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The Paris Target, Human Rights, and IPCC Weaknesses: Legal Arguments in Favour of Smaller Carbon Budgets

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Abstract: The Paris Climate Agreement (PA) provides an overall target which limits global warming to "well below 2 °C above pre-industrial levels" and "pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels" (Art. 2 para. 1 PA). This article assesses the extent to which new insights can be derived from recent IPCC reports for the interpretation of Art. 2 para. 1 PA from a legal perspective. To this end, the article analyses the contributions of Working Groups I and III of the sixth assessment report. Methodologically, we compare the findings with previously published IPCC reports, namely the 1.5 °C report and the fifth assessment report. A legal interpretation of the Paris Agreement and of core concepts of human rights follows. Several empirical indications show that current global greenhouse gas budget calculations are quite generous. We provide five empirical arguments that clearly point in that direction. These empirical arguments, combined with legal arguments, demonstrate that the budgets must be smaller than those estimated by the IPCC. The legal arguments are based on Art. 2 of the Paris Agreement, as well as on human rights and the precautionary principle. These norms contain an obligation to minimise the risk of significant damage, i.e., to take rapid and drastic climate protection measures. This implies: 1.5 °C is the legally binding temperature target; adherence requires a very high probability of achieving the target; temperature overshoot and geoengineering tend to be prohibited, and budget calculations must be based on sceptical factual assumptions. These findings have also been confirmed by recent rulings of supreme courts, such as the ground-breaking climate decision of the German Federal Constitutional Court. The Paris Agreement and human rights underline a legally binding obligation for smaller global greenhouse gas budgets as those estimated in the greenhouse gas budgets of the IPCC—even compared to the 83 percent scenario in the latest assessment. Thus, climate policy will have to raise its ambitions towards zero fossil fuels and a drastic reduction of livestock farming in times of the Ukraine war.

Keywords: climate change; Paris Agreement; human rights; IPCC; climate policy; Climate Litigation; precautionary principle

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1. Introduction

In December 2015, nations worldwide agreed on a new global climate treaty. The Paris Agreement (PA) was generally met with great enthusiasm, especially since successful negotiations were not expected. However, just over six years after its adoption, many questions remain unanswered, most notably how effective the Agreement is and will be. The PA commits Parties to take ambitious action to halt climate change (mitigation), adapt to the consequences of unavoidable climate change (adaptation), and provide financial assistance to countries harmed by climate change (loss and damage). The PA provides an overall target which limits global warming to "well below 2 °C above pre-industrial levels" and "pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels" (Art. 2 para. 1 PA; on nature and history of climate targets [1,2]). Further, Art. 4 para. 1 PA requires "In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible . . . , so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century."

In line with the adoption of the Paris Agreement (2015), in 2018, the Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) decided to invite the Intergovernmental Panel on Climate Change (IPCC) to prepare a special report on the impacts of a 1.5 °C increase in global temperature above the pre-industrial levels. The IPCC accepted this invitation and prepared a corresponding report. The Special Report (SR15) provides different scenarios and pathways to reduce global greenhouse gas (GHG) emissions, while promoting sustainable development [3]. While the IPCC had only a limited number of studies for its previously published Fifth Assessment Report (AR5) that addressed scenarios for limiting global temperature rise to 1.5 °C or below by 2100 [4,5] (p. 16), it was clear that achieving this target was entirely possible but would require massive efforts to reduce global emissions. In 2022, the IPCC published its sixth assessment report (AR6), including the contributions of Working Group I (WGI) and WG III that contribute to the question of the remaining greenhouse gas budgets, too.

Before this background, this article aims to assess the extent to which new insights can be derived from SR15 and WGI and WG III of AR6 for the interpretation of Art. 2 para. 1 PA from a legal perspective. To this end, findings from these reports will frequently be compared with AR5. Furthermore, building on our previous considerations, we analyse Art. 2 para. 1 PA and underlying human rights issues in more detail. This includes the question of whether the IPCC (legally speaking), when calculating its greenhouse gas budget, adopts a correct understanding of the norm [6,7]. This is highly relevant as courts in various countries have started dealing with Art. 2 PA. *Our thesis is that the IPCC budget must be substantially smaller if the legal perspective is considered—and, consequently, climate policy will have to raise its ambitions even more than usually called for.*

2. Materials and Methods: Budgets, Reduction Pathways, Scenarios—Zero Emissions until When?

Methodologically, this article provides a legal interpretation of the Paris Agreement. As a basis, we analysed estimates from natural sciences of the emission reduction implications of the targets of the Paris Agreement. Legal norms are interpreted grammatically, systematically, teleologically, and historically. This meant according to their literal meaning, their relation to other legal norms, their purpose, and their evolution. Usually, grammatical and systematic interpretation is applied since the other two approaches are prone to several problems. In the Anglo-Saxon legal sphere, case law would also serve as a source of interpretation. This is different to the continental legal sphere we are based in. Therefore, court verdicts function only as illustration of the practical relevance of our arguments derived from the wording and system of the Paris Agreement. A (very long and) detailed analysis of all court rulings on climate change, the 1.5 °C target and human rights is presented elsewhere [8]. Regarding the empirical data, we provide a text analysis of the recent IPCC reports AR5, AR6, and SR1.5 and discuss the estimated global carbon budgets. We compare the estimates of WGI und WGIII (WGII does not calculate a budget). Importantly, the IPCC is not a research institution but a UN platform. The IPCC does not do research but summarises research findings from primarily natural science (and economic) research.

Nota bene: Regarding the epistemological background, legal interpretation is—like ethics—normative science, not empirical science; law and ethics make statements of ought rather than statements of being. Therefore, legal interpretation does not require collecting data and facts, i.e., legal interpretation is not a case study as a case study empirically describes a process (see in detail [9–11]—also on the criticism of empiricism in epistemology that, since the 17th century, sometimes suggests that science can only deal with facts, not with norms).

Article 2 para. 1 PA enshrines the legal obligation to limit global warming to well below 2 °C and to make efforts to achieve 1.5 °C. However, what does keeping global warming below 1.5 °C exactly mean? The answer to this question depends in part on the difficult empirical question of humanity's remaining time to reduce its emissions to stay within the temperature limits and achieve the 1.5 °C within the next few decades (for the weaknesses of projections, see [12]; see also [13,14]). SR15 underscores the long-term climate goal from Article 2 par. 1 PA: The transformations needed to limit warming to 1.5 °C are more pronounced and much faster than those for the 2 °C limit. SR15 and WGI of AR6 show that human activities have caused a 1.0 °C, respectively, 1.09 °C increase in global temperature above pre-industrial levels [15] (pp. 2–39). According to SR15, if global warming continues at the current rate, a temperature increase of 1.5 °C is likely to be reached between 2030 and 2052 [16] (p. 4). The assessment of WGI of AR6 finds that even under the lowest GHG emissions scenario 1.5 °C warming is reached *more likely than not* [15] (pp. 4–37). The projections presented by WGIII are mostly consistent with the observed overall increase in global surface temperature from WGI of AR6. The largest contributor to historical human-induced warming is CO_2, with historical cumulative CO_2 emissions from 1850 to 2019 being 2400 ± 240 $GtCO_2$ [17] (SPM-28).

In its reports, the IPCC compiles data from a wide range of climate research including on the effects of emissions, global warming, and the potential consequences of climate change. In doing so, projections are provided. These projections have no normative force but deal with the empirical world [5]. All climate scenarios face several variables whose trends and interactions are unknown but still have major implications for the results [18]. In addition, multiple empirical assumptions feed into each scenario, which highlights the uncertainty of climate projections. The climate system is a complex and highly volatile system in which a variety of factors respond to different changes [7,19,20]. As a result, reliable long-term forecasts are almost impossible and traceable scenarios can be created for a few decades only [21–24]. Consequently, in the scientific literature, remaining emission budgets range from zero to figures larger than those of the IPCC (see below).

Analysing all different models, as done in the IPCC reports, helps to react to this phenomenon [25–27]. However, since these models are highly complex and based on many assumptions, comparing all the details is beyond the scope of a primarily legal analysis. Nevertheless, we provide a general overview [28,29] as a basis for discussing legal issues and challenges regarding the underlying empirical data in the following two chapters.

There are two general types of models which estimate the future development of climate change and its consequences for society (on details and challenges see [7]): (1) integrated assessment models (IAM), which exponentiate GHG emissions while attempting to capture economic and industrial developments, and (2) earth system models (ESM), which simulate the complex carbon cycle [29,30]. All models suffer from uncertainties due to feedbacks and physical processes associated with global warming which are not fully understood and therefore, not adequately accounted for. This includes water vapor, lapse rates, clouds, snow, and ice. In addition, natural cycles, such as the carbon cycle, cannot yet be fully anticipated, e.g., sink and source developments and capacities (this applies to both the Earth and the oceans) [31,32]. Besides, there are three types of emission budget calculations. First, budgets (calculated based on the models) that include only CO_2-induced warming, which is subtracted from the climate response to cumulative CO_2 emissions [33,34]. However, the application of this budget is limited since other GHGs cannot be included (attempts to build models for the N cycle, for example, have failed because of its complexity [34]). Second, threshold exceedance budgets aim to determine how much CO_2 may be cumulatively emitted to reach a given temperature target. In this budget, other GHG sources can be included. The problem is that delayed climate responses are not accounted for. Third, threshold abatement budgets estimate, with a given probability, the remaining emissions budget to stay below a temperature target either within a specific time frame or until maximum warming (for the interplay of the various factors, see e.g., [19,35–38]; on net zero see [39]).

