world. To Feyerabend's mind, whereas a written account detailing the final empirico-logical, 'Popperian', reasoning of a scientific finding might be highly structured, its background processes needn't be and rarely are:

> *"'The external conditions,' writes Einstein, 'which are set for [the scientist] by the facts of experience do not permit him to let himself be too much restricted in the construction of his conceptual world by the adherence to an epistemological system.* ***He therefore must appear to the systematic epistemologist as a type of unscrupulous opportunist . . .' "*** (Feyerabend 1970, p. 18)

> *"The development of the Copernican point of view from Galileo up to the twentieth century is a perfect example of the situation we want to describe. We start with a strong belief that runs counter to contemporary reason. The belief spreads and finds support from other beliefs (…) new kinds of instruments are built, 'evidence' is related to theories in new ways until there arises a new ideology that is rich enough to provide independent arguments for any particular part of it and mobile enough to find such arguments whenever they seem to be required. Today we can say that Galileo was on the right track, (…) and this is not an exception-it is the normal case: theories become clear and 'reasonable' only after incoherent parts of them have been used for a long time. Such* ***unreasonable, nonsensical, unmethodical foreplay thus turns out to be an unavoidable precondition of clarity and of empirical success."*** (ibid, p. 25)

These examples distinctly pinpoint areas of natural science showcasing that developing knowing is never solely about adherence to the rigor inherent in validated theories. In the former case this applies to the individual or the concrete group of scientists, and in the latter to the collective of scientists and knowledge across time.

As identified above, the needs inherent in the research questions here point towards a qualitative and non-linear methodology. We are, moreover, venturing a field of positivist natural science namely that of radiative forcing, global warming and climate system 'tipping points'. By siding with Feyerabend and the scientists whose practice he claims are prime examples of epistemological anarchy in the sciences, one can claim not to break with methodological history when treating quantitative problems qualitatively, iteratively and rather loosely. It is noteworthy that the study conducted here, as seen in the Research Questions above, will rely on interpretations and synthesis of subjective attitudes towards metrics and risk where each individual attitude is an amalgamation of normativity **and** positivity. One should interpret the purpose of this study as being a *meta-study on climate risk and -strategies*, specifically metric-strategies as a guiding part of climate action. The purpose also necessitates, and the interview methods detailed below enable, *conceptual reasoning on the topic of metric design* (see Research Question 4). With inspiration from *Against method*, this study undertakes these kinds of techniques onto problems which at their core are of a physical nature.

2.4 An Evolving Analytic Framework

As we shall see below, this work employs a predominantly iterative method of data gathering and analysis (Figure 2). This notwithstanding, it is useful to have a starting point from which to begin to understand the various questions concerning different metrics, and the potential and downsides these might have in the eyes of climate experts. After having read the official IPCC breakdown of what constitutes 'common metrics' (IPCC 2013, ch. 8.7) a basic *analytic framework* for assessing metrics was created to serve as this starting point. This framework consists of six *criteria* which are found in Table 1 below. The goal is here not to necessarily use these six criteria in the final analysis. Rather, they form the first stage in an iterative process of which we find a final thematization in the Results & Analysis, section 4. Because the criteria were formed by a non-expert and after only an initial screening of the field, these criteria and the framework they make up must be considered a naïve, and not wholly methodologically stringent, approach.

Table 1: Analytic framework, with criteria

The six criteria acting as perspectives through which one can view different metrics in how they function to describe climate impact and guide policies. Criteria 1-3 are what we might call scientific-technological criteria, while criteria 4-6 are pragmatic and political considerations.

No.	Criteria
1	**Scientific precision**: The scientific assumptions inherent to the model for creating the metric. How does the metric relate to physics? Which climate phenomena does it map (e.g. temperature change, radiative forcing…) and how? What are the sources of error, precision and limitations?
2	**Risk-awareness**: How does a metric, and the choosing of a metric, reflect a value judgement on risk assessment? What time-frames are present, and what risks are taken by neglecting certain time-frames and phenomena?
3	**Embedding of technological development**: On the flip-side of risk: How does the metric account for future advancements in mitigating technologies?
4	**Pedagogic design**: How easy is a metric, or collection of metrics, to use? Does it inspire trust among policy-makers and the public?
5	**Wide support/potential as a compromise**: Do metrics point to changes in energy- and resource policy which can be accepted by a diverse field of actors?

	Are key players being singled out, and thus reluctant, by the frame a metric puts on the climate issue or can many agree on this framing?
6	**Feasibility of implementing resulting policy**: Given a particular metric strategy, what are the logical ramifications? If the most obvious mitigation strategy suggested using a certain metric is unrealistic, this is a problem which might stand in the way of momentum in the transition.

All of these criteria are used as a conceptual lens throughout interviews, reading, synthetization and assessment of the covered material. However, several other aspects will naturally turn up as work progresses. These then, iteratively, form an ever more nuanced understanding of questions related specifically to metrics, as well as questions related to risk and the surrounding body of phenomena at large. By considering the six criteria above and the final thematization, the reader will gain some insight into the workings of the analytic process. It is here deemed difficult and not productive to attempt a full account of this process; however, the dynamics of the interview methodology is detailed below.

3 Methods & Materials

This study will collect empirical material by means of *interviews*, with some selected reading of literature. The empirical material consists of recorded interviews and notes, which altogether aid in updating the analytic framework seen above, as well as broader contextual understanding. These methods undertaken are informed by requirements inherent in the research questions and the cross-disciplinary nature of these. Justifications for this is found below.