It is important to note that the Working Groups of the IPCC base their scenarios on different assumptions. In AR5, Working Groups I and III use different ways of calculating the carbon budget. WGI calculated carbon budgets from 2011 for different levels of warming relative to the 1861–1880 period using "Representative Concentration Pathways". WGIII estimated its budgets from a set of available pathways that have a greater than 50 percent probability of exceeding 1.5 °C by mid-century and greater than 66 percent probability of returning to 1.5 °C or below in 2100. SR15 adopts these differences in further basic assumptions of the Working Groups. This includes the observed time periods, sets of multi-gas and aerosol emission scenarios, and concepts of carbon budgets. WGI of AR6 largely adopts the approach of previous IPCC assessments [15] (pp. TS-63 and 1–102). To be consistent with WGI, WGIII of AR6 reports historical cumulative CO_2 emissions from 1850-2019 with a confidence interval of 68 percent [17] (SPM-5). Still, GHG emissions by 2030 for pathways that limit global warming to 1.5 °C are higher in absolute terms in WGIII of AR6 than in SR1.5 [17] (SPM-21). According to WGIII of AR6, pathways that limit warming to 1.5 °C with 50 percent probability, with no or limited overshoot, are associated with net cumulative CO_2 emissions to net-zero CO_2 of 510 $GtCO_2$ [17] (SPM-31), while WGI of AR6 assumes 500 $GtCO_2$ for 50 percent probability [15] (SPM-38). WGIII of AR6, in general, not only seems to be more optimistic than WGI of AR6, but also compared to SR1.5 and WGIII of AR5: WGIII of AR6 indicates a larger remaining CO_2 budget than SR1.5, which estimates the remaining carbon budget at 580 $GtCO_2$ at a probability of 50 percent, but only 420 $GtCO_2$ at a probability of 66 percent [16] (p. 96). WGIII of AR5 assumes that only concentrations of 480–530 ppm CO_2eq have a probability of greater than 66 percent to keep the temperature rise below 2 °C [5] (p. 441) while WGIII of AR6 estimates pathways that limit warming to 2 °C with a probability of 67 percent at 890 $GtCO_2$ [17] (SPM-31). This could be due to, among other things, the use of different base years. While AR5 refers to 1750 as the reference year, AR6 uses 1850 as the starting point, which neglects emissions in the first century of industrialisation [17] (SPM-5) [40] (p. 44). In addition, methodical developments as well as different attitudes of the Working Groups regarding the permissibility of an overshoot lead to different remaining CO_2 budgets.

Therefore, it is challenging to compare the calculated carbon budgets across Working Groups [16] (pp. 66, 99, 104) [41–44]. Furthermore, WGII does not calculate an own budget but accepts an overshoot [45] (SPM-19, -25, -31, TS-44, -60, -69, pp. 136–137). Apart from that, the findings of WGII on the impacts of climate change serve as a basis for the IPCC's recommendation to drastically reduce greenhouse gas emissions.

Interestingly, WGI of AR6 includes calculations with an 83 percent probability of achieving a temperature target. The remaining budget for 1.5 °C is at 300 $GtCO_2$ (starting from 1/1/2020) and the budget for 2 °C is at 900 $GtCO_2$ [15] (TS-63). Outside the IPCC, according to recent reviews, the estimated carbon budget for 1.5 °C ranges from below zero to more than 1000 Gt CO_2 as of 2018, and for 2 °C from less than 800 Gt CO_2 to nearly 2000 Gt CO_2 [20,46,47]. This is since different baselines are used, and different factors and variables included [48]. Ultimately, the large variability of the CO_2 budgets also raises the question of the consequences for policy makers and mitigation and adaptation measures [46].

The remaining budgets partly contradict (not only with estimated annual emissions of other studies but also) with calculated emissions of the reports themselves. As seen above, SR15 assumes a remaining CO_2 budget of 420 $GtCO_2$ from 2018 until the time of net zero global emissions. WGI of AR6 sets the remaining CO_2 budget consistent with limiting global warming to 1.5 °C with 67 percent probability at approximately 400 $GtCO_2$. This implies a difference of 20 $GtCO_2$ for two years, which corresponds to only 20 $GtCO_2$ emissions from 2018 to 2020 [15] (TS-61,16, p. 96). However, for 2019, one study estimates that total anthropogenic emissions were at approximately of 42 $GtCO_2$ [49] while WGIII of AR6 calculates global net anthropogenic GHG emissions for 2019 at 59 $GtCO_2$-eq, 54 percent higher than in 1990 [17] (SPM-4). Furthermore, according to WGIII of AR6, the annual average in the decade 2010–2019 was 56 $GtCO_2$-eq. This is the highest increase in average decadal emissions since records began [17] (SPM-4). Above all, considering the annual anthropogenic CO_2 emissions, very (!) little time remains to stay within 1.5 °C warming and to make the transitions needed.

Furthermore, when calculating the emission reductions as required by Art. 2 para. 1 PA, it is crucial whether emissions will be reduced immediately or whether they will continue to rise for a few more years and be reduced thereafter [15] (pp. 4–80) [24,39,50,51]. As mentioned earlier, the (non-) integration of overshoots plays another important role. WGI of AR6 estimates that even the very low GHG emissions scenario includes a temperature overshoot of "no more than 0.1 °C above 1.5 °C global warming" [15] (TS-28), while WGIII allows and overshoots of 0.15–0.3 °C and returning to 1.5 °C by 2100 with a probability of at least 50 percent [17] (SPM-17). Likewise, most of the SR15 scenarios assume that the temperature limit will be exceeded to about 1.8 °C first before reducing the temperature to 1.5 °C by the end of the century through negative emissions. This adds 400 to 1600 $GtCO_2$ to the carbon budget, equivalent to 10 to 40 years of current emission levels [16] (pp. 107, 122, 185, 221–227). In general, WGIII seems to calculate the overshoot more generously [17] (SPM-18). However, temperature overshoots are likely to induce substantial and irreversible risks like a non-recovery of arctic sea ice and stark additional sea level rises [52,53]. In any case, calculations with or without emissions overshoot compared to the 1.5 °C limit contribute to the variation of remaining carbon budgets [7,54,55] (for a set of scenarios beyond 2100 see also [43].

The accumulation of short-lived aerosols (pollutant particles) in the atmosphere adds further uncertainties. Short-lived aerosols delay climate impacts of anthropogenic GHG emissions (albedo effect). Methane, which has a very high climate impact, can be removed from the atmosphere comparatively quickly. Many human-made CO_2 emission sources also produce aerosols that have a net cooling effect due to the presence of sulfate and nitrate aerosols. Therefore, reducing CO_2 sources could reduce (these) aerosols, resulting in short-term warming but long-term cooling [15] (pp. 3–19ff) [28,31,35,56,57]. The storage capacity of the oceans for CO_2 and heat also affects the projections; the colder they are, the higher their storage capacity for GHG emissions, yet climate change induced storms are likely to increase the release of CO_2 [58–60].

In addition, there are societal developments that make detailed predictions extremely difficult. Gross national product, population development [61] (detailed on regional scenarios also [62]), economic growth, digitalisation, international trade, globalisation, and automation are complex variables that lead to a range in the projections [6,7,12,61,63–65].

Consequently, there are divergent scientific statements for translating the budgets into years and reduction pathways [66]. This problem is also evident in the AR5. The report is based on different reduction pathways, but only a few of them envisage a 1.5 °C compliant reduction in the next 50 years. Most pathways envision a much longer period to reduce GHGs and achieve the 1.5 °C, in some cases as far out as 2125 [66–68]. Thus, many reduction and transformation pathways for the 1.5 °C target, especially in the energy sector, are similar in many sub-sectors to the 2 °C compliant scenarios but envisage a faster increase in adaptation actions [66,69,70]. As discussed elsewhere, the critical literature on AR 5 shows that when adopting a linear reduction pathway to achieve 1.5 °C, global zero emissions must be achieved by the mid-2030s. This discussion arrives at this result without even considering our arguments for smaller budgets than those estimated by the IPCC (see below) [2].

The budget of the German Advisory Council on the Environment (Sachverständigenrat für Umweltfragen/SRU) is an example of IPCC-based budgets understood in different ways. In line with the wording "well below 2 degrees", the SRU adopts a temperature limit of 1.75 °C. For the temperature increase to not exceed 1.75 °C with a probability of 67 percent, no more than 800 gigatons CO_2 are to be emitted from the year 2018. This value is considered an 'absolute upper limit' derived from the targets of the Paris Agreement. The SRU at the same time admits that the actual budget available could be smaller due to uncertainties in the calculation [71,72]. When transformed into a German national budget, the SRU budget is normatively oriented to equal per capita emissions for 67 percent probability. However, this does not consider offsetting historical emissions or issues of national performance (the IPCC does not address these normative issues, nor national remaining budgets in general).

3. Results: Empirically and Legally

3.1. Empirical Basis of Legal Analysis: Challenges in the Data—Time Period, Probability, Gases, Climate Sensitivity, Overshoot

As regards the implementation of Art. 2 PA and its temperature limit, there is balancing leeway for policy makers where natural scientific research meets uncertainty [9,73–75]. Budgets to stay within 1.5 °C global warming provide an estimate of the evolution of global climate under certain forcings but are no concrete calculations in a strict sense [6,7,76]. Art. 2 para. 1 PA stipulates that the consequences of global warming of 1.5 °C—or at most "well below 2 degrees"—is the limit of normatively acceptable adverse impacts on ecosystems and livelihoods. This target is measured against the IPCC's climate projections [34]. The 1.5 °C target calls for neutralising remaining GHG emissions, i.e., "a balance between anthropogenic emissions of GHGs by sources and removals by sinks" should be achieved in the second half of this century (Art. 4 para. 1 PA) (for an interpretation of "balance", see [77]; for an interpretation of Art. 2 and 4 PA see [6,78]). To get to net-zero emissions, it is necessary to, on the one hand, effectively minimise GHG emissions as much and as soon as possible. On the other hand, remaining GHG emissions, which cannot be mitigated to zero (even with a reduction of fossil energy sources down to zero and a drastically reduced livestock farming) must be compensated [7,9,79].

However, we argue that several empirical indications show that current calculations and budgets are quite generous. Below we provide five arguments that clearly point in that direction. Together with a couple of normative arguments that are developed in Chapter 4, this shows that budgets must be even smaller than in AR 6 (and even AR 5). Projections or forecasts must therefore be based on scenarios with smaller budgets.