It is the objective here to find out what experts in the field who are familiar with using CO_2-equivalents think of various uses of metrics. In this manner, the study aims at a focal point at which natural science and policy strategy meet. Because the research field to be ventured is vast and untidy, it is necessary to be pragmatic in terms of how the scope of literature is limited. Furthermore, several aspects of the questions considered here address processes involving professionals in the field, on a personal level. This goes for risk assessments and -perceptions, but it also goes for lived experience of negotiations and the inertia involved in decision making. The data springing from both literature and interviews here will consist of both scientifically verifiable statements and subjective judgements and sentiments. In the case of 'softer' sentiments, a more interactive process (such as interviews) is likely to help collecting, interpreting and synthesizing data for instance in the sense that follow-up questions can be posed whenever important topics surface, or points which need clarification.

With these factors in play (cross-disciplinarity, need for qualitative assessment, difficulty of covering the field using only textual sources), it was identified early on that the focus should be on interviews rather than on literature. Interviews have the potential to become dynamic 'search-trees' where aspects come to life which could be hard for a lone researcher to find aided only by databases. Also, since the study tries to determine the potential for change in metric use, finding out attitudes of flesh-and-blood experts is of the essence. Focusing on interviews also lifts some weight off the question concerning 'pragmatic literature selection' mentioned above. It also creates and ample opportunity for receiving reading suggestions from interviewees. This approach is likely to point to influential papers within the field, which needn't filter through as easily or clearly in the route of scientific databases. Moreover, the complex nature of the interplay between the domains of policy and science suggests that an iterative, rather than a linear, method of data collection and analysis is suitable from a practical standpoint and likely to render more refined results and conclusions. This non-linearity also affects the forming of (temporary) conclusions, re-shaping of research questions as mentioned in the Introduction, and re-shaping of the analytic framework as mention in the Theory section (see #7 in Figure 2 below). Another consequence of the 'iterative-ness' is that this account of the method will not include any explicit detailing of limitations. What is considered a relevant topic can only be determined along the iterative trajectory and an attempt at pinning this down would be nonsensical or at best a tedious read. With this design, as motivated by the scope and purpose, in mind, the methods, choice of materials and how these facets interact, follows.

3.1 Literature

The study will consider as object for its study, various metrics on global warming and different assessments and perceptions on risk related to global warming in the coming decades. The history behind choice of metrics, the current scientific discussion comparing different metrics as well as the feasibility and/or need for new metrics to inform policy decisions will all be considered here. This means that certain literary sources are top-of-mind and will be used without being motivated by a systematic method for literary review. These sources are:

- UNFCCC history, as found in their database on decisions (UNFCCC 2020b)
- The IPCC AR5, primarily Chapter 8.7 on Common Metrics (IPCC 2013)
- The IPCC 1.5°C report (IPCC 2018)

These sources aim to form the basis of how metric-use have developed over time, and how they relate to one another. At a later stage in the process, based on the findings from the interviews, a focused reading into metrics is made possible give what elements of the sphere of metrics have found a place among professionals in the field.

Aside from these, a general understanding is needed on the topics of methane, feedback-loops and how metrics are discussed outside of the IPCC/UNFCCC-context. This will be gathered without using a rigorous methodology for searching literature. Rather, as states above, the method for finding literature rests on suggestions from participants (see #5 in Figure 2 below).

3.2 Interview methodology: Selection and Enactment

All interviews conducted in this study are of a variety one might call '*semi-structured elite interview*'. The 'elite' status of the participants, given their knowledge and experience, means that the question posed may sometimes be 'the wrong question' (Gillham 2005, p. 83). Participants are informed that they may rephrase questions, abruptly diverge for sakes of relevance and are asked at the end of the interview if they noticed any topical questions that were not posed. The interviews are also *semi-structured* (Lantz 1993, pp. 18-21; Gillham 2005, p. 70) in the sense that both fixed questions and spontaneity will be present. Since the study aims at comparing and synthesizing attitudes, judgments and knowledge between participants, it is beneficial for there to be a set of pre-determined questions. Partly to yield some common ground and comparability in the answer-space and partly to diverge, in the different interviews, at least partly from the same point namely these pre-determined questions. Further, since the subjects are experts it is likely that what questions are relevant can only be grasped while immersed in the interview at hand. The latter fact suggests that the interview should be heavy on the 'unstructured' rather than on the 'structured' side. A semi-structed interview also lends itself well when the purpose entails performing both qualitative and quantitative analysis (Lantz 1993, p. 21). The analysis will here be chiefly qualitative, but a few structured questions will make it possible to get concrete answers that in some manner forma quantitative picture of a prevalence of attitudes and judgments. Further, an iterative building of framework and thematization will take place which means that a rather free form of interview is beneficial.

At the start of each interview, the subject is asked to briefly outline their competence areas and experience within climate science and -policy, and related issues. The answer here serves both as a backdrop from which to interpret claims made by the subjects, but also as inspiration for the interviewer as to what paths along follow-up questions are likely to be valuable. Subsequently, two fixed questions put forth to all subjects are, with translation into English and the Swedish original:

i. "What metrics for establishing CO_2-equivalents are you familiar with?" ("*Swe: Vilka mått för att ta fram CO_2-ekvivalenter känner du väl till?"*)
ii. "Do you believe there is good reason to replace GWP_{100} with some other metric, to complement GWP_{100} with some other metric(s) or would you rather keep it the way it is?" (*Swe: Anser du att det finns goda skäl till att ersätta GWP_{100}, komplettera med andra mått eller är det bäst att behålla det som det är?*)

Question (i) tests the participants familiarity with different concepts, which gives context to question (ii). Additionally, the collected answers to question (i) will illustrate what metrics tend to surface in the practical-professional sphere.[5] Question (ii) is central to answering all research question; 1, 2 and 4 directly, 3 indirectly. A third, more interactive, question was initially included and posed during the interviews with staff at the S-EPA but was omitted for the other interviews (see below for the two groups of participants) since, by that time, a more nuanced way of approaching thematization had revealed itself. This question, (iii) consists of showing respondents the analytic framework (Table 1) and asking them to comment on its make-up as such as well as comment on what they could say about concrete metrics as viewed through the criteria in the framework.

Although these questions; the one concerning competence, (i), (ii) and (iii), are fixed, wording, intonation and, importantly, body language and social interaction may change when asking different respondents these questions. The same goes for intuitively emergent follow-up questions likely to be posed to many respondents, as well as for the full interview itself with its overlapping as well as unique topics. Wording of phrases and questions are hard to control from one interview to another and attempting to be precise here could come at the expense of the interview situation at hand and its 'flow'. This fact is an inherent challenge in all interview methodology. Farrelly (2012) state that "qualitative methods ask mostly 'open-ended' questions that are not necessarily worded in exactly the same way with each participant", and this is potentially more of an attractive feature, rather than an annoying bug (Farrelly, 2012, p. 2).

The set of participants will be selected by a combined process of asking supervisors for relevant people in the field, some independent research into the matter, and 'snowball sampling'. The latter is a method whereby ideas of who to interview next and/or concrete suggestions turn up in the interview process (Alvehus 2013, p. 68). As work progressed, it became clear that there would be a possibility for, and benefit from, covering two distinct groups of respondents: those working with mitigation issues at the S-EPA on the one hand and those involved in academia/research on the other. Methodologically, as part of the interview situation and its unstructured territory, it is assumed that the staff at the S-EPA will be more familiar with political processes and the academic researchers more with recent research in biophysical fields. Indeed, the difference in insight may vary more between individuals than groups and it is the goal to identify and get to the heart of whatever knowledge relevant for this study participants have by way of an open-minded interview process.

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[5] The academic sphere debates at least 8 different models for metrics recognized at the IPCC-level, with an infinite number of possible actual metrics drawn from these models (IPCC 2013, ch. 8.7).

Participants are asked whether they agree to the interview being recorded. This will be done using a voice recording app on a smartphone. When there is a need for a digital interview it will be conducted over Skype, with the same method of recording applied. It is not possible nor productive to describe here how the process of moving from the initial six criteria to the totality of themes progresses. Lending from Feyerabend, above, we may justify this by concluding that (sought) 'clarity and empirical success' can be obtained by 'nonsensical' patterns and analysis which would be hard to pin down and tiresome for the reader to follow.

The outcome in terms of selection is a result of the iterative methodology. For this reason, the set of participants is treated as a result in its own right and thus included in the Results section, 4, below.

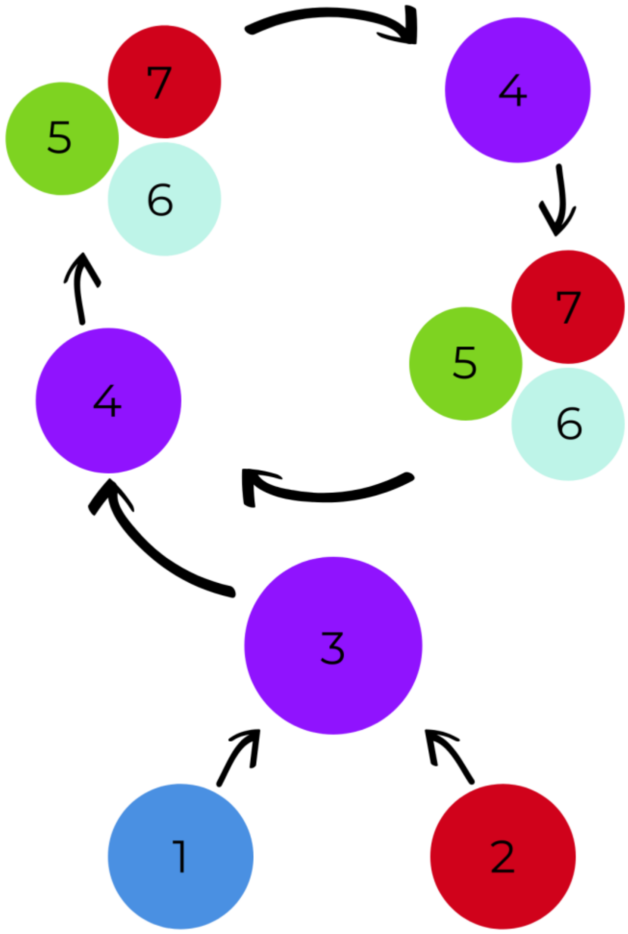


Figure 2: The iterative method
By number, the components of the method are: Base: 1 – Consulting the UNFCCC and the IPCC for the history of metrics and their varied forms. 2 – Theory and the criteria of the first framework (Table 1). Iterative method: 3 – The interviews methodology as such. 4 – Each conducted interview. 5 – Receiving and studying reading suggestions from respondents. 6 – Figuring out relevant subsequent interviewees within the scope of the interview situation and contact with participants prior to and after the interview (Snowball sampling). 7 – Re-examining the analytic framework after each interview and building a new "theory" as to how to thematize the results. Also, re-examining formulation of research question. Clearly, the loop is illustrative and does not suggest the same two participants are interviewed iteratively.

4 Results & Analysis

The combined planned- and snowball sampling resulted in 16 interviews. In eight of these, the respondent was staff at the Climate Department at the S-EPA and the other eight were researchers from universities and other institutions external to the S-EPA. All staff at the Climate Department worked either at the Climate Policy Unit (N=3) or the Climate Objectives Unit (N=5). All external researchers have attained at least the degree of PhD within a relevant field. The length of interviews ranged from 24 to 70 minutes with an average of 47 minutes. All participants agreed to have the interview recorded.

We can present the response to the two fixed interview questions outlined above, in tabular form (Table 2). Most of the focal points and substance from interviews, however, appeared in the context of adjacent- and follow up questions. The interview material in its entirety, together with literature found via interviews (Fig 1) forms the basis for the main qualitative analysis found below.