- Firstly, not all budgets include non-carbon-dioxide emissions (see above). The inclusion of non-CO_2 emissions in the scenario calculations has different implications, since they have individual global warming potentials (GWP; lifetime in the atmosphere and radiative efficiency). For example, a possible additional release of carbon could emerge be due to thawing of permafrost soils and consequently further reduce the remaining carbon budget [7,16] (p. 12); (for permafrost-carbon feedback on global warming see also [80,81]). Where scenarios in SR15 include non-CO_2 emissions, they cover all anthropogenic emissions except those that result in radiative forcing. Non-CO_2 scenarios include short-lived climate warmers such as methane (CH_4), some fluorinated gases, ozone (O_3) precursors, aerosols, or aerosol precursors, such as black carbon and sulfur dioxide, and long-lived GHGs, such as nitrous oxide (N_2O), or other fluorinated gases [16] (p. 555). However, these variables are very complex and changes of their amount lead to changes in the overall calculation. Therefore, current scenarios make use of a fixed level of non-CO_2 emissions. This led recent studies to suggest that the influence of non-CO_2 emissions on the projections is currently underestimated [33,35,56,82]. However, since these GHGs do not remain in the atmosphere as long as carbon dioxide for example, they cannot be neglected when calculating the remaining budget [83–85].
- Secondly, the budget calculations are also strongly influenced by the choice of the base year. In setting the base year of the "pre-industrial level" (Art. 2 para. 1 PA) quite late, namely when climate change has already started, calculations become very liberal [6,86,87]. This not only leads to an underestimation of human-made global warming (IPCC data are also compiled at [48]) but also neglects the fact that—despite the lack of concrete records—there has been human-induced warming even before that time. In general, a uniform baseline is needed to be able to perform consistent calculations. The question of what the term "pre-industrial" means leads to the question of when exactly industrialisation, respectively the increase of emissions

started. Although the IPCC mentions 1750 as the starting point of the industrial revolution and uses it in part as a basis year or starting point of the observed period in WG III of AR5 [5] (pp. 7, 45) [30] (pp. 11–13, 50, 56) [88], the Special Report from 2018 uses the reference period 1850–1900 without stating an exact reference year [16] (e.g., pp. 58, 81). Likewise, WG I of AR6 adopts 1850–1900 as baseline [15] (SPM-5) while also stating that since 1750, climate changing drivers have been dominated by human activities [ibid, p. TS-35]. It is reasonable to assume that in most cases 1850 is taken as the reference year since record-keeping of temperature started then. However, reliable data are limited to the Northern Hemisphere [5,30]. The increase of carbon dioxide before 1850 is estimated for a temperature rise of 0.1 to 0.2 °C Celsius [89]. "Pre-industrial level" from the legally binding Art. 2 PA points obviously and almost compellingly to 1750 as the base year because this is when the industrial revolution began in Western countries—rather than the very vague period between 1850 and 1900 [6].

- Thirdly, existing calculations seem quite liberal if compared with other assumptions on climate sensitivity. Equilibrium climate sensitivity (ECS) [83] indicates the temperature increase when CO_2 equivalents in the atmosphere double. Therefore, it is an important reference for climate modelling and ultimately for determining the temperature limit of Art. 2 para. 1 PA [30]. WG I of AR5 adopts an ECS in the range of 1.5–4.5 °C, based on an analysis of energy budget changes over the historical period [90]. WGI of AR6 adopts an ECS in the range of 2.5–4 °C with a best estimate of 3 °C [15] (pp. 7–111). However, recent studies suggest that the lower bound of the ECS could be revised upward [91,92], which would reduce the chances of limiting warming below 1.5 °C [91,93–96]. For example, paleoclimatic research shows that climate sensitivity changes with the state of the climate. During warm periods, the ECS is significantly higher; 4.88 °C according to the calculations of [92] which is well above the IPCC ranges. Furthermore, WGI of AR6 presents estimations for additional human-induced warming, expressed as global surface temperature from 2010–2019 which is likely to be 0.8–1.3 °C, with a best estimate of 1.07 °C relative to 1850–1900. Historical CO_2 emissions between 1850 and 2014 were estimated to be around 2180 ± 24 $GtCO_2$, while an additional 210 $GtCO_2$ were emitted from 2015 until the end of 2019. However, different factors contribute to the estimations varying by ±220 $GtCO_2$ depending on the level of non-CO_2 emissions at the time when global anthropogenic CO_2 emissions reach net zero. Geophysical uncertainties in the climate response to these non-CO_2 emissions add at least ±220 $GtCO_2$ of uncertainty, and uncertainties in the level of historical warming may add ±550 $GtCO_2$ [15] (TS-63).
- Fourthly, global carbon budget calculations accept a high probability of missing the temperature limit. While the IPCC assumed a probability of success of 50 or 55 percent in WG III of AR5, it has increased to up to 67 percent in SR15 [16] (pp. 100, 207). WGI of AR6 supplements its assessment with a 17 percent probability at the lower and an 83 percent probability at the upper end of its estimates [15] (TS-63). But even this increase is still not the same as the clear obligation towards the target of the Paris Agreement especially since the IPCC's underlying assumptions also tend to be generous as seen [7,20]. Rather, net-zero emissions must be achieved promptly in no more than two decades to drastically reduce the risk of reaching critical tipping points such as further melting of the Greenland or West Antarctic ice sheets and coral bleaching [6,7,51,97].
- Fifthly, SR15 creates several pathways toward 1.5 °C warming where global emissions peak within the next decade [16] (pp. 32, 56, 126) [20,62,90,98–101]. For this purpose, the report increasingly relies on carbon dioxide removal methods, very often taking an overshoot into account as seen in bioenergy with carbon capture and storage and afforestation and reforestation [16] (pp. 118–123) despite stating that compensating an overshoot and "CDR deployed at scale (are) unproven, and reliance on such technology is a major risk in the ability to limit warming to 1.5 °C" [ibid p. 96]. In principle, WGIII

of AR6 is open to the use of CDR. For pathways that aim to limit temperature rise to 1.5 °C, total cumulative net negative emissions, including the use of CDR, amount to 20–660 $GtCO_2$ [17] (SPM-33, SPM-53). According to WGIII of AR6, pathways aiming to limit global warming to 1.5 °C require a certain level of CDR to offset remaining emissions, even if substantial direct emission reductions are achieved in all sectors and regions [17] (SPM-53). Using afforestation and reforestation is largely supported and appreciated in science and politics as a key component of climate protection strategies. However, there is strong criticism that even large-scale reforestation projects can only sequester a portion of annual emissions and that the potentials of forests are overestimated [24,102–105], (see for critiques on CDR methods [106–110]). Using bioenergy with carbon capture and storage is even more contested, also due to the ambivalent character of bioenergy for various environmental challenges [111,112]. Indeed, the IPCC sees limits to using bioenergy with carbon capture and storage due to energy, water, and nutrient requirements, as well as limited available safe disposal options and competing policy goals such as food security; nevertheless, the IPCC projects increased deployment of bioenergy with carbon capture and storage in the second half of the century, highlighting the potential of bioenergy deployment in several areas of the energy sector in integrated assessment models, including electricity generation, liquid fuels, biogas, and hydrogen [16] (pp. 122–124). However, studies criticise the energy required for biomass production and the loss of efficiency due to CO_2 capture [113,114]. Furthermore, various ambivalences regarding other environmental challenges such as biodiversity loss as well as threats to food security must be considered [39,67,111,112]. Besides, the impact of climate change on the potential of bioenergy and renewable energy, such as hydropower generation, wind, and solar power generation need to be considered [115,116]. At last, many models relying on CDR have limited applicability and are unable to calculate pathways to meet the nationally determined contributions (NDCs) by 2030 and bring global warming below 1.5 °C by 2100 [79,117]. Another method to reduce carbon dioxide is through large-scale geoengineering such as solar radiation modification (SRM). SRM aims to alter Earth's radiative budget to limit global warming [15] (pp. 5–99). WGI of AR6 discusses different technical large-scale interventions like SRM across multiple chapters (Chapters 4 and 5). However, the IPCC excludes SRM from its mitigation and adaptation definitions [15 Annex VII] and states that "SRM contrasts with climate mitigation because it introduces a 'mask' to the climate change problem by altering the Earth's radiation budget, rather than attempting to address the root cause of the problem, which is the increase in GHGs in the atmosphere" [7] [15] (p. 4–79) [118]. Nevertheless, the other challenges of negative emission approaches discussed in the present bullet point cannot be ruled out.

3.2. Legal Arguments for a Smaller Global GHG Budget

The critical empirical points above strongly suggest that a clearly smaller budget requiring decarbonisation within a few years is consistent with the 1.5 °C limit. This favours a more ambitious interpretation of Art. 2 PA and allows for further legal justifications. On this basis, there are several legal (i.e., normative) aspects that further underline the obligation to minimise the risk of significant damage, i.e., to take rapid and drastic climate protection measures and base climate policy on smaller global budgets than AR 6 (and even AR 5), as we will show in the following. The legal arguments are based on the Paris Agreement on the one hand, and on human rights and the precautionary principle on the other hand.

The basic target commitment of the Paris Agreement and the system of nationally chosen reduction targets based on this target commitment are legally binding. Art. 2, 3, 4 PA provide corresponding arguments. The wording and evolution, i.e., the negotiation process, of the Paris Agreement suggest that 1.5 °C are to be achieved, unless already impossible. Furthermore, it is undisputed that the Agreement, as such, is constructed as a binding international treaty [119]. The wording of Art. 2–4 PA specifically does not provide arguments for that it is not meant to be binding [4,6,120,121]. While modal verbs such as "will" or "aim" can be interpreted as non-binding, the words "are to" and "shall", as used in Art. 3, 4 PA clearly indicate the legally binding nature (as in [119]). This was acknowledged by the German Federal Constitutional Court in 2021 in its landmark ruling on climate law and human rights. This alone is referred to and relevant for this paper. Legally binding force must not be confused with enforceability. Here, we will not discuss the complicated question of which national, EU, or international law court decides on Paris Agreement obligations (for example, Art. 2 PA plays a role in the successful climate lawsuit before the German Federal Constitutional Court; for background [9]).

Based on the arguments of the legally binding character of Art. 2 PA, it is not enough to limit global warming to "well below 2 degrees". If well below 2 °C was sufficient, the wording "pursuing efforts" would not make any sense. Consequently, governments cannot accept staying within 1.7 to 1.8 °C. Rather, real and serious efforts must be undertaken to reach 1.5 °C. To this end, more emissions than necessary to stay within 1.7 or 1.8 °C must be reduced. According to SR15, the 1.5 °C goal is feasible and will have greater benefits than the "well below 2 degrees" target [16] (pp. 41, 255).

Furthermore, Art. 2 para. 1 PA is the overarching target norm of the Paris Agreement and prevails over Art. 4 para. 1 PA. We have presented various arguments on this point in an earlier article [6]: *Firstly*, while Art. 2 PA defines the core objective of the Agreement, Art. 4 PA is dedicated to concrete strategies for its implementation in a subordinate manner [4,6]. Consequently, Art. 4 para. 1 PA contains the idea of what Parties recognise as necessary to achieve the temperature target of Art. 2 para. 1 lit. a PA [1]. This interpretation is *secondly* confirmed in Art. 3 PA, which—similar to Art. 4 para. 1 PA—explicitly refers to Art. 2 para. 1 PA and aims to achieve the target described there. *Thirdly*, results of a historical interpretation (referring to the genesis of the norm) show that Art. 4 para. 1 PA, norm-historically and according to its purpose, is primarily addressed at developing and newly industrialising countries, i.e., primarily to a certain group of states [2]. This circle of addressees further supports the prevalence of Art. 2 para 1 PA. Therefore, only developing countries and explicitly not industrialised countries are granted a longer period of time to achieve the temperature target from Art. 2 para. 1 PA. Consequently, it is questionable if there is a contradiction between Art. 2 para. 1 PA and Art. 4 para. 1 PA for industrialised countries at all [2,4,6]. *Fourthly*, the hierarchy of norms provides further arguments. If the normative relationship is interpreted in favour of Art. 4 para. 1 PA, Art. 2 para. 1 PA would always be violated [6], since the time period for achieving emission reductions in Art. 4 para. 1 PA is much greater than in Art. 2 para. 1 PA. If, however, the normative relationship was interpreted in favour of Art. 2 para. 1 PA, Art. 4 para. 1 PA would not be violated, since Art. 4 PA does not contain any prohibition to achieve the temperature target faster than prescribed [2,4,6]. Fifthly, Art. 2 PA concretises the UNFCCC. Art. 2 para. 1 PA represents the overarching target of an international climate law to mitigate the negative human influence on climate change. Thus, Art. 2 para. 1 PA also has the task to create a preventive effect, which, however, can only be achieved if it has priority over Art. 4 para. 1 PA [6]. Before this background, it is quite remarkable that the court rulings briefly mentioned above did not deal with the relation between Art. 2 and Art. 4 PA.

Having said all this, Art. 2 para. 1 PA also clearly speaks in favour of high probabilities, no overshoot, and a focus on zero fossil fuels, drastically reduced livestock farming and well-approved negative emission options such as forest and peatland management (before risky large-scale options such as solar radiation management). This is since Art. 2 para. 1 PA is legally binding and does not provide any option for missing and later meeting the target. Using uncertain probabilities to meet the target violates Art. 2 para. 1 PA. The legally binding character, the character as 1.5 °C (not 2 °C) target, and the criticism of geoengineering and overshoot in general was also acknowledged by the German Federal Constitutional Court as well as in rulings in The Hague against Shell [122] and the Netherlands [123], and a ruling in France [124]. Furthermore, as mentioned earlier, "pre-industrial level" from the legally binding Art. 2 PA points obviously and almost compellingly to 1750 as the base year because this is when the industrial revolution began in Western countries—rather than the very vague period between 1850 and 1900 [6].

A further argument for all these interpretations of Art. 2 para. 1 PA (regarding its legally binding character, focus on 1.5 °C, probabilities, no overshoot, and a focus on well-approved options regarding negative emissions) can be found in Art. 4 para. 3 PA. In order to achieve the long-term temperature target, set out in Art. 2 para. 1 PA, Art. 3 PA establishes an important mechanism, which has been the subject of lengthy negotiations. The NDCs of the Parties are a core element of the Paris Agreement. Compared to the pretty clear substantive standard in Art. 2 para. 1 PA, the wording of Art. 4 PA is sometimes very imprecise. On the one hand, this enables a differentiation between developing and industrialised countries. In doing so, Art. 4 PA strengthens the idea that developed countries should take a leading role in fighting climate change and recognises that developing countries need more time to reach the temperature target. Art. 4 PA also encourages many countries to join the Agreement. On the other hand, imprecise formulations—especially regarding the voluntarily defined contributions—enable wide interpretations by the Parties to the Agreement. This bears the danger that the Parties to the Agreement will only do as much as is necessary and that, as a result, an "equitable distribution of effort" [125] will not be achieved. Still, Art. 4 para. 3 PA contains a further requirement for the NDCs, i.e., a "non-regression clause", which requires that all future contributions submitted by the Parties have to represent progress or an "increase" compared to the previous contribution [126]. However, there are no further details to the "progression requirement" [127] so that even a minimal increase would fulfil the requirements of Art. 4 para. 3 PA [4]. In addition, the treaty text uses the word "will" which is less precise than "shall"—also regarding the obligatory character (see above). This not only increases the scope for interpretation but also for decision-making by the Parties to the Agreement. Finally, the question arises to what extent Art. 4 para. 3 PA is legally binding [127]. The progression requirement established in Art. 4 para. 3 PA is also significant for subsequent articles of the Agreement. For example, given the insufficient collective ambition in the first round of NDCs, the Paris Agreement requires Parties to submit revised, more ambitious NDCs every five years (Art. 4 para. 3 in connection with Art. 4 para. 9 PA) [128]. Art. 14 PA also establishes the idea of a (joint) progress of all countries—together with national responsibilities, capabilities and circumstances—as a central aspect in the global stocktaking to evaluate the results achieved so far to achieve the temperature target from Art. 2 para. 1 PA [125]. In addition, Art. 4 para. 3 PA establishes targets through normative due diligence obligations; each Party "shall reflect its highest possible ambition" to achieve the long-term temperature target by its NDC. Furthermore, Art. 4 para. 3 PA emphasises that while national efforts and measures serve a common goal, the different national circumstances of the Parties must always be considered. Consequently, Art. 4 para. 3 PA establishes a duty of care or a certain standard of conduct for each Party and considers common responsibilities but also national circumstances and capabilities to achieve the highest possible goal [121]. These standards of care are intended to remind governments to take climate action in line with their national capabilities, to progressively increase their ambition, and to ultimately keep the increase in global temperature well below 2 °C [129]. Consequently, Art. 4 para. 3 PA can be seen as "softer, desirable" target [126]. At the same time, the provision shows that the Convention is open to change in some places [125]. However, this could cause tensions with the ambitious target set out in Art. 2 para. 1 PA.

The ambitious interpretation of Art. 2 para. 1 PA presented above (high probabilities, no overshoot, orientation towards 1.5 °C, no geoengineering) is furthermore supported by human rights on international, EU and national level as various courts have confirmed during the last years, focussing on some overall core ideas of human rights—as acknowledged by the German Constitutional Court [130], courts in The Hague (Urgenda [123] and Shell [122]) Ireland [131], France [124], and Melbourne [132]: The preamble of the PA explicitly mentions that human rights are of enormous importance for climate protection: Human rights establish the obligation to secure elementary conditions of freedom, namely life, health, and subsistence [9,18,73,133–137]. As rights of freedom, human rights furthermore logically imply the right to the elementary prerequisites for freedom. These prerequisites include a relatively stable world climate and environmental conditions that allow people to maintain their livelihoods [6,7,9,138]. A resulting human rights obligation to combat climate change is left primarily to political leeway (for example, due to the conflicting liberties of businesses and consumers). Nevertheless, the political scope for decision-making ends where political action or inaction endangers the liberal democratic order as such [9] (for interpretation rules, see also [74,75]). This is precisely the effect that inadequately mitigated climate change could have [1,25,26,71]. For this reason, an ambitious climate policy is imperative from a human rights perspective [6] and includes addressing that societal transformation toward a 1.5 °C warmer world does not exacerbate poverty and vulnerability or creates new inequities but promotes equitable change [139,140].

This is further underlined by the precautionary principle as a general principle of international law. Precaution means taking measures in view of long-term, cumulating, or uncertain damages [9,141–145]. The precautionary principle does not fully prohibit the pursuit of an action, which bears the chance of causing irreversible harm (since precaution also implies balancing different risks and opportunities, and even daily life entails irreversible risks), but shows a tendency in this direction in light of huge risks. Climate change exceeding the target of Art. 2 para. 1 PA will lead to such irreversible negative consequences globally and therefore needs to be mitigated. Even if some dispute the role of the precautionary principle in general [146,147], the principle is clearly codified on several levels in national, EU, and international law, i.e., Art. 3 para. 3 UNFCCC, Art. 191 Treaty on the Functioning of the European Union and Art. 20a of the German Constitution (Grundgesetz). Moreover, precaution is included in human rights [122,123,133]. Basic rights not only protect against certain dangers today but also protect against future dangers if future dangers are irreversible at the moment of occurrence; and exactly this applies to climate change. If that was not the case, the protection established in basic rights would run empty. Human rights thus contain a precautionary principle even beyond codification [6,9,138]. The connection to human rights highlights: the bigger the impending damage in its occurrence, the more ambitious necessary protection measures must be. In dealing with existential dangers, it is therefore not enough to accept moderate probabilities for the defence of human rights even if 100 percent certainty about future events can never be achieved [1]. Consequently, ambitious climate protection with drastic GHG reductions is required.

4. Discussion and Conclusions

Several empirical indications have shown that current global GHG budget calculations are unduly generous. We provided five empirical arguments that clearly point in that direction. These empirical points/arguments demonstrate, combined with legal arguments, that the budgets must be smaller than those estimated by the IPCC. The legal arguments are based on Art. 2 and 4 para. 3 of the Paris Agreement as well as on human rights and the precautionary principle. These norms contain an obligation to minimise the risk of significant damage, i.e., to take rapid and drastic climate protection measures. 1.5 °C (no more) is the legally binding temperature target; adherence requires a very high probability of achieving the target; temperature overshoot and geoengineering tend to be prohibited, and budget calculations must be based on sceptical factual assumptions. These normative insights have also been confirmed by recent rulings of supreme courts such as the ground-breaking climate decision of the German Federal Constitutional Court. However, determining the exact extent of actions and the distribution of the costs for mitigation (as well as adaptation and loss and damage) under the premises of limited (!) fact-based and balancing-related vagueness can only be done by elected politicians to preserve the democratic process and the system of checks and balances.

Applying the balancing rules derived from human rights guarantees for freedom and preconditions of freedom (suitability, necessity, efficiency, polluter-pays principle, and many more) enables to not only determine a common obligation to preserve the climate but to also draw rough conclusions for burden sharing. Ostensibly, this might not seem important given that the objective is zero emissions for all states, and for the budget in general the emissions distribution and questions like "per capita yes or no" do not matter. Consequently, courts did not discuss this point by now. However, it is important to discuss the allocation of expenses for globally necessary measures in mitigation, adaptation and loss, and damage. EU Member States like Germany have emitted and continue to emit high amounts of GHGs per capita, which are still in the atmosphere. The reference to capacities and the polluter pays principle—which both follow as balancing rules from freedom and are implied in Art. 2 Abs. 2, 4 Abs. 4 PA—requires these countries to take actions beyond the required, respectively increased, obligation to bear the costs of measures taken in the Global South (discussed in [18,34,35,39]). In any case, a country cannot claim more emission rights than it is entitled to per capita based on its population [9], because an existential good for whose genesis no one has contributed is endangered. However, this does not rule out the possibility to buy emission rights from other countries—or that, for reasons of capacity and the polluter pays principle (and therefore a higher historical responsibility of Western states), an unequal distribution towards the Global South even seems mandatory, given the fair share emphasis of Paris Agreement and Art. 3 UNFCCC. The remaining budget of an industrialised country is therefore, at most as high as would result from a distribution per capita but rather (substantially) lower, given the arguments mentioned in the present section. Determining the exact extent of actions and the distribution of the costs for mitigation (as well as adaptation and loss and damage) under the premises of limited fact-based and balancing-related vagueness can only be done by elected politicians to preserve the democratic process and the system of checks and balances.