Table 2: Interviews conducted: Individuals, expertise and perception on metrics
The eight first interviews, EPA1-8 are personnel at the S-EPA) in Sweden. The subsequent eight, R1-8, are researchers not associated with the S-EPA. Most interviews were conducted face to face (N=11), the exceptions being R2, R3, R4, R7, R8 which were all conducted using Skype's video-call function on a laptop (N=5). All interviews took place in silent privacy apart for R5 which for reasons of logistics took place at a moderately noisy café. The units at the S-EPA are abbreviated CPU for Climate Policy Unit and COU for Climate Objectives Unit.

Interview ID and Date.	Name	Background and Field of Competence / (Unit within the EPA) (Current professional association, for Researchers)	"What metrics for establishing CO_2-equivalents are you familiar with?"	"Do you believe there is good reason to replace GWP_{100} with something else, to complement GWP_{100} with some other metric(s) or would you rather keep it the way it is?"
EPA1, 20191023	Flemming Hedén	Finance, LCA, responsible/sustainable investments. (CPU)	GWP	Not been faced with this question explicitly. "Something I ought to reflect on more than I do."
EPA2, 20191023	Dr. Björn Boström	Forest- and soil science, boreal carbon cycle, bioenergy, Swedish- and	GWP, GTP	GWP_{100} is established, and a good compromise between temporal perspectives.

		EU-level. (COU)		Different time-frames of climate effects could potentially merit different metrics.
EPA3, 20191024	Malin Kanth	Limnology, climate data, LULUCF, environmental surveying, international issues. (COU)	GWP, GTP	If one can show that GWP_{100} is scientifically "way off", then we should change. However, since a change of metric would be so complicated to implement it would have to be "way off" to merit a change.
EPA4, 20191024	Mats Björsell	Environmental economics, natural science, mitigation, transports. (CPU)	GWP, GTP	Yes, we clearly need to complement GWP_{100} with others. Certainly contextually, and maybe across contexts. "One could use GWP_{100} and GWP_{20} in parallel in most contexts"
EPA5, 20191028	Erik Adriansson	Environmental engineering, national and international coverage of anthropogenic climate change. (COU)	GWP, GTP	Temperature change can be logical to use, tied to targets being in temperature change. However, while reasons to change exist it's too late in the game to change at this point for the international context. One could use complementary metrics "on the side". In the international context, the big discussion is whether to include climate carbon feedback into metrics.
EPA6, 20191028	Per Andersson	Geology, chemistry, mitigation primarily in transport sector. (CPU)	GWP	Complementary shorter time horizon (20, 30 years) makes sense since many goals relate to 2050, 30 years in the future.
EPA7, 20191029	Julien Morel	Engineering physics, climate science and energy systems, climate policy. (CPU, currently at the Swedish Ministry of the Environment)	GWP, GTP, GWP*, Radiative Forcing treated outside of the GWP context	Worthwhile to develop new metric (approaches). Choice of metrics is value-based and always up for discussion. Practically difficult and potentially a loss of momentum to change metric-paradigm, especially internationally.
EPA8, 20191031	Dr. Johannes Morfeldt	Theoretical physics, mitigation in industry, energy- and climate policy, international climate negotiations,	GWP, GTP, GWP*	From a policy perspective there are issues, especially if both time-frame and model is changed. However, the aim is always limiting

		statistics. (CPU)		anthropogenic climate change, so analyzing the effects of our strategies can benefit from multiple metrics.
R1, 20191108	Dr. Jacob Nordangård	Natural- and cultural geography, biofuels, network analysis of economic interests. (Stockholm University)	None	Critical evaluation of the current paradigm is always valuable. "What are he weaknesses in the current framework?"
R2, 20191118	Prof. Lennart Olsson	Geography, livelihoods and poverty in climate context, agriculture in Africa, land degradation. (Lund University)	GWP	The dynamics of different gases and substances are so different and complex that making simple statements on best time-frames is a barren argument if void of context.
R3, 20191119	Ass. Prof. Åsa Kasimir	Biologist, LULUCF, carbon cycle in soil and water. nitrous oxide. (University of Gothenburg)	GWP, Radiative Forcing treated outside of the GWP context	If any change in metric use takes place it ought to be a shift towards shorter time horizons. "I have not given the topic much thought".
R4, 20191125	Ass. Prof. Stefan Wirsenius	Environment- and resource analysis, land use, agricultural systems. (Chalmers University of Technology)	GWP, GTP, different climate model based approaches, e.g. "temperature modeling" as per Smith et. al. (2012)	Model based approaches with basis in temperature change are more accurate, but GTP is perhaps the least useful metric. "I have for a long time held the opinion that we need a broader selection of metrics". "Many people who use GWP_{100} don't know why, thinking: 'I'll use CO_2-equivalents, great!'".
R5, 20191127	Prof. Markku Rummukainen	Meteorology, climatology, contributions to IPCC work, as well as UN climate negotiations. (Lund University)	GWP, GTP, has insight into Chapter 8.7 of IPCC AR5 and the 'common metrics' sphere in general. Does not specifically mention other metrics, however.	Different metrics emphasise different aspects and time horizons. If we talk about near-term change or other aspects than temperature, then some other metric than GWP_{100} might be relevant. As GWP_{100} is well-established in methodologies, benefits from changing to another metric would need to be well motivated also for practical reasons
R6, 20191204	Prof. Emerit. Henning Rodhe	Chemical meteorology, acidification and climate science, climate sensitivity, IPCC lead author on aerosols. (Stockholm University)	GWP (one of the first to develop the concept in the early 90s), GTP, has encountered	There is a risk of getting tangled up, and losing credibility, when using multiple metrics, and there is an analogy to climate sensitivity: one definition

			alternative metrics but not delved deeper	suffices. One can see temperature measures as relevant in some contexts. Using different time scales in parallel is easier pedagogically than different species of metrics.
R7, 20191204	Dr. Paul Miller	Climate modelling, wetland methane emissions, earth system models with dynamic vegetation (Lund University)	GWP, Radiative Forcing treated outside of the GWP context	Not including feedbacks (e.g. climate carbon feedback) in metrics is a problem, but doing so can turn very complex in practice if one does. Perhaps altering, shortening, the time horizon is better in this context.
R8, 20191205	Dr. Maria Berglund	Energy- and environmental systems, rural economy and agricultural societies. (Rural Economy and Agricultural Society)	GWP, GTP, GWP*	A gas-by-gas and a sector-by-sector approach is relevant (with related chosen metrics). The framing that "the model says that this is reality" is not fruitful for small actors wishing or needing to have a mitigation strategy, due to loss of context.