Overall, the Paris Agreement and human rights underline a legally binding obligation for smaller global GHG budgets as those estimated in the greenhouse gas budgets of the IPCC—even compared to the 83 percent scenario in the latest assessment. Climate policy will have to raise its ambitions towards zero fossil fuels and a drastic reduction of livestock farming (and compensation measures for residual emissions such as forest and peatland management). Claims that radical climate policy is unrealistic is not a legally valid objection. If the corresponding demands do not violate the laws of nature, "unrealistic" is neither a legal nor a natural scientific category. Apart from that, the Ukraine war currently highlights that the protection of freedom and security—another elementary precondition of freedom besides a stable global climate and others—also suggests a very rapid shift away from fossil fuels. The fact that the IPCC does not offer more radical scenarios does not prove anything; scenarios are merely predictions of possible futures, but do not prove that other transformations are impossible. The extent to which this transformation demands renewable energy, energy efficiency, politically induced sufficiency, negative emissions from peatlands and forests, power-to-x and hydrogen remains an important question that is discussed elsewhere [105,148,149].

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References

1. Rajamani, L.; Werksman, J. The Legal Character and Operational Relevance of the Paris Agreement's Temperature Goal. *Philos. Trans. R. Soc. London. Ser. A Math. Phys. Eng. Sci.* **2018**, *376*, 20160458. [CrossRef] [PubMed]
2. Ekardt, F.; Wieding, J.; Zorn, A. *Paris Agreement, Human Rights and Climate Litigation. Legal Opinion Issued by Solarenergie-Förderverein Deutschland*; Research Unit Sustainability and Climate Policy: Leipzig/Berlin, Germany, 2018.
3. Intergovernmental Panel on Climate Change about. Available online: https://www.ipcc.ch/sr15/about/ (accessed on 13 January 2022).
4. Ekardt, F.; Wieding, J. Rechtlicher Aussagegehalt des Paris-Abkommen—eine Analyse der einzelnen Artikel. *ZfU* **2016**, *39*, 36–57.
5. Intergovernmental Panel on Climate Change (Ed.) *Climate Change 2014: Mitigation of Climate Change: Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: New York, NY, USA, 2014.
6. Ekardt, F.; Wieding, J.; Zorn, A. Paris Agreement, Precautionary Principle and Human Rights: Zero Emissions in Two Decades? *Sustainability* **2018**, *10*, 2812. [CrossRef]
7. Wieding, J.; Stubenrauch, J.; Ekardt, F. Human Rights and Precautionary Principle: Limits to Geoengineering, SRM, and IPCC Scenarios. *Sustainability* **2020**, *12*, 8858. [CrossRef]
8. Ekardt, F.; Heß, F. Intertemporaler Freiheitsschutz, Existenzminimum und Gewaltenteilung nach dem BVerfG-Klima-Beschluss: Freiheitsgefährdung durch Klimawandel oder durch Klimapolitik? *ZUR* **2021**, 579–585. Available online: www.sustainability-justice-climate.eu/files/texts/Klimaklage-ZUR.pdf (accessed on 20 August 2022).
9. Ekardt, F. *Sustainability. Transformation, Governance, Ethics, Law*; Springer International Publishing: Cham, Switzerland, 2020.
10. Ekardt, F. *Economic Evaluation, Cost-Benefit Analysis, Economic Ethics. A Review with Regard to Climate Change—Figures in the Sustainability Discourse*; Springer International Publishing: Cham, Switzerland, 2022.
11. Habermas, J. *Auch eine Geschichte der Philosophie*; Suhrkamp: Berlin, Germany, 2019.
12. Ma, J.; Oppong, A.; Acheampong, K.N.; Abruquah, L.A. Forecasting Renewable Energy Consumption under Zero Assumptions. *Sustainability* **2018**, *10*, 576. [CrossRef]
13. Rogelj, J.; Schleussner, C.-F.; Hare, W. Getting It Right Matters: Temperature Goal Interpretations in Geoscience Research: Temperature Goal Interpretations. *Geophys. Res. Lett.* **2017**, *44*, 10662–10665. [CrossRef]
14. Pfleiderer, P.; Schleussner, C.-F.; Mengel, M.; Rogelj, J. Global Mean Temperature Indicators Linked to Warming Levels Avoiding Climate Risks. *Environ. Res. Lett.* **2018**, *13*, 064015. [CrossRef]
15. Intergovernmental Panel on Climate Change. *Climate Change 2021. The Physical Science Basis. Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change—Approved Version*; Intergovernmental Panel on Climate Change (IPCC): Geneva, Switzerland, 2021.
16. Intergovernmental Panel on Climate Change. *Global Warming of 1.5 °C. An IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*; Intergovernmental Panel on Climate Change (IPCC): Geneva, Switzerland, 2019.
17. Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2022. Mitigation of Climate Change. Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Intergovernmental Panel on Climate Change (IPCC): Geneva, Switzerland, 2022.
18. Rajamani, L. The Increasing Currency and Relevance of Rights-Based Perspectives in the International Negotiations on Climate Change. *J. Environ. Law* **2010**, *22*, 391–429. [CrossRef]
19. Rogelj, J.; Meinshausen, M.; Schaeffer, M.; Knutti, R.; Riahi, K. Impact of Short-Lived Non-CO_2 Mitigation on Carbon Budgets for Stabilizing Global Warming. *Environ. Res. Lett.* **2015**, *10*, 075001. [CrossRef]
20. Vrontisi, Z.; Luderer, G.; Saveyn, B.; Keramidas, K.; Lara, A.R.; Baumstark, L.; Bertram, C.; de Boer, H.S.; Drouet, L.; Fragkiadakis, K.; et al. Enhancing Global Climate Policy Ambition towards a 1.5 °C Stabilization: A Short-Term Multi-Model Assessment. *Environ. Res. Lett.* **2018**, *13*, 044039. [CrossRef]
21. Spangenberg, J. Scenarios and Indicators for Sustainable Development: Towards a Critical Assessment of Achievements and Challenges. *Sustainability* **2019**, *11*, 942. [CrossRef]
22. Bossel, H. Policy Assessment and Simulation of Actor Orientation for Sustainable Development. *Ecol. Econ.* **2000**, *35*, 337–355. [CrossRef]
23. Allen, P.M. Evolutionary Complex Systems and Sustainable Development. In *Theory and Implementation of Economic Models for Sustainable Development*; Bergh, J.C.J.M., Hofkes, M.W., Eds.; Economy & Environment; Springer: Dordrecht, The Netherlands, 1998; Volume 15, pp. 67–99.
24. Spangenberg, J.H.; Neumann, W.; Klöser, H.; Wittig, S.; Uhlenhaut, T.; Mertens, M.; Günther, E.; Valentin, I.; Große Ophoff, M. False Hopes, Missed Opportunities: How Economic Models Affect the IPCC Proposals in Special Report 15 "Global Warming of 1.5 °C" (2018). An Analysis From the Scientific Advisory Board of BUND. *J. Appl. Bus. Econ.* **2021**, *23*, 49–72. [CrossRef]
25. Rahmstorf, S. Die Koalitionsgespräche und das Deutsche Emissionsbudget. Available online: https://scilogs.spektrum.de/klimalounge/die-koalitionsgespraeche-und-das-deutsche-emissionsbudget/ (accessed on 4 April 2022).
26. Schmidt, G. Climate Models Produce Projections, Not Probabilities. Available online: https://thebulletin.org/roundtable/the-uncertainty-in-climate-modeling/ (accessed on 4 April 2022).

27. Tollefson, J. Is the 2 °C World a Fantasy? *Nature* **2015**, *527*, 436–438. [CrossRef] [PubMed]
28. Rogelj, J.; Schaeffer, M.; Friedlingstein, P.; Gillett, N.P.; van Vuuren, D.P.; Riahi, K.; Allen, M.; Knutti, R. Differences between Carbon Budget Estimates Unravelled. *Nat. Clim. Chang.* **2016**, *6*, 245–252. [CrossRef]
29. Hausfather, Z. Analysis: How Much 'Carbon Budget' Is Left to Limit Global Warming to 1.5C? Available online: https://www.carbonbrief.org/analysis-how-much-carbon-budget-is-left-to-limit-global-warming-to-1-5c (accessed on 4 April 2022).
30. Intergovernmental Panel on Climate Change. *Climate Change 2013. The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2013.
31. Friedlingstein, P.; Meinshausen, M.; Arora, V.K.; Jones, C.D.; Anav, A.; Liddicoat, S.K.; Knutti, R. Uncertainties in CMIP5 Climate Projections Due to Carbon Cycle Feedbacks. *J. Clim.* **2014**, *27*, 511–526. [CrossRef]
32. Jian, J.; Bailey, V.; Dorheim, K.; Konings, A.G.; Hao, D.; Shiklomanov, A.N.; Snyder, A.; Steele, M.; Teramoto, M.; Vargas, R.; et al. Historically Inconsistent Productivity and Respiration Fluxes in the Global Terrestrial Carbon Cycle. *Nat. Commun.* **2022**, *13*, 1733. [CrossRef]
33. Millar, R.J.; Friedlingstein, P. The Utility of the Historical Record for Assessing the Transient Climate Response to Cumulative Emissions. *Philos. Trans. R. Soc. A Math. Phys. Eng. Sci.* **2018**, *376*, 20160449. [CrossRef]
34. MacDougall, A.H. The Transient Response to Cumulative CO2 Emissions: A Review. *Curr. Clim. Chang. Rep.* **2016**, *2*, 39–47. [CrossRef]
35. Collins, W.J.; Webber, C.P.; Cox, P.M.; Huntingford, C.; Lowe, J.; Sitch, S.; Chadburn, S.E.; Comyn-Platt, E.; Harper, A.B.; Hayman, G.; et al. Increased Importance of Methane Reduction for a 1.5 Degree Target. *Environ. Res. Lett.* **2018**, *13*, 054003. [CrossRef]
36. Rochedo, P.R.R.; Soares-Filho, B.; Schaeffer, R.; Viola, E.; Szklo, A.; Lucena, A.F.P.; Koberle, A.; Davis, J.L.; Rajão, R.; Rathmann, R. The Threat of Political Bargaining to Climate Mitigation in Brazil. *Nat. Clim. Chang.* **2018**, *8*, 695–698. [CrossRef]
37. Edelenbosch, O.Y.; McCollum, D.L.; van Vuuren, D.P.; Bertram, C.; Carrara, S.; Daly, H.; Fujimori, S.; Kitous, A.; Kyle, P.; Broin, E.Ó.; et al. Decomposing Passenger Transport Futures: Comparing Results of Global Integrated Assessment Models. *Transp. Res. Part D Transp. Environ.* **2017**, *55*, 281–293. [CrossRef]
38. Grubler, A.; Wilson, C.; Bento, N.; Boza-Kiss, B.; Krey, V.; McCollum, D.L.; Rao, N.D.; Riahi, K.; Rogelj, J.; De Stercke, S.; et al. A Low Energy Demand Scenario for Meeting the 1.5 °C Target and Sustainable Development Goals without Negative Emission Technologies. *Nat. Energy* **2018**, *3*, 515–527. [CrossRef]
39. Fankhauser, S.; Smith, S.M.; Allen, M.; Axelsson, K.; Hale, T.; Hepburn, C.; Kendall, J.M.; Khosla, R.; Lezaun, J.; Mitchell-Larson, E.; et al. The Meaning of Net Zero and How to Get It Right. *Nat. Clim. Chang.* **2022**, *12*, 15–21. [CrossRef]
40. Intergovernmental Panel on Climate Change (IPCC). *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*; Intergovernmental Panel on Climate Change (IPCC): Geneva, Switzerland, 2015.
41. Meinshausen, M.; Smith, S.J.; Calvin, K.; Daniel, J.S.; Kainuma, M.L.T.; Lamarque, J.-F.; Matsumoto, K.; Montzka, S.A.; Raper, S.C.B.; Riahi, K.; et al. The RCP Greenhouse Gas Concentrations and Their Extensions from 1765 to 2300. *Clim. Chang.* **2011**, *109*, 213–241. [CrossRef]
42. Matthews, H.D.; Landry, J.-S.; Partanen, A.-I.; Allen, M.; Eby, M.; Forster, P.M.; Friedlingstein, P.; Zickfeld, K. Estimating Carbon Budgets for Ambitious Climate Targets. *Curr. Clim. Chang. Rep.* **2017**, *3*, 69–77. [CrossRef]
43. Stocker, T. (Ed.) Technical Summary. In *Climate Change 2013. The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2013; pp. 33–115.
44. Intergovernmental Panel on Climate Change. Assessing Transformation Pathways. In *Climate Change 2014: Mitigation of Climate Change: Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A., Baum, I., Brunner, S., Eickemeier, P., et al., Eds.; Cambridge University Press: New York, NY, USA, 2014; Chapter 6; pp. 413–510.
45. Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2022. Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Intergovernmental Panel on Climate Change (IPCC): Geneva, Switzerland, 2022.
46. Lahn, B. A History of the Global Carbon Budget. *WIREs Clim. Chang.* **2020**, *11*, e636. [CrossRef]
47. Rogelj, J.; Forster, P.M.; Kriegler, E.; Smith, C.J.; Séférian, R. Estimating and Tracking the Remaining Carbon Budget for Stringent Climate Targets. *Nature* **2019**, *571*, 335–342. [CrossRef]
48. CarbonBrief Analysis: Only Five Years Left before 1.5C Carbon Budget Is Blown. Available online: https://www.carbonbrief.org/analysis-only-five-years-left-before-one-point-five-c-budget-is-blown (accessed on 4 April 2022).
49. Friedlingstein, P.; O'Sullivan, M.; Jones, M.W.; Andrew, R.M.; Hauck, J.; Olsen, A.; Peters, G.P.; Peters, W.; Pongratz, J.; Sitch, S.; et al. Global Carbon Budget 2020. *Earth Syst. Sci. Data* **2020**, *12*, 3269–3340. [CrossRef]
50. Hasegawa, T.; Fujimori, S.; Frank, S.; Humpenöder, F.; Bertram, C.; Després, J.; Drouet, L.; Emmerling, J.; Gusti, M.; Harmsen, M.; et al. Land-Based Implications of Early Climate Actions without Global Net-Negative Emissions. *Nat. Sustain.* **2021**, *4*, 1052–1059. [CrossRef]
51. Mendez, A.; Farazmand, M. Investigating Climate Tipping Points under Various Emission Reduction and Carbon Capture Scenarios with a Stochastic Climate Model. *Proc. R. Soc. A Math. Phys. Eng. Sci.* **2021**, *477*, 20210697. [CrossRef]

52. Tachiiri, K.; Silva Herran, D.; Su, X.; Kawamiya, M. Effect on the Earth System of Realizing a 1.5 °C Warming Climate Target after Overshooting to the 2 °C Level. *Environ. Res. Lett.* **2019**, *14*, 124063. [CrossRef]
53. Palter, J.B.; Frölicher, T.L.; Paynter, D.; John, J.G. Climate, Ocean Circulation, and Sea Level Changes under Stabilization and Overshoot Pathways to 1.5 K Warming. *Earth Syst. Dynam.* **2018**, *9*, 817–828. [CrossRef]
54. Drouet, L.; Bosetti, V.; Padoan, S.A.; Aleluia Reis, L.; Bertram, C.; Dalla Longa, F.; Després, J.; Emmerling, J.; Fosse, F.; Fragkiadakis, K.; et al. Net Zero-Emission Pathways Reduce the Physical and Economic Risks of Climate Change. *Nat. Clim. Chang.* **2021**, *11*, 1070–1076. [CrossRef]
55. Riahi, K.; Bertram, C.; Huppmann, D.; Rogelj, J.; Bosetti, V.; Cabardos, A.-M.; Deppermann, A.; Drouet, L.; Frank, S.; Fricko, O.; et al. Cost and Attainability of Meeting Stringent Climate Targets without Overshoot. *Nat. Clim. Chang.* **2021**, *11*, 1063–1069. [CrossRef]
56. Kriegler, E.; Luderer, G.; Bauer, N.; Baumstark, L.; Fujimori, S.; Popp, A.; Rogelj, J.; Strefler, J.; van Vuuren, D.P. Pathways Limiting Warming to 1.5°C: A Tale of Turning around in No Time? *Philos. Trans. R. Soc. A Math. Phys. Eng. Sci.* **2018**, *376*, 20160457. [CrossRef]
57. Mauritsen, T.; Pincus, R. Committed Warming Inferred from Observations. *Nat. Clim. Chang.* **2017**, *7*, 652–655. [CrossRef]
58. Cheng, L.; Abraham, J.; Hausfather, Z.; Trenberth, K.E. How Fast Are the Oceans Warming? *Science* **2019**, *363*, 128–129. [CrossRef]
59. Johnson, G.C.; Lyman, J.M. Warming Trends Increasingly Dominate Global Ocean. *Nat. Clim. Chang.* **2020**, *10*, 757–761. [CrossRef]
60. Nicholson, S.-A.; Whitt, D.B.; Fer, I.; du Plessis, M.D.; Lebéhot, A.D.; Swart, S.; Sutton, A.J.; Monteiro, P.M.S. Storms Drive Outgassing of CO2 in the Subpolar Southern Ocean. *Nat. Commun.* **2022**, *13*, 158. [CrossRef] [PubMed]
61. Drouet, L.; Emmerling, J. Climate Policy under Socio-Economic Scenario Uncertainty. *Environ. Model. Softw.* **2016**, *79*, 334–342. [CrossRef]
62. Rose, S.K.; Richels, R.; Blanford, G.; Rutherford, T. The Paris Agreement and next Steps in Limiting Global Warming. *Clim. Chang.* **2017**, *142*, 255–270. [CrossRef]
63. Cifci, E.; Oliver, M.E. Reassessing the Links between GHG Emissions, Economic Growth, and the UNFCCC: A Difference-in-Differences Approach. *Sustainability* **2018**, *10*, 334. [CrossRef]
64. Liu, J.-Y.; Fujimori, S.; Takahashi, K.; Hasegawa, T.; Su, X.; Masui, T. Socioeconomic Factors and Future Challenges of the Goal of Limiting the Increase in Global Average Temperature to 1.5 °C. *Carbon Manag.* **2018**, *9*, 447–457. [CrossRef]
65. Woodard, D.L.; Davis, S.J.; Randerson, J.T. Economic Carbon Cycle Feedbacks May Offset Additional Warming from Natural Feedbacks. *Proc. Natl. Acad. Sci. USA* **2019**, *116*, 759–764. [CrossRef]
66. Akimoto, K.; Sano, F.; Tomoda, T. GHG Emission Pathways until 2300 for the 1.5 °C Temperature Rise Target and the Mitigation Costs Achieving the Pathways. *Mitig. Adapt. Strateg. Glob. Chang.* **2018**, *23*, 839–852. [CrossRef]
67. Luderer, G.; Pietzcker, R.C.; Bertram, C.; Kriegler, E.; Meinshausen, M.; Edenhofer, O. Economic Mitigation Challenges: How Further Delay Closes the Door for Achieving Climate Targets. *Environ. Res. Lett.* **2013**, *8*, 034033. [CrossRef]
68. Sanderson, B.M.; O'Neill, B.C.; Tebaldi, C. What Would It Take to Achieve the Paris Temperature Targets?: ACHIEVING THE PARIS TEMPERATURE TARGETS. *Geophys. Res. Lett.* **2016**, *43*, 7133–7142. [CrossRef]
69. Rogelj, J.; Luderer, G.; Pietzcker, R.C.; Kriegler, E.; Schaeffer, M.; Krey, V.; Riahi, K. Energy System Transformations for Limiting End-of-Century Warming to below 1.5 °C. *Nat. Clim. Chang.* **2015**, *5*, 519–527. [CrossRef]
70. Bauer, N.; Rose, S.K.; Fujimori, S.; van Vuuren, D.P.; Weyant, J.; Wise, M.; Cui, Y.; Daioglou, V.; Gidden, M.J.; Kato, E.; et al. Global Energy Sector Emission Reductions and Bioenergy Use: Overview of the Bioenergy Demand Phase of the EMF-33 Model Comparison. *Clim. Chang.* **2020**, *163*, 1553–1568. [CrossRef]
71. Sachverständigenrat für Umweltfragen (SRU). *Pariser Klimaziele Erreichen Mit Dem CO2-Budget*; Sachverständigenrat für Umweltfragen (SRU): Berlin, Germany, 2021.
72. Knopf, B.; Geden, O. *Ist Deutschland auf dem 1,5-Grad-Pfad? Eine Einordnung der Diskussion über ein nationales CO_2-Budget*; Mercator Research Institute on Global Commons and Climate Change: Berlin, Germany, 2022.
73. Calliess, C. *Rechtsstaat und Umweltstaat. Zugleich ein Beitrag zur Grundrechtsdogmatik im Rahmen mehrpoliger Verfassungsrechtsverhältnisse*; Mohr Siebeck: Tübingen, Germany, 2001.
74. Šušnjar, D. *Proportionality, Fundamental Rights, and Balance of Powers*; Brill Nijhoff: Leiden, The Netherlands, 2010.
75. Meßerschmidt, K. *Gesetzgebungsermessen*; Berliner Juristische Universitätsschriften Reihe Öffentliches Recht; Berlin-Verlag Spitz & Nomos Verlagsgesellschaft: Berlin, Germany, 2000.
76. Prigogine, I. *The End of Certainty: Time, Chaos, and the New Laws of Nature*; Free Press: New York, NY, USA, 1997.
77. Fuglestvedt, J.; Rogelj, J.; Millar, R.J.; Allen, M.; Boucher, O.; Cain, M.; Forster, P.M.; Kriegler, E.; Shindell, D. Implications of Possible Interpretations of 'Greenhouse Gas Balance' in the Paris Agreement. *Trans. R. Soc. London. Ser. A Math. Phys. Eng. Sci.* **2018**, *376*, 20160445. [CrossRef] [PubMed]
78. Tanaka, K.; O'Neill, B.C. The Paris Agreement Zero-Emissions Goal Is Not Always Consistent with the 1.5 °C and 2 °C Temperature Targets. *Nat. Clim. Chang.* **2018**, *8*, 319–324. [CrossRef]
79. Luderer, G.; Vrontisi, Z.; Bertram, C.; Edelenbosch, O.Y.; Pietzcker, R.C.; Rogelj, J.; De Boer, H.S.; Drouet, L.; Emmerling, J.; Fricko, O.; et al. Residual Fossil CO_2 Emissions in 1.5–2 °C Pathways. *Nat. Clim. Chang.* **2018**, *8*, 626–633. [CrossRef]
80. Hugelius, G.; Loisel, J.; Chadburn, S.; Jackson, R.B.; Jones, M.; MacDonald, G.; Marushchak, M.; Olefeldt, D.; Packalen, M.; Siewert, M.B.; et al. Large Stocks of Peatland Carbon and Nitrogen Are Vulnerable to Permafrost Thaw. *Proc. Natl. Acad. Sci. USA* **2020**, *117*, 20438–20446. [CrossRef]