4.1 Tendencies and Emergent Themes from Interviews and related Literature

4.1.1 Metrics at play and metric strategy: Credibility and momentum in mitigation efforts

Judging from the fixed questions in Table 2, the interviews paint a couple of clear pictures. First of all, out of the 16 participants, GWP was part of the practical vocabulary of 15 participants, for GTP this number was 10, for GWP* 4. Given contextual understanding of interviews it is possible that a few additional participants are familiar with GWP*. Some other metrics were mentioned, such as radiative forcing in a wider context and "temperature modeling", but interestingly no respondents concretely mentioned GDP, GCP, CETP or other more complex model-based metrics. Even if the number of participants is low, not a single participant mentioned the set of approaches (GDP, GDP, CETP) which one might categorize as (economically) model-based, these metrics are likely rather obscure in the world of climate practice. R7, who works specifically with modeling climate carbon feedbacks suggested that capturing the risk of feedbacks is perhaps better suited in the phase of choosing time-frame inherent in the metric, rather than integrating the feedback in metrics, and a similar sentiment was expressed by R4. Making metrics dependant on model-based data could make them vulnerable to constant, substantial, change due to advancements in the field of climate modeling. In all, this outcome of interviews guides the focus of analysing literature towards GWP, GTP and to a lesser extent GWP*. Furthermore, if one believes that a change in metric paradigm requires that new approaches are based on somewhat *established methods*, it is somewhat likely that designs based on GWP and GTP are most fruitful. There simply aren't other metrics which so far have gained substantial traction, judging from these respondents.

A vast majority of respondents saw the clear utility in integrating a shorter time-frame in practice, but the opportunities and hurdles seen, differ. One group is worried that adding one or more metrics into the mix could complicate matters due to added levels of interpretation and weighing entering the policy process (EPA5, R2). Other hurdles mentioned were the need to change old databases (R5), the loss of credibility when multiple metrics surface in the discourse (EPA3, R8). There seems to be a tendency that those who have worked substantially with international negotiations (EPA2, EPA3, EPA5, R5, R6) interpret the practice of diversifying metric use as a question of establishing a new dominant international norm. On the other hand, others are to a varying degree considering metrics as strategic tools employable much more smoothly, potentially at a lower institutional level in a sector-by-sector or even case-by-case fashion. This was clearest with EPA4, EPA7, EPA8, R2, R8. All these respondents brought up nuances tied to such a 'custom-made' metrics strategy. For instance, EPA8 held the view that while agreements and targets are more locked to GWP100, when one looks retroactively at effects, for instance to analyse the effectiveness of policy, it is easier to open up for multiple time-perspectives. Further, when pushing for improvements (mitigations) made related to the local gas supply in Stockholm, one could make use of a metric emphasizing the seriousness of climate effects from leaking methane (EPA4). However, when asked if and how the municipality of Stockholm should go about implementing and motivating, for instance $GWP_{20,}$ across all sectors it was readily admitted that "I do not know". Although it can be frustrating to have to rely so centrally on GWP_{100}, which may not be perfect at a practical, (small) business level, it can be equally frustrating that different metrics actually do surface. R8 mentions being informed about a conference where an adviser within the agricultural sector brought up the existence of GWP_{20} and GTP_{100} aside from the established GWP_{100}. When faced with methane being either 4 or 84 times more potent than CO_2, farmers, even the ones eager to learn about how they may adapt agriculture in a future oriented fashion, are indeed frustrated and simply lose trust, and rightly so, in the concept of CO_2-equivalents.

4.1.2 'Tipping points': How soon is now?

R4 and R7, whom both study vegetation and land-use explicitly, were clearest in their assessment of which potential process to look out for in terms of 'tipping-points' in the near term, and they both mention the same one: certain tropical forests becoming bi-stable. Forests that have been accounted for as 'deterministically' forest areas (i.e. in such a state of humidity and other conditions that is prevails as a forest area for a foreseeable future) suddenly find themselves in drier weather and can potentially start deteriorating. This means losses of carbon to the atmosphere, more warming, more perturbed precipitation patterns and more areas risking becoming bi-stable. Events such as extensive fires in the Amazon could then become more prevalent, adding even more factors into a potential feedback, or 'tipping point' mechanism. If one goes looking for justifications of viewing metrics as something which should include shorter time-frames than 100-years, this was the clearest such example in the empirical material. Figure 3 showcases what occurred in the Amazon rain forest during the (northern hemisphere) summer of 2019.

Figure 3: The result of Amazon fires
With the risk of sounding like a news-anchor: "Will we see significantly more of this in the near future? Yes, say the experts". Image from near Porto Velho, Rondonia state, Brazil, on August 24 2019.

Image source: (Yale Environment360 2019)

R4, R5 and R7 all commented on the boreal permafrost melting that, although it is a very serious problem and potential 'tipping point', it is not likely to have the kind of effect this side of the turn of the century for it to merit a change in metric to something close to GWP_{20}.