81. Li, H.; Väliranta, M.; Mäki, M.; Kohl, L.; Sannel, A.B.K.; Pumpanen, J.; Koskinen, M.; Bäck, J.; Bianchi, F. Overlooked Organic Vapor Emissions from Thawing Arctic Permafrost. *Environ. Res. Lett.* **2020**, *15*, 104097. [CrossRef]
82. Fuss, S.; Lamb, W.F.; Callaghan, M.W.; Hilaire, J.; Creutzig, F.; Amann, T.; Beringer, T.; de Oliveira Garcia, W.; Hartmann, J.; Khanna, T.; et al. Negative Emissions—Part 2: Costs, Potentials and Side Effects. *Environ. Res. Lett.* **2018**, *13*, 063002. [CrossRef]
83. Buhofer, S. *Der Klimawandel und die internationale Klimapolitik in Zahlen: Eine Übersicht*; Oekom Verlag: Munich, Germany, 2017.
84. Rogelj, J.; Popp, A.; Calvin, K.V.; Luderer, G.; Emmerling, J.; Gernaat, D.; Fujimori, S.; Strefler, J.; Hasegawa, T.; Marangoni, G.; et al. Scenarios towards Limiting Global Mean Temperature Increase below below 1.5 °C. *Nat. Clim. Chang.* **2018**, *8*, 325–332. [CrossRef]
85. Leach, N.J.; Millar, R.J.; Haustein, K.; Jenkins, S.; Graham, E.; Allen, M.R. Current Level and Rate of Warming Determine Emissions Budgets under Ambitious Mitigation. *Nat. Geosci.* **2018**, *11*, 574–579. [CrossRef]
86. Schurer, A.P.; Cowtan, K.; Hawkins, E.; Mann, M.E.; Scott, V.; Tett, S.F.B. Interpretations of the Paris Climate Target. *Nat. Geosci.* **2018**, *11*, 220–221. [CrossRef]
87. Hawkins, E.; Ortega, P.; Suckling, E.; Schurer, A.; Hegerl, G.; Jones, P.; Joshi, M.; Osborn, T.J.; Masson-Delmotte, V.; Mignot, J.; et al. Estimating Changes in Global Temperature since the Preindustrial Period. *Bull. Am. Meteorol. Soc.* **2017**, *98*, 1841–1856. [CrossRef]
88. Meinshausen, M.; Wigley, T.M.L.; Raper, S.C.B. Emulating Atmosphere-Ocean and Carbon Cycle Models with a Simpler Model, MAGICC6—Part 2: Applications. *Atmos. Chem. Phys.* **2011**, *11*, 1457–1471. [CrossRef]
89. Schurer, A.P.; Mann, M.E.; Hawkins, E.; Tett, S.F.B.; Hegerl, G.C. Importance of the Pre-Industrial Baseline for Likelihood of Exceeding Paris Goals. *Nat. Clim. Chang.* **2017**, *7*, 563–568. [CrossRef] [PubMed]
90. Rogelj, J.; den Elzen, M.; Höhne, N.; Francsen, T.; Fekete, H.; Winkler, H.; Schaeffer, R.; Sha, F.; Riahi, K.; Meinshausen, M. Paris Agreement Climate Proposals Need a Boost to Keep Warming Well below 2 °C. *Nature* **2016**, *534*, 631–639. [CrossRef]
91. Tan, I.; Storelvmo, T.; Zelinka, M.D. Observational Constraints on Mixed-Phase Clouds Imply Higher Climate Sensitivity. *Science* **2016**, *352*, 224–227. [CrossRef]
92. Friedrich, T.; Timmermann, A.; Tigchelaar, M.; Elison Timm, O.; Ganopolski, A. Nonlinear Climate Sensitivity and Its Implications for Future Greenhouse Warming. *Sci. Adv.* **2016**, *2*, e1501923. [CrossRef]
93. Sherwood, S.C.; Bony, S.; Dufresne, J.-L. Spread in Model Climate Sensitivity Traced to Atmospheric Convective Mixing. *Nature* **2014**, *505*, 37–42. [CrossRef]
94. Zhai, C.; Jiang, J.H.; Su, H. Long-Term Cloud Change Imprinted in Seasonal Cloud Variation: More Evidence of High Climate Sensitivity: Cloud Feedback and Seasonal Variation. *Geophys. Res. Lett.* **2015**, *42*, 8729–8737. [CrossRef]
95. Brown, P.T.; Caldeira, K. Greater Future Global Warming Inferred from Earth's Recent Energy Budget. *Nature* **2017**, *552*, 45–50. [CrossRef]
96. Knutti, R.; Rugenstein, M.A.A.; Hegerl, G.C. Beyond Equilibrium Climate Sensitivity. *Nat. Geosci.* **2017**, *10*, 727–736. [CrossRef]
97. Sully, S.; Burkepile, D.E.; Donovan, M.K.; Hodgson, G.; van Woesik, R. A Global Analysis of Coral Bleaching over the Past Two Decades. *Nat. Commun.* **2019**, *10*, 1264. [CrossRef] [PubMed]
98. den Elzen, M.; Admiraal, A.; Roelfsema, M.; van Soest, H.; Hof, A.F.; Forsell, N. Contribution of the G20 Economies to the Global Impact of the Paris Agreement Climate Proposals. *Clim. Chang.* **2016**, *137*, 655–665. [CrossRef]
99. Fujimori, S.; Su, X.; Liu, J.-Y.; Hasegawa, T.; Takahashi, K.; Masui, T.; Takimi, M. Implication of Paris Agreement in the Context of Long-Term Climate Mitigation Goals. *SpringerPlus* **2016**, *5*, 1620. [CrossRef] [PubMed]
100. Rogelj, J.; Fricko, O.; Meinshausen, M.; Krey, V.; Zilliacus, J.J.J.; Riahi, K. Understanding the Origin of Paris Agreement Emission Uncertainties. *Nat. Commun.* **2017**, *8*, 15748. [CrossRef]
101. Benveniste, H.; Boucher, O.; Guivarch, C.; Treut, H.L.; Criqui, P. Impacts of Nationally Determined Contributions on 2030 Global Greenhouse Gas Emissions: Uncertainty Analysis and Distribution of Emissions. *Environ. Res. Lett.* **2018**, *13*, 014022. [CrossRef]
102. Bastin, J.-F.; Finegold, Y.; Garcia, C.; Mollicone, D.; Rezende, M.; Routh, D.; Zohner, C.M.; Crowther, T.W. The Global Tree Restoration Potential. *Science* **2019**, *365*, 76–79. [CrossRef]
103. Bastin, J.-F.; Finegold, Y.; Garcia, C.; Gellie, N.; Lowe, A.; Mollicone, D.; Rezende, M.; Routh, D.; Sacande, M.; Sparrow, B.; et al. Response to Comments on "The Global Tree Restoration Potential". *Science* **2019**, *366*, eaay8108. [CrossRef]
104. Luedeling, E.; Börner, J.; Amelung, W.; Schiffers, K.; Shepherd, K.; Rosenstock, T. Forest Restoration: Overlooked Constraints. *Science* **2019**, *366*, 315. [CrossRef] [PubMed]
105. Stubenrauch, J.; Garske, B.; Ekardt, F.; Hagemann, K. European Forest Governance: Status Quo and Optimising Options with Regard to the Paris Climate Target. *Sustainability* **2022**, *14*, 4365. [CrossRef]
106. Strefler, J.; Bauer, N.; Kriegler, E.; Popp, A.; Giannousakis, A.; Edenhofer, O. Between Scylla and Charybdis: Delayed Mitigation Narrows the Passage between Large-Scale CDR and High Costs. *Environ. Res. Lett.* **2018**, *13*, 044015. [CrossRef]
107. Williamson, P. Emissions Reduction: Scrutinize CO_2 Removal Methods. *Nature* **2016**, *530*, 153–155. [CrossRef] [PubMed]
108. Obersteiner, M.; Bednar, J.; Wagner, F.; Gasser, T.; Ciais, P.; Forsell, N.; Frank, S.; Havlik, P.; Valin, H.; Janssens, I.A.; et al. How to Spend a Dwindling Greenhouse Gas Budget. *Nat. Clim. Chang.* **2018**, *8*, 7–10. [CrossRef]
109. Anderson, K.; Peters, G. The Trouble with Negative Emissions. *Science* **2016**, *354*, 182–183. [CrossRef] [PubMed]
110. van Vuuren, D.P.; Stehfest, E.; Gernaat, D.E.H.J.; van den Berg, M.; Bijl, D.L.; de Boer, H.S.; Daioglou, V.; Doelman, J.C.; Edelenbosch, O.Y.; Harmsen, M.; et al. Alternative Pathways to the 1.5 °C Target Reduce the Need for Negative Emission Technologies. *Nat. Clim. Chang.* **2018**, *8*, 391–397. [CrossRef]