4.1.3 The dynamics of methane

A few respondents brought up the fact that the short half-life of methane is 'so short' that an instant reduction in emissions leads to an instant reduction in the effects of said emission the subsequent year, and that one can even argue in this context that methane is *over*estimated using GWP_{100}. This is a narrative also found in literature, such as driven by Allen et. al. (2018a) and Allen et. al. (2018b). For instance, EPA2 had the clear impression that CO_2 should receive all focus now, and that methane mitigation can wait until an optimal point in time given technological opportunities and the like. Indeed, there is nothing wrong with such reasoning, but this does beg the question of whether this continuously pushes mitigation efforts, when it comes to methane, until 'tomorrow' because it'll all be fine, 'tomorrow'.

4.1.4 The finance sector

The finance sector holds both promise and problems as a player in future mitigation work. An important aspect brought up by EPA1 is that the finance sector is (i) risk aware, (ii) data-driven and quick to act and (iii) conscious that at some point de-carbonisation will happen no matter what. The latter can be summarized into the concept of 'inevitable policy response', which in essence is the potential for a sudden shift in climate-political policy (due to emergency, public outcry, regime change or the like) which dramatically changes the market conditions (UNPRI 2020). Presenting shorter timespans as crucial risk-wise for the finance sector could spur divestments. EPA1 further notes that one can view large financial institutes as belonging to one of three camps: one believing that we will follow a business-as-usual trajectory, and investing accordingly, a second believing that we will manage the climate crisis in an ordered manner and a third group believing that we will manage it in a chaotic manner. These different philosophies represent different attitude to various financial and biophysical risks. R1, who like EPA1 is acquainted with analysing economic interests, re-iterates that, unfortunately, a lot of capital is being invested in believing in chaotic events. As long as one can make money out of climate chaos, it will be exploited. It is hard to see whether different metric strategies increase or reduce volatility.

4.1.5 Lobbying, national interests and geopolitics

The study is situated in a Swedish context, and in Sweden's national interest one must take into account the relatively slow-growing forests. The same is true for all countries with substantial boreal forests. EPA2 pinpoints the fact that carbon sinks will also have to be measured with a new metric, if it is employed across all sectors. This would not benefit Sweden, so he deems it unlikely than Sweden, as a whole, would lobby for such a thing.

Many respondents at the S-EPA have encountered countries with a large agricultural sector, primarily Brazil, argue for GTP_{100} which would reduce the perceived importance of methane. Whether this is scientifically sound is debatable, but it is always relevant to factor in who lobbies for what.

Dependence on Russian gas for electricity and heating is a hot-button issue in Eastern Europe and the Baltic region. This is a strategic issue well beyond the scope of this study, but EPA6 nonetheless points out that a (metric) strategy hurting methane would be a geopolitical statement with regards to Russia, in Sweden's part of the world.

4.1.6 "Every sector matters", and dual metrics

R2 and R5 are, in a certain sense, pragmatic and both have worked closely with the IPCC. They both echo the sentiment 'every sector matters' and they see clear possibilities for different actors to use different metrics contextually in a pragmatic manner without having to slavishly rely on GWP_{100}. R5 specifically mentions actors such as the Climate & Clean Air Coalition, CCAC who use GWP_{20} as part of their work on black carbon and air quality.

CCAC clearly carry out studies where GWP20 and GWP100 are presented side by side for the reader to create their own take home message, for instance when comparing diesel and gas in public transport investment (CCAC 2015). This kind of approach is something virtually any organisation could use if they make sure they explain what the different metrics showcase, as not to create confusion,

4.1.7 Infrastructure

It is important, mentioned R4, not to forget that biofuels are also methane. He was willing to simply scrap calling a certain source of gas 'natural', 'fossil' or 'bio'. Biofuels needn't be of great concern, but the way the infrastructure operates at the moment, it can be. It is not economically justifiable to keep methane leakage from biogas reactor facilities at 0. There is always a certain amount of residue of bio-materials in the reactor when the optimal time for fuel outtake has been reached. This residue is moved to a different tank and the resulting methane is lost to the atmosphere. If one were to become harsher, policy-wise, towards methane this would result either in economic issues for bio-gas facilities or exempting these in some fashion. It is important to note, as R8 does, that this is not an issue in the same way when it comes to biogas from manure, since methane from this particular biomaterial would have been lost to the atmosphere in any case.

When it comes to leakages in the methane infrastructure globally, EPA4, EPA6 and R4 suspect these are underestimated. If that is the case, then perhaps using GWP_{20} in a targeted manner to justify looking closer into a forgotten area of mitigation potential could be of value.

Questions concerning projected future technology are hard to answer, but if they can it is likely that so can consumption patterns (e.g. meat) comments EPA8. He also emphasizes that in terms of narratives of projected developments, one can gain from speaking of trends which include both technology and behavior as not to single out or favor certain developments in sensitive areas of discourse.

4.1.8 Practical example

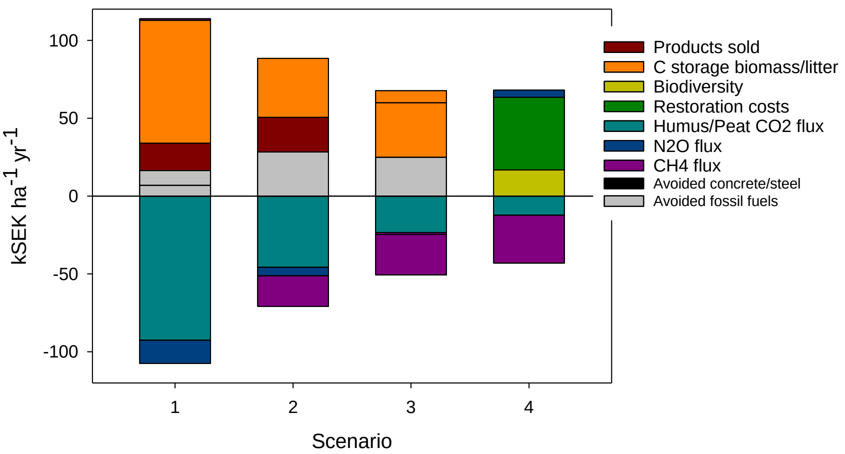
The most striking example of a practical case in which choice of metric poses difficult questions towards whole areas of research came up while talking to R3. Her own research has included experimenting with different levels of re-wetting peatland