111. Ekardt, F.; von Bredow, H. Extended Emissions Trading Versus Sustainability Criteria: Managing the Ecological and Social Ambivalences of Bioenergy. *Renew. Energy Law Policy Rev.* **2012**, *3*, 49–64.
112. Hennig, B. *Nachhaltige Landnutzung und Bioenergie. Ambivalenzen, Governance, Rechtsfragen*; Metropolis-Verlag: Marburg, Germany, 2017.
113. Minx, J.C.; Lamb, W.F.; Callaghan, M.W.; Fuss, S.; Hilaire, J.; Creutzig, F.; Amann, T.; Beringer, T.; de Oliveira Garcia, W.; Hartmann, J.; et al. Negative Emissions—Part 1: Research Landscape and Synthesis. *Environ. Res. Lett.* **2018**, *13*, 063001. [CrossRef]
114. Biermann, F.; Möller, I. Rich Man's Solution? Climate Engineering Discourses and the Marginalization of the Global South. *Int. Environ. Agreem. Politics Law Econ.* **2019**, *19*, 151–167. [CrossRef]
115. Cronin, J.; Anandarajah, G.; Dessens, O. Climate Change Impacts on the Energy System: A Review of Trends and Gaps. *Clim. Chang.* **2018**, *151*, 79–93. [CrossRef]
116. van Vliet, J.; Hof, A.F.; Mendoza Beltran, A.; van den Berg, M.; Deetman, S.; den Elzen, M.G.J.; Lucas, P.L.; van Vuuren, D.P. The Impact of Technology Availability on the Timing and Costs of Emission Reductions for Achieving Long-Term Climate Targets. *Clim. Chang.* **2014**, *123*, 559–569. [CrossRef]
117. Erickson, P.; Kartha, S.; Lazarus, M.; Tempest, K. Assessing Carbon Lock-In. *Environ. Res. Lett.* **2015**, *10*, 084023. [CrossRef]
118. Biermann, F.; Oomen, J.; Gupta, A.; Ali, S.H.; Conca, K.; Hajer, M.A.; Kashwan, P.; Kotzé, L.J.; Leach, M.; Messner, D.; et al. Solar Geoengineering: The Case for an International Non-use Agreement. *WIREs Clim. Chang.* **2022**. [CrossRef]
119. Bodansky, D. The Paris Climate Change Agreement: A New Hope? *Am. J. Int. Law* **2016**, *110*, 288–319. [CrossRef]
120. Allan, J.I. Dangerous Incrementalism of the Paris Agreement. *Glob. Environ. Politics* **2019**, *19*, 4–11. [CrossRef]
121. Voigt, C. The Paris Agreement: What Is the Standard of Conduct for Parties? *Zoom* **2016**, *26*, 17–28.
122. C/09/571932/HA ZA 19-379. 2021. Available online: https://uitspraken.rechtspraak.nl/inziendocument?id=ECLI:NL:RBDHA:2021:5339 (accessed on 4 April 2022).
123. Verschuuren, J. The State of the Netherlands v Urgenda Foundation: The Hague Court of Appeal Upholds Judgment Requiring the Netherlands to Further Reduce Its Greenhouse Gas Emissions. *Rev. Eur. Comp. Int. Environ. Law* **2019**, *28*, 94–98. [CrossRef]
124. N°1904967, 1904968, 1904972, 1904976/4-1; 2021. Available online: paris.tribunal-administratif.fr/content/download/179360/1759761/version/1/file/1904967190496819049721904976.pdf (accessed on 4 April 2022).
125. Voigt, C.; Ferreira, F. Differentiation in the Paris Agreement. *Clim. Law* **2016**, *6*, 58–74. [CrossRef]
126. Böhringer, A.-M. Das neue Pariser Klimaübereinkommen. Eine Kompromisslöung mit Symbolkraft und Verhaltenssteuerungspotential. *Z. Für Ausländisches Offentl. Recht Völkerrecht* **2016**, *76*, 753–795.
127. Nückel, D. Rechtlicher Charakter des Pariser Übereinkommens—Hard Law oder Soft Law. *ZUR* **2017**, *10*, 525–531.
128. Waisman, H.; Bataille, C.; Winkler, H.; Jotzo, F.; Shukla, P.; Colombier, M.; Buira, D.; Criqui, P.; Fischedick, M.; Kainuma, M.; et al. A Pathway Design Framework for National Low Greenhouse Gas Emission Development Strategies. *Nat. Clim. Chang.* **2019**, *9*, 261–268. [CrossRef]
129. Voigt, C.; Ferreira, F. 'Dynamic Differentiation': The Principles of CBDR-RC, Progression and Highest Possible Ambition in the Paris Agreement. *Transnatl. Environ. Law* **2016**, *5*, 285–303. [CrossRef]
130. Federal Constitutional Court. *1 BvR 2656/18*; Federal Constitutional Court: Karlsruhe, Germany, 2021.
131. Friends of the Irish Environment -v- The Government of Ireland & Ors [2020] IESC 49. 2020. Available online: https://www.courts.ie/view/judgments/681b8633-3f57-41b5-9362-8cbc8e7d9215/981c098a-462b-4a9a-9941-5d601903c9af/2020_IESC_49.pdf/pdf (accessed on 4 April 2022).
132. Sharma by Her Litigation Representative Sister Marie Brigid Arthur v Minister for the Environment [2021] FCA 560; 2021. Available online: https://www.fedcourt.gov.au/services/access-to-files-and-transcripts/online-files/minister-for-the-environment-v-sharma/vid-389-of-2021-filed-documents/judgment-2021FCA560.pdf (accessed on 4 April 2022).
133. Koch, T. *Der Grundrechtsschutz des Drittbetroffenen: Zur Rekonstruktion der Grundrechte als Abwehrrechte*; Jus Publicum; Mohr Siebeck: Tübingen, Germany, 2000.
134. Skillington, T. Climate Change and the Human Rights Challenge: Extending Justice beyond the Borders of the Nation State. *Int. J. Hum. Rights* **2012**, *16*, 1196–1212. [CrossRef]
135. Verheyen, R. *Climate Change Damage and International Law: Prevention, Duties and State Responsibility*; Developments in international law; M. Nijhoff & Brill: Boston, MA, USA; Leiden, The Netherlands, 2005.
136. Unnerstall, H. *Rechte Zukünftiger Generationen*; Königshausen & Neumann: Würzburg, Germany, 1999.
137. Schmidt-Radefeldt, R. *Ökologische Menschenrechte: Ökologische Menschenrechtsinterpretation der EMRK und ihre Bedeutung für die Umweltschützenden Grundrechte Des Grundgesetzes*; Leipziger Schriften zum Völkerrecht Europarecht und ausländischen öffentlichen Recht; Nomos Verlagsgesellschaft: Baden-Baden, Germany, 2000.
138. Read, R.; Riordan, T. The Precautionary Principle Under Fire. *Environ. Sci. Policy Sustain. Dev.* **2017**, *59*, 4–15. [CrossRef]
139. Patterson, J.J.; Thaler, T.; Hoffmann, M.; Hughes, S.; Oels, A.; Chu, E.; Mert, A.; Huitema, D.; Burch, S.; Jordan, A. Political Feasibility of 1.5°C Societal Transformations: The Role of Social Justice. *Curr. Opin. Environ. Sustain.* **2018**, *31*, 1–9. [CrossRef]
140. Robinson, M.; Shine, T. Achieving a Climate Justice Pathway to 1.5 °C. *Nat. Clim. Chang.* **2018**, *8*, 564–569. [CrossRef]
141. O'Riordan, T.; Cameron, J. *Interpreting the Precautionary Principle*; Routledge: London, UK, 2013.
142. Sands, P.; Peel, J. *Principles of International Environmental Law*, 4th ed.; Cambridge University Press: Cambridge, UK, 2018.
143. Gardiner, S.M. A Core Precautionary Principle*. *J. Political Philos.* **2006**, *14*, 33–60. [CrossRef]
144. Garske, B. *Ordnungsrechtliche und Ökonomische Instrumente der Phosphor-Governance*; Metropolis: Marburg, Germany, 2019.

145. Stubenrauch, J. *Phosphor-Governance in Ländervergleichender Perspektive—Deutschland, Costa Rica, Nicaragua. Ein Beitrag zur Nachhaltigkeits-und Bodenschutzpolitik*; Metropolis: Marburg, Germany, 2019.
146. Sunstein, C.R. *Laws of Fear: Beyond the Precautionary Principle*; Cambridge University Press: Cambridge, UK, 2005.
147. Gardiner, S.M. *A Perfect Moral Storm—The Ethical Tragedy of Climate Change*; Oxford University Press: Oxford, UK, 2011.
148. Ekardt, F.; Jacobs, B.; Stubenrauch, J.; Garske, B. Peatland Governance: The Problem of Depicting in Sustainability Governance, Regulatory Law, and Economic Instruments. *Land* **2020**, *9*, 83. [CrossRef]
149. Rath, T.; Ekardt, F. Die EU-Emissionshandels-Reform und die Wärmewende. *Klima und Recht* **2022**, *6*, 138–142.