(Kasimir et. al. 2018). Figure 4 shows results from a study where the four scenarios are explored. Here, scenarios 1 to 4 represent water levels of 40, 20, 10 and 0 centimetres below ground levels respectively. With more water, tending toward scenario 4, we get less CO_2 flux (dark turquoise) but more methane generated (purple). Economic gains for each scenario are calculated (whatever gain will be the net of the positive and negative side of each bar). Naturally, these numbers (k Swedish krona / hectare /year) are calculated using carbon pricing and CO_2-equivalents, and the standard GWP_{100} is used for methane. Which scenario is better depends on substitution is accounted for or not (grey and black), but it could also change if we were to question GWP_{100}, making scenarios producing less methane look all the better.

Figure 4: Re-wetting of peatland

How saturated with water should one make a peatland for maximal net-positive climate effect? The answer to this can depend on the answer to the question "How soon is now?". In many other applications mitigation is simply a question of whether a certain strategy is worthwhile (e.g. cost-effective). In this case, however, the peatland is sitting there no matter what we do. We can do something (re-wet, drain), but what should we do? This is the 'science' of metric interpretation at its most crucial.

Image proivided via e-mail by R3, image is realted to Kasimir et. al., 2018.



5 Discussion

5.1 Method Discussion

There is an extent to which "interviews may feel authentic, but not necessarily reflecting what would emerge in a different context" (Alvehus 2013, p. 86). However, the partly verifiable and wholly professional nature of the questions posed here is likely to reduce the effect of this particular kind of bias. Also, naturally, there is a causality which cannot be circumvented; knowing how to find the right follow-up questions will become easier as more interviews have been conducted, which can increase the quality of later interviews. All of this creates bias, but there is no way of mapping its extent or nature here. There was an element of creating a 'research habitat' for myself, involved in the study; I was actively working in the same environment as the S-EPA respondents. This did create a problem: I became focused on facilitating interviews (including a lot of e-mail correspondence to find the right times, going by train to Norrköping to meet R1, and a lot of other logistics) and also re-listening to the interviews several times in different orders to understand my empirical material. Indeed, not a problem as such, but it did severely damage the amount of reading I performed. Looking back on Figure 2, the green balls (#5), i.e. picking up on reading material from respondents were not as big a part of the work as was hoped. Nobody could claim that this has been anything but a pure expert interview study. However, the 'research habitat' was in many other ways highly beneficial as it was possible to build trust with the respondents at the S-EPA prior to interviews, which also substantially aided the snowball sampling (for instance, EPA3 suggested talking to R3 who then suggested I talk to R8). It may also be in order to discuss the entirety of the snowball sampling method. Respondents were found as follows:

> Suggested by my supervisor at the S-EPA (himself EPA4): EPA2, EPA3, EPA7, EPA8, R4
>
> Suggested by EPA3: EPA5, R3
>
> Suggested by R3: R8

Suggested by my supervisor at Lund University: R2, R5 (also suggested by EPA4), R7

Chosen on my own accord, (by chatting to people at the S-EPA to gather who was able and knowledgeable, and from looking outside the S-EPA for interesting voices): EPA1, EPA6, R1, R6

Seen like this, it appears as if only three respondents (EPA5, R3, R8) were found purely by snowball sampling (would not have been found without it). However, the case is not this simple. R7 was suggested to me only after having discussed what I had found at that stage of the process, R6 was found as part of a literature search mid-process. R2 and R4 were suggested to me after having discussed some initial ideas in the process. Somewhere between three and seven respondents found their way into the material by way of snowball sampling, depending on interpretation, and it is clear that this method contributed substantially to the overall substance of the result.

5.2 Results Discussion

An interesting finding was the discrepancy between those experts, on the one hand, interpreting a shift in metric strategy as a paradigmatic shift on the international level and those on the other who had in mind a more custom-made case-by-case approach. One or the other was not specified in the fixed interview question ("number" ii). This can be both a weakness (we are now getting answers to, essentially, different questions due to interpretation) but also a strength (capturing the experiences and attitudes behind the fact that it is conceived as different questions).

The study set out to find important themes starting from the 'criteria' of Table 1. It is interesting to note that, without there being any conscious effort to this end, the criteria were all ways of assessing metrics directly whereas the majority of themes deemed interesting to present in the Results & Analysis section were of a different character; more about surrounding factors affecting how one may view and use metrics than factors describing metrics themselves. In this way, we have moved from a parametrization of metric internally to a connection between metrics and the outside, physical and social world.

5.3 General and Theory Discussion

The Theory section introduced some thoughts by Davies, 2019, with emphasis on his take on work by Hanna Arendt in the realm of science/policy interaction. Although this was in the back of my head during the whole project, it is hard to concretely pinpoint what this brought to bear, apart from the few examples brought up in the Results & Analysis section. Questions in the interviews tended to become quite practical, somewhat void of more philosophical enquiry. It felt natural not to force philosophical matters into the interviews. With EPA4 and R1 discourses surfaced surrounding what strong capital interests do or don't do in the climate policy sphere. There was a measure of cynicism in both of these cases, with EPA4 concluding with bewilderment that certain segments of world's financial elite care, seemingly, nothing for the climate, or philanthropy in general, even if it could lend them goodwill. R1, who has studied lobbying substantially, mentioned both possibilities and hurdles in 'following the money'; it can be easy to analyse who benefits from what policy(proposal), or for that matter metric choice. However, many large corporations also sponsor NGO:s to do their bidding (R1).

One shouldn't underestimate the undercurrent of the philosophical questions of the Anthropocene present in all of these discussions, anyway. 'Big questions' on the bio-geo-physical are by their very nature existential. When we speak of 'climate' and 'resources' it is sometimes easy to forget that we are speaking about 'nature' and the planet as a whole, to which we have an age-old relationship. Both of trying to understand it, and to exploit it. Anthropogenic climate change may be a post-industrial phenomenon, but the science-politics debate is not. The 16th century Danish astronomer Tycho Brahe famously chose the following Latin inscription on his observatory[6] (Lindbom & Larsén 2008): "*Nec fasces, nec opes, sola artis sceptra perennant*". *Not might nor wealth, only the dominion of art remains*. Indeed, in Brahe's day, mention of 'art' was commonly equivalent with art **and** science, inseparably. Maybe we can reattribute this calling for our day? Keep force and money in politics at a bare minimum, but let art and science thrive? Is this excessively poetic, pathetic? As a poetic counterpoint, the modernist poet T.S Eliot depicts in his *The Lovesong of J. Alfred Prufrock* (Eliot 1915) an elderly, and seemingly sickly, man. Bitter about his predicament, the man contemplates, hesitatingly:

[6] An inscription which today can be found at a memorial monument well in Helsingborg, Sweden

(…)Would it have been worth while,
To have bitten off the matter with a smile,
To have squeezed the universe into a ball
To roll it towards some overwhelming question,(…)

Is our civilization an elderly and bitter man? Old as Brahe and the Enlightenment which followed him? Outdated? Perhaps. But we are likely not gaining anything from paralysis by analysis, doubt and geriatric hesitation. We are all free to dislike the, strikingly technocratic, pursuits of using metrics to change the world. But maybe we must bite the matter off with a smile. Maybe we need smart ways of squeezing the world into a ball, a metric, and courage to roll it towards some overwhelming question about concrete and large-scale energy transitions. We are still likely to need colourful questions like "How soon is now?" to guide our enterprise.

6 Conclusions

6.1 Coming back to the Research Questions

With plenty of themes to think about, it is relevant to concretize what findings can be seen in relation to the research questions:

1) *What can the history of and current debate surrounding 'common metrics' tell us about the feasibility of a changed policy for metric use and consequences for practitioners in the field?*

   This is entirely level-dependant. UNFCCC does not outlaw using metrics outers than GWP_{100} but it is practically tricky at the most central and highest institutional levels. However, nothing stops competent analysts from convincing actors of various insights using other metrics than GWP_{100}.

2) *What are the strengths and weaknesses inherent in different metrics, or combinations of metrics?*

   Given the aim related to methane we can clearly see three different ways forward involving GWP20. These are, with pros and cons:

   i) Using GWP_{20}, solely. This has been done by various activist groups (Fossilgasfällan 2019; Baltic Pipe? Nej Tak! 2020) and 'packs a lot of punch'. However, for any institution that for any reasons needs to look also at the year 2100 perspective this is inadvisable since it reduces credibility.
   ii) Presenting GWP_{100} and GWP_{20} side by side. Is certainly employed by credible actors (CCAC 2015). Good if one believes that the actor receiving such an analysis will draw competent conclusions, weaker if a 'bottom line figure' is sought
   iii) Combining the two into one metric: $a*GWP_{100}+b*GWP_{20}$. Good for the bottom-line case, but has weaknesses since it introduces assumptions one might one to leave to the actor receiving the analysis. In a way the opposite of (ii), strategically.

3) *How does the contemporary understanding on climate risk, specifically surrounding tipping-points, manifest itself in its relation to a change in metric use?*

   Assessing precise climate risk is tricky. Several respondents issued opinions to the effect that one can indeed see the climate problem as a dual problem: a short-term component with some risks of 'tipping points' and the like entering the picture and a more long-term problem where target temperatures at the end of this century are sketched out. This kind of thinking can, with the specific knowledge of certain 'tipping points' related to deforestation and other phenomena, add fuel to fire of multiple metrics.

4) *How can a metric well-suited for guiding policy surrounding SLGHGs be designed?*

   Somewhat answered in (2), but it is important to note that GWP_{20} and GWP_{100} are not fixed building blocks. From a risk perspective, discounting and damage calculations notwithstanding, an interesting path to explore would be an integral of the product of GWP and some time-dependant risk function. This would weigh GWP and could create, seen form a certain perspective, an 'optimal time frame'. A possible topic for continued research is one of somehow quantifying risk as probabilities over time and weighing a gas-impact function, like GWP, with this risk. This type of climate risk distribution covering 'tipping points' and key time-frames was something expert participants claimed does not exist, without making clear whether or not it would be useful if it did.

6.2 A Final Word

As we enter into the 2020's, much seems to be at stake in terms of climate commitments and goals, locally and globally. It is clear that raising questions on metrics as done here is not popular with everyone, nor should it be. This study set out to look for potential ways of tackling methane emissions, but it has in no way performed a complete consequence analysis of how such aims, using specialized metric strategies, would affect de-carbonization as a whole. The conclusion of this study must be that there certainly are justifications for toying with GWP_t, where t is smaller than 100 years, in some fashion. The consequence is then that methane needs a closer look. The reverse is also true, if climate analysts face a particular set of methane problems and seek justification for tackling them then they can indeed look to shorter timespans and relate this to risks and precautionary principles in the near-term. However, it is entirely up to the professionals nuancing, albeit complicating, matters by implementing such analyses to bear the burden of doing so in a responsible manner.

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Interview material

As per agreement, the audio file from each interview is kept by the author until it is deleted upon request by the respondent. Table 2 in the Results & Analysis section details each of the 16 interviews with name of respondent and respondent-ID.

